OST
Eastern Switzerland
University of Applied Sciences

Discover the power of the Segment Routing encapsulation

SwiNOG #37, Berne

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INS – Institute for Networked Solutions, Rapperswil (CH)

Agenda

- Introduction
- Segment Routing Overview
- SR-MPLS
- SRv6
- Benefits
- Applications

Introduction

Who are we? Who am I?

INS @ OST

INSTITUTE FOR NETWORKED SOLUTIONS

- INS - Institute for Networked Solutions
- OST - Eastern Switzerland University of Applied Science
- Different competences
  - Software Engineering, Cloud Networking, Network Automation, Security
- Analyzing and researching newest technologies and trends
- Reflecting knowledge in education, courses and industry projects

About me

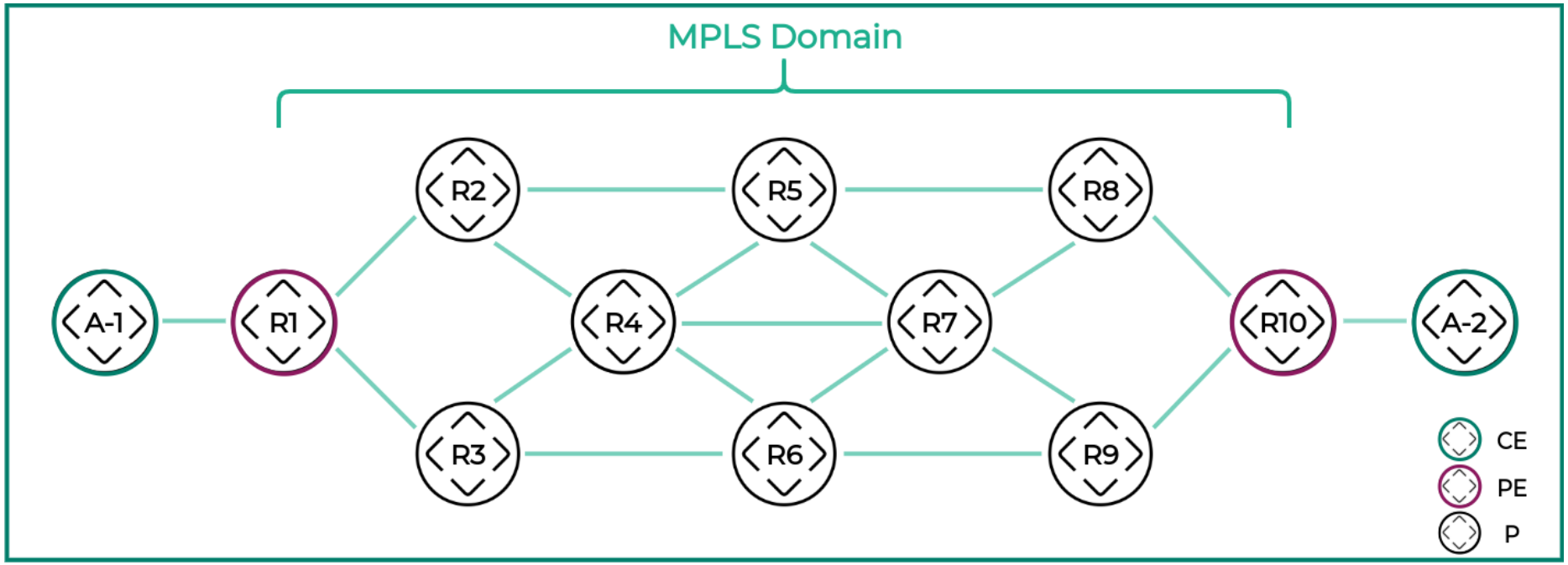
- Severin Dellsperger
- BSc. in CS
- Pursue MSc. in SDN
- Cloud Networking team
- Segment Routing (applications)
- https://www.segment-routing.ch/

Recap of traditional networks

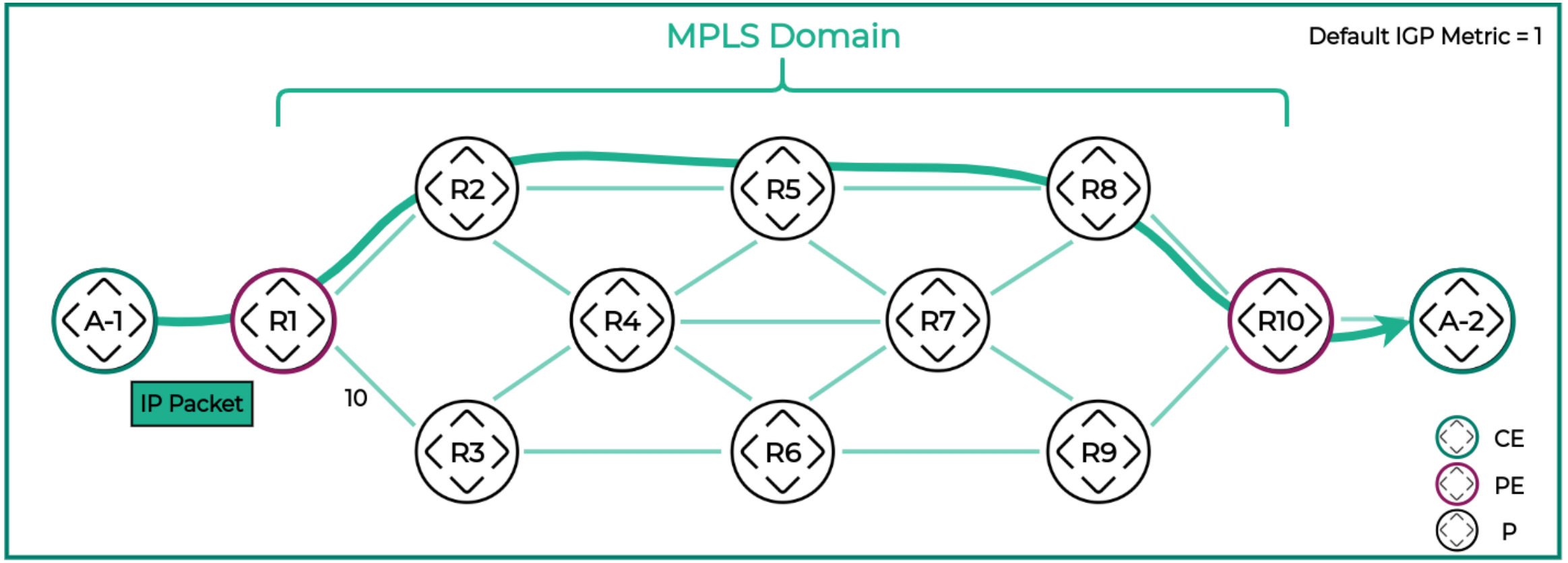
How are today's networks built?

Overview of a "modern" provider network

- MPLS
- LDP
- IGP
- MP-BGP



Packet transport



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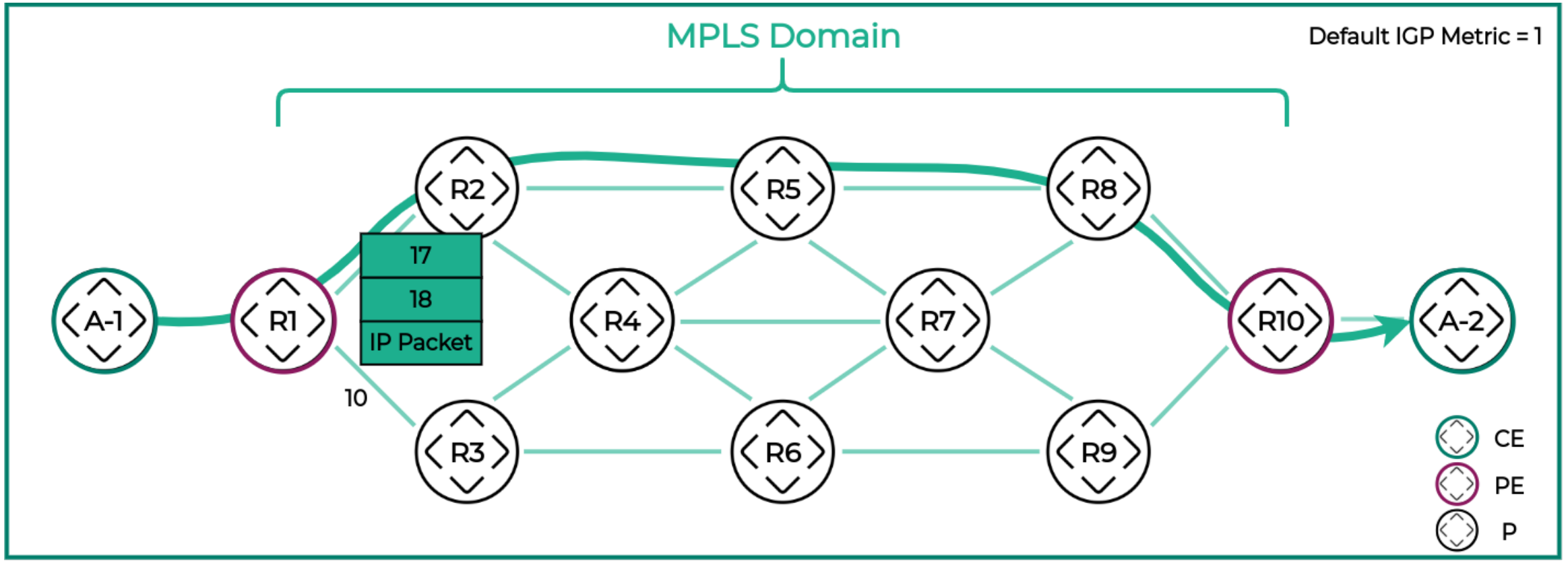

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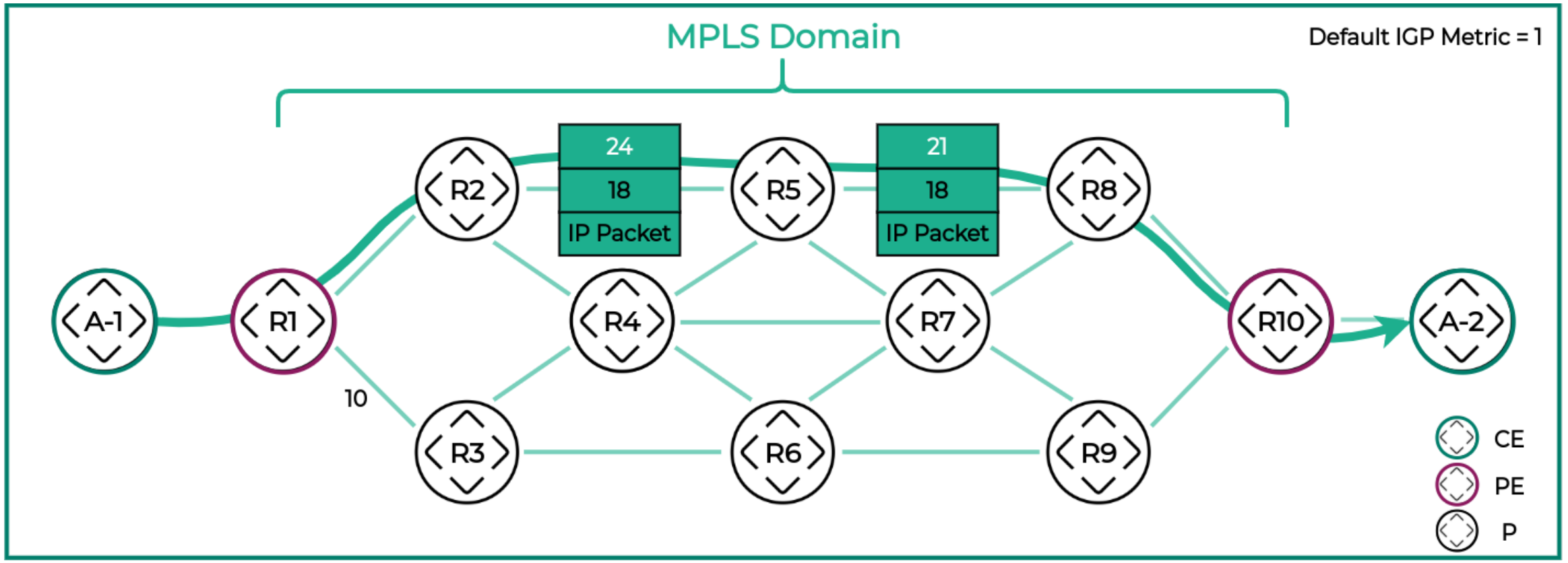
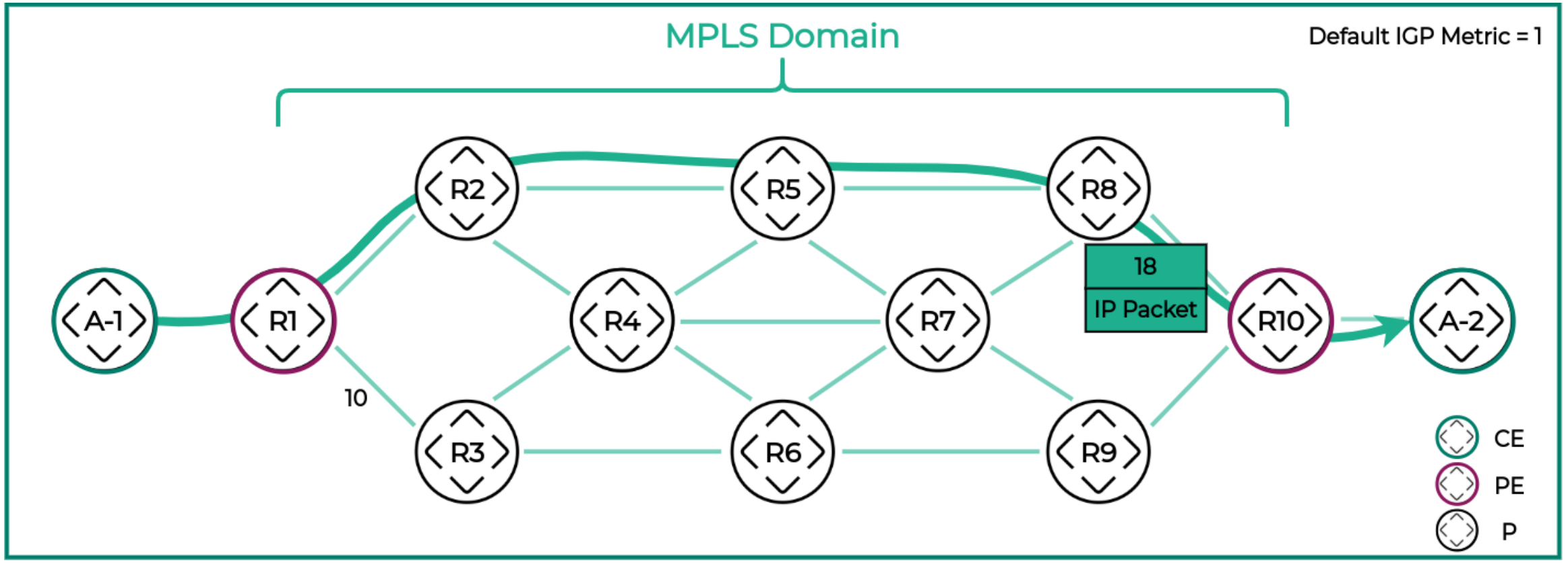
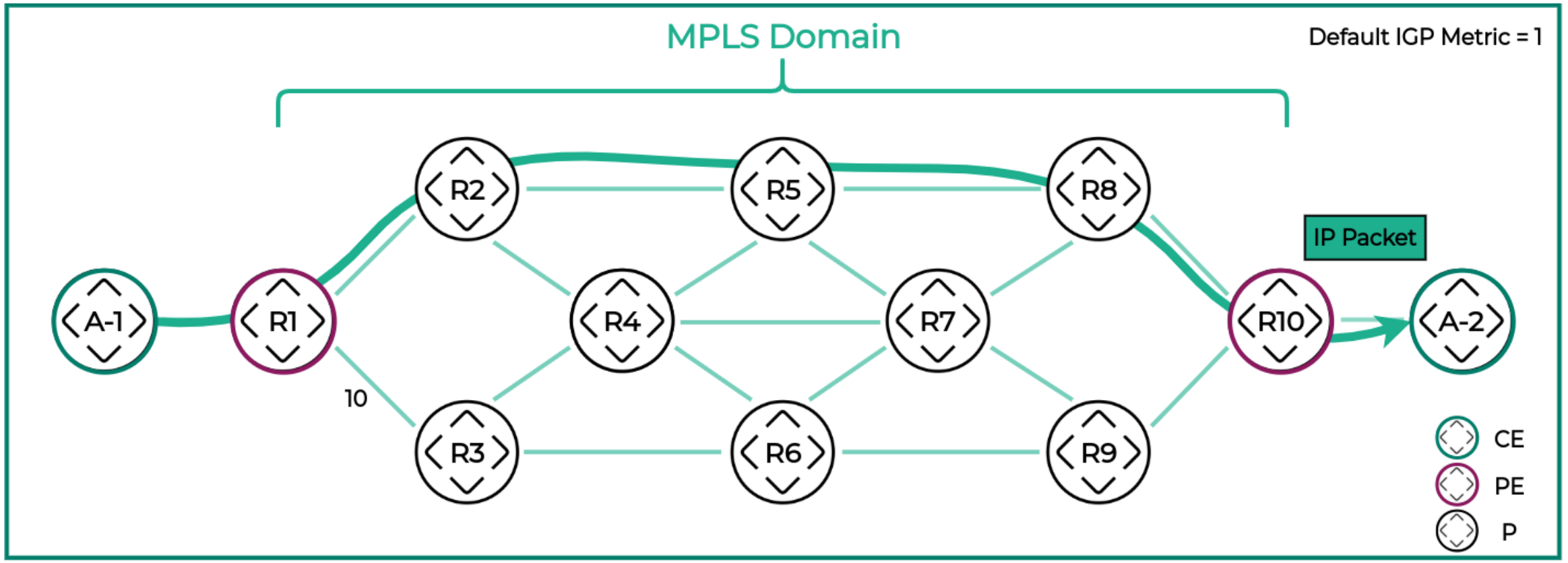


Packet transport



Packet transport



Do you believe our future networks will stay like that?

Drawbacks

- Control plane complexity (LDP & RSVP-TE)
- Limitations in scalability
- OAM difficulties[1]
  - Troubleshooting
  - Traffic Engineering
- Problems regarding FRR[2] coverage and microloops

[1] Operation, Administration, Management
[2] Fast Reroute

General Overview

What is Segment Routing about in general?

Segment Routing

- Standardized in RFC8402 [5]
- Source routing paradigm
- Packet steering according list of instructions
  - Instructions added to the packet header (at source node)
- Nodes simply execute instructions found in packet header
  - Intermediate nodes don't maintain per-flow state information
  - State is in the packet
  - Source node controls traffic steering

Control & Data Plane

Control Plane

- No specific control plane implementation
- Segments/Instructions exchange via ISIS, OSPF, BGP
  - ISIS Extension RFC8667 [8]
  - OSPF Extensions RFC8665 [10], RFC8666 [9]
  - BGP Extensions RFC9086 [7]
- Simplification: Removes unnecessary protocols

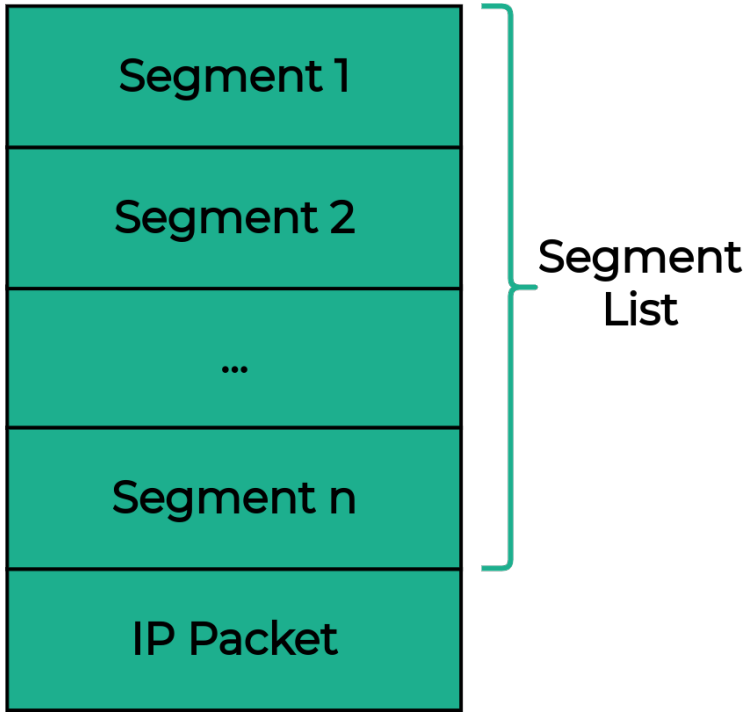
Data Plane

- MPLS data plane: SR-MPLS
- IPv6 data plane: SRv6

Concept of Segments

Each entry in the SID List is an instruction to complete one section or segment of the whole path, therefore the term "segment" in Segment Routing [2]

- Instruction = Segment
- SID = Segment Identifier
- Represents any kind of instruction
  - Topological:
    - *Forwarding traffic on shortest ECMP path to destination*
    - *Forwarding traffic through a specific interface*
  - Service-based
    Deliver packet to specific service and process it there
- Ordered list of instructions = Segment List
- Simple but powerful



Segment Types

IGP Segments

- IGP Prefix segment
- IGP Node segment
- IGP Anycast segment
- IGP Adjacency segment
- Layer-2 Adjacency-SID
- Group Adjacency-SID

BGP Segments

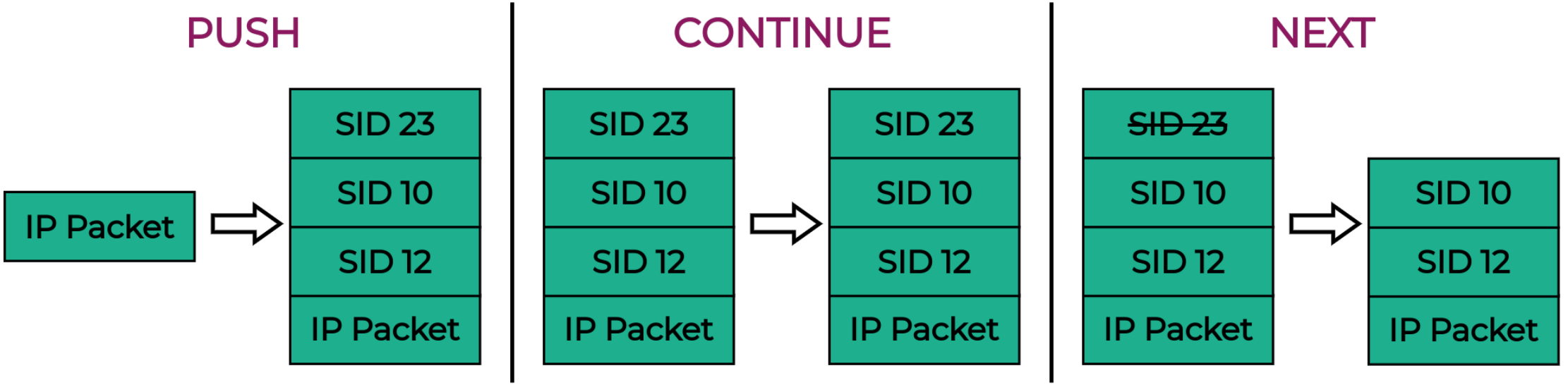
- BGP Prefix segment
- BGP Anycast segment
- BGP peer segment

Segment List Operations

PUSH insert segments to packet header and set active segment

CONTINUE the active segment is not finished and remains active

NEXT the active segment is completed - activate next segment in SID List



Segment Significance

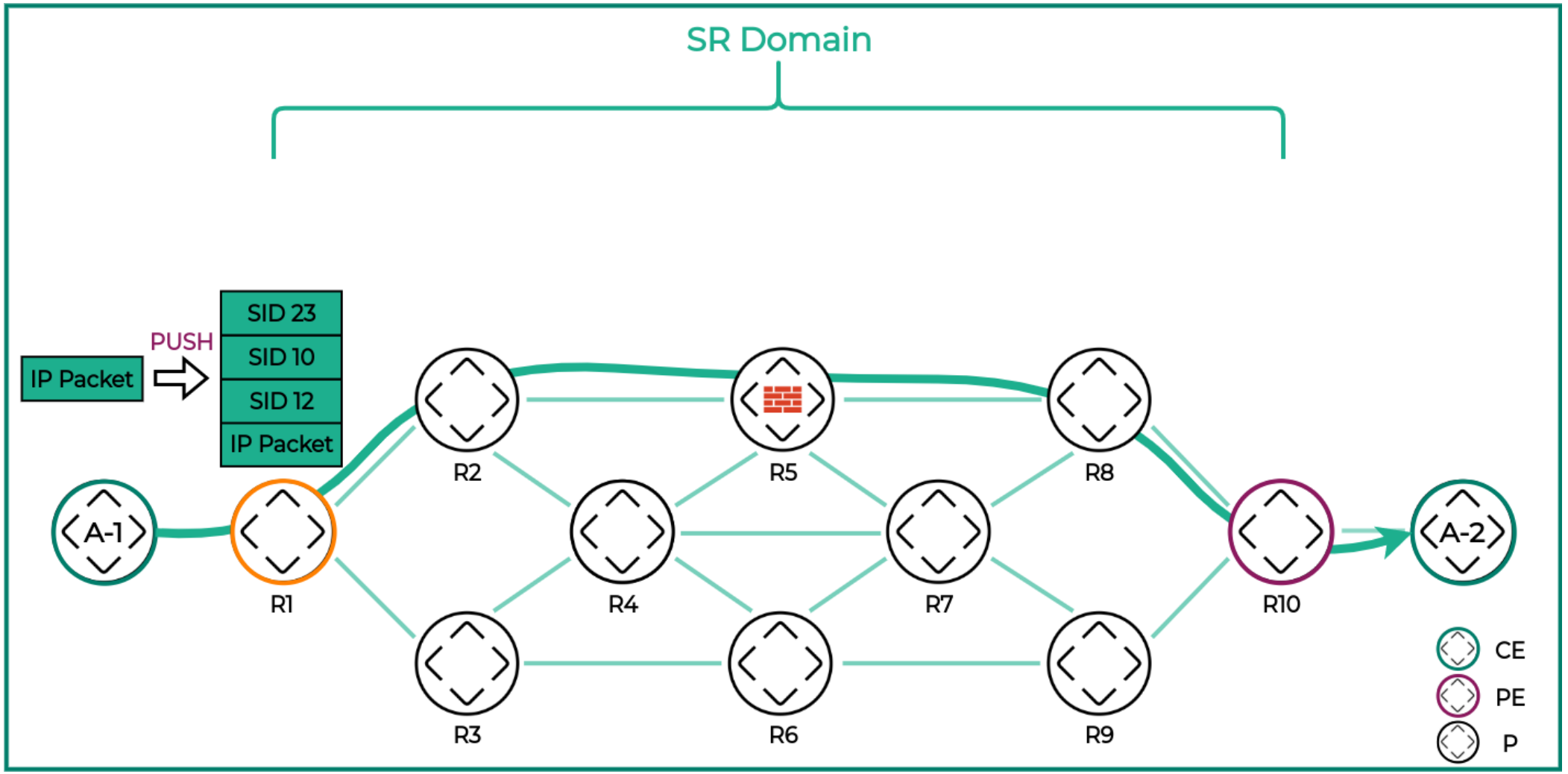
Global Segments

- All SR-enables nodes in SR Domain support these instructions
- Each node installs these segments in forwarding table
- Example: *forward packet according shortest path to Node1*

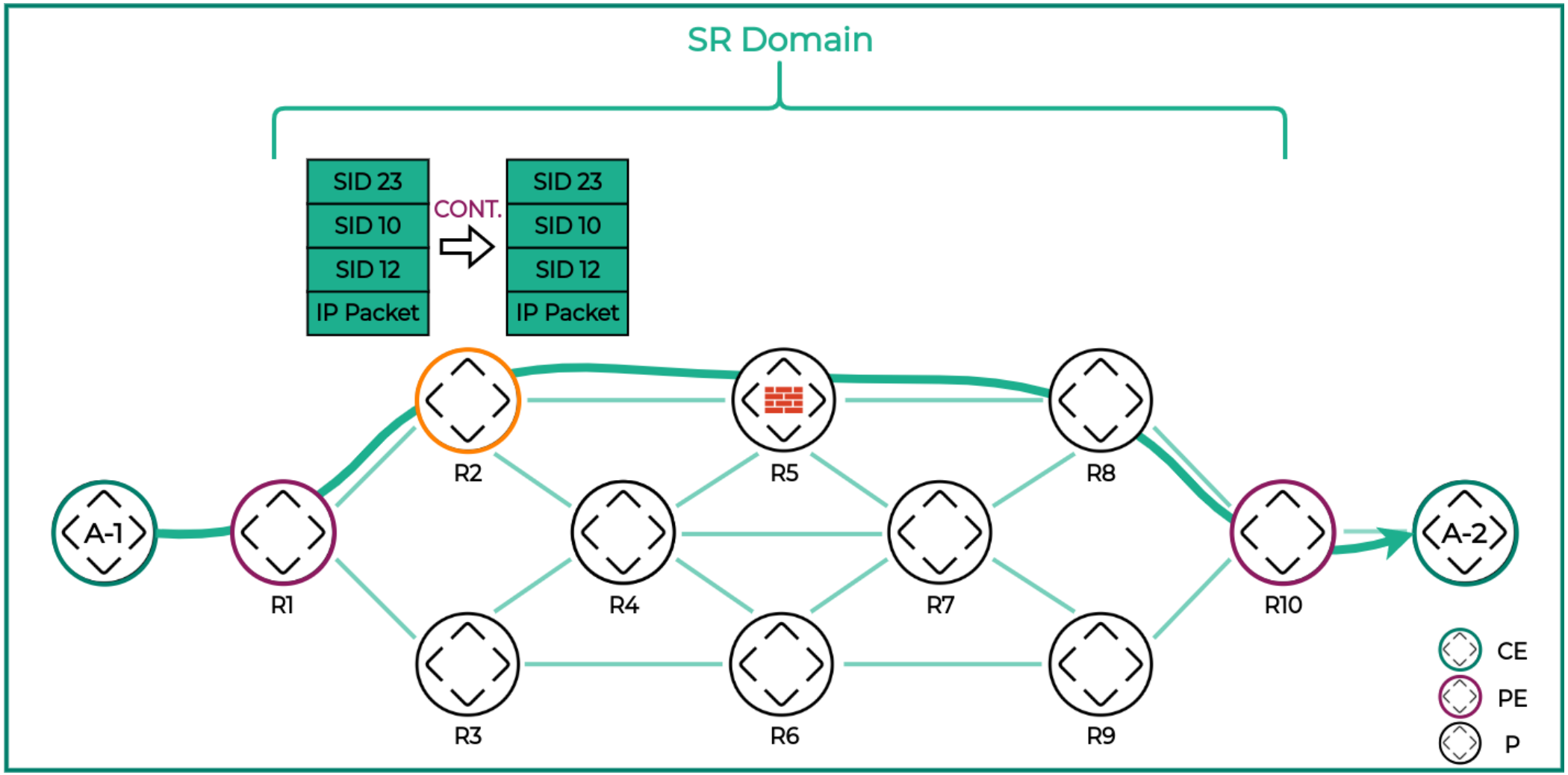
Local Segments

- Only originating node supports these instructions
- Therefore only originating node writes them into forwarding table
- Other nodes have to know about their existence and meaning
- Example: *forward packet on interface to Node2*

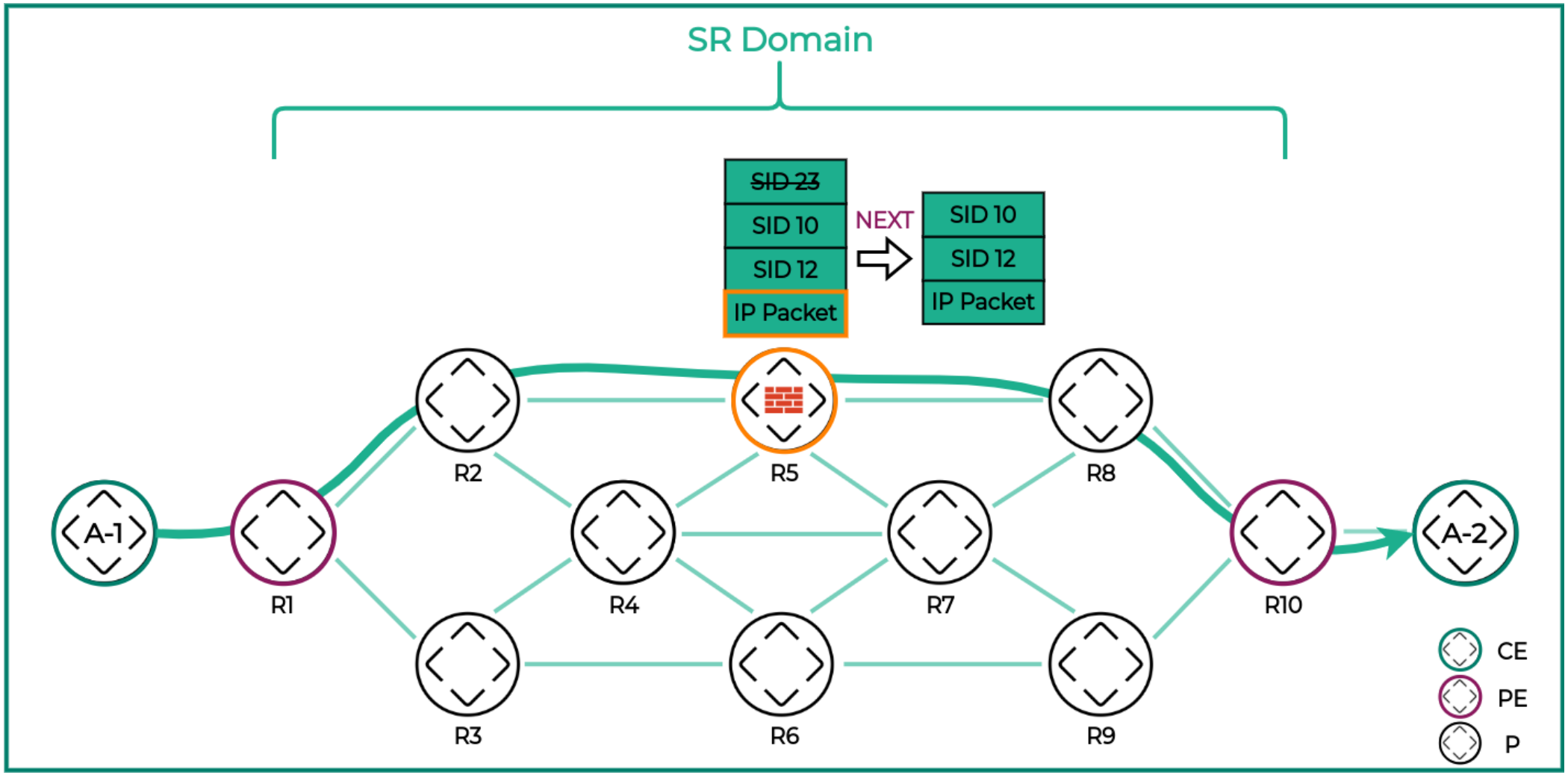
Example Path Traversal



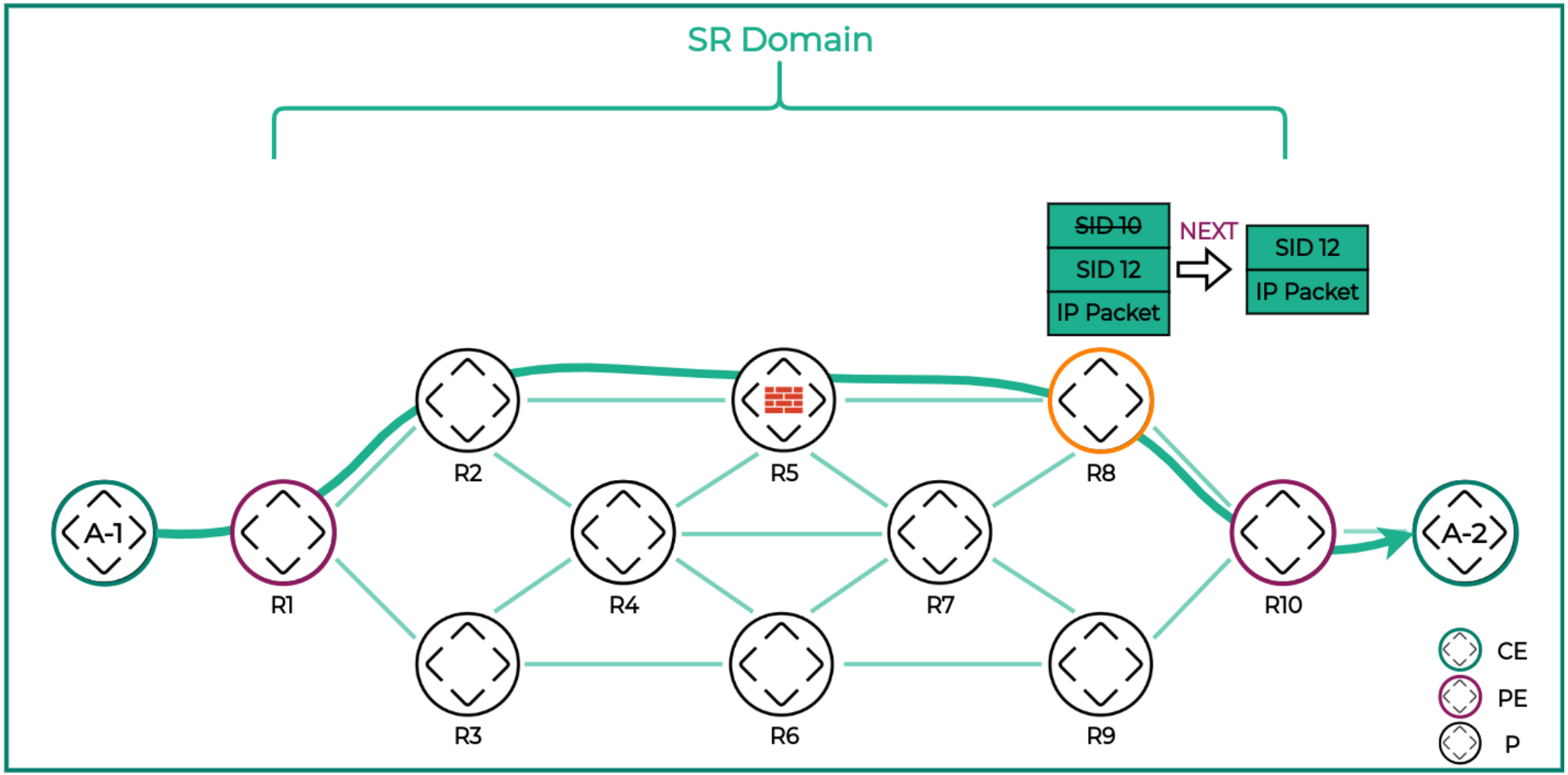
Example Path Traversal



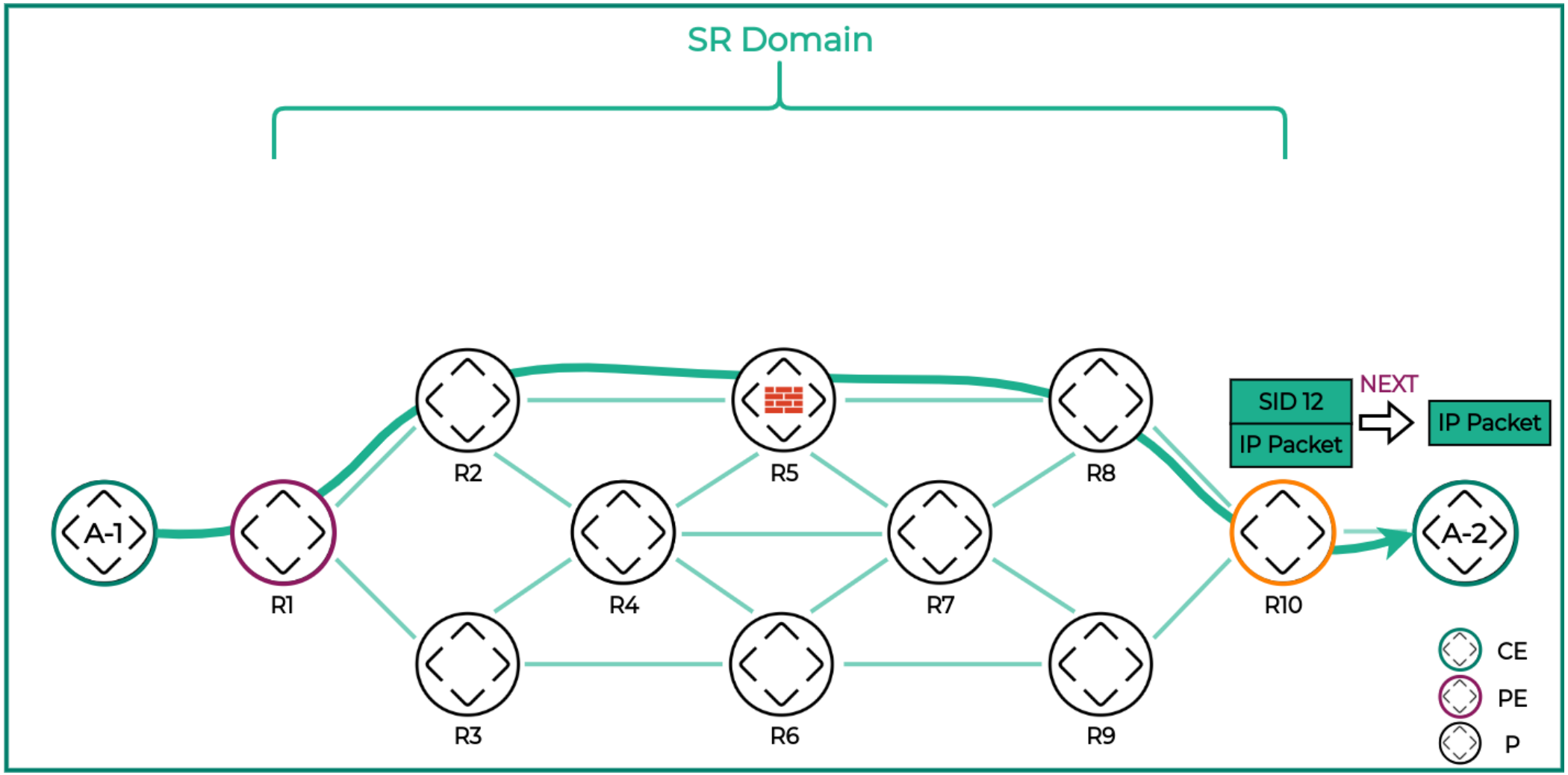
Example Path Traversal



Example Path Traversal



Example Path Traversal



SR-MPLS

Segment Routing over MPLS

An overview

- SR-MPLS re-uses MPLS data plane without any change
  - Apply to existing MPLS architecture
- Segments are represented by MPLS labels
  - Segment List is stack of MPLS label
  - Segment to process (Active Segment) on top
- Segments are distributed over IGP (or BGP)
  - No need for LDP anymore
  - Interoperability with LDP possible (mapping server)
- IPv4 & IPv6 address families

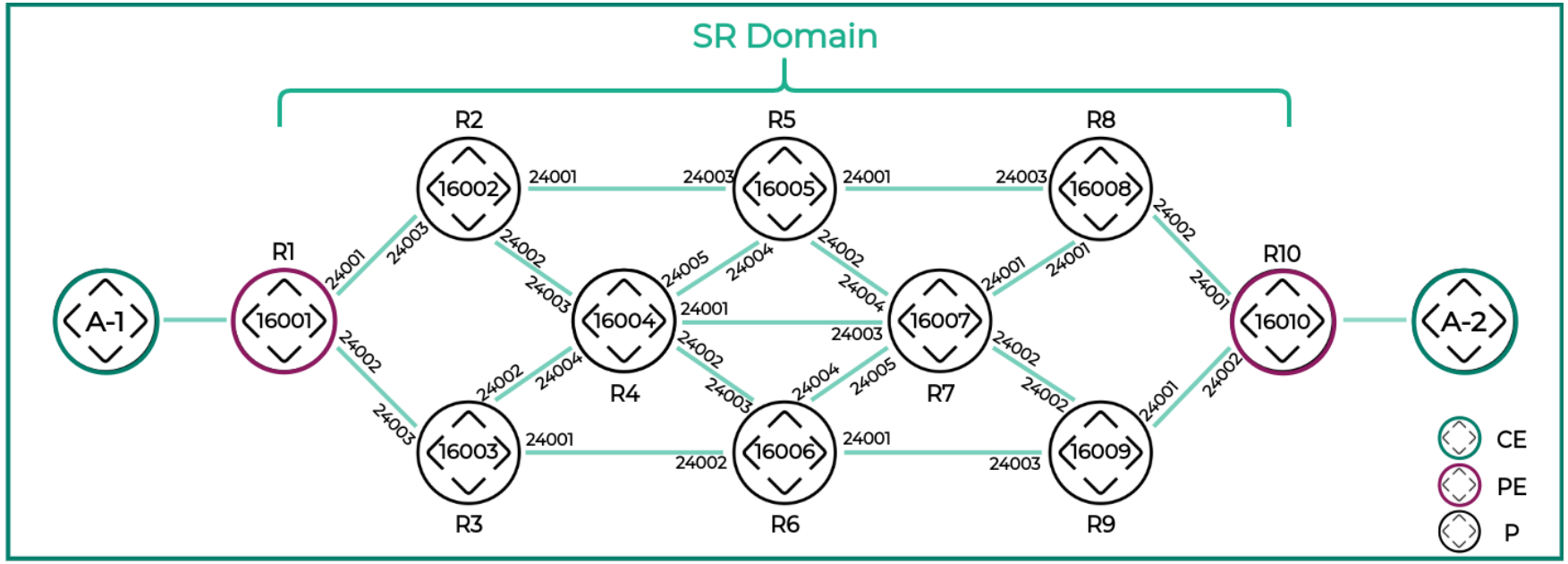
Global vs. Local

Global Segments

- Defined in the SR Global Block (SRGB)
- Recommended: use identical SRGBs

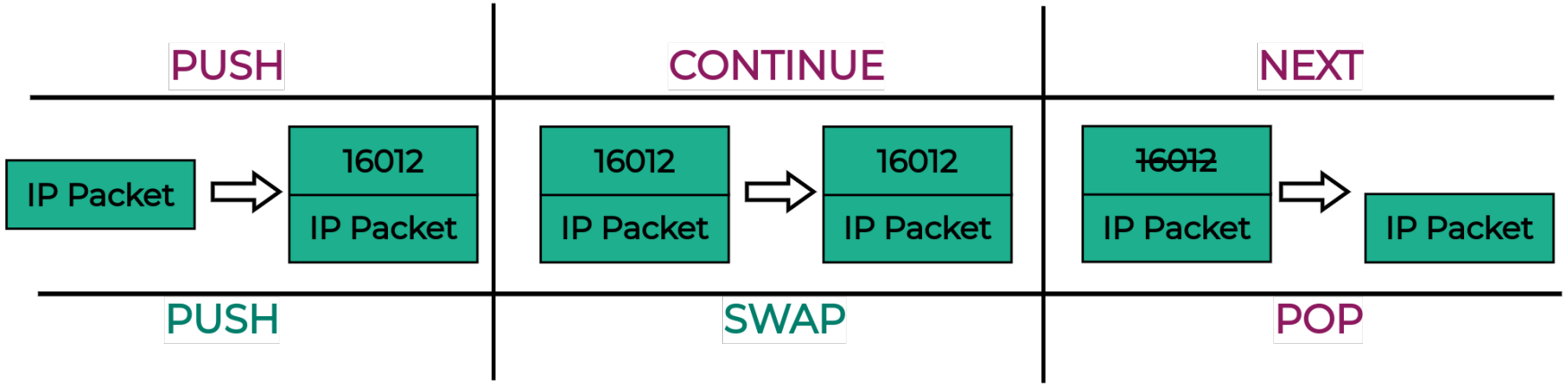
Local Segments

- Defined in SR Local Block (SRLB)
- Local property of an SR node

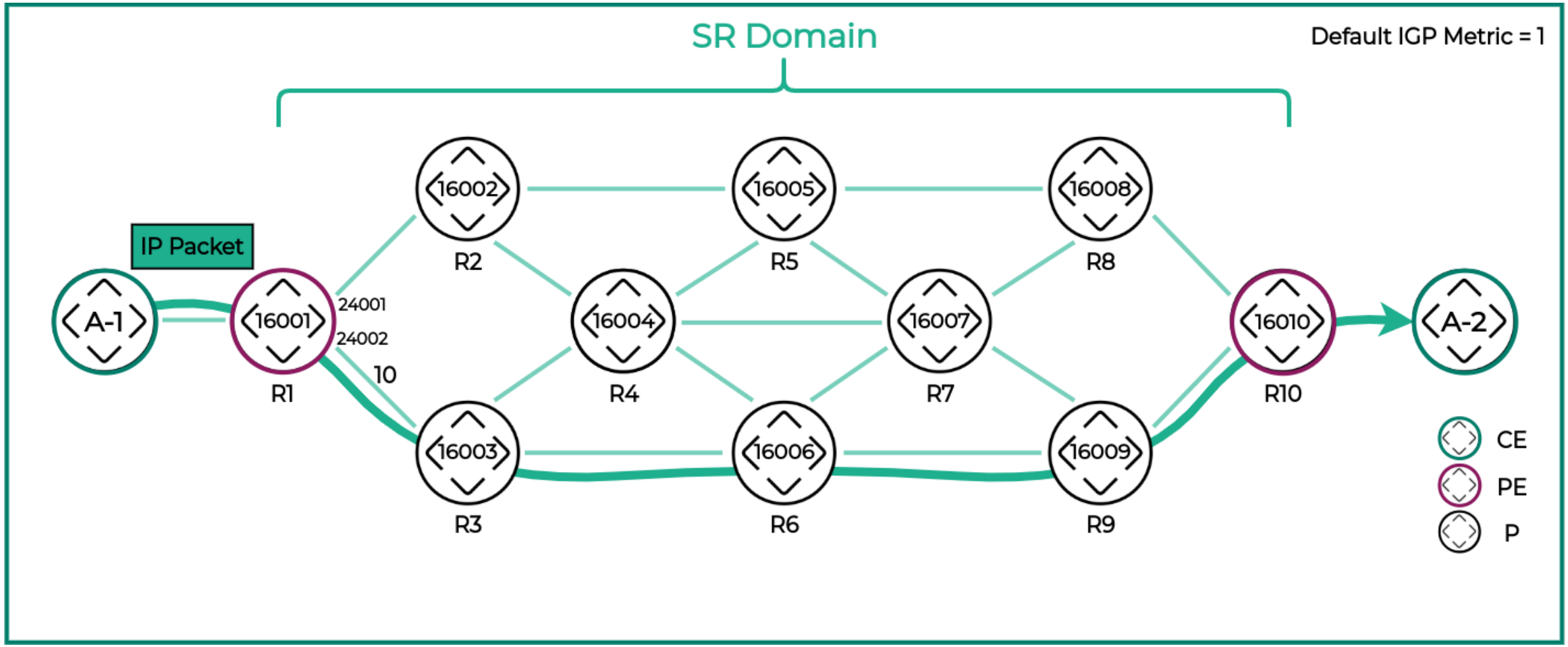


Label Stack Operation

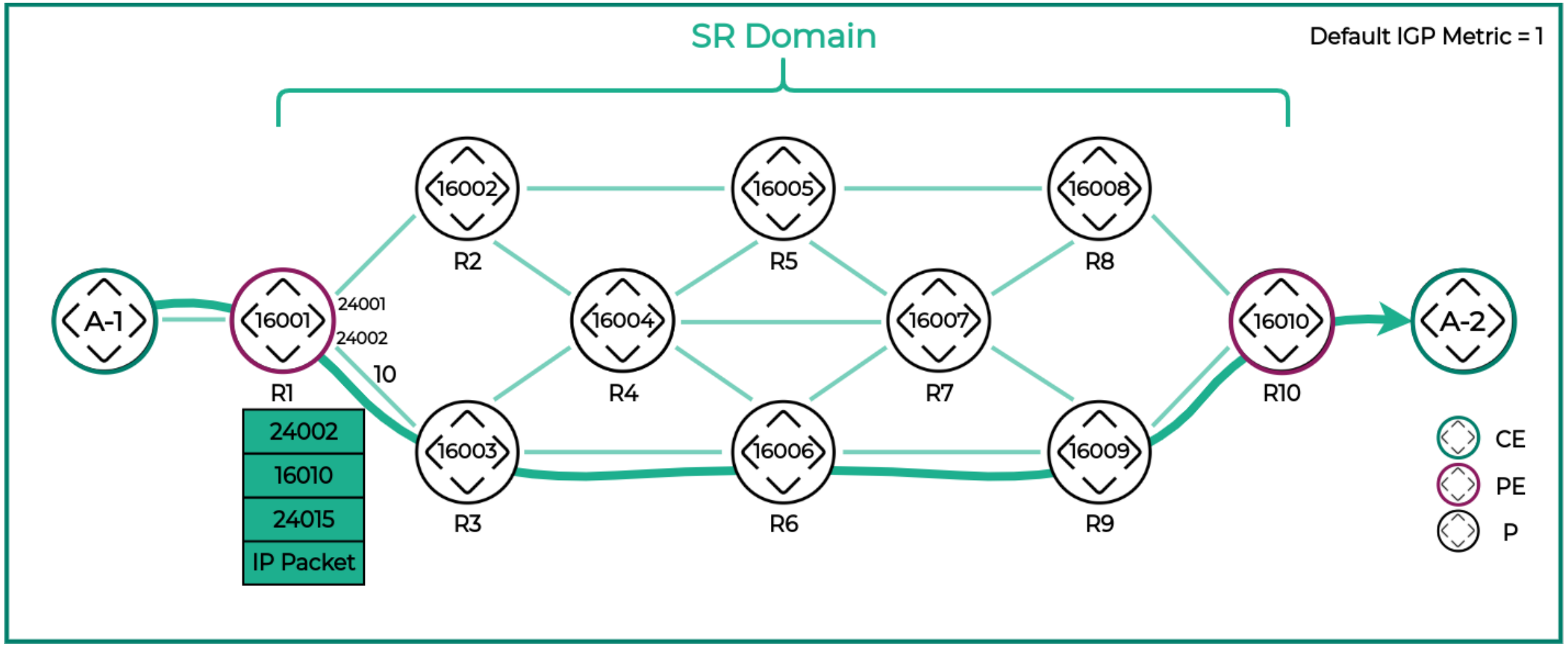
Segment List Operation	MPLS Label Stack Operation
PUSH	PUSH
CONTINUE	SWAP
NEXT	POP



Example


SR Domain
Default IGP Metric = 1
IP Packet
A-1
16001
R1
24001
24002
10
16002
R2
16003
R3
16004
R4
16005
R5
16006
R6
16007
R7
16008
R8
16009
R9
16010
R10
A-2
CE
PE
P

Example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16006
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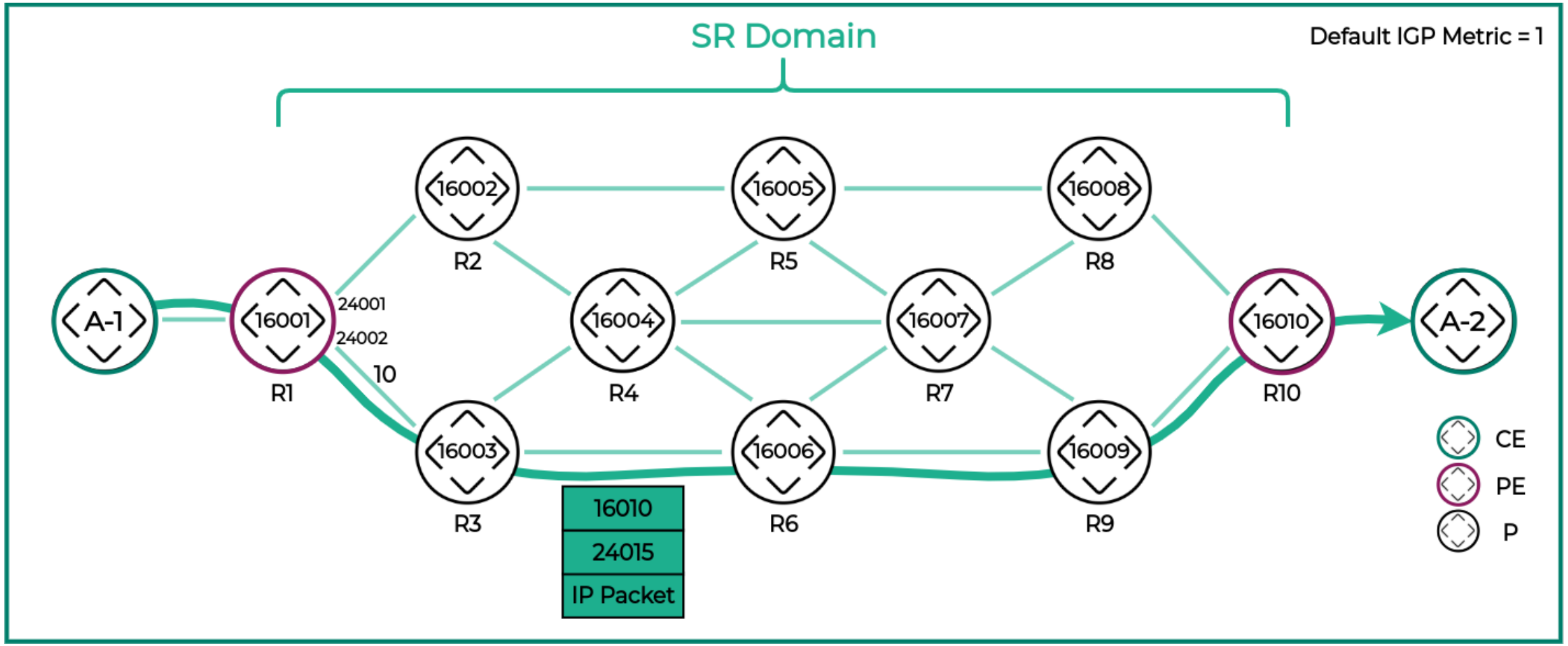
R8
16009
R9
16010
R10
A-2
24002
16010
24015
IP Packet
CE
PE
P

Example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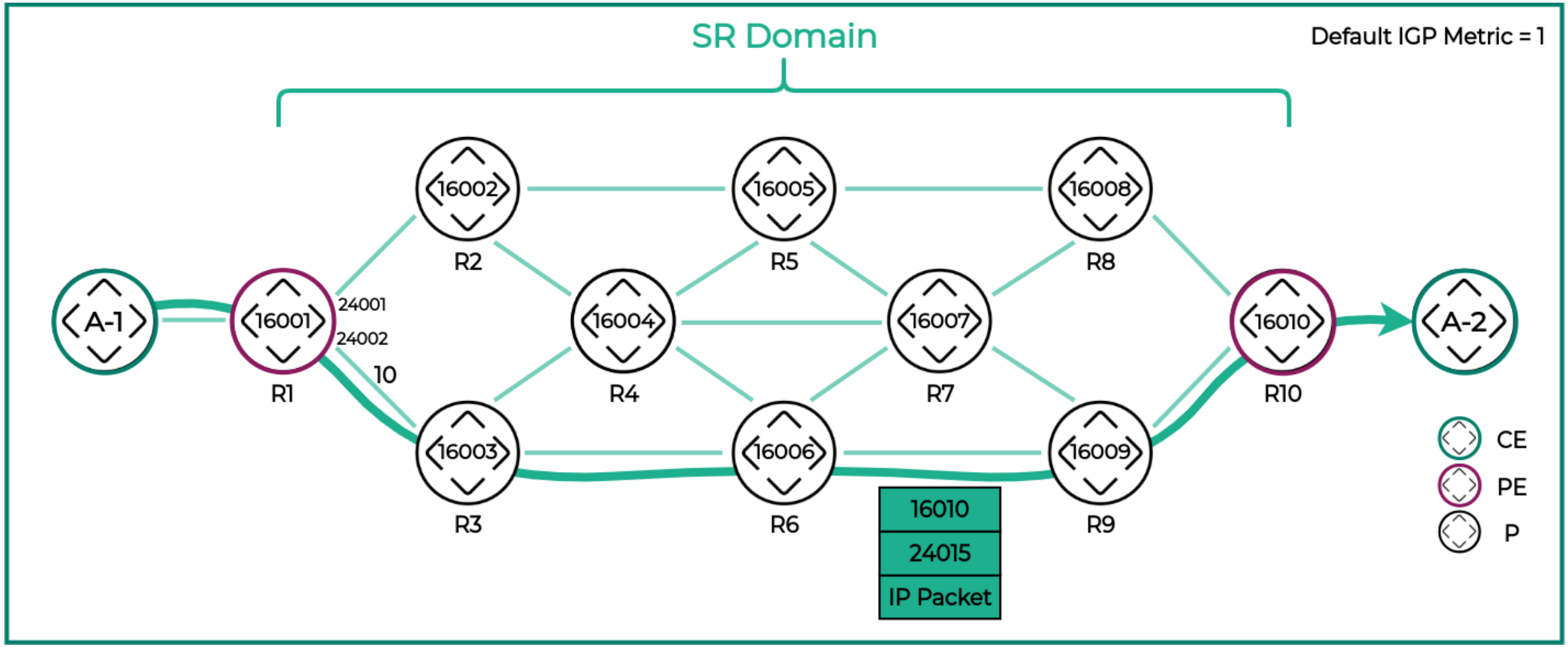
Example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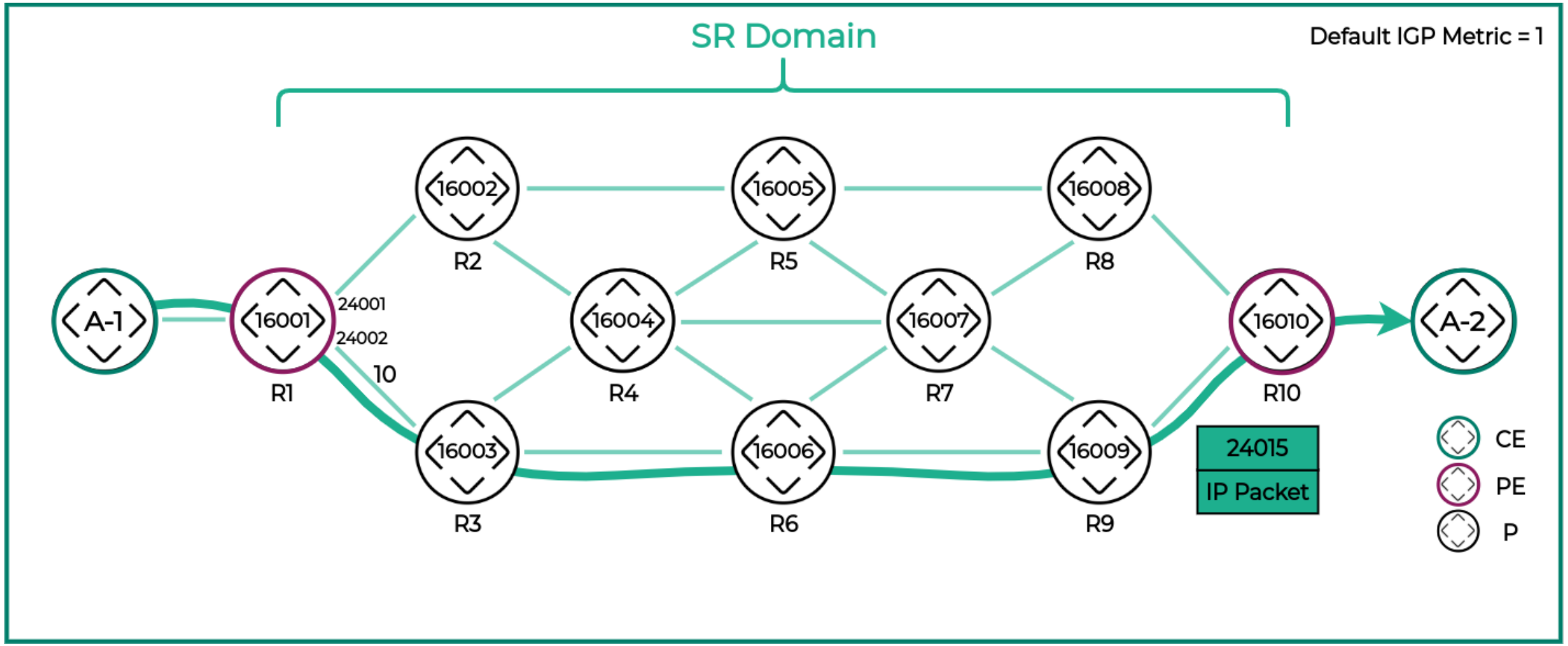
Example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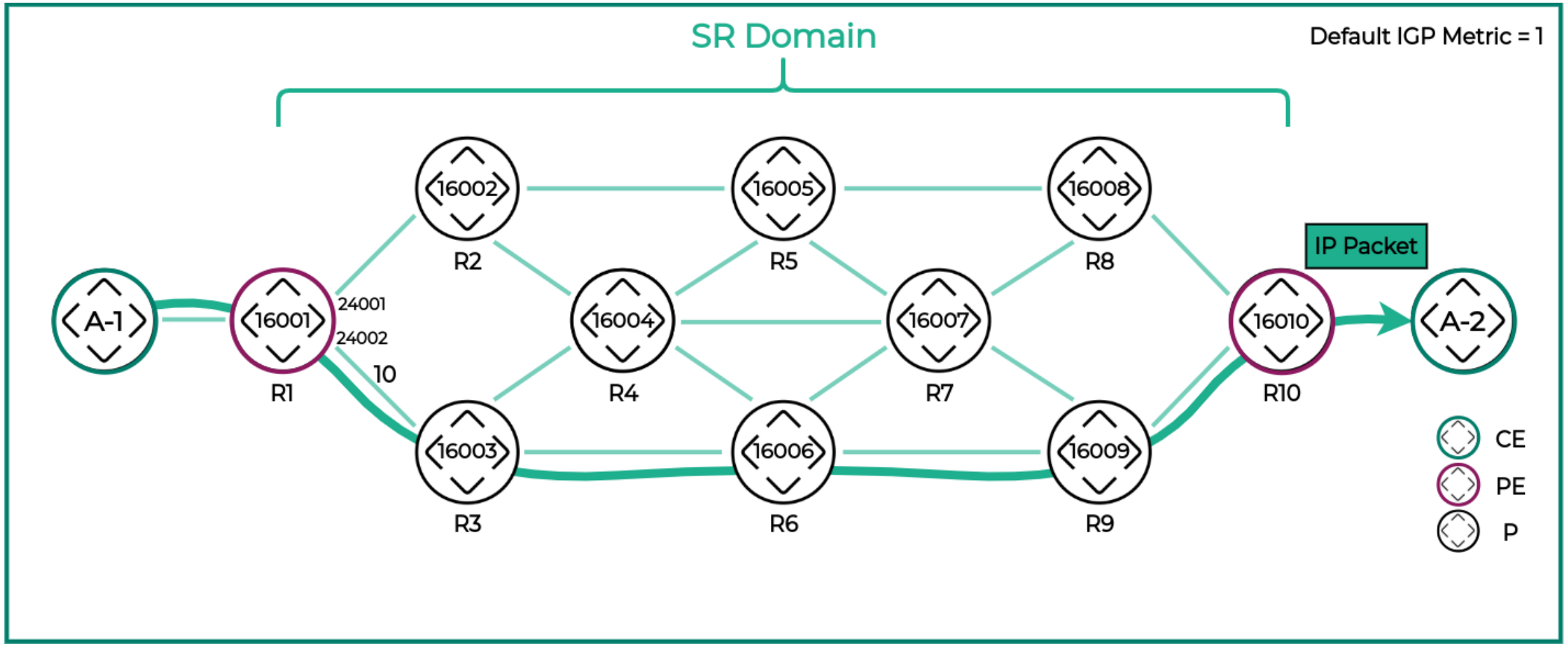
Example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16003
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R9
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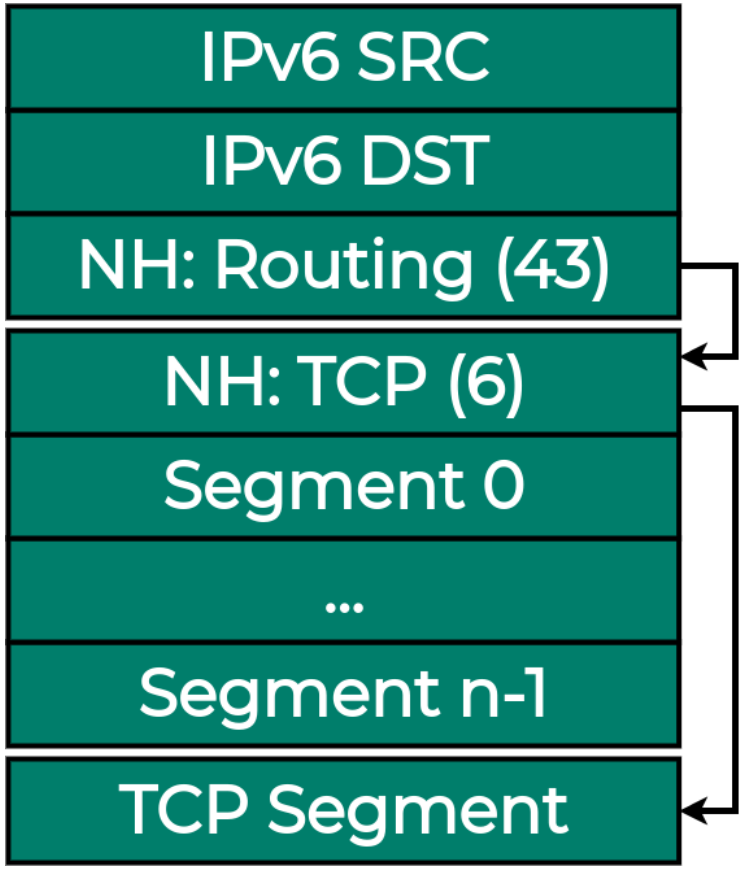
PE
P

SRv6

Segment Routing over IPv6

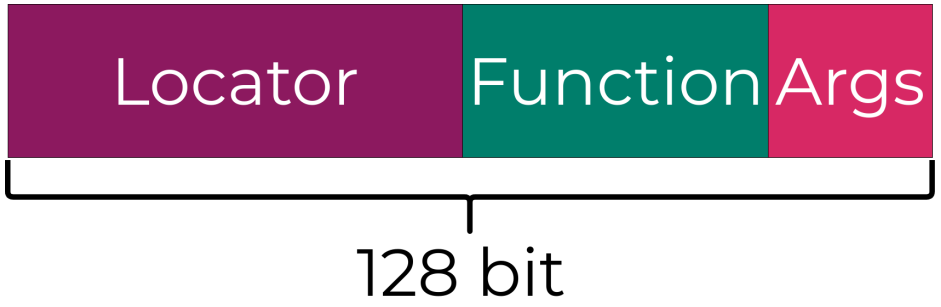
An overview

- Use IPv6 as data plane [1]
- Uses IPv6 Segment Routing Header (SRH) [3]
- Based on IPv6 Routing Headers [1]
  - Extension Header ID 43
  - Defines intermediate nodes to be "visited"



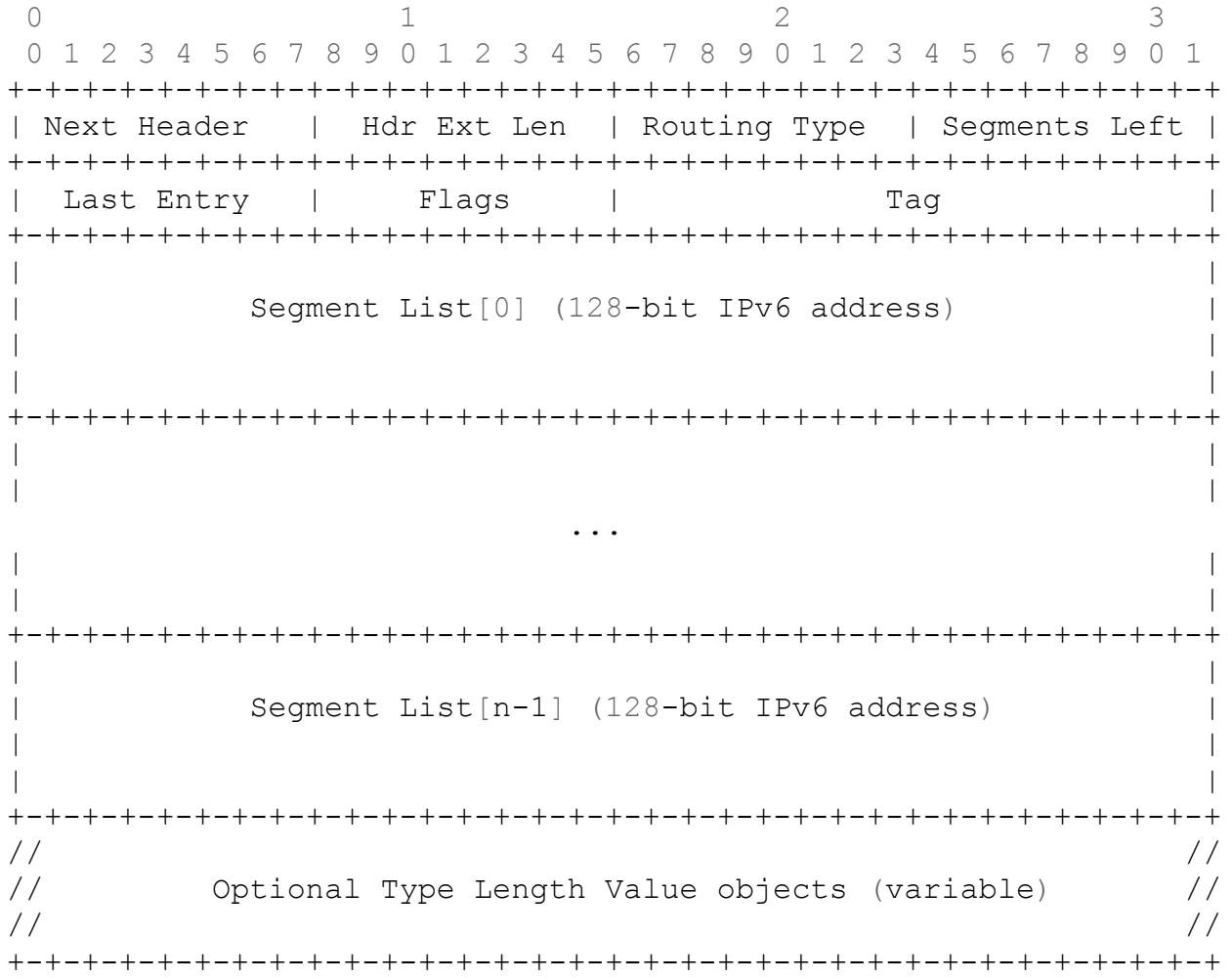
Segments

- Segments are represented IPv6 addresses
  - Overall length 128
  - Format [6]
    Locator - Routes to the node
    Function - Identifies the function to execute
    Arguments - Passed to the function
- Segment List imposed on the SRH
- Simpler and better scale
  - No MPLS signaling (only advertise IPv6 addresses)
  - Summarization (not possible in MPLS)



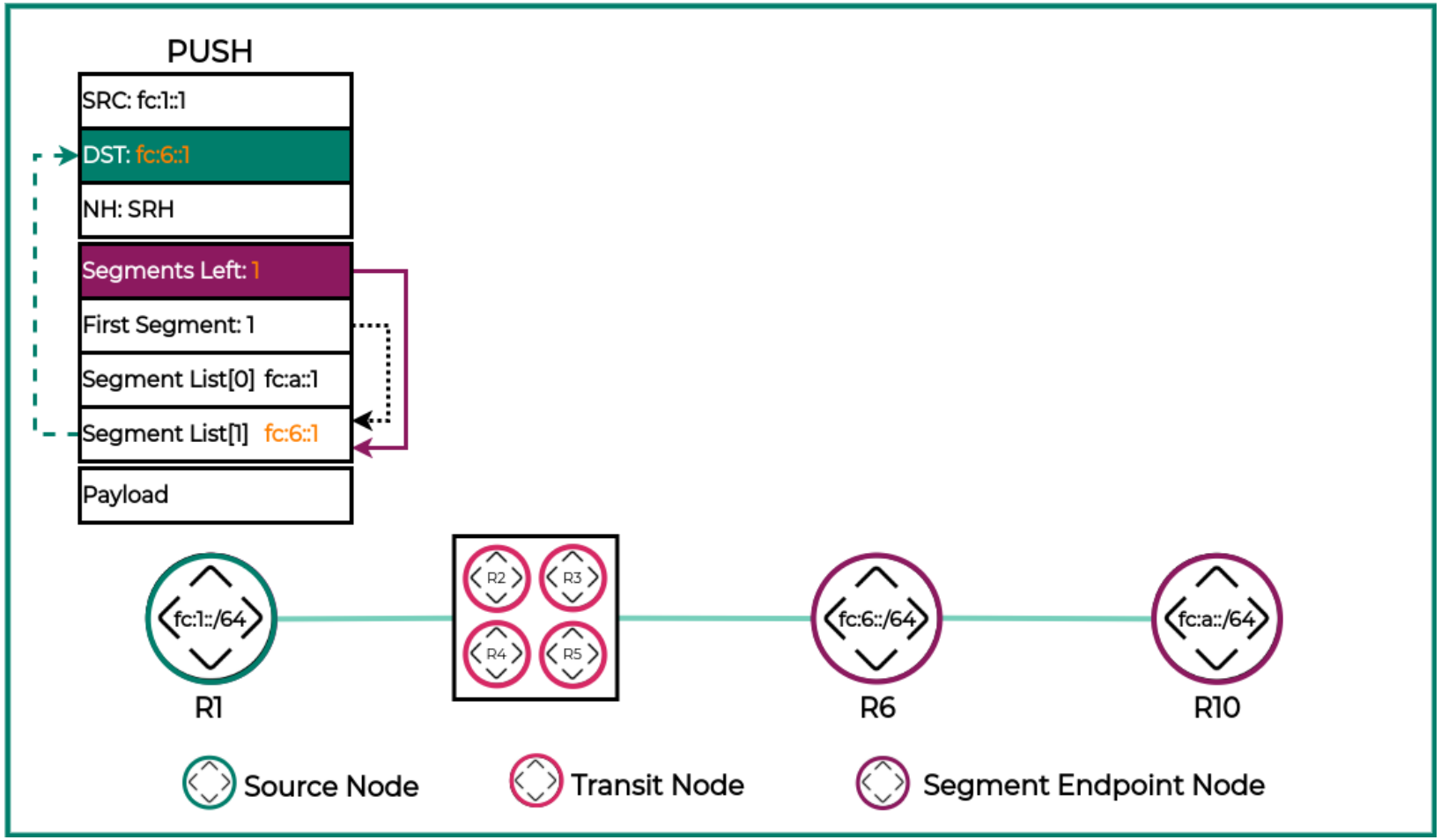
Segment Routing Header

- Routing Type = 4 (Segment Routing)
- Segments Left = Pointer Active Segment
- Last Entry = First Segment (Segment List[n-1])



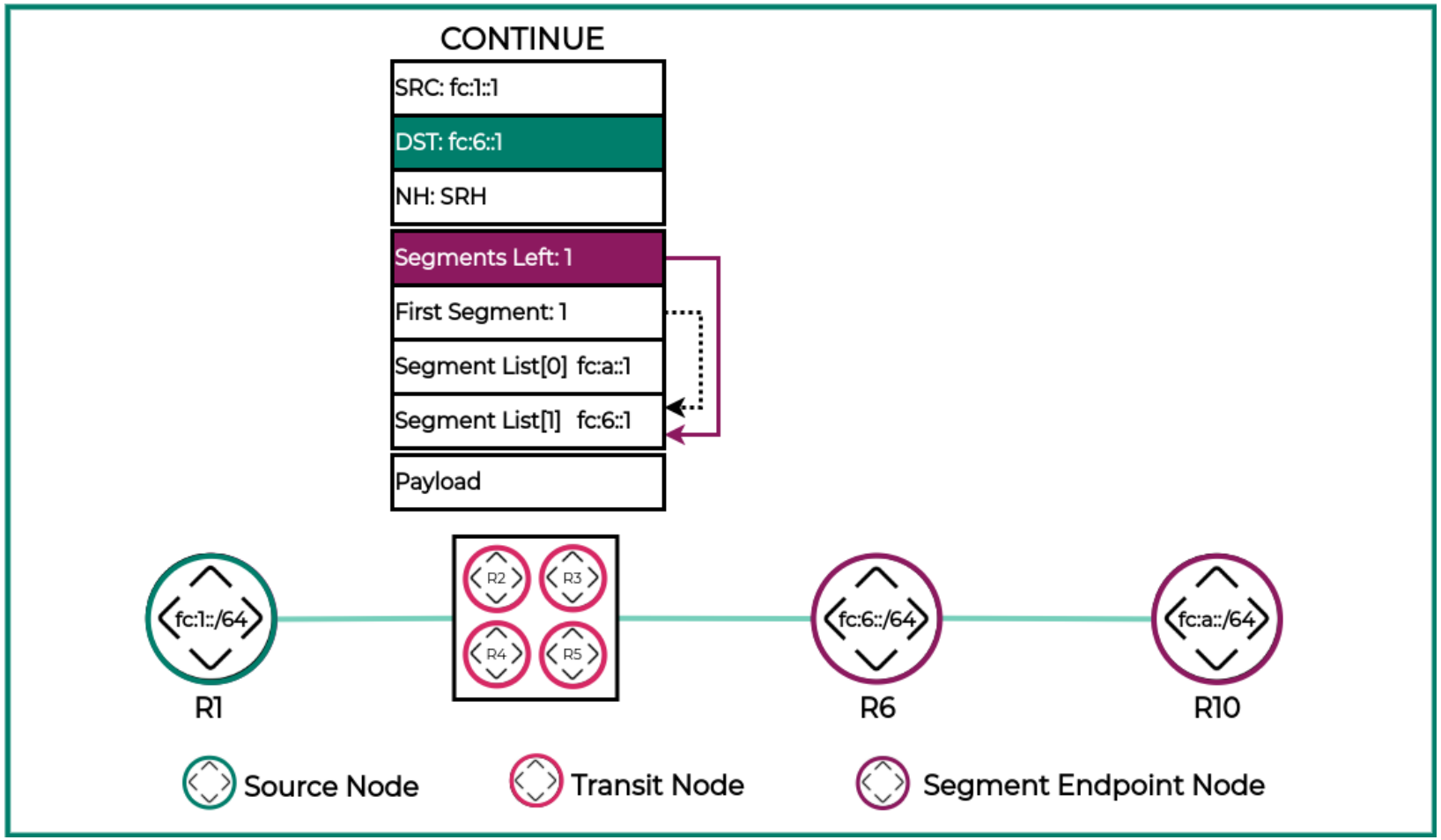
SRH Procedure: Push

Source Node : SR-capable, craft SRH



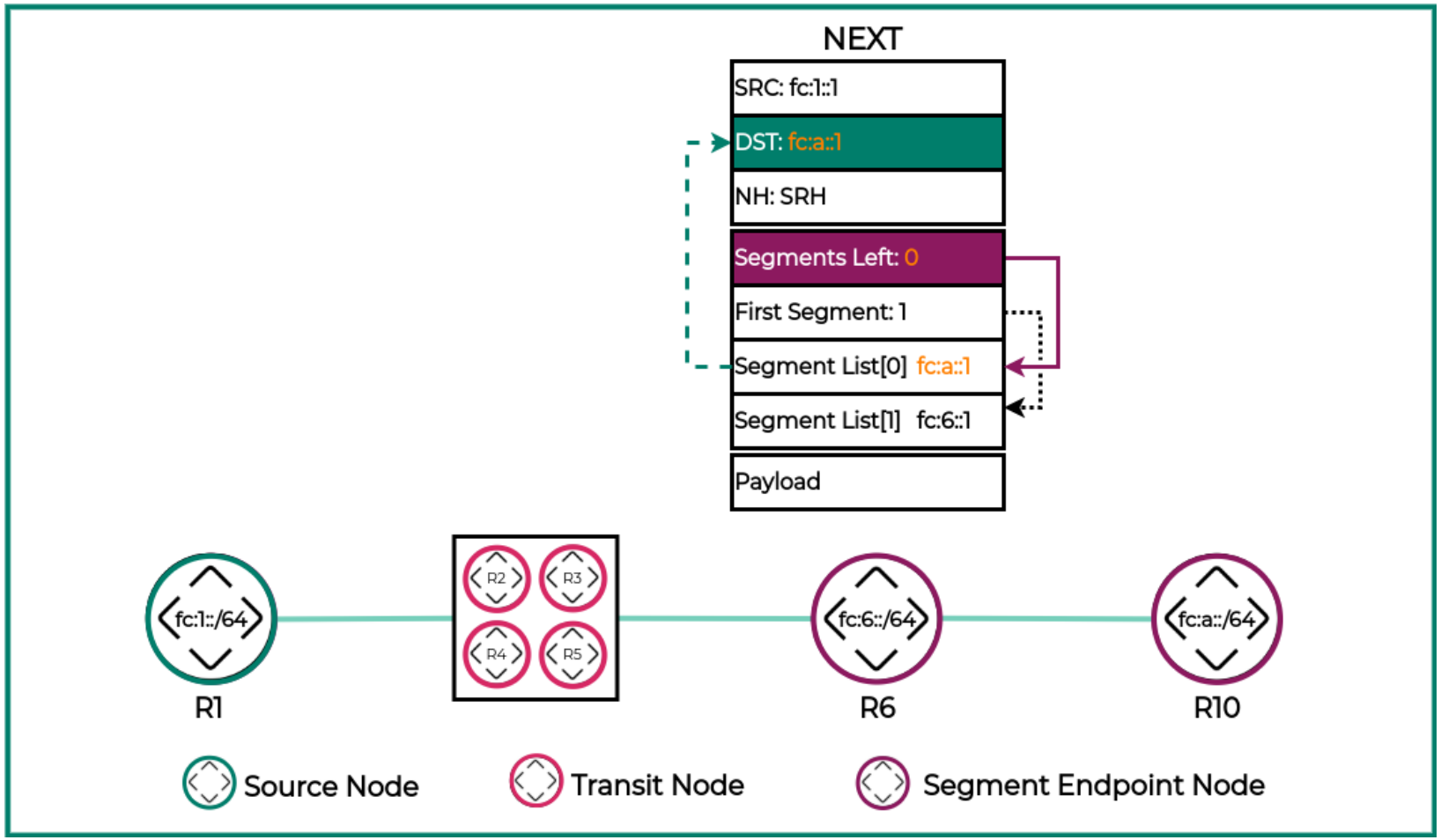
SRH Procedure: Continue

Transit Node : Plain IPv6 forwarding



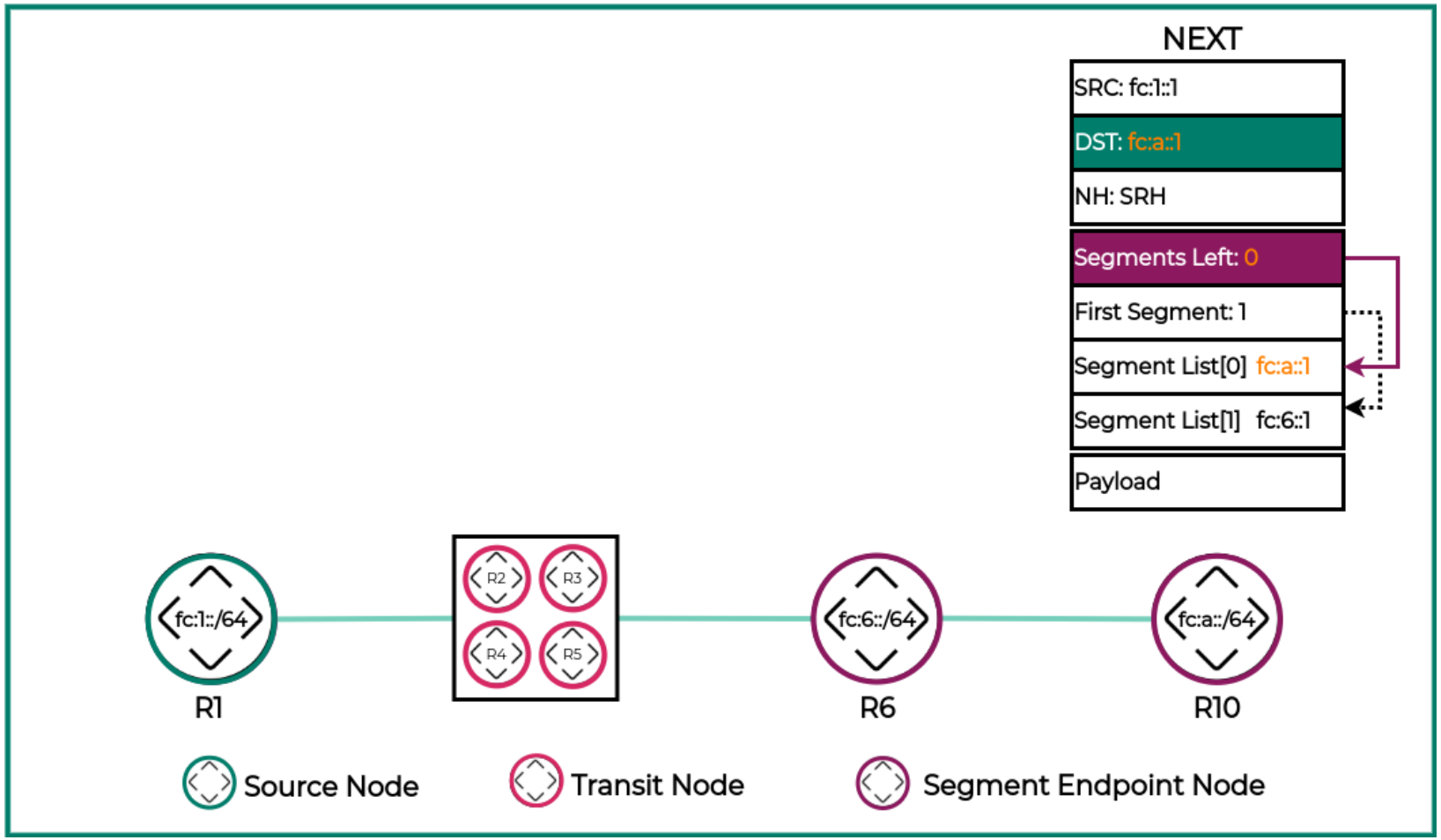
SRH Procedure: Next

Segment Endpoint Node : SR-capable, execute Active Segment



SRH Procedure: Next

Segment Endpoint Node : SR-capable, execute Active Segment



Benefits

What are the benefits of Segment Routing?

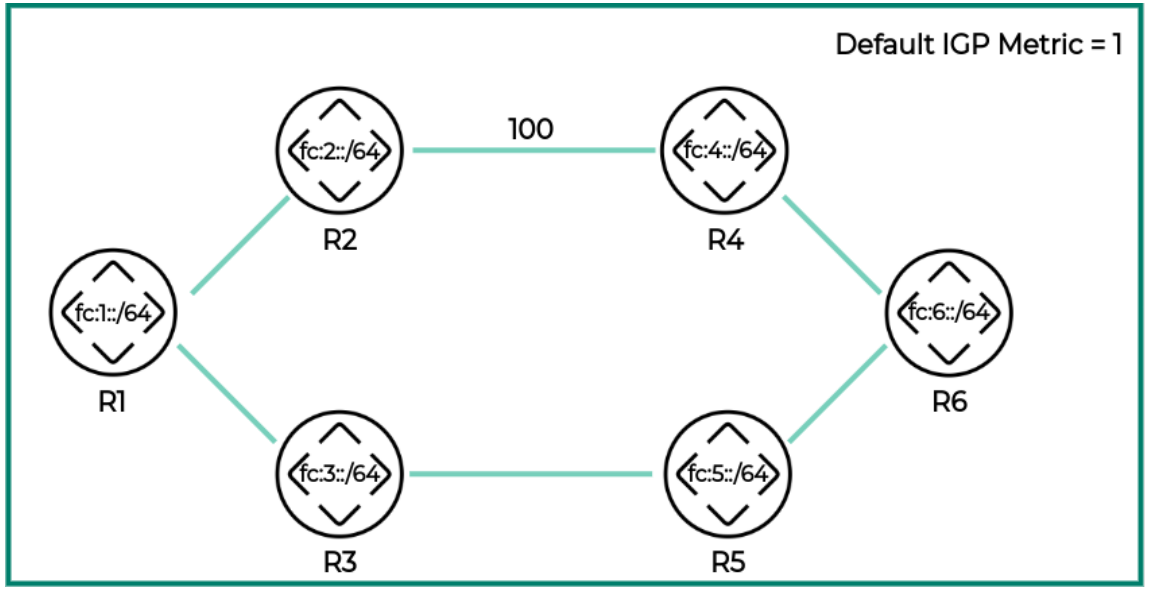
Why SR?

A source-routing architecture that seeks the right balance between distributed intelligence and centralized optimization. [11]

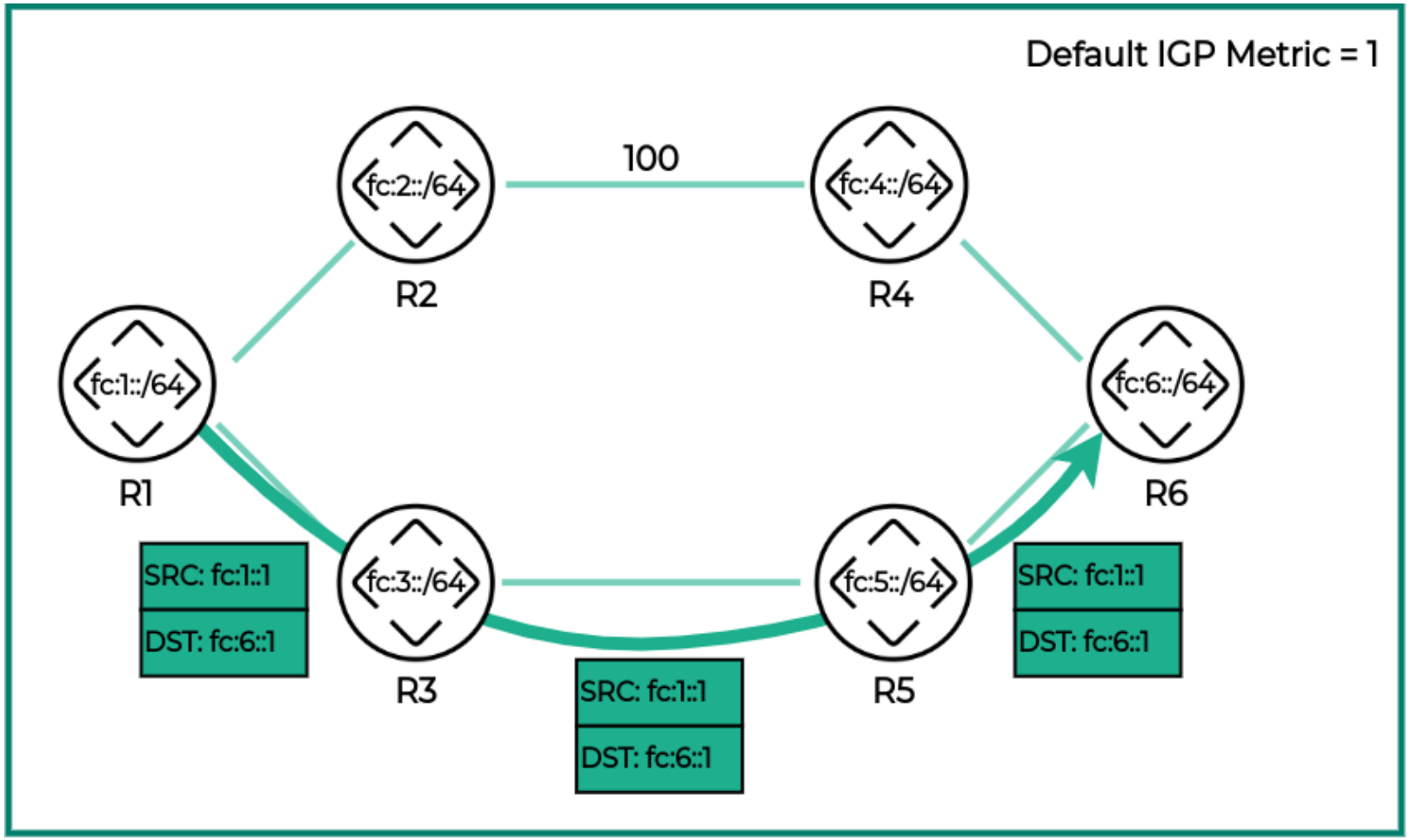
- Simplification
  - Removes unnecessary protocols
  - Simpler OAM
- Scalability
  - Per-flow state only at Ingress
  - No any path signaling
- Enhanced Traffic Engineering possibilities
- Seamless deployment
  - Based on standards
  - Reuses architecture/data plane
- Robustness
  - TI-LFA (100% coverage, <50ms)
  - Micro-loop avoidance
- Leads fundamental for network innovation

TI-LFA

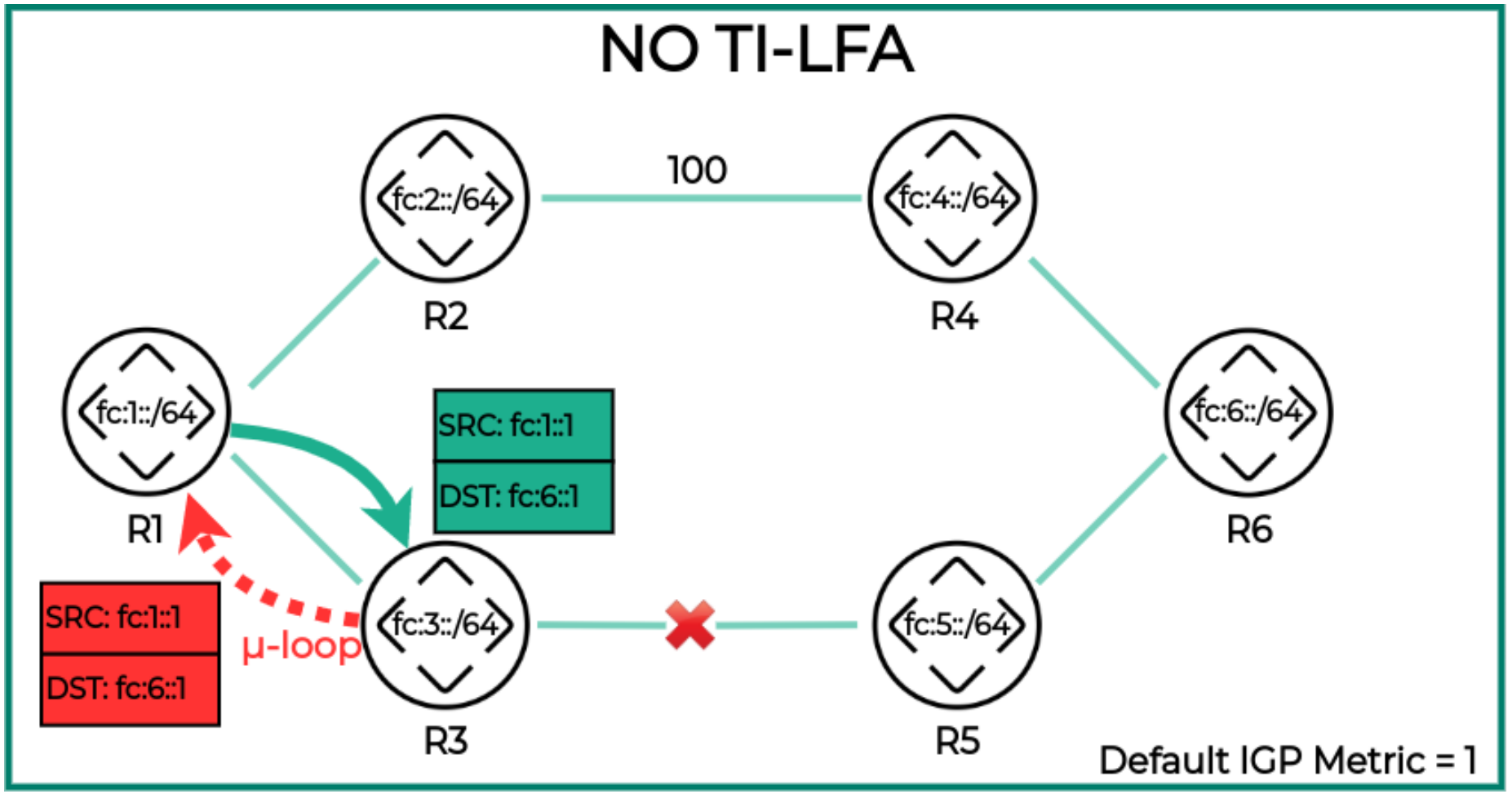
- Topology Independent Loop Free Alternate
- Prevents congestion and sub-optimal routing
- Sub-50ms in any topology any failure (node or link)
- Uses strength of Segment Routing



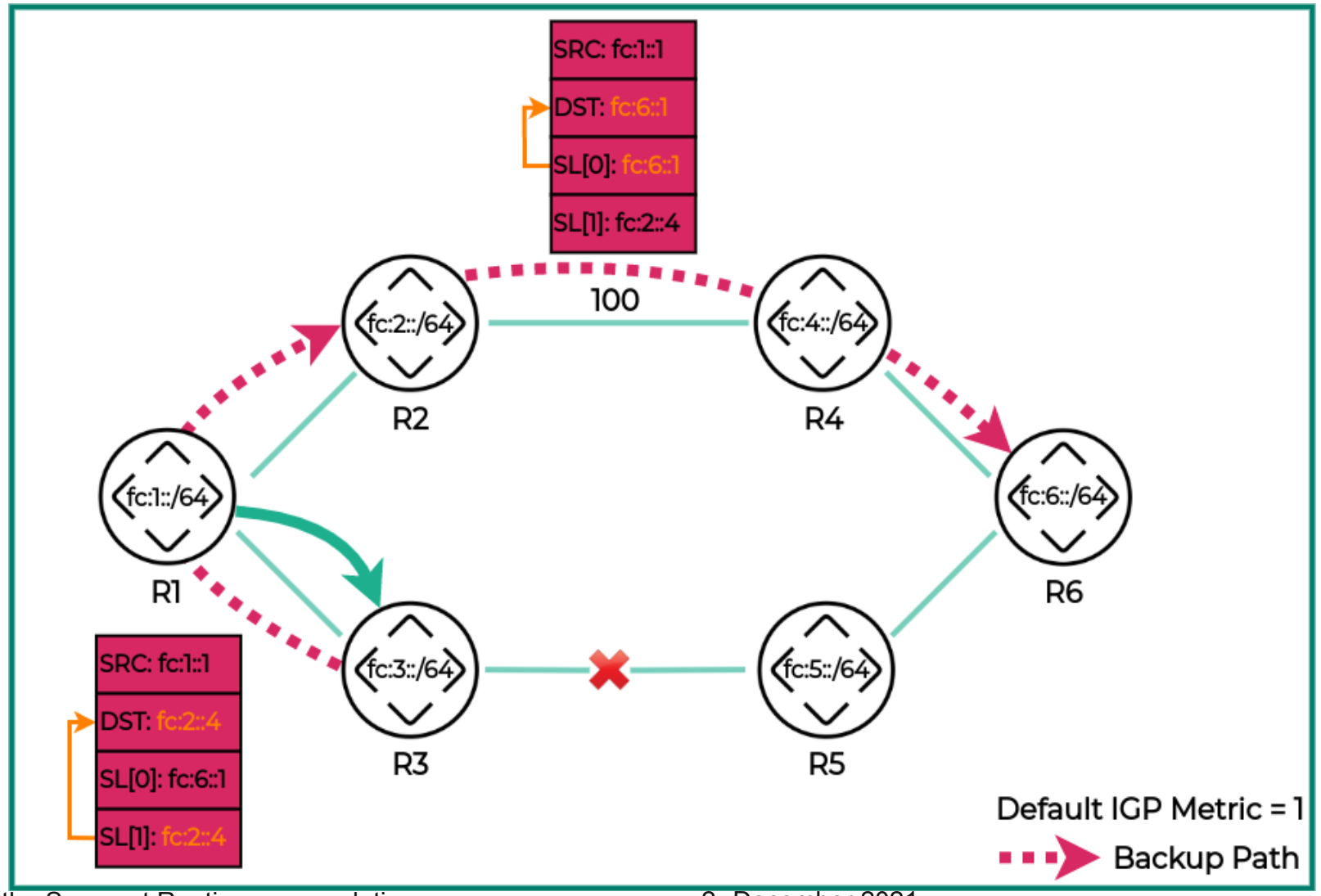
Plain IPv6 Forwarding



Missing Protection



Functionality



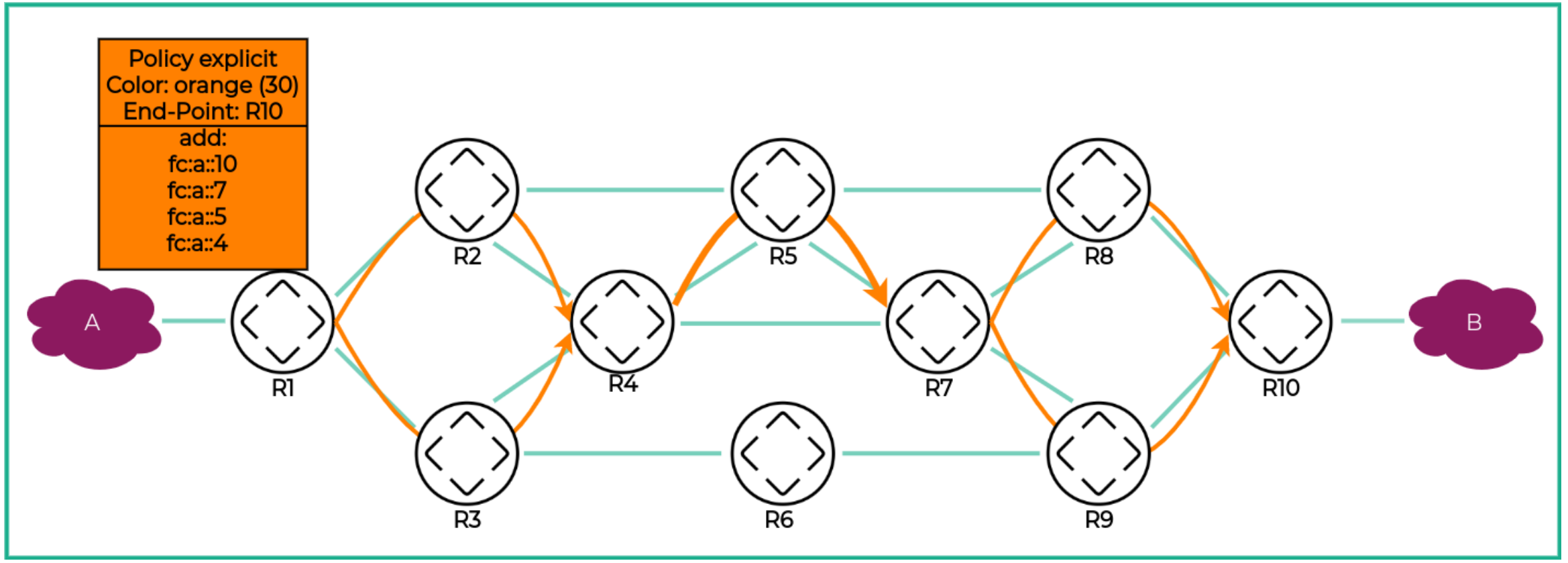
Enhanced Traffic Engineering

Segment Routing Traffic Engineering *has changed that game and has become the undisputed solution to deliver Traffic Engineering capabilities at scale. [4]*

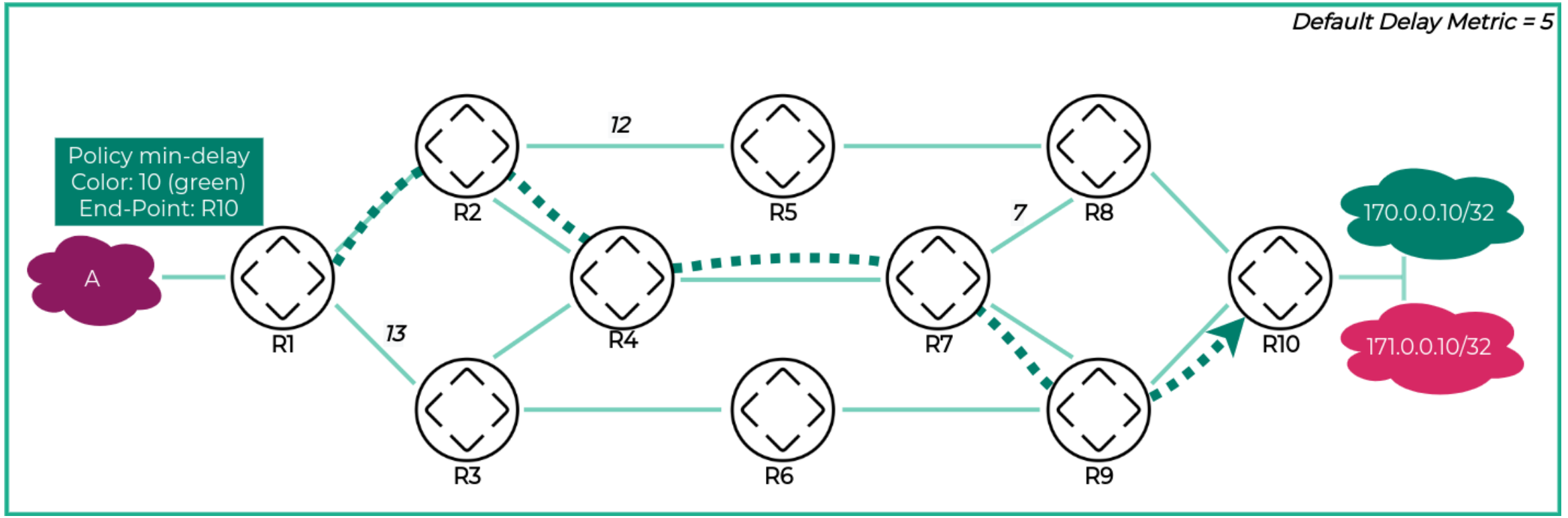
- Route traffic according to own desire
  - IGP metric
  - Delay
  - Packet loss
  - Etc.
- Use own algorithm (Flex-Algo)
- Use affinity attributes (exclude links, nodes, etc.)
- Use a explicit or dynamic method
- Use a controller (SR-PCE[3]) or not

[3] SR Path Computation Element

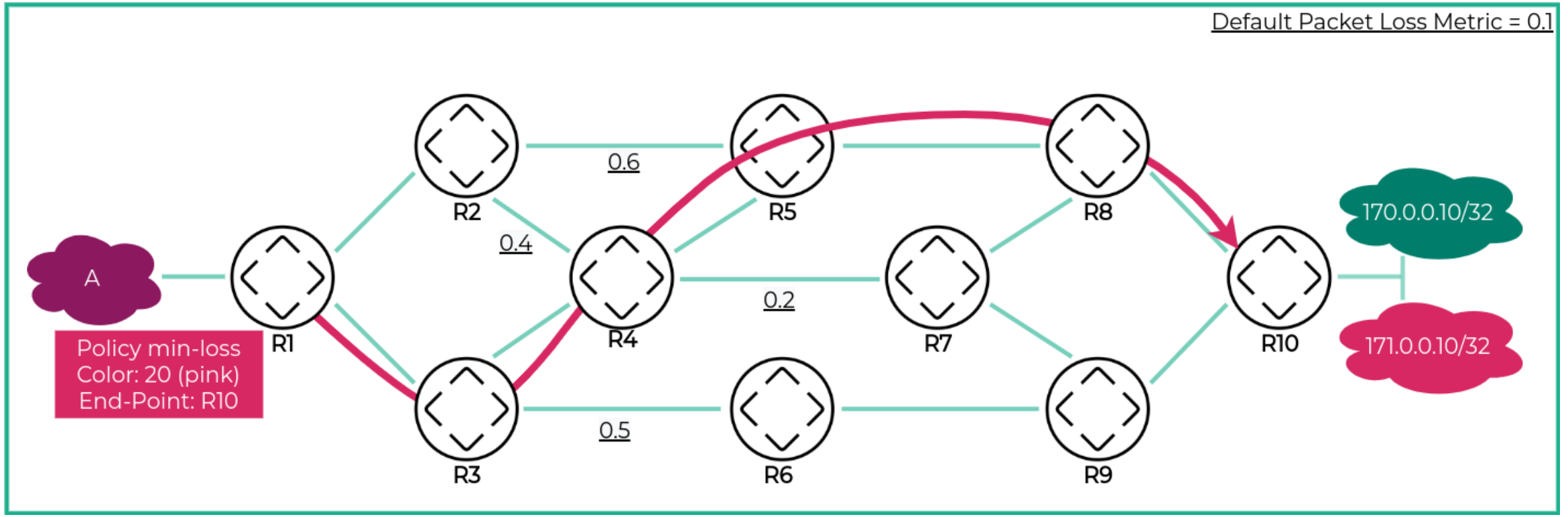
Explicit Policy



Example Minimum Delay Policy



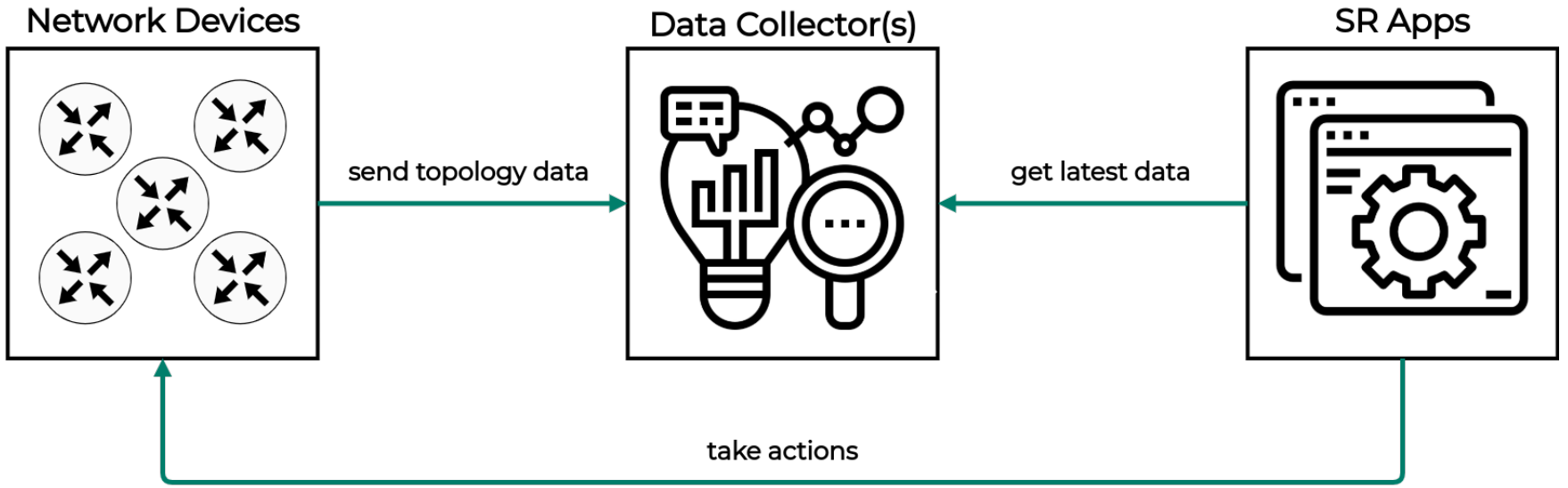
Example Minimum Packet Loss



Applications

How can we use Segment Routing to improve modern networks?

General



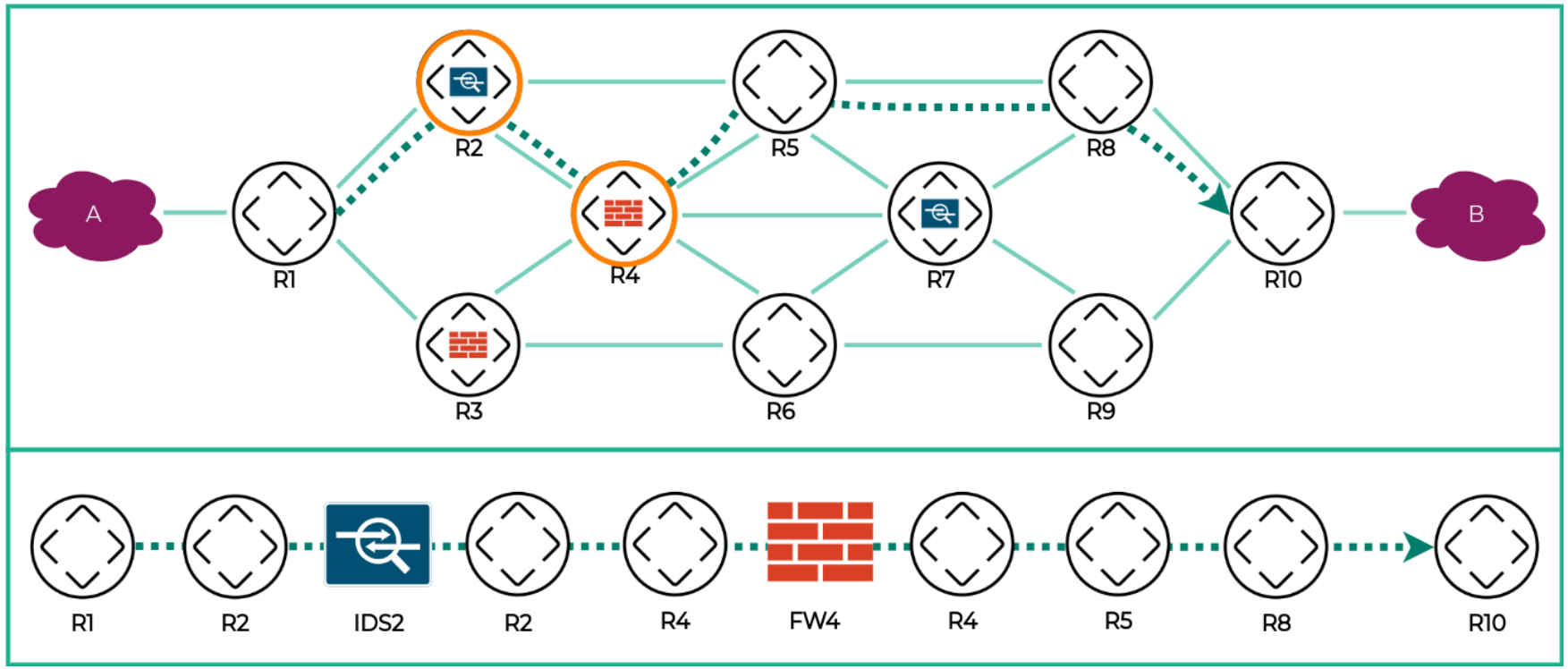
SerPro - Segment Routing Service Programming[4]

Link Saturation Prediction [5]

[4]Developed by J.Klaiber & S. Dellsperger

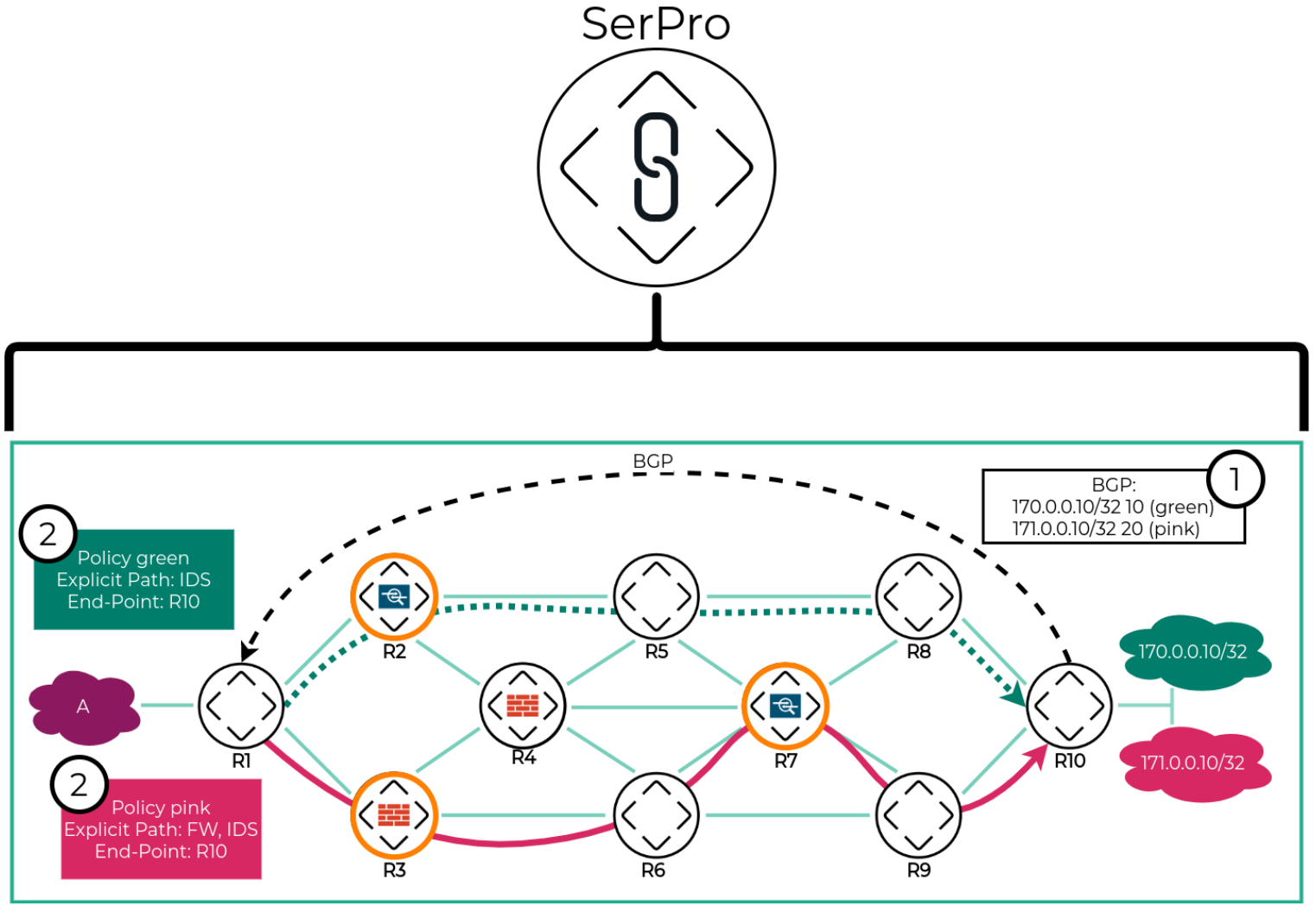
[5]Developed by M.Bongard & D.Illi

SerPro - Segment Routing Service Programming

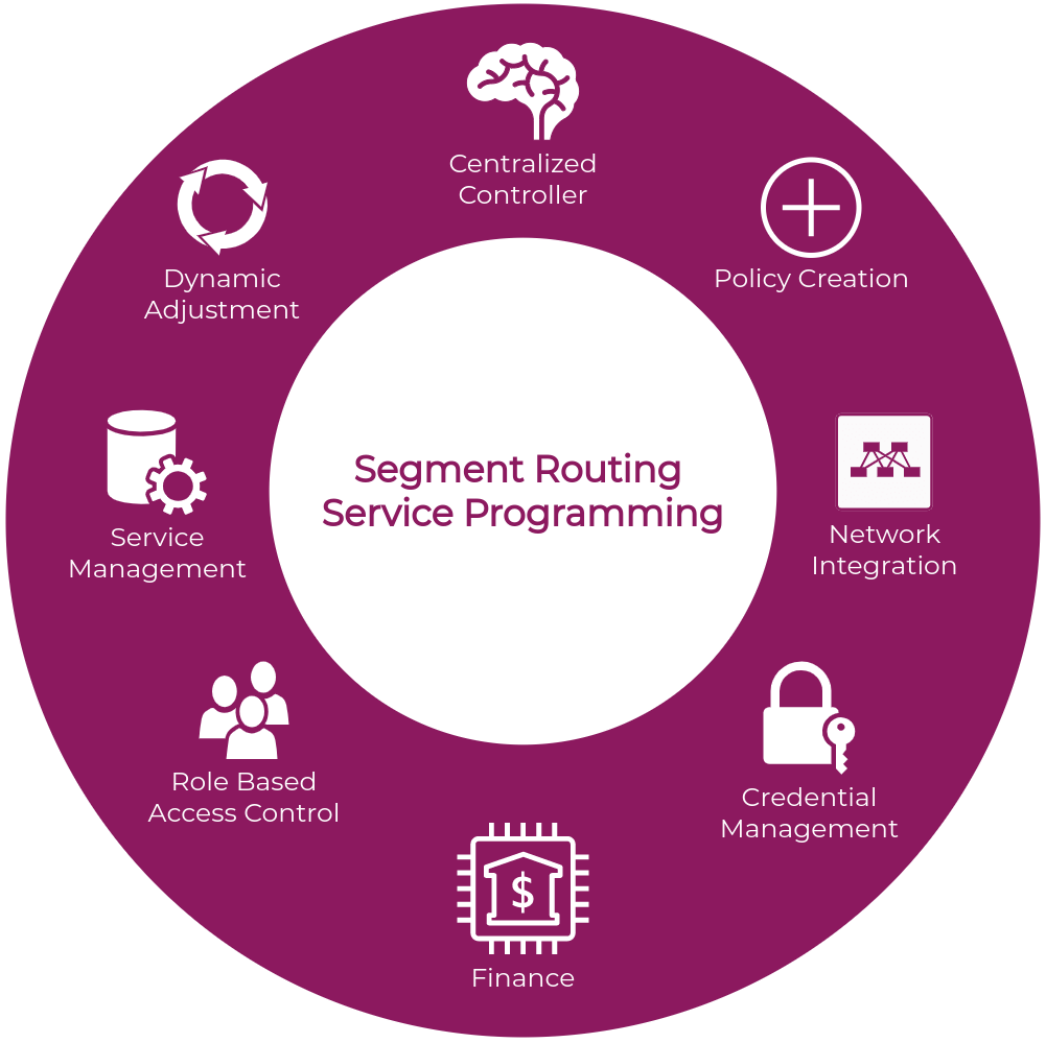


Service Programming delivers a dynamic way to program a predefined path trough the network and solves the problem of static service consumption. SerPro calculates and deploys so called SR service policies to the network in order to steer the traffic through predefined services.

Functionality

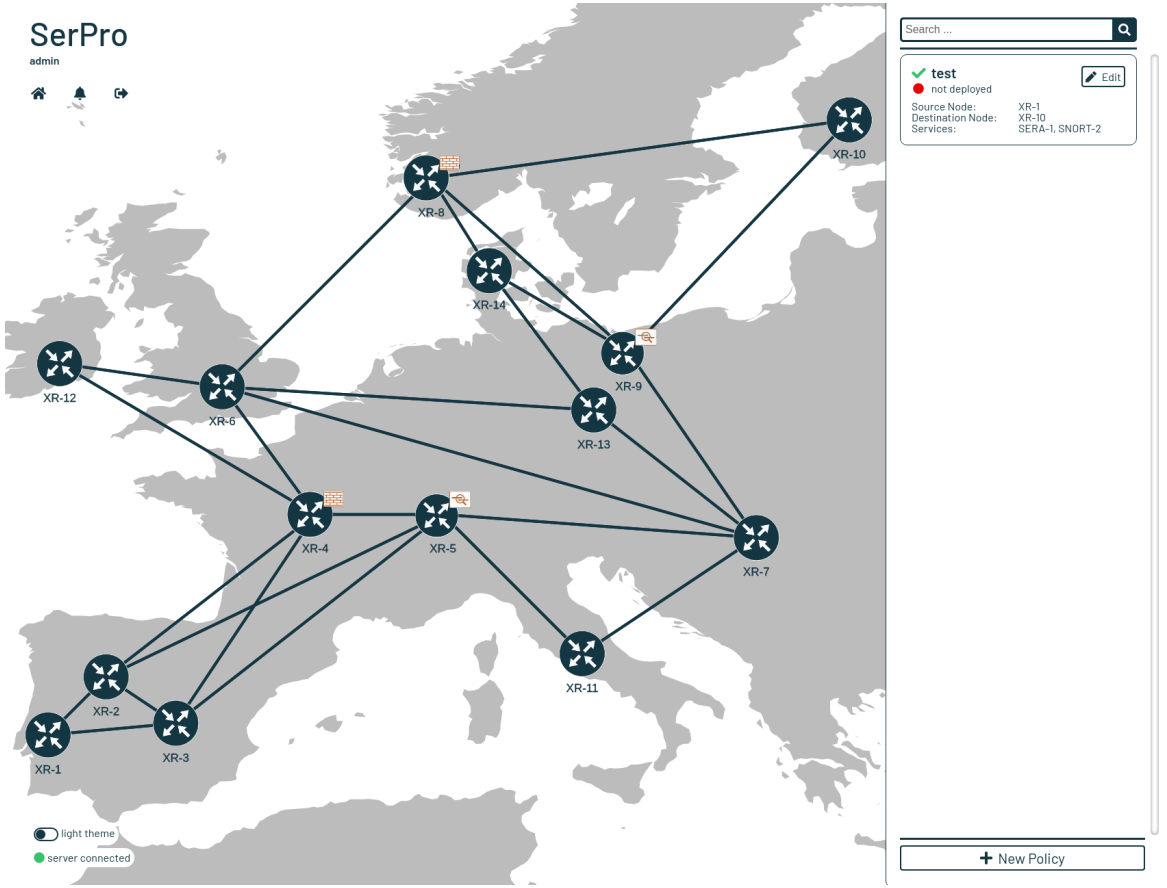


Customer Value



Demo

More information: https://www.segment-routing.ch/projects/project-serpro/
Paper submitted: Dynamic Service Programming with Preprocessing



Link Saturation Prediction

"This project focused on the development of an application in the field of analytics to provide information about the general network health state and link saturation in case of topology changes."

#1 View current network state

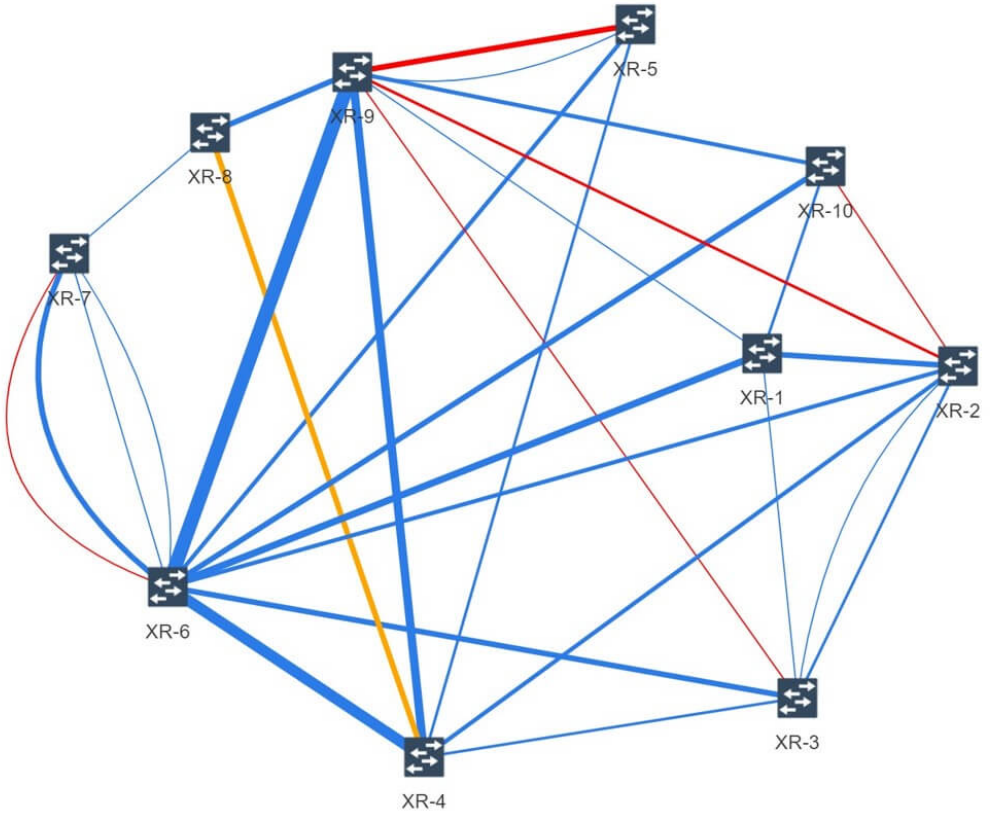
#2 Calculate network saturation

#3 Simulate topology changes

Link Quality Assessment I

Color coding

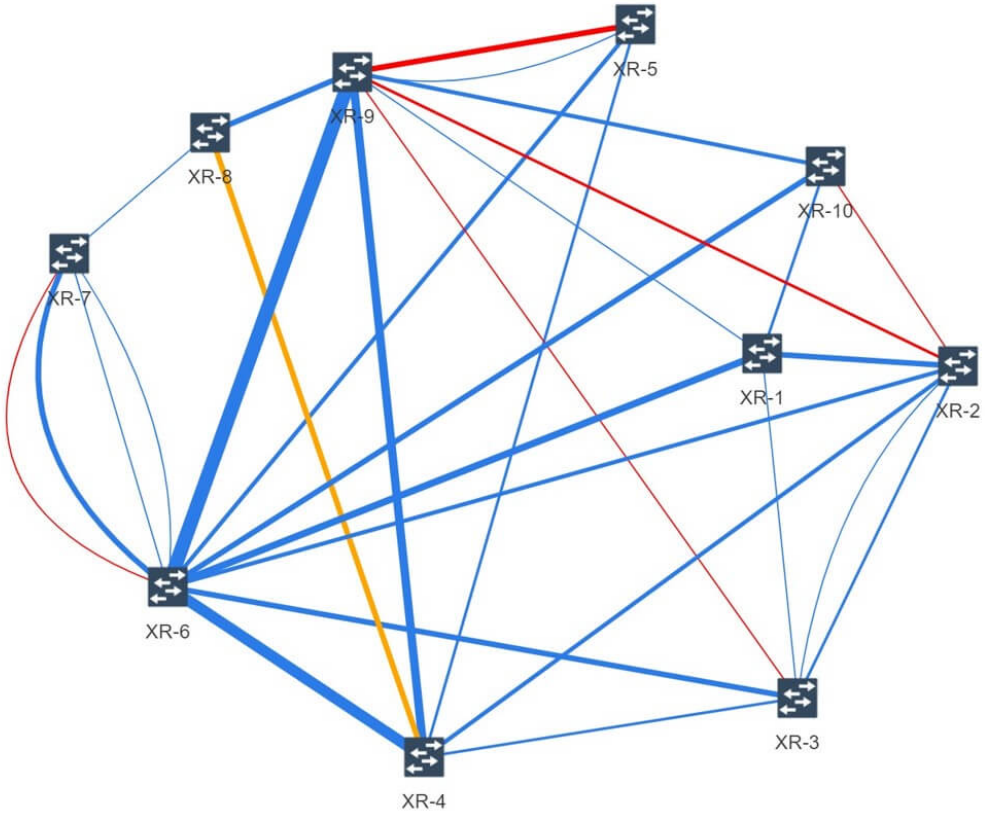
- Link colors based on quality
  - Blue: low
  - Orange: medium
  - Red: high
- Different metrics
  - Link delay
  - Packet loss
  - Link saturation



Link Quality Assessment II

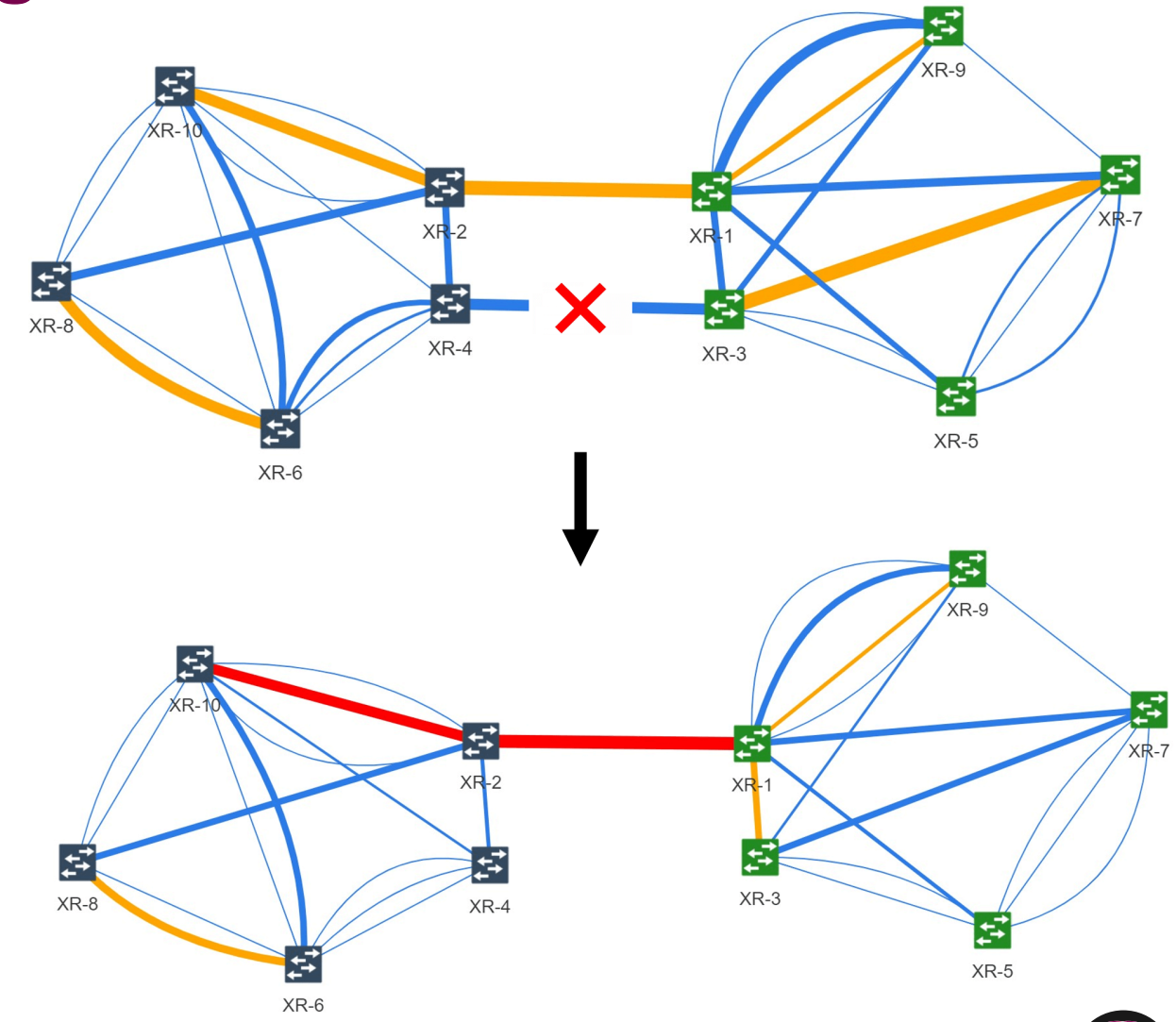
Link Thickness

- Represents importance
- The thicker the more important
- Based on # of shortest paths



Simulate Network Changes

- Changes trigger recalculation
- Changes such as:
  - Removing/Adding links
  - Removing/Adding nodes
  - Adjust link/node properties



Demo

More information: https://www.segment-routing.ch/projects/project-lsp/

Questions

Do you have any **questions**?

Please do not hesitate to contact `cloud-networking@ost.ch` or visit https://www.segment-routing.ch

References I

[1] Dr. Steve E. Deering and Bob Hinden. *Internet Protocol, Version 6 (IPv6) Specification*. RFC 8200. July 2017. DOI: 10.17487/RFC8200. URL: https://rfc-editor.org/rfc/rfc8200.txt.

[2] Clarence Filsfils, Kris Michielsen, and Ketan Talaulikar. *Segment Routing. Part 1*. Independently published, 2016.

[3] Clarence Filsfils et al. *IPv6 Segment Routing Header (SRH)*. RFC 8754. Mar. 2020. DOI: 10.17487/RFC8754. URL: https://rfc-editor.org/rfc/rfc8754.txt.

[4] Clarence Filsfils et al. *Segment Routing. Part 2*. Independently published, 2019.

[5] Clarence Filsfils et al. *Segment Routing Architecture*. RFC 8402. July 2018. DOI: 10.17487/RFC8402. URL: https://rfc-editor.org/rfc/rfc8402.txt.

[6] Clarence Filsfils et al. *Segment Routing over IPv6 (SRv6) Network Programming*. RFC 8986. Feb. 2021. DOI: 10.17487/RFC8986. URL: https://rfc-editor.org/rfc/rfc8986.txt.

References II

[7] Stefano Previdi et al. *Border Gateway Protocol - Link State (BGP-LS) Extensions for Segment Routing BGP Egress Peer Engineering*. RFC 9086. Aug. 2021. DOI: 10.17487/RFC9086. URL: https://rfc-editor.org/rfc/rfc9086.txt.

[8] Stefano Previdi et al. *IS-IS Extensions for Segment Routing*. RFC 8667. Dec. 2019. DOI: 10.17487/RFC8667. URL: https://rfc-editor.org/rfc/rfc8667.txt.

[9] Peter Psenak and Stefano Previdi. *OSPFv3 Extensions for Segment Routing*. RFC 8666. Dec. 2019. DOI: 10.17487/RFC8666. URL: https://rfc-editor.org/rfc/rfc8666.txt.

[10] Peter Psenak et al. *OSPF Extensions for Segment Routing*. RFC 8665. Dec. 2019. DOI: 10.17487/RFC8665. URL: https://rfc-editor.org/rfc/rfc8665.txt.

[11] Unknown. *Segment Routing Website*. https://segment-routing.net. [Online; accessed 30-November-2021]. 2021.