



# Inter-Domain Color-Aware Routing with BGP-CAR

## Overview and Interoperability Demonstration

Cisco Systems  
April 2023

# Objectives

- Overview of BGP Color-Aware Routing (BGP-CAR)
- BGP-CAR interoperability demonstration between Cisco Systems and Arrcus



# Agenda

- Color-Aware Routing Principles – Reminder
- BGP-CAR Overview
- BGP-CAR Demonstration and Interop

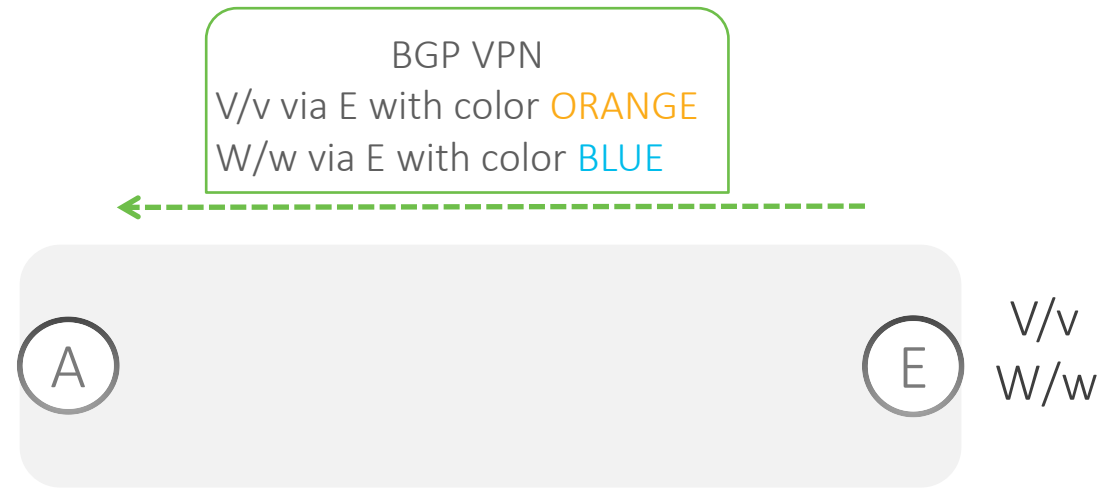
Reminder

Color-Aware Routing Principles

# Intent encoded as a color

- Color is a standard way to signal intent
  - A 32-bit number
- Mapping an intent to a color:
  - Low-latency: BLUE
  - Low-cost: ORANGE
- Colored Service Routes – requesting a particular intent
- Color-aware Transport Routes – satisfying a particular intent
- A colored service route is steered over a color-aware route of same intent

# Colored service route

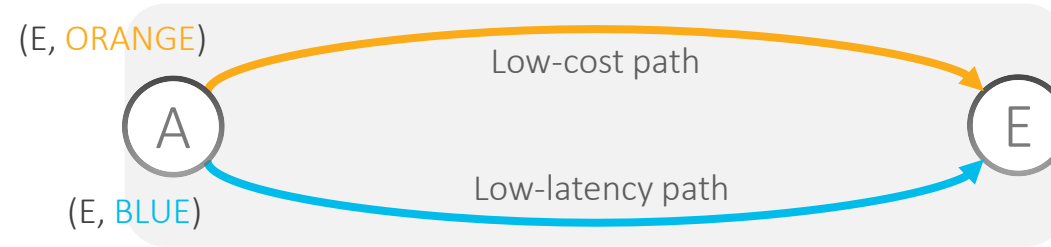


- E sends colored service routes, each **requesting** a particular intent
- Route coloring is done by using the BGP Color Extended-Community
  - Standard ([RFC5512](#) / [RFC9012](#)), supported by all major BGP implementations
- Any service route can be colored (L3VPN, EVPN, Internet routes)

# Color-aware transport routes

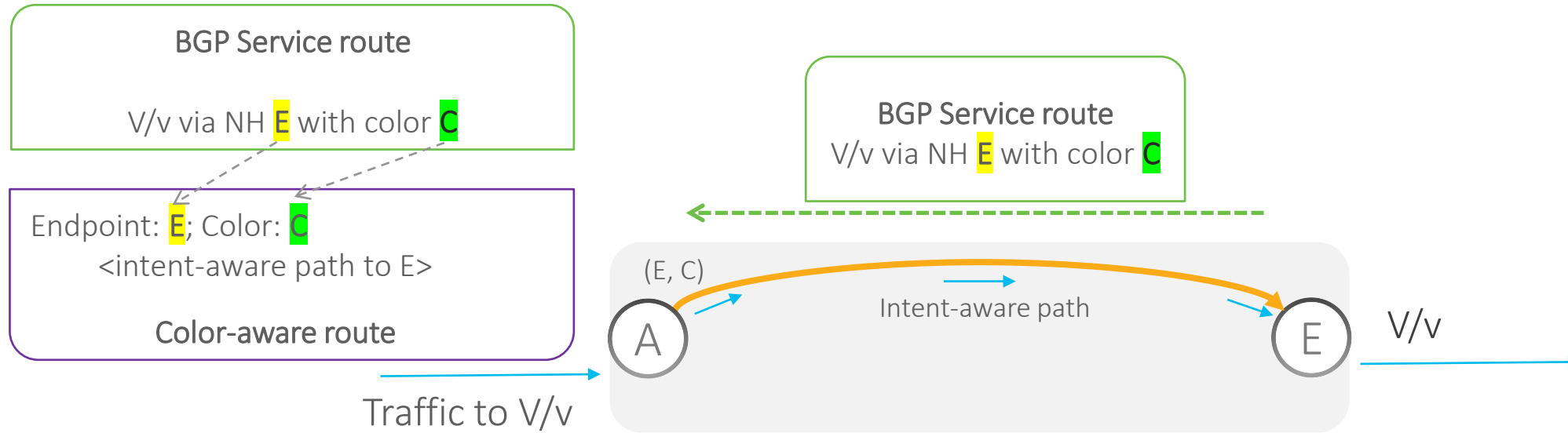
Color-aware routes @ A:

Endpoint	Color	Path
E	ORANGE	<low-cost path A to E>
E	BLUE	<low-latency path A to E>



- A color-aware route satisfies a particular intent
- A color-aware route is identified by the tuple (Endpoint and Color); in short (E,C)
- A color-aware route can be signaled/instantiated by different mechanisms

# Service routes steered on color-aware route



- A colored service route is steered over a color-aware route of same intent
  - Traffic destined to prefix V/v via **E** with color **C** is steered over color-aware route (E, C)

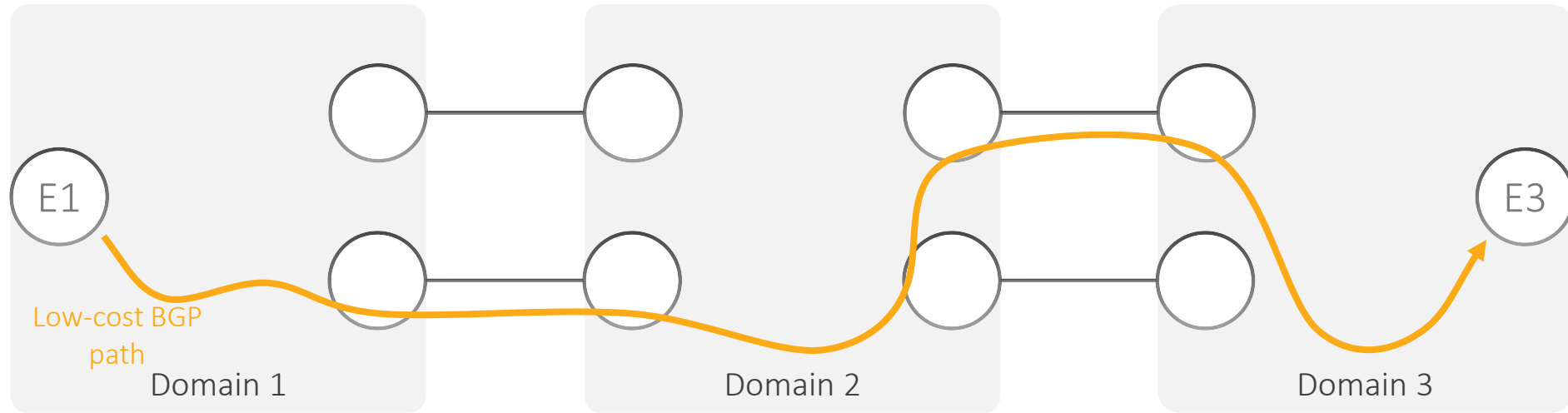


# Color-aware route suppliers

- Color-aware transport route suppliers
  - SR Policy ([RFC9256](#)) ✓ Shipping / Deployed
  - IGP Flex Algo ([RFC9350](#)) ✓ Shipping / Deployed
  - BGP Color-Aware Routing (BGP-CAR) A new alternative

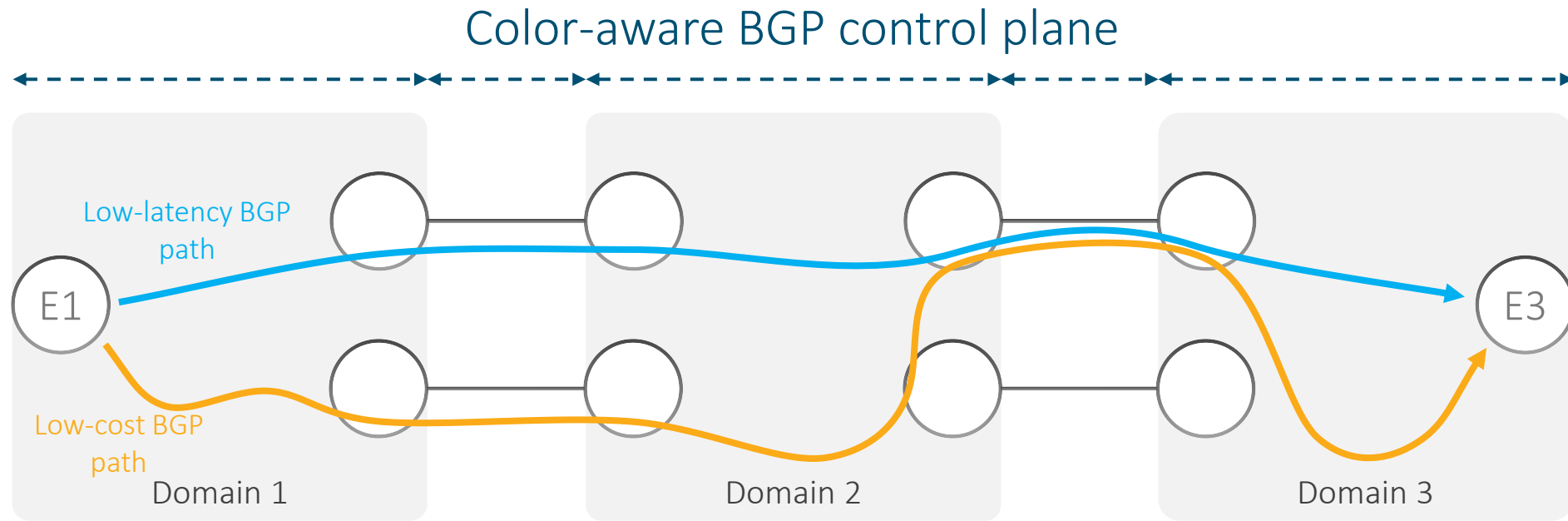
# Introducing BGP Color-Aware Routing (BGP-CAR)

# Introducing BGP-CAR



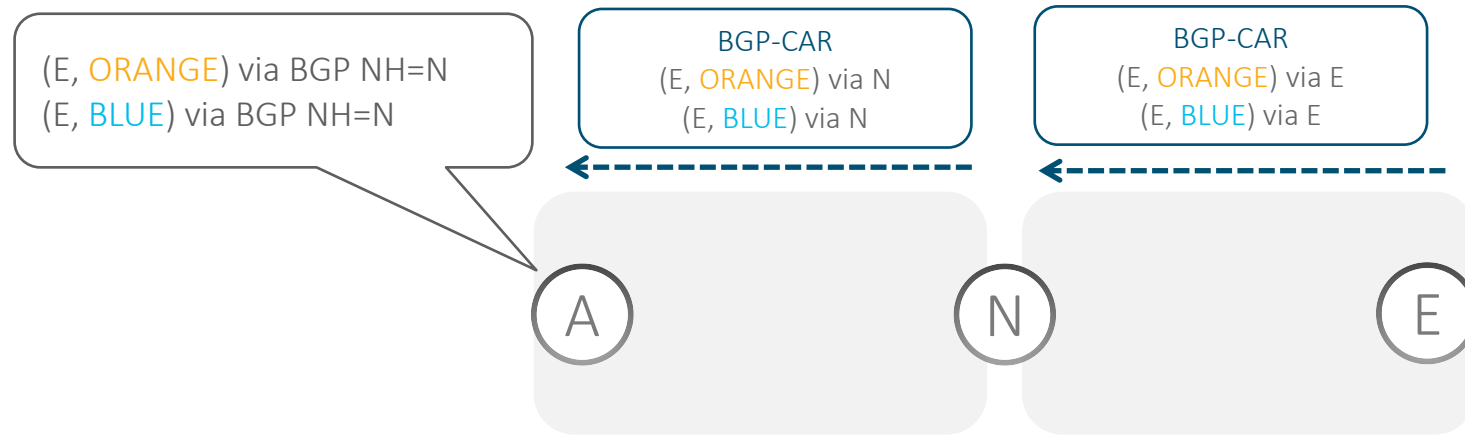
- Inter-domain Best Effort path provided by BGP-LU ([RFC3107](#) / [RFC8277](#)) / BGP-SR ([RFC8669](#))

# Introducing BGP-CAR



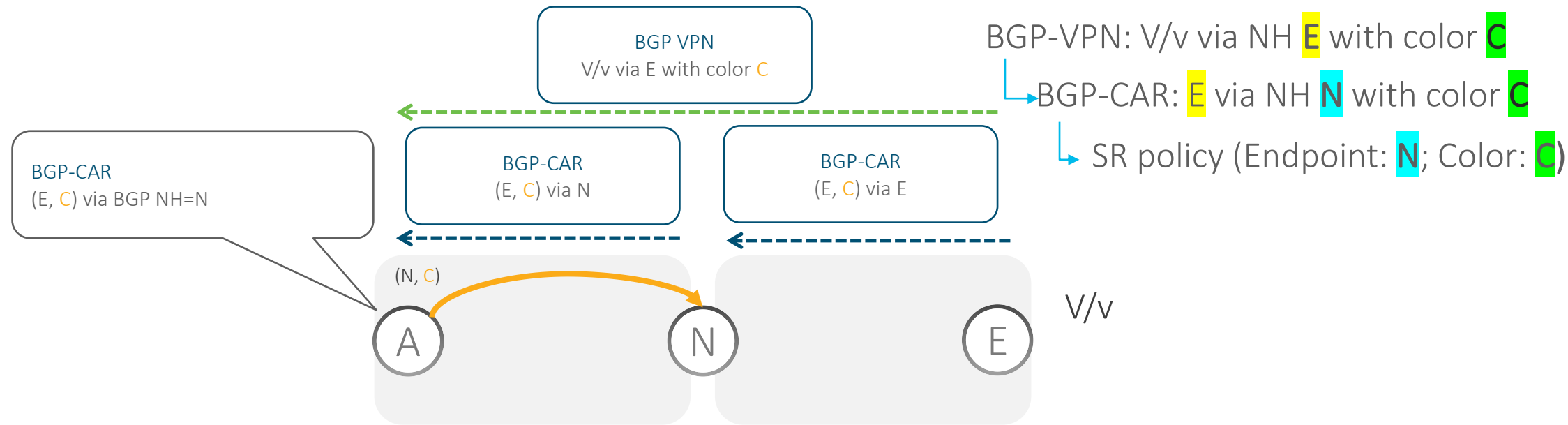
- BGP-CAR provides [inter-domain Color-Aware \(intent\) path](#) using any type of encapsulation
  - Inter-domain within an AS (multiple IGP domains) or across ASes
- References – [Problem Statement](#) / [Draft](#)

# Color-aware route (E, C) provided by BGP route via N



- New BGP SAFI to signal a color-aware route (E, C):
  - A BGP hop-by-hop routed path to E which satisfies the intent mapped to color C

# BGP-CAR route resolution on color-aware route (N, C)



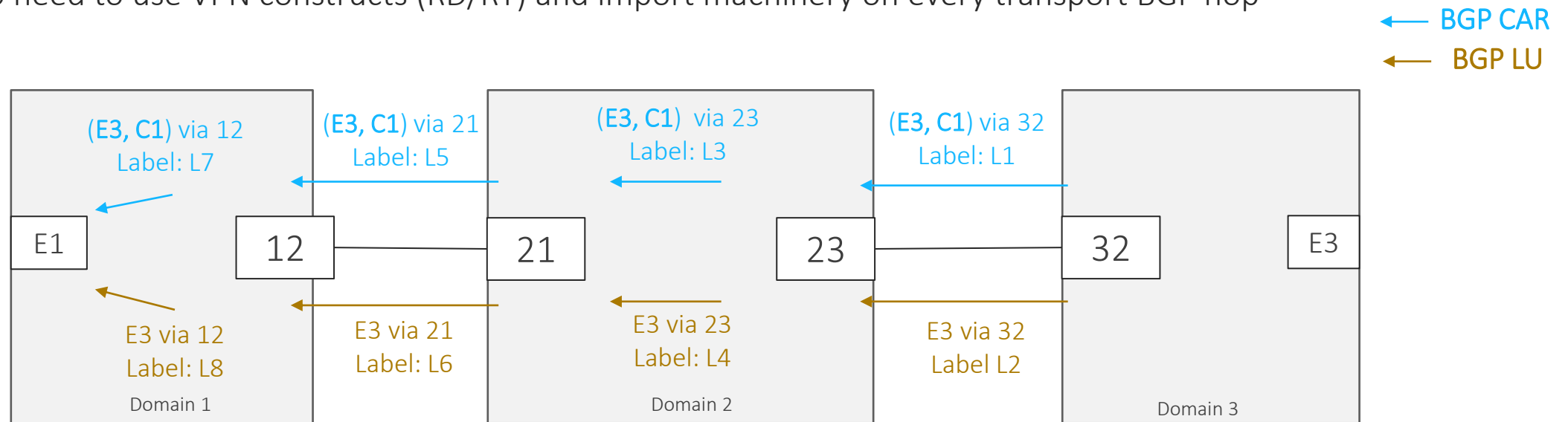
1. BGP service route V/v via E is colored C
2. V/v via E with C is steered on color-aware route (E, C)
3. (E, C) via N is recursively resolved on color-aware route (N, C)

It is simply routing like 20 years ago... just via color-aware paths!

BGP-CAR SAFI

# BGP-CAR SAFI

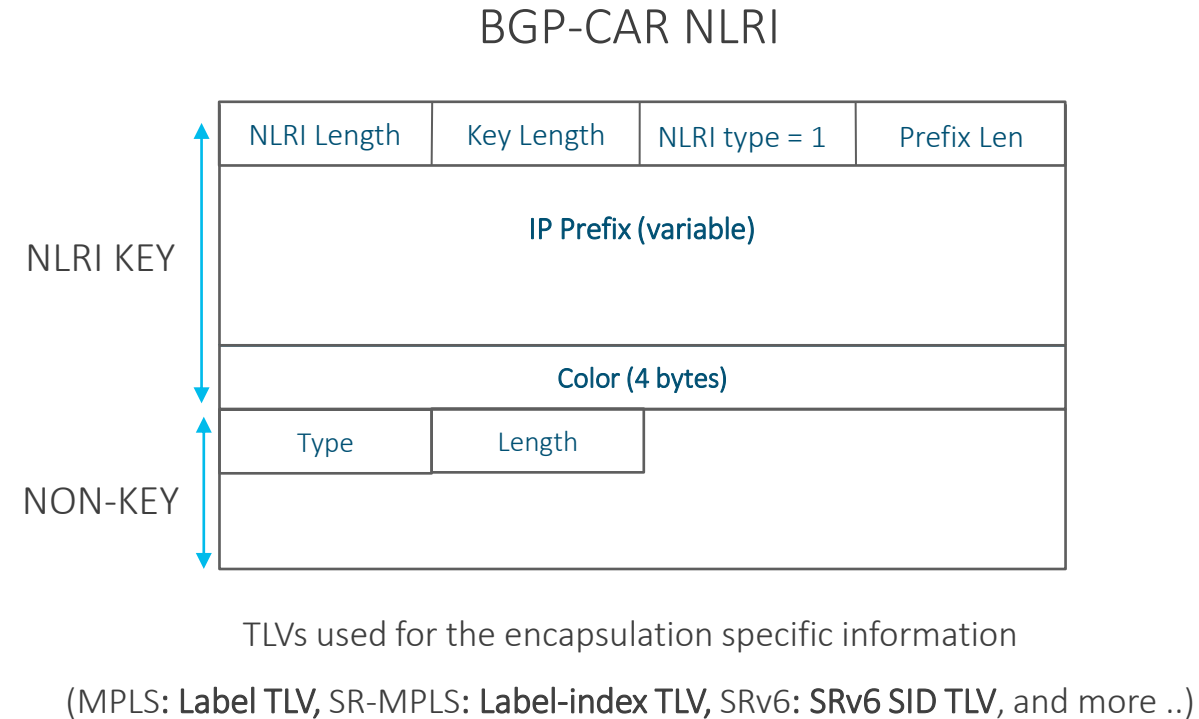
- Signal multiple instances of the same prefix for each color (i.e., intent)
- Evolution of best effort BGP-LU SAFI ([RFC3107](#) / [RFC8277](#))
  - > Modernize and address limitations of BGP-LU
- Maintain functional and operational consistency with BGP-LU
  - > Flat routing model, same as BGP-LU/IP
  - > No need to use VPN constructs (RD/RT) and import machinery on every transport BGP hop





# BGP-CAR – Modern SAFI definition

- NLRI key is **Prefix:Color**
  - Consistent with other color-aware routes (SR-TE)
  - Most efficient implementation (single copy/bestpath, no VPN import)
- **Flexible, extensible** encoding:
  - Ready for new use cases (route-types)
  - Accommodate multiple encapsulations natively, efficiently (non-key TLVs)
  - Preserve, optimize BGP update packing (per-prefix data in NLRI, e.g., label-index)
  - Simpler, efficient migration (e.g., MPLS to SRv6)
    - > Simultaneous multiple encapsulations
    - > Avoid route duplication, dual RR sessions



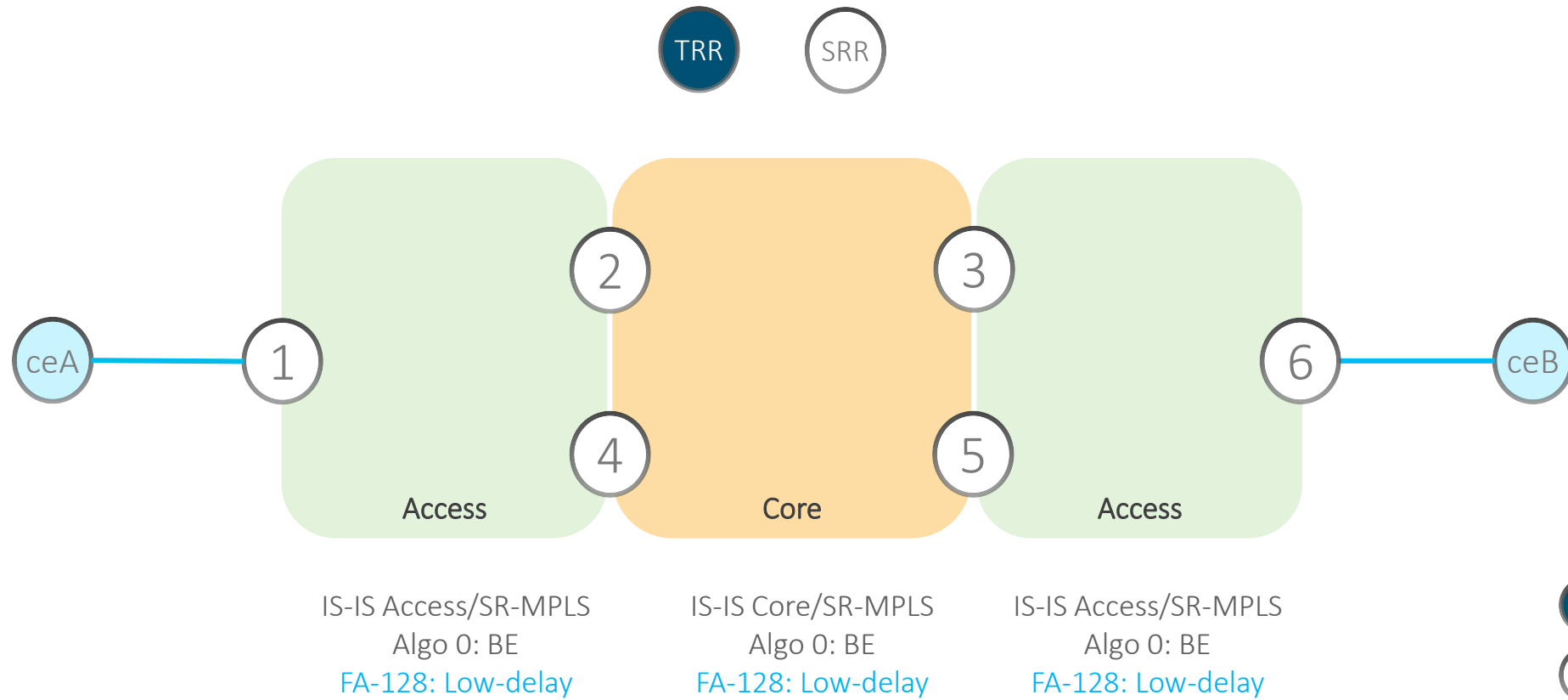
# Demonstration and Interoperability



# Overview

- Multi-vendor network composed of:
- Cisco XRv9000 –PE, ABR
- Arrcus ArcRR – BGP RR

# Topology Overview



T-RR = BGP transport RR  
S-RR = BGP service RR

# Topology Overview

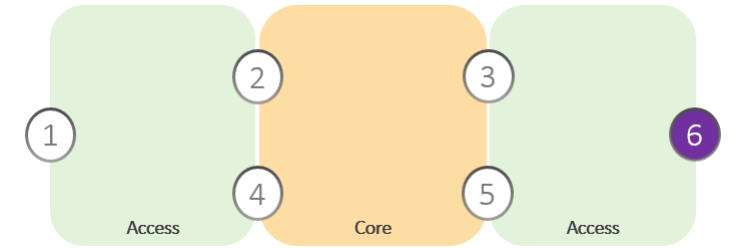
- Flex-Algo 128 enabled in each IGP domain with metric type delay
- BGP sessions are running between ABRs, T-RR and PEs
- BGP CAR (SAFI 83) and BGP LU (SAFI 4) are configured on these sessions
- R1 and R6 are ingress and egress PEs
- BGP VPN (SAFI 128) advertise services prefixes from R6 to R1, via inline RRs
- Color 128 represents low delay multi-domain path, provided by BGP-CAR
  - Resolves via ISIS Flex-Algo 128 within each IGP domain
- BGP AIGP attribute provides cumulative e2e metric for low-delay path

Demonstration

# Configuration

BGP-LU – best-effort reachability (existing)

```
router bgp 1000
  address-family ipv4 unicast
    network 6.6.6.6/32 route-policy SID(6)
  !
  !
```



BGP-CAR – low-delay reachability ([new](#))

```
router bgp 1000
  address-family ipv4 car
    car-color 128
    network 6.6.6.6/32
  !
  !
```



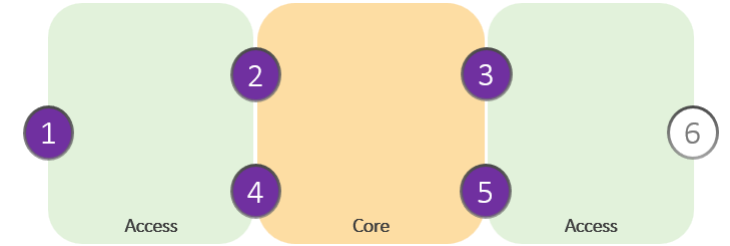
Consistent configuration with BGP-LU, extended for CAR

# Configuration

```
router bgp 1000
  address-family ipv4 unicast
    additional-paths selection route-policy BGP-PIC
    allocate-label all
  !
!
```



```
router bgp 1000
  address-family ipv4 car
    additional-paths selection route-policy BGP-PIC
  !
!
```

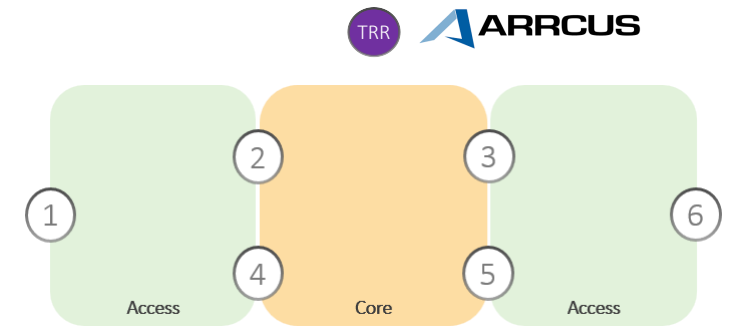


Consistent configuration with BGP-LU, i.e., BGP-PIC policy on ABRs



# Configuration

```
protocol BGP default
  global as 1000
  global router-id 9.9.9.9
  !
  global afi-safi IPV4_LABELED_UNICAST
  !
  global afi-safi CAR_IPV4
  !
  neighbor 2.2.2.2
    peer-as 1000
    transport local-address 9.9.9.9
    route-reflector route-reflector-client true
    afi-safi IPV4_LABELED_UNICAST
    exit
  !
  afi-safi CAR_IPV4
  exit
  !
  !
  neighbor 3.3.3.3
    peer-as 1000
    transport local-address 9.9.9.9
    route-reflector route-reflector-client true
    afi-safi IPV4_LABELED_UNICAST
    exit
  !
  afi-safi CAR_IPV4
  exit
  !
```



# BGP-CAR – Egress PE (Node 6)

```
RP/0/RSP0/CPU0:R6#show bgp ipv4 car [1][32][6.6.6.6][128]/72
```

BGP routing table entry for [1][32][6.6.6.6][128]/72

Versions:

Process	bRIB/RIB	SendTblVer
Speaker	57	57

Local Label: 3

Last Modified: Mar 23 01:53:46.115 for 00:02:46

Paths: (1 available, best #1)

Advertised to update-groups (with more than one peer):  
0.2

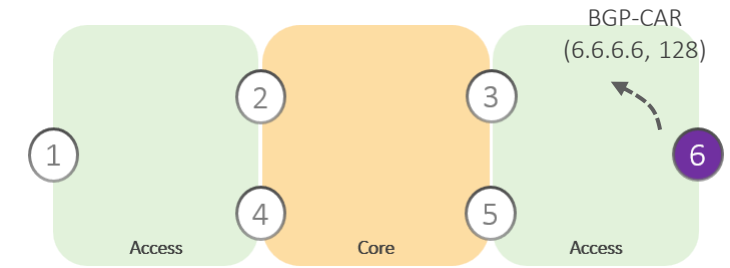
Path #1: Received by speaker 0

Advertised to update-groups (with more than one peer):  
0.2

Local

0.0.0.0 from 0.0.0.0 (6.6.6.6)

Origin IGP, metric 0, localpref 100, weight 32768, valid, local, best, group-best  
Received Path ID 0, Local Path ID 1, version 57



BGP-CAR route advertised with Imp-Null label – consistent with BGP-LU

# BGP-CAR – ABR (Node 3)

```
RP/0/RSP0/CPU0:R3#show bgp ipv4 car [1][32][6.6.6.6][128]/72
```

BGP routing table entry for [1][32][6.6.6.6][128]/72

Versions:

Process	bRIB/RIB	SendTblVer
Speaker	150	150

Local Label: 24053

Last Modified: Mar 23 01:55:01.546 for 00:10:20

Paths: (1 available, best #1)

Advertised to update-groups (with more than one peer):  
0.2

Path #1: Received by speaker 0

Advertised to update-groups (with more than one peer):  
0.2

Local, (Received from a RR-client)

6.6.6.6 C:128 (bsid:24052) (metric 11) from 6.6.6.6 (6.6.6.6)

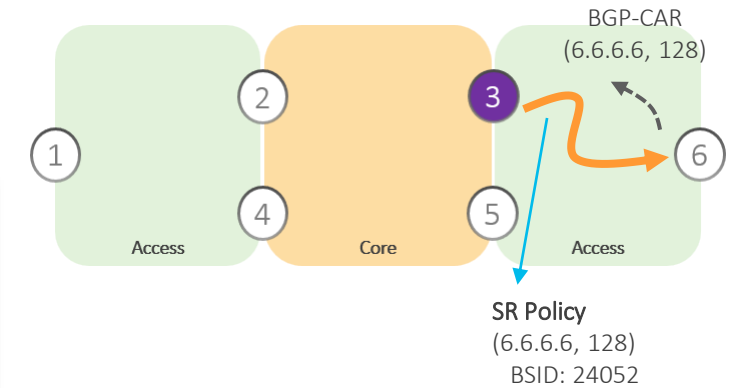
Received Label 3

Origin IGP, metric 0, localpref 100, aigp metric 0, valid, internal, best, group-best

Received Path ID 0, Local Path ID 1, version 150

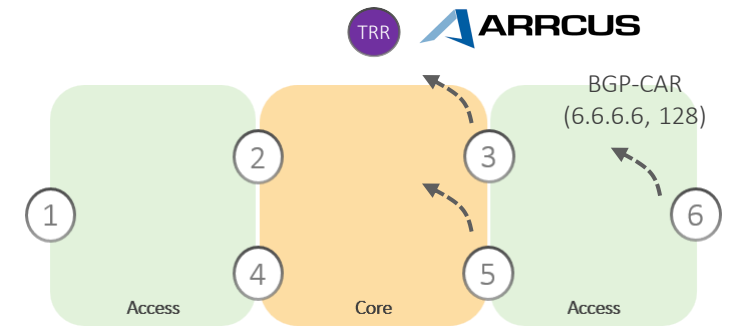
Total AIGP metric 11

SR policy color 128, up, registered, bsid 24052, if-handle 0x020005a0



BGP-CAR color-aware route (E,C) via N resolves automatically over (N,C) color-aware route  
(N,C) color-aware route for color 128 provided by IS-IS Flex-Algo 128 (binding-sid of SR policy with FA 128 constraint)

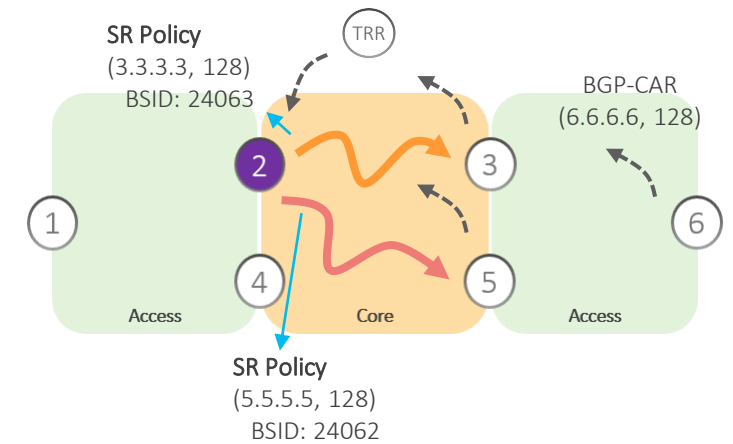
# BGP-CAR – Transport RR



```
root@localhost# show network-instance default protocol BGP default rib afi-safi CAR_IPV4 loc-rib routes
loc-rib routes route 1:[128][6.6.6.6/32] 3.3.3.3 0
state prefix 1:[128][6.6.6.6/32]
state origin 3.3.3.3
state path-id 0
state attr-index 221
state last-modified 0
state valid-route true
state label-tlv labels [ 24053 ]
state next-hop 3.3.3.3
state versions path-version 228
state tx-path-id 0
state path-types [ BEST_PATH ]
state path-lists [ NEXT_HOP_PATH_LIST UPDATE_PATH_LIST ]
state rib-outs best-path neighbor-count 4
state rib-outs best-path neighbors [ 2.2.2.2 3.3.3.3 4.4.4.4 5.5.5.5 ]
state rib-outs add-path neighbor-count 0
state stale-route false
attributes state origin IGP
attributes state med 0
attributes state local-pref 100
attributes state originator-id 6.6.6.6
attributes state cluster-list [ 0.0.1.100 ]
attributes state weight 0
attributes state aigp-metric 11
attributes state as-path-string ""
```



# BGP-CAR – ABR (Node 2)



```
RP/0/RSP0/CPU0:R2#show bgp ipv4 car [1][32][6.6.6.6][128]/72
```

```
BGP routing table entry for [1][32][6.6.6.6][128]/72
```

```
Versions:
```

Process	bRIB/RIB	SendTblVer
Speaker	210	210

```
Local Label: 24059
```

```
Last Modified: Mar 23 01:55:01.240 for 00:25:04
```

```
Paths: (3 available, best #1)
```

```
Advertised to update-groups (with more than one peer):
```

```
0.2
```

```
Path #1: Received by speaker 0
```

```
Advertised to update-groups (with more than one peer):
```

```
0.2
```

```
Local, (Received from a RR-client)
```

```
3.3.3.3 C:128 (bsid:24063) (metric 11) from 3.3.3.3 (6.6.6.6)
```

```
Received Label 24053
```

```
Origin IGP, metric 0, localpref 100, aigp metric 11, valid, internal, best, group-best
```

```
Received Path ID 0, Local Path ID 1, version 210
```

```
Originator: 6.6.6.6, Cluster list: 0.0.1.100
```

```
Total AIGP metric 22
```

```
SR policy color 128, up, registered, bsid 24063 if-handle 0x02000620
```

```
Path #2: Received by speaker 0
```

```
Not advertised to any peer
```

```
Local, (Received from a RR-client)
```

```
5.5.5.5 C:128 (bsid:24062) (metric 15) from 5.5.5.5 (6.6.6.6)
```

```
Received Label 24053
```

```
Origin IGP, metric 0, localpref 100, aigp metric 20, valid, internal, backup, add-path
```

```
Received Path ID 0, Local Path ID 2, version 210
```

```
Originator: 6.6.6.6, Cluster list: 0.0.1.100
```

```
Total AIGP metric 35
```

```
SR policy color 128, up, registered, bsid 24062 if-handle 0x02000660
```

<cont.>

```
Path #3: Received by speaker 0
```

```
Not advertised to any peer
```

```
Local, (Received from a RR-client)
```

```
3.3.3.3 C:128 (bsid:24063) (metric 11) from 9.9.9.9 (6.6.6.6)
```

```
Received Label 24053
```

```
Origin IGP, localpref 100, aigp metric 11, valid, internal
```

```
Received Path ID 0, Local Path ID 0, version 0
```

```
Originator: 6.6.6.6, Cluster list: 9.9.9.9, 0.0.1.100
```

```
Total AIGP metric 22
```

```
SR policy color 128, up, registered, bsid 24063 if-handle 0x02000620
```

# BGP-CAR – Ingress PE (Node 1)

```
RP/0/RSP0/CPU0:R1#show bgp ipv4 car [1][32][6.6.6.6][128]/72
```

```
BGP routing table entry for [1][32][6.6.6.6][128]/72
```

```
Versions:
```

Process	bRIB/RIB	SendTblVer
Speaker	11	11

```
Local Label: 24014
```

```
Last Modified: Mar 23 01:55:01.114 for 01:26:31
```

```
Paths: (2 available, best #1)
```

```
Not advertised to any peer
```

```
Path #1: Received by speaker 0
```

```
Not advertised to any peer
```

```
Local
```

```
2.2.2.2 C:128 (bsid:24048) (metric 11) from 2.2.2.2 (6.6.6.6)
```

```
Received Label 24059
```

```
Origin IGP, metric 0, localpref 100, aigp metric 22, valid, internal, best group-best
```

```
Received Path ID 0, Local Path ID 1, version 11
```

```
Originator: 6.6.6.6, Cluster list: 0.0.0.124, 0.0.1.100
```

```
Total AIGP metric 33
```

```
SR policy color 128, up, registered, bsid 24048, if-handle 0x020003e0
```

```
Path #2: Received by speaker 0
```

```
Not advertised to any peer
```

```
Local
```

```
4.4.4.4 C:128 (bsid:24047) (metric 11) from 4.4.4.4 (6.6.6.6)
```

```
Received Label 24055
```

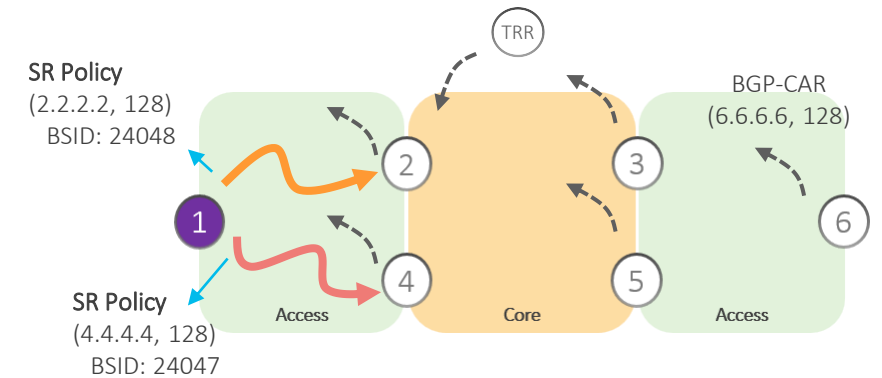
```
Origin IGP, metric 0, localpref 100, aigp metric 26, valid, internal, backup add-path
```

```
Received Path ID 0, Local Path ID 2, version 11
```

```
Originator: 6.6.6.6, Cluster list: 0.0.0.124, 0.0.1.100
```

```
Total AIGP metric 37
```

```
SR policy color 128, up, registered, bsid 24047, if-handle 0x02000420
```



BGP-CAR NLRI data model (E,C) automatically provides multipath/PIC consistent with BGP-LU

# BGP-CAR – Ingress PE (Node 1)

```
RP/0/RSP0/CPU0:R1#show segment-routing traffic-eng policy binding-sid 24048
```

```
SR-TE policy database
```

```
Color: 128, End-point: 2.2.2.2
```

```
Name: srte_c_128_ep_2.2.2.2
```

```
Status:
```

```
Admin: up Operational: up for 03:53:15 (since Mar 22 23:31:15.017)
```

```
Candidate-paths:
```

```
Preference: 200 (BGP ODN) (active)
```

```
Requested BSID: dynamic
```

```
Constraints:
```

```
Prefix-SID Algorithm: 128
```

```
Protection Type: protected-preferred
```

```
Maximum SID Depth: 10
```

```
PCE Group: test
```

```
Dynamic (valid)
```

```
Metric Type: TE, Path Accumulated Metric: 11
```

```
16802 [Prefix-SID: 2.2.2.2, Algorithm: 128]
```

```
<...>
```

```
Attributes:
```

```
Binding SID: 24048
```

```
Forward Class: Not Configured
```

```
Steering labeled-services disabled: no
```

```
Steering BGP disabled: no
```

```
IPv6 caps enable: yes
```

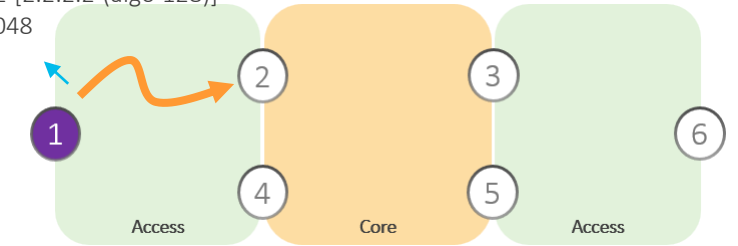
```
Invalidation drop enabled: no
```

```
Max Install Standby Candidate Paths: 0
```

SR Policy (2.2.2.2, 128)

SL: 16802 [2.2.2.2 (algo 128)]

BSID: 24048



BGP-CAR route (6.6.6.6, 128) via R2 resolves over BSID of SR policy (2.2.2.2, 128) that maps to Flex-Algo 128

# BGP-CAR – Colored service route

```
RP/0/RSP0/CPU0:R1#show bgp vrf CE1 200.1.6.0/24
```

BGP routing table entry for 200.1.6.0/24, Route Distinguisher: 1:1

Versions:

Process	bRIB/RIB	SendTblVer
Speaker	58	58

Last Modified: Mar 23 00:04:55.114 for 03:49:45

Paths: (1 available, best #1)

Advertised to CE peers (in unique update groups):  
10.1.100.2

Path #1: Received by speaker 0

Advertised to CE peers (in unique update groups):  
10.1.100.2

400

6.6.6.6 (metric 60) from 2.2.2.2 (6.6.6.6)

Received Label 24029

Origin IGP, localpref 100, valid, internal, best, group-best, import-candidate, imported

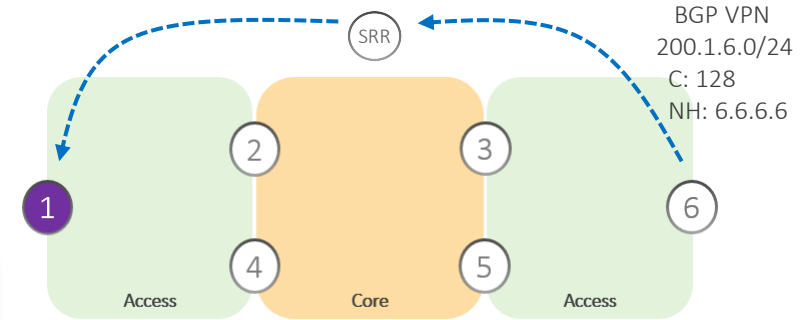
Received Path ID 0, Local Path ID 1, version 58

Extended community: Color:128 RT:1:1

Originator: 6.6.6.6, Cluster list: 0.0.0.124, 0.0.1.100

SR policy color 128, down, registered, bsid none, if-handle 0x02000460

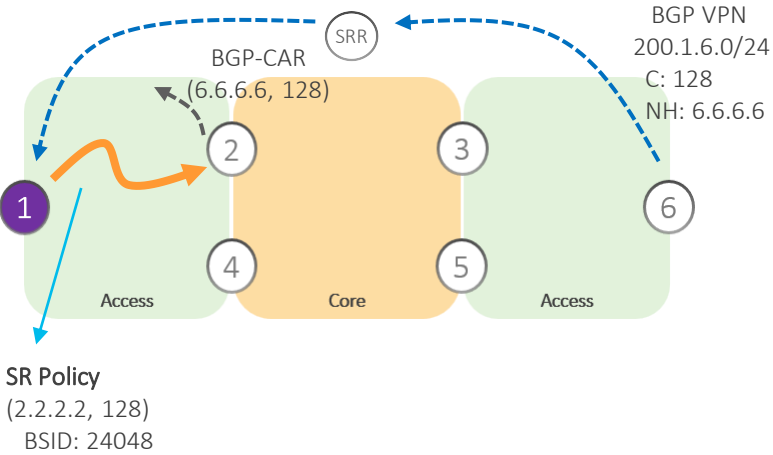
Source AFI: VPNv4 Unicast, Source VRF: default, Source Route Distinguisher: 2:1



VPN service route advertised with BGP color extended community value 128



# BGP-CAR – Colored service route steering



```
RP/0/RSP0/CPU0:R1#show cef vrf CE1 200.1.6.0/24

200.1.6.0/24, version 79, internal 0x5000001 0x30 (ptr 0x78b9a06c) [1], 0x0 (0x0), 0xa08 (0x79f570c8)
Updated Mar 23 00:04:55.538
Prefix Len 24, traffic index 0, precedence n/a, priority 3
gateway array (0x789c0c80) reference count 1, flags 0x2038, source rib (7), 0 backups
[1 type 1 flags 0x40441 (0x79f96970) ext 0x0 (0x0)]
LW-LDI[type=0, refc=0, ptr=0x0, sh-ldi=0x0]
gateway array update type-time 3 Mar 23 01:55:01.507
LDI Update time Mar 23 01:55:01.507
via local-label 24014, 3 dependencies, recursive [flags 0x6000]
path-idx 0 NHID 0x0 [0x7a0827d0 0x0]
recursion-via-label
next hop VRF - 'default', table - 0xe0000000
next hop via 24014/0/21
next hop srte_c_128_e labels imposed {ImplNull 24059 24029}

Load distribution: 0 (refcount 1)

Hash OK Interface Address
0 Y recursive 24014/0
```

Annotations in the code block:

- Red dashed boxes around `next hop via 24014/0/21` and `next hop srte_c_128_e labels imposed {ImplNull 24059 24029}`.
- Blue arrows pointing from the red dashed boxes to labels: "BGP-CAR out label" (pointing to 24014/0) and "Service label" (pointing to 24059 and 24029).

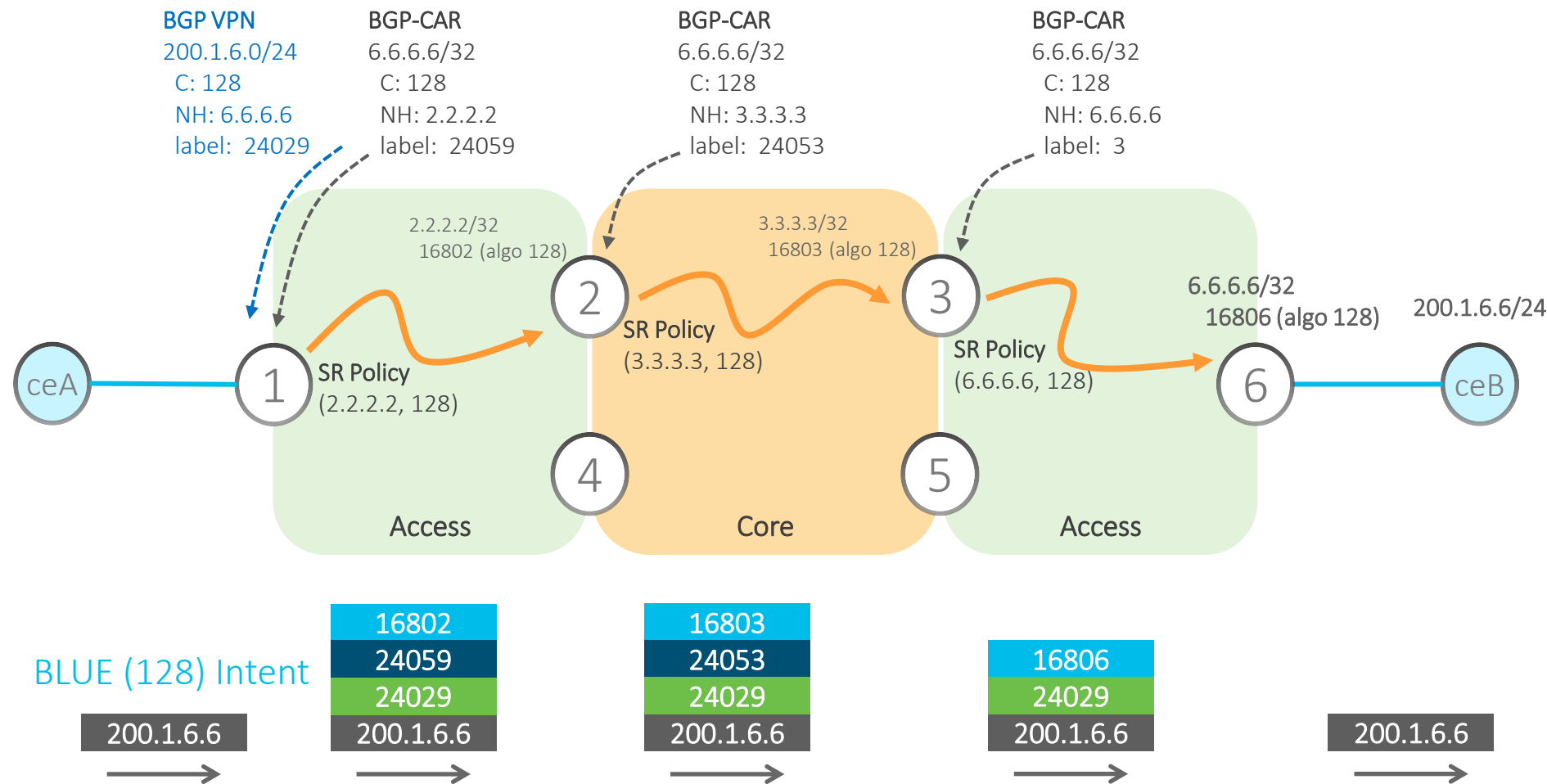
BGP: 200.1.6.0/24 via NH 6.6.6.6 with color 128

↳ BGP-CAR: 6.6.6.6 via NH 2.2.2.2 with color 128

↳ SR policy (Endpoint: 2.2.2.2, Color: 128)

VPN service route with BGP color ext. community value 128 steered over BGP CAR route (6.6.6.6, 128) on Node 1

# BGP-CAR – Data-plane



Conclusion

# Conclusion

- BGP-CAR evolves BGP-LU
  - Addresses intent-aware use-cases efficiently without complex VPN import procedures and overhead
- BGP-CAR SAFI is extensible, built to accommodate new use-cases, multiple encapsulations efficiently
  - Defines a base framework that can be extended with low overhead
- BGP-CAR definitions focus on better BGP protocol performance & scaling
  - Preserves BGP update packing efficiency, memory storage
  - Avoids route duplication during migration
- BGP-CAR is compatible and consistent with SR-Policy/IGP-FA solution
  - Use of Color Ext-Comm for automated steering of service routes
  - Also uses the same Color Ext-Comm for BGP-CAR next-hop resolution
- BGP-CAR works seamlessly across traditional networks (LDP/RSVP-TE/BGP-LU)

Less is more

Source Routing

Network Programming

Seamless Deployment

SR Header

Unified IP data-plane

Prefix Summarization

Pure IP Forwarding

Ingenuous leverage of CIDR

Rich Vendor Eco-System

Simplicity Always Prevails

End-to-End integrity

Stateless IP Fabric

Best MTU Overhead

Optimum load-balancing

Native extension of IPv6

Hardware Friendliness

Optimal MTU efficiency

Better HW scale

Mature Open-Source eco-system

Successful Interops

SRv6 is Proposed Standard

End-to-end Unified IP data-plane

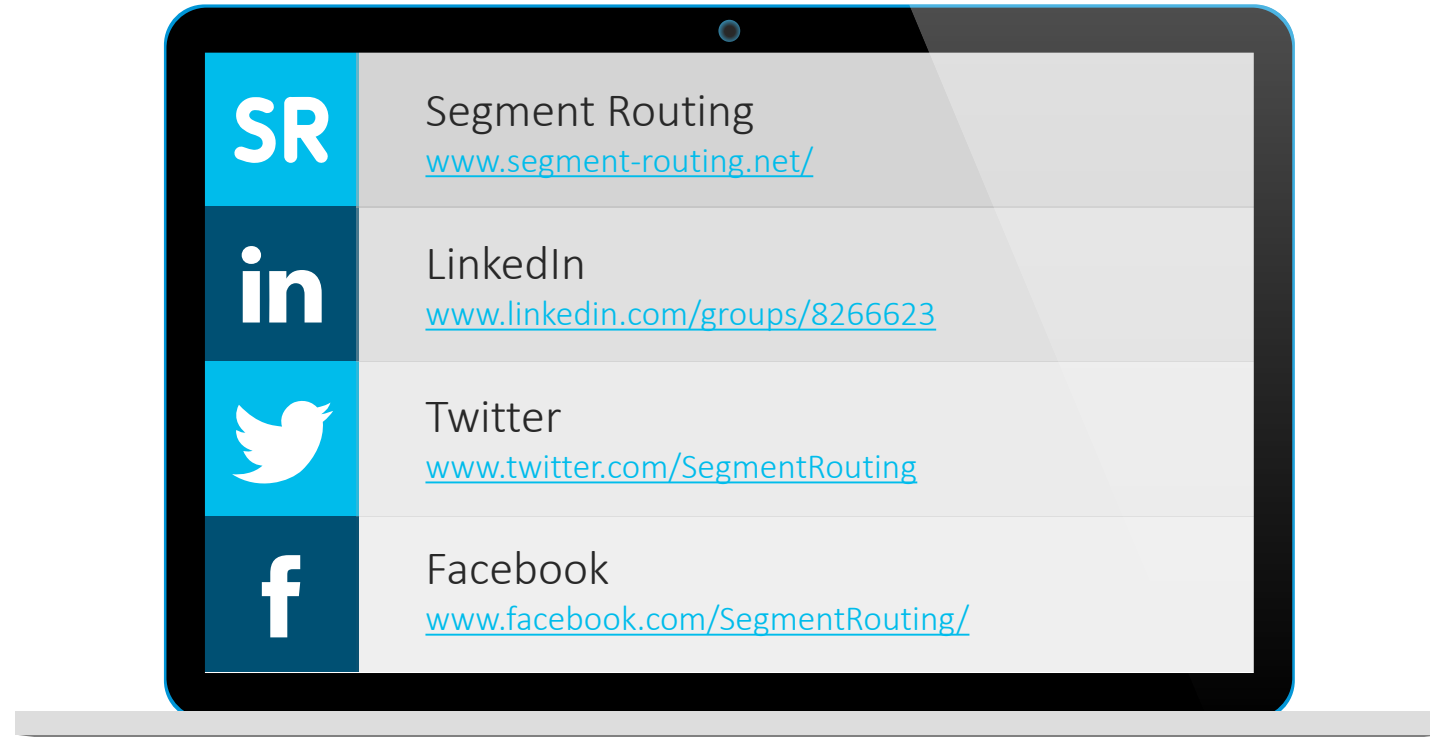
Micro Segment

Record Speed Deployments

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SRv6 Part  
III  
Coming by  
Summer  
2022

