

了解并排除ISIS中的灵活算法

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简介

本文档介绍ISIS中灵活算法(Flex-Algo)的运行过程，并提供用于验证和故障排除的相关命令。

先决条件

要求

- 思科建议您具备ISIS分段路由流量工程的基本知识。

使用的组件

- 本文档中的信息基于Device:聚合服务路由器9000(ASR9K)。
- 本文档中的信息都是基于特定实验室环境中的设备编写的。用于本文的所有设备始于初始（默认）配置。如果您的网络处于活动状态，请确保您了解所有命令的潜在影响。

Flex-Algo概述

- Flexible Algo(Flex-Algo)是以0-255范围内的数值来标识的；保留值0-127，而用户定义的值128-255。
- Flex-Algo由度量类型(内部网关协议(IGP)度量、延迟度量或TE度量)和约束集(例如链路相关性、共享风险链路组(SRLG))定义。
- 利用Flex-Algo，网络可以实施网络切片，即网络的逻辑分段，其中路径计算被限制在满足所定义约束的拓扑中。

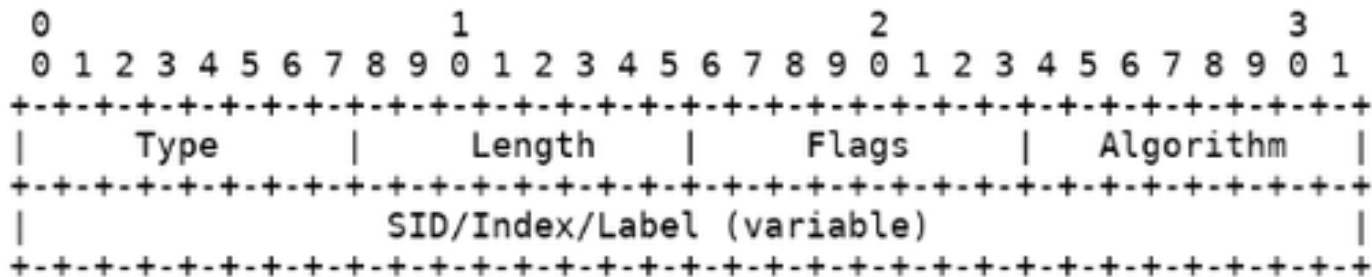


图 1：Prefix-SID Sub-TLV Format (带算法字段)

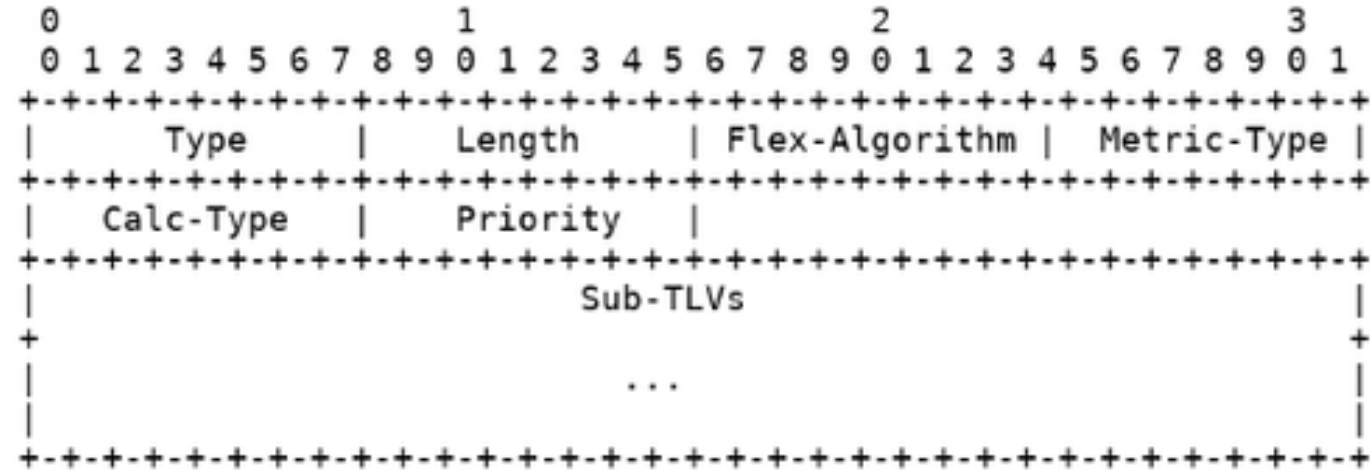


图 2：Flex-Algo定义(FAD)TLV格式

网络拓扑

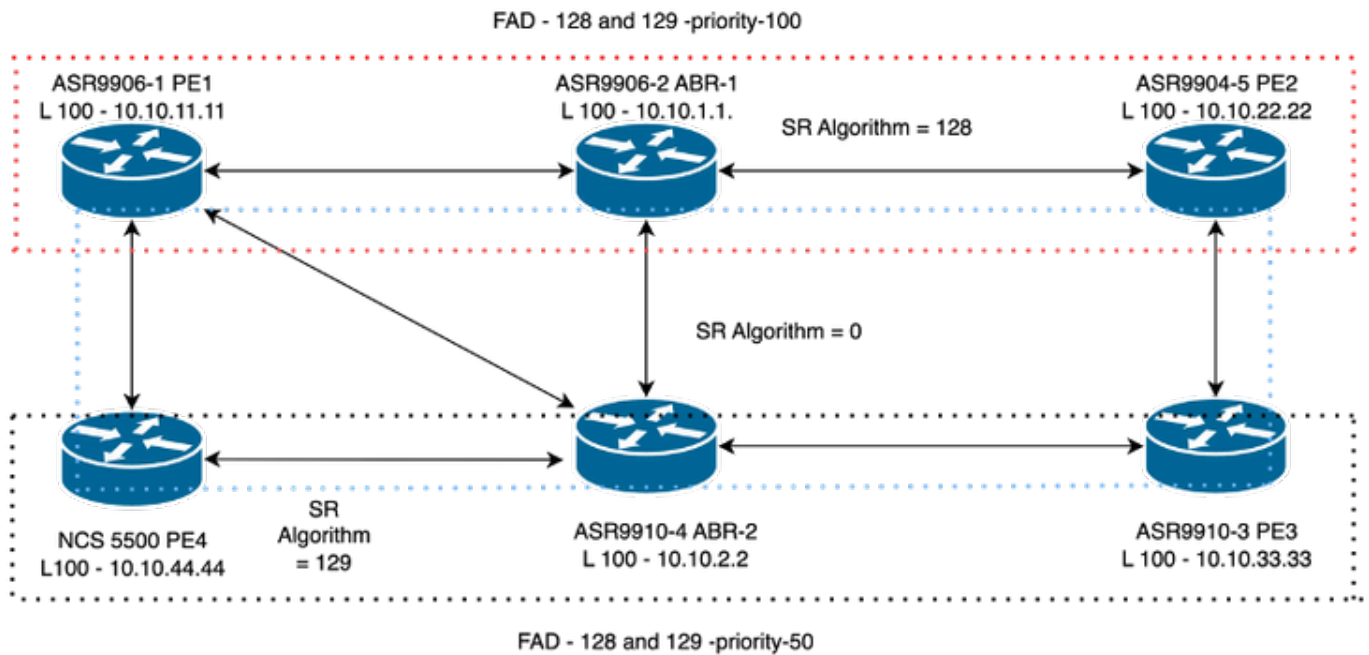


图 3：网络拓扑图

网络

- 算法128 → 定义延迟优化切片。
- 算法129 → 定义TE优化切片。
- ABR1和ABR2在IS-IS链路状态协议数据单元(LSP)中通告其Flex-Algo定义(FAD TLV)。
- FAD发起方可以是IS-IS域中的任何路由器；路由器无需参与每个Flex-Algo即可通告其定义。

Flex-Acl配置

```
<#root>
```

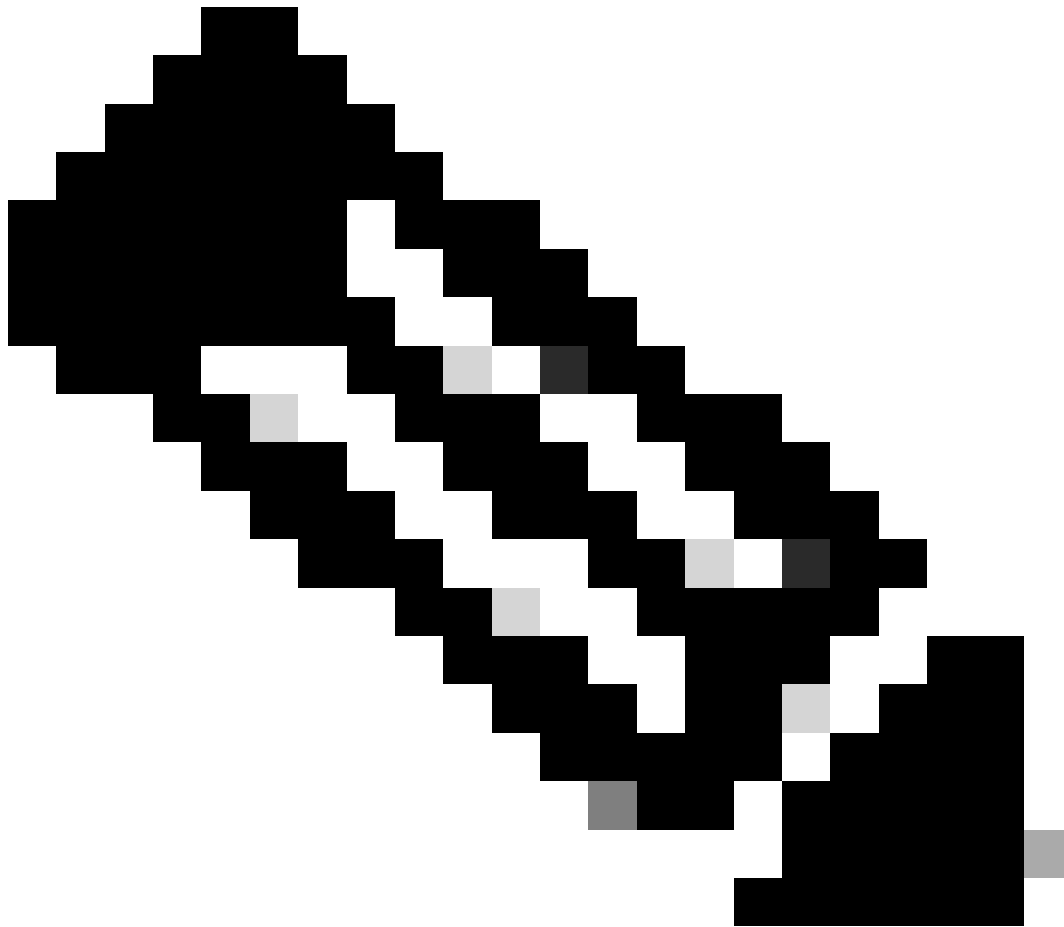
```
router isis core
flex-algo 128
  interface Loopback100
    passive
    address-family ipv4 unicast
```

```
prefix-sid index 11
```

```
explicit-null
```

```
prefix-sid algorithm 128 index 811
```

```
explicit-null
```



注意：

- 索引11 — 绑定到Flex-Algo 0的前缀SID(默认最短路径优先(SPF))。
- 索引811 — 绑定到Flex-Algo 128的前缀SID。
- Flex-Algo Prefix-SIDs enable network slicing (启用网络切片)。对于给定前缀 (例如Loopback100)，可以通告多个前缀SID — 每个前缀绑定到特定Flex-Algo。
- 第一个Prefix-SID (索引11) 自动与Flex-Algo 0 (默认IGP最短路径算法) 关联。
- 第二个Prefix-SID (索引811) 与Flex-Algo 128 (用户定义的算法) 显式关联。

Flex-Algo 129由度量类型TE定义

配置

在ABR2上：

<#root>

```
router isis core
flex-algo 129
  priority 50
  metric-type te
  advertise-definition

interface Loopback100
  address-family ipv4 unicast

    prefix-sid algorithm 129 index 92 explicit-null >>
```

Prefix-SID bound to Flex-Algo 129

```
interface HundredGigE0/1/0/2
  point-to-point
  address-family ipv4 unicast
    fast-reroute per-prefix
    fast-reroute per-prefix ti-lfa
```

```
te-metric flex-algo 20 level 2 >>
```

20 is the TE metric value for this link , need to be enabled on the links only between those routers pa

确认

<#root>

```
PE3#show isis flex-algo 129
IS-IS core Flex-Algo Database
Flex-Algo 129:
  Level-2:
```

Definition Priority: 100

Definition Source: ASR9906-2-ABR-1.00

Definition Equal to Local: No

Definition Metric Type: TE

Definition Flex-Algo Prefix Metric: No
<snip>

FRR Disabled: No

Microloop Avoidance Disabled: No

UCMP Disabled: No

Data Plane Segment Routing: Yes

Data Plane IP: Yes

<#root>

PE3#show isis database 55A1-2-PE4.00-00 verbose internal

IS-IS core (Level-2) Link State Database

LSPID	LSP Seq Num	LSP Checksum	LSP Holddtime/Rcvd	ATT/P/OL	Len	Received	From
55A1-2-PE4.00-00	0x00000149	0xfe2f	995 /1200	0/0/0	282	09:21:39	ASR9910-4-

<snip>

TLV code:242

length:28

Router Cap: 10.10.44.44 D:0 S:0

SubTLV code:2 length:9

Segment Routing: I:1 V:0, SRGB Base: 16000 Range: 8000

SubTLV code:23 length:2

Node Maximum SID Depth:

Label Imposition: 12

SubTLV code:19 length:3

SR Algorithm:

Algorithm: 0

Algorithm: 1

Algorithm: 129

SubTLV code:29 length:1

IP Algorithm:

Algorithm: 129

TLV code:22

length:117

Metric: 10 IS-Extended ASR9910-4-ABR-2.00

SubTLV code:4 length:8

Local Interface ID: 32, Remote Interface ID: 38

SubTLV code:6 length:4

Interface IP Address: 10.10.244.44

SubTLV code:8 length:4

Neighbor IP Address: 10.10.244.2

SubTLV code:9 length:4

Physical BW: 10000000 kbits/sec

SubTLV code:16 length:9

Application Specific Link Attributes:

L flag: 0, SA-Length: 1, UDA-Length: 1

Standard Applications: 0x10 FLEX-ALGO

User Defined Applications: 0x10

SubTLV code:18 length:3

Admin. Weight: 20 >>>>>>>> configured TE metric

<#root>

PE3#show isis topology flex-algo 129

IS-IS core paths to IPv4 Unicast (Level-2) routers

System Id	Metric	Next-Hop	Interface	SNPA
-----------	--------	----------	-----------	------

ASR9910-4-ABR-2				
-----------------	--	--	--	--

20

ASR9910-4-ABR-2	Hu0/1/0/0	*PtoP*	>> 1 hop away from PE3
-----------------	-----------	--------	------------------------

55A1-2-PE4

40

ASR9910-4-ABR-2	Hu0/1/0/0	*PtoP*	>> 2 hops away from PE3
-----------------	-----------	--------	-------------------------

由度量类型延迟定义的Flex-Algo 128

配置

<#root>

router isis core

flex-algo 128

priority 100

metric-type delay

advertise-definition

performance-measurement

interface HundredGigE0/1/0/0

delay-measurement

>>> this CLI needs to be enabled only on those interfaces between those routers participating in Flex-
!

!

interface HundredGigE0/1/0/3

delay-measurement

确认

<#root>

PE1#show isis flex-algo 128
IS-IS core Flex-Algo Database
Flex-Algo 128:
 Level-2:

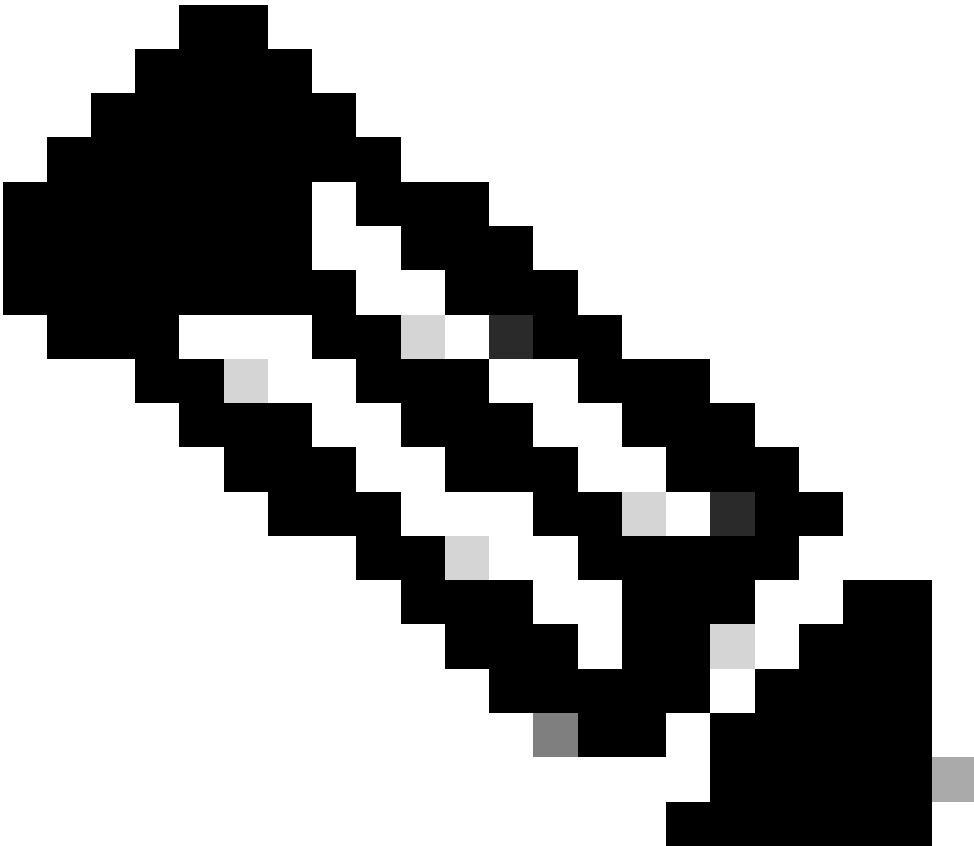
 Definition Priority: 100

 Definition Source: ASR9906-2-ABR-1.00

 Definition Equal to Local: No

 Definition Metric Type: Delay

 Definition Flex-Algo Prefix Metric: No



注意：在PE2上，静态配置了PE2和ABR 1 delay-measurement advertise-delay 100 >>延迟之间的性能测量接口HundredGigE0/1/0/1 >>链路。这会将从PE2到PE1的延迟度量增加+100，因此从PE2到达ABR 1的延迟为100。

<#root>

```
PE1#show isis database ASR-9904-5-PE2.00-00 verbose internal
IS-IS core (Level-2) Link State Database
LSPID                LSP Seq Num  LSP Checksum  LSP Holdtime/Rcvd ATT/P/OL LSP Length
ASR-9904-5-PE2.00-00 0x00000231  0x6084        1131 /1200      0/0/0   310
<snip>
```

TLV code:242

```
length:25
<snip>
```

SubTLV code:19

```
length:3
SR Algorithm:
  Algorithm: 0
  Algorithm: 1
  Algorithm: 128
```

TLV code:22

```
length:144
Metric: 10          IS-Extended ASR9906-2-ABR-1.00
SubTLV code:4 length:8
  Local Interface ID: 17, Remote Interface ID: 22
SubTLV code:6 length:4
  Interface IP Address: 10.10.221.22

SubTLV code:8 length:4
  Neighbor IP Address: 10.10.221.1

SubTLV code:9 length:4
  Physical BW: 99999998 kbits/sec
SubTLV code:33 length:4
```

Link Average Delay: 100 us

```
SubTLV code:34 length:8
```

Link Min/Max Delay: 100/100 us

```
SubTLV code:35 length:4
```

Link Delay Variation: 0 us

SubTLV code:16 length:14
Application Specific Link Attributes:
L flag: 0, SA-Length: 1, UDA-Length: 1

Standard Applications: 0x10 FLEX-ALGO
User Defined Applications: 0x10
SubTLV code:34 length:8

Link Min/Max Delay: 100/100 us >>> delay calculated on this link due to the confoguration

<#root>

PE2#show isis topology flex-algo 128
IS-IS core paths to IPv4 Unicast (Level-2) routers

System Id	Metric	Next-Hop	Interface	SNPA
ASR9906-2-ABR-1				
100				
ASR9906-2-ABR-1		Hu0/1/0/1		*PtoP*
ASR9906-1-PE1				
112				
ASR9906-2-ABR-1		Hu0/1/0/1		*PtoP*

如果接口上未配置手动通告延迟，并且使用接口上启用的默认延迟测量配置文件，则会在链路上发送探测功能以测量接口上的延迟。

<#root>

ABR-1#show performance-measurement sessions

0/1/CPU0

Transport type : Interface
Measurement type : Delay Measurement
Interface name : HundredGigE0/1/0/0
Nexthop : Unknown

Delay Measurement session:
Session ID : 4097
Profile Keys:

Profile name : default

Profile type. : Interface Delay Measurement

Last advertisement:
Advertised at: Sep 26 2025 14:00:36.179 (247623.282 seconds ago)
Advertised reason: Periodic timer, min delay threshold crossed

Advertised delays (uSec): avg: 12, min: 12, max: 13, variance: 0
A flag set: False

Next advertisement:
Threshold check scheduled in 2 more probes (roughly every 120 seconds)
Aggregated delays (uSec): avg: 12, min: 11, max: 12, variance: 1

Rolling average (uSec): 11

Current computation:
Started at: Sep 29 2025 10:47:17.373 (22.88 seconds ago)

Packets Sent: 8, received: 8

Measured delays (uSec): avg: 12, min: 11, max: 12, variance: 1 >>>>>>>>>> the delay measured using pro

Next probe scheduled at: Sep 29 2025 10:47:47.369 (in 7.908 seconds)

Next packet will be sent in 1.908 seconds

Packet sent every 3.0 seconds

Responder IP : 10.10.111.11

Number of Hops : 1

<#root>

ABR-1#show isis database ASR9906-1-PE1.00-00 verbose internal
IS-IS core (Level-2) Link State Database
LSPID LSP Seq Num LSP Checksum LSP Holdtime/Rcvd ATT/P/OL LSP Length
ASR9906-1-PE1.00-00 0x00000777 0x13ef 497 /1200 0/0/0 370
<snip>

TLV code:22

length:197
Metric: 10 IS-Extended ASR9906-2-ABR-1.00
SubTLV code:4 length:8
Local Interface ID: 40, Remote Interface ID: 21
SubTLV code:6 length:4

Interface IP Address: 10.10.111.11

SubTLV code:8 length:4

Neighbor IP Address: 10.10.111.1

SubTLV code:9 length:4
Physical BW: 99999998 kbits/sec
SubTLV code:33 length:4

Link Average Delay: 12 us >>>>>>>>>> the calculated delay is propagated via ISIS which is used by th

SubTLV code:34 length:8

Link Min/Max Delay: 12/13 us

SubTLV code:35 length:4

Link Delay Variation: 0 us

SubTLV code:16 length:14

Application Specific Link Attributes:

L flag: 0, SA-Length: 1, UDA-Length: 1

Standard Applications: 0x10 FLEX-ALGO

User Defined Applications: 0x10

SubTLV code:34 length:8

Link Min/Max Delay: 12/13 us

<#root>

PE1#show isis topology flex-algo 128

IS-IS core paths to IPv4 Unicast (Level-2) routers

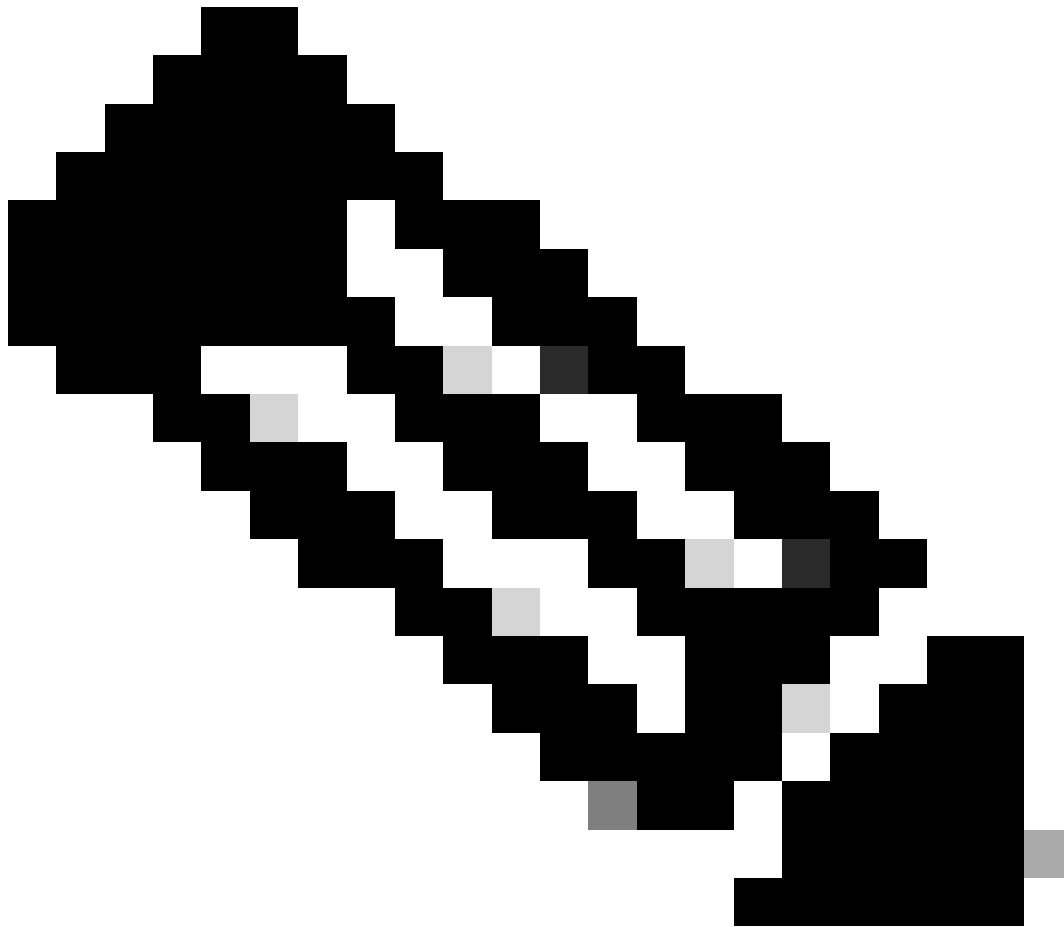
System Id	Metric	Next-Hop	Interface	SNPA
ASR9906-2-ABR-1				

12

ASR9906-2-ABR-1	Hu0/1/0/0	*PtoP*
ASR-9904-5-PE2		

24

ASR9906-2-ABR-1	Hu0/1/0/0	*PtoP*
-----------------	-----------	--------



注意：

- 从PE1到ABR 1，只有12个用户延迟
- 从PE1到PE2，存在24个用户延迟

FLEX-ALGO 129上的拓扑无关无环备用(TI-LFA)和微环规避(MLA)

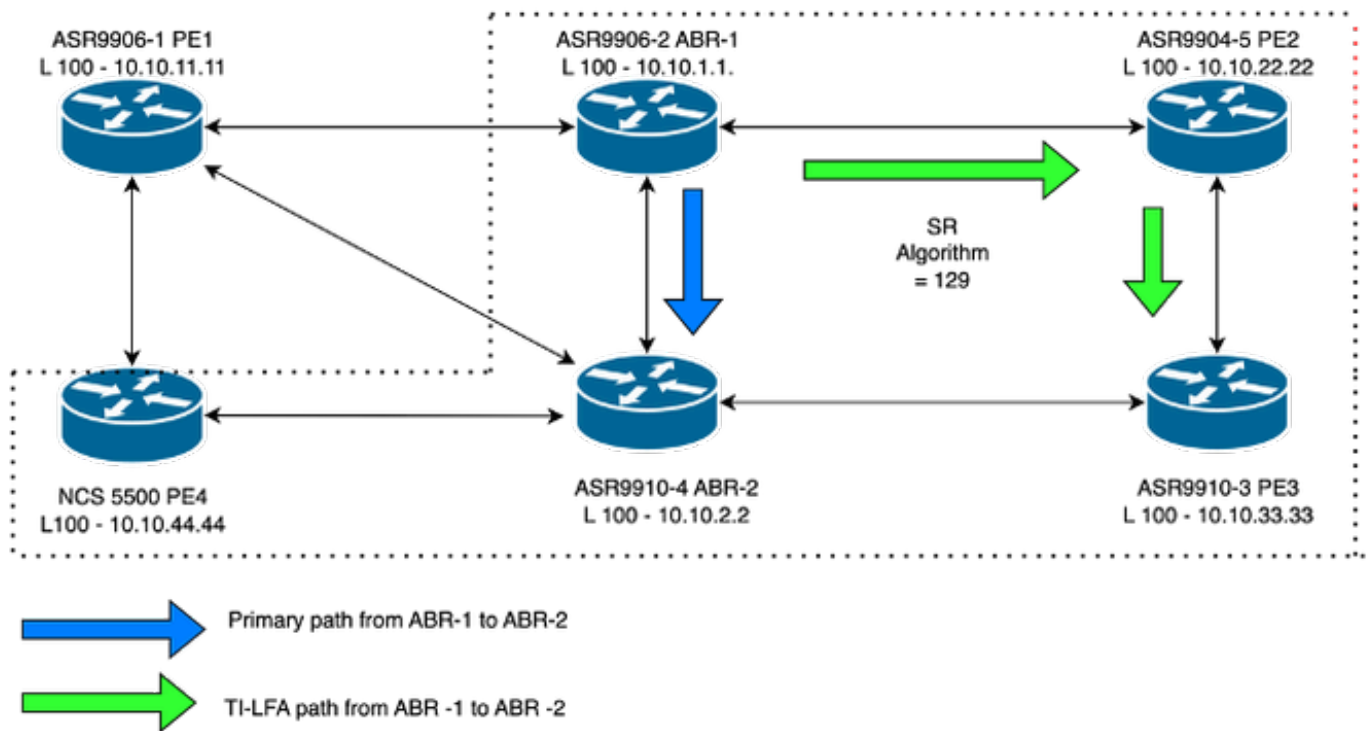


图 4：用于演示Flex- Algo 129的TI-LFA和MLA的网络拓扑图

<#root>

```
ABR-1#show isis fast-reroute flex-algo 129 10.10.2.2/32 detail
L2 10.10.2.2/32 [20/115] Label: 16092, medium priority
  Installed Sep 17 10:40:08.503 for 00:16:25
    via 10.10.12.2, HundredGigE0/1/0/1, Label: Exp-Null-v4, ASR9910-4-ABR-2, SRGB Base: 16000, Weight:
```

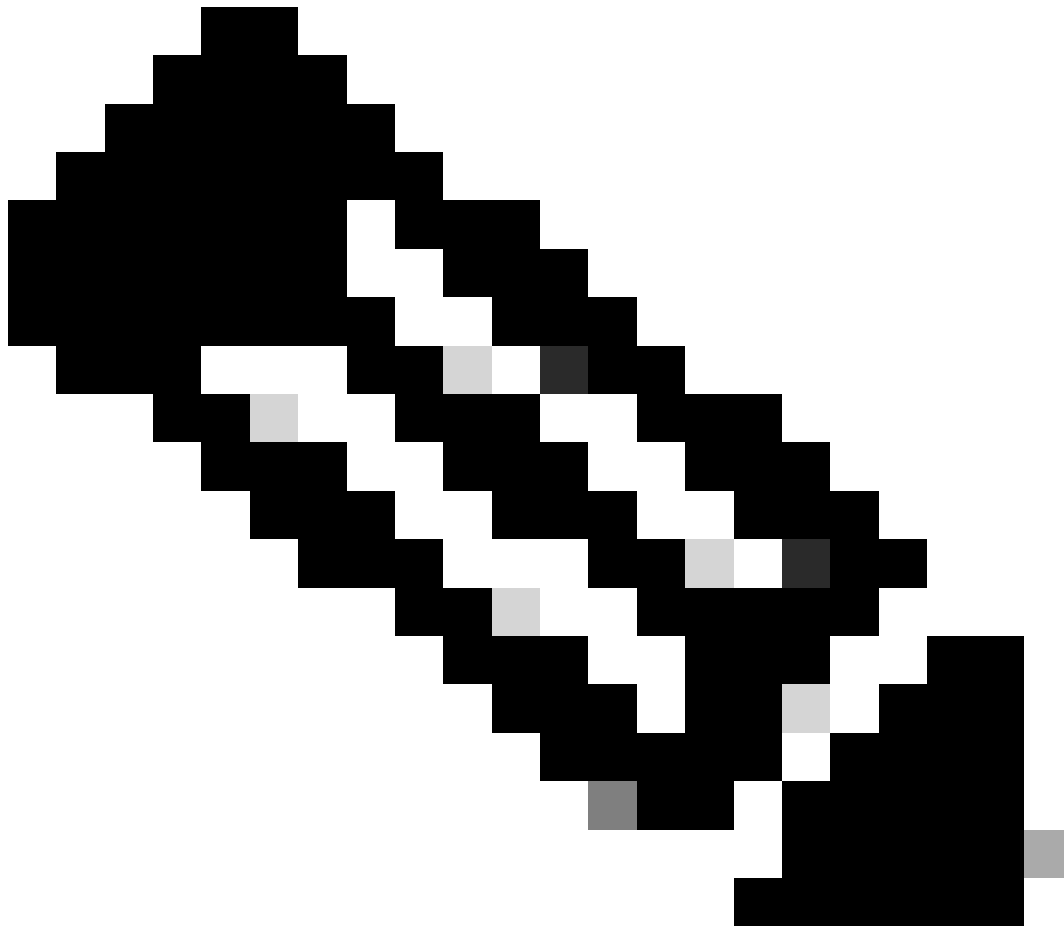
Backup path: TI-LFA (link),

```
via 10.10.221.22, HundredGigE0/1/0/3 ASR-9904-5-PE2, SRGB Base: 16000, Weight: 0, Metric: 60
```

P node: ASR9910-3-PE3.00 [10.10.33.33], Label: 16933 >>>>>>>> TI-LFA precomputed path for FRR

Prefix label: 16092

```
Backup-src: ASR9910-4-ABR-2.00
P: No, TM: 60, LC: No, NP: No, D: No, SRLG: Yes
src ASR9910-4-ABR-2.00-00, 10.10.2.2, prefix-SID index 92, R:0 N:1 P:1 E:1 V:0 L:0, Alg:129
```



注意：

- 16933 PE3 Flex-Algo 129标签
- 16092 ABR -2 Flex-Algo 129标签
- TI-LFA路径也使用flex algo 129的逻辑网络片进行限制

在ABR-1上，当ABR 1和2之间的链路关闭时，会触发MLA隧道：

<#root>

ABR-1 #show isis microloop avoidance 10.10.2.2/32 flex-algo 129 detail

10.10.2.2/32 participated in 1 of 6 microloop avoidance events

number	start	spf	duration	cleanup	duration	pins: ipv4	ipv6
---	---	---	---	---	---	---	---
5	restart	10:59:16.440	0 ms	10:59:16.643		3	0

trigger: Link down, near node: ASR9906-2-ABR-1.00, far node: ASR9910-4-ABR-2.00
via 10.10.221.22, Hu0/1/0/3,

Labels: 16933

在TI-LFA和MLA中，Flex-Algo 129运行其自身的约束SPF，预计算符合Algo 129约束的快速重路由隧道，仅使用FLEX-ALGO 129标签。

链路关联映射限制

- 关联性是与IGP链路关联的32位属性，由操作员管理性分配。
- 每个位位置对应于由运算符定义的语义含义。
- 这些关联位在IGP(OSPF/IS-IS)中作为链路TE属性的一部分进行通告。

当Flex-Algo计算其最短路径树(SPF)时，它在路径选择期间应用关联约束：

- Include-Any(IA):计算出的路径必须至少经过设置了任何指定关联位的链路。
- Include-All(IAI):计算出的路径必须仅遍历包含所有指定关联位的链路。
- 排除 — 任意(EA):计算出的路径必须避免包含任何指定关联位的所有链路。

配置

在ABR 1和2上：

```
<#root>
```

```
On ABR 1and 2
router isis core
```

```
affinity-map ALGO-129 bit-position 6
```

```
flex-algo 129
  priority 100
  metric-type te
  advertise-definition

  affinity exclude-any ALGO-129
```

在通告的FAD上发布此配置。

确认

```
<#root>
```

```
PE4#show isis database ASR9906-2-ABR-1.00-00 verbose internal
```

```
IS-IS core (Level-2) Link State Database
```

LSPID	LSP Seq Num	LSP Checksum	LSP Holddtime/Rcvd	ATT/P/OL	Len	Received	From
ASR9906-2-ABR-1.00-00	0x0000023f	0xa89f	871 /1200	0/0/0	453	11:12:43	ASR9906-1

```
TLV code:242 length:44
  Router Cap:      10.10.1.1 D:0 S:0
    <snip>
  SubTLV code:19 length:4
    SR Algorithm:
```



```
Algorithm: 0
Algorithm: 1
Algorithm: 128
Algorithm: 129
```

SubTLV code:26

```
length:4
```

Flex-Algo Definition:

Algorithm: 129 Metric-Type: 2

Alg-type: 0 Priority: 100
SubTLV code:1 length:4

Flex-Algo Exclude-Any Ext Admin Group: >>> FAD to exclude any link with this bit position set

0x00000040

<#root>

```
PE4#show isis flex-algo 129
IS-IS core Flex-Algo Database
Flex-Algo 129:
  Level-2:
    Definition Priority: 100
    Definition Source: ASR9906-2-ABR-1.00
    Definition Equal to Local: No
    Definition Metric Type: TE
    Definition Flex-Algo Prefix Metric: No
    Exclude Any Affinity Bit Positions: 6
```

未在任何链路上配置链路关联映射时从PE4到PE3的路径：

```
PE4#traceroute sr-mp1s labels 16933 lsp-end-point 10.10.33.33
Type escape sequence to abort.
 0 10.10.244.44 MRU 1500 [Labels: 16933/explicit-null Exp: 0/0] >>>> PE4
 L 1 10.10.244.2 MRU 1500 [Labels: explicit-null/explicit-null Exp: 0/0] 5 ms >>>> ABR2
! 2 10.10.32.33 4 ms >>>> PE3
```

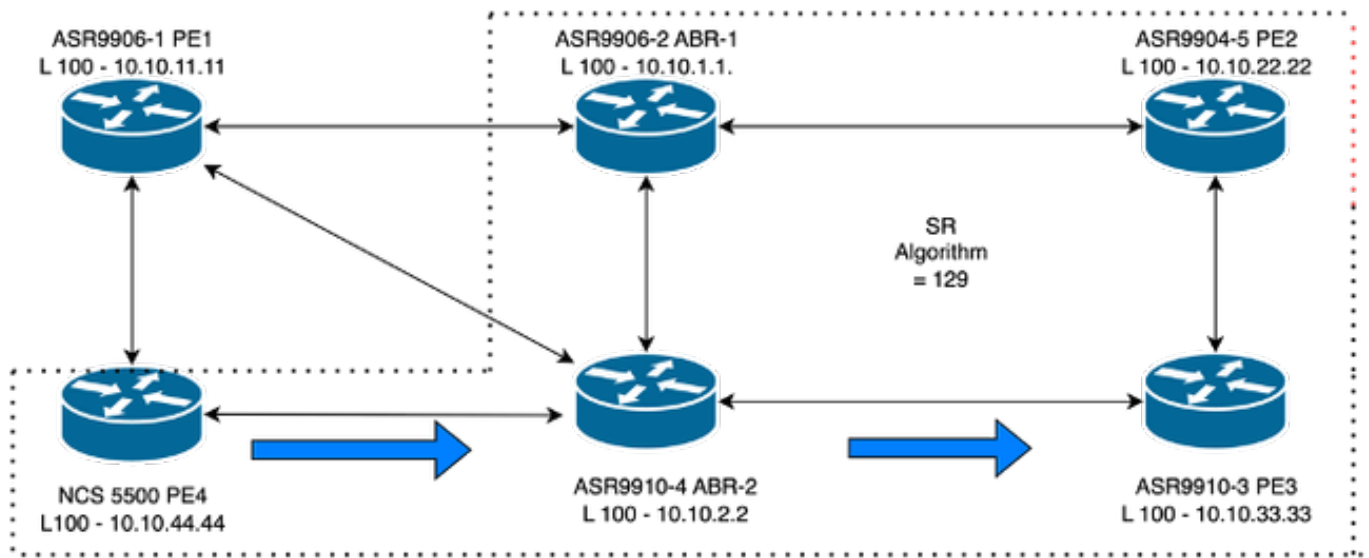


图 5：在没有定义关联映射的PE4到PE3之间的Traceroute

关联映射的ABR-2上的配置

```
<#root>
router isis core
affinity-map ALGO-129 bit-position 6 >
> define the bit position and associate it with a name
router isis core
interface HundredGigE0/1/0/2
>>> link between ABR-2 to PE3

affinity flex-algo ALGO-129
>>>> link affinity map
point-to-point
address-family ipv4 unicast
fast-reroute per-prefix
fast-reroute per-prefix ti-lfa
te-metric flex-algo 20 level 2
```

确认

```
<#root>
PE4#show isis database ASR9910-4-ABR-2.00-00 verbose internal
<snip>
TLV code:22 length:193
<snip>
SubTLV code:6 length:4
```

Interface IP Address: 10.10.32.2

SubTLV code:8 length:4

Neighbor IP Address: 10.10.32.33

SubTLV code:9 length:4

Physical BW: 99999998 kbits/sec, 12499999744 bytes/sec

SubTLV code:16 length:21

Application Specific Link Attributes:

L flag: 0, SA-Length: 1, UDA-Length: 1

Standard Applications: 0x10 FLEX-ALGO

User Defined Applications: 0x10

SubTLV code:14 length:4

Ext Admin Group:

```
0x00000040 >>>>> link affinity flooded via IGP
```

SubTLV code:3 length:4

Affinity: 0x00000040

SubTLV code:18 length:3

Admin. Weight: 20

根据Flex Algo 129从PE4到PE3的FAD，它需要排除任何具有关联映射位位置6的链路。

```
PE4#traceroute sr-mp1s labels 16933 lsp-end-point 10.10.33.33
```

[illegible]

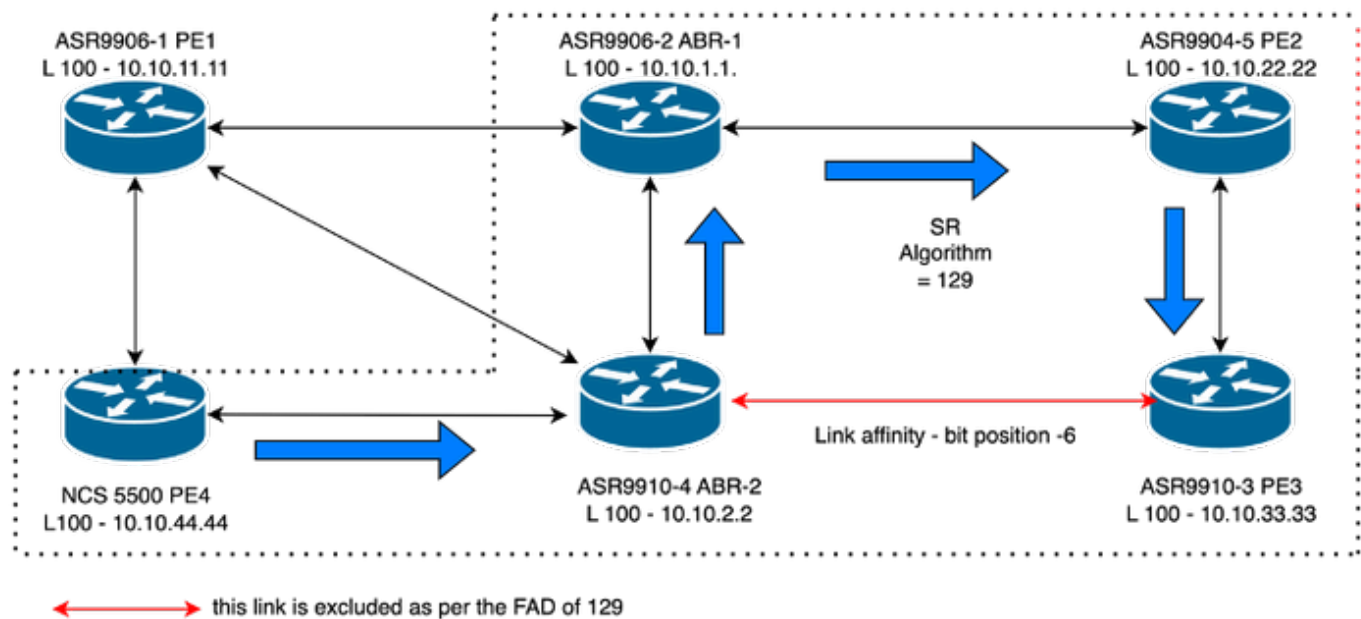
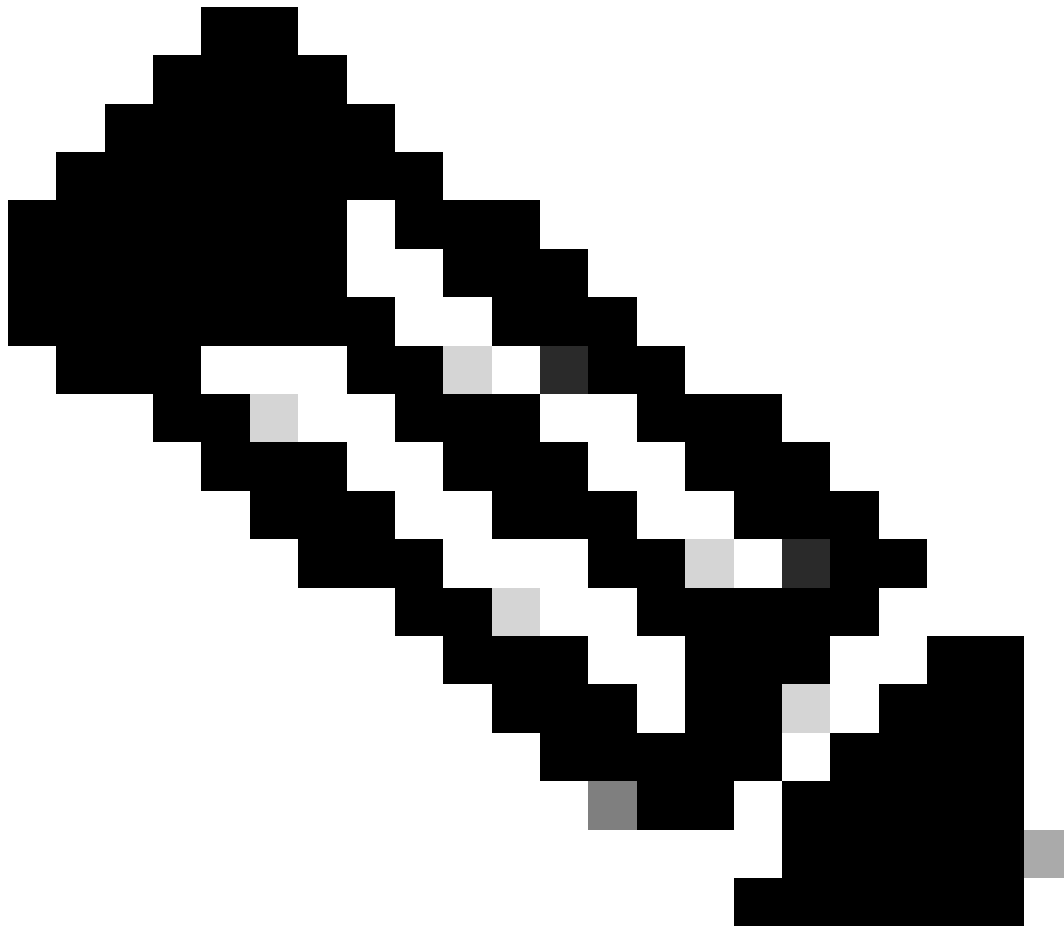


图 6：配置关联映射后从PE4到PE3的路径



注意：同样，在flex algo的FAD中使用“include any”和“include all”，我们可以影响从头端到尾端的路径计算。

结论

本文档介绍如何使用灵活算法(Flex-Algo)将IS-IS域逻辑切分为多个网络切片。每个片可以定义自己的路径计算规则和限制，从而根据SLA要求或流量敏感性对流量流进行区别处理。

命令

```
show isis flex-algo <>
show isis flex-algo 129 neighbors
show isis topology flex-algo
show isis database <> verbose detail
show isis route <> flex-algo <> detail
show mpls forwarding labels <> detail
```

```
show isis microloop avoidance <> flex-algo <> detail
show isis fast-reroute flex-algo <> <prefix> detail
```

关于此翻译

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