

ISIS中靈活演算法的理解與故障排除

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簡介

本檔案將介紹ISIS中的靈活演算法(Flex-Algo)的運行過程，並提供用於驗證和故障排除的相關命令。

必要條件

需求

- 思科建議您瞭解ISIS分段路由流量工程的基本知識。

採用元件

- 本檔案中的資訊是根據Device:聚合服務路由器9000(ASR9K)。
- 本文中的資訊是根據特定實驗室環境內的裝置所建立。文中使用到的所有裝置皆從已清除（預設）的組態來啟動。如果您的網路運作中，請確保您瞭解任何指令可能造成的影響。

Flex-Algo概述

- Flexible Algo(Flex-Algo)是以0-255範圍內的數值來識別的；保留值0-127，而使用者定義的值為128-255。
- Flex-Algo由度量型別(內部網關協定(Interior Gateway Protocol，IGP)度量、延遲度量或TE度量)和一組約束(例如鏈路相關性、共用風險鏈路組(Shared Risk Link Group，SRLG))定義。
- 利用Flex-Algo，網路可以實施網路切片，即網路的邏輯分段，其中路徑計算被限制在滿足定義的約束的拓撲結構中。

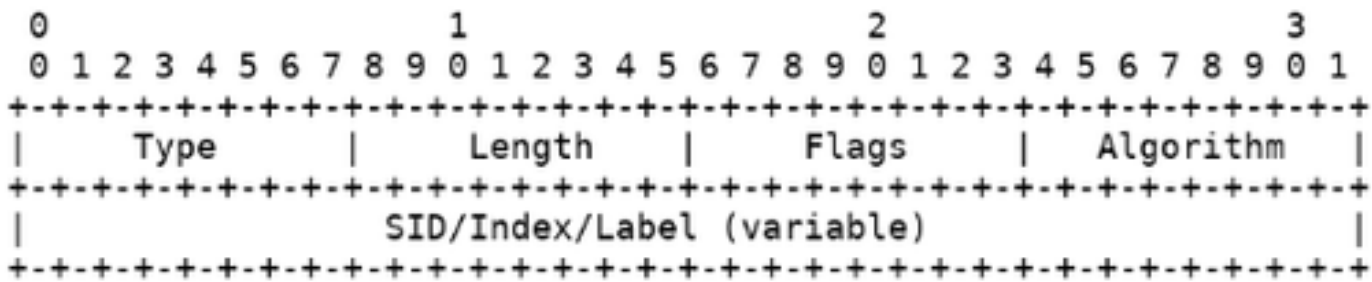


圖 1:Prefix-SID Sub-TLV Format (帶演算法欄位)

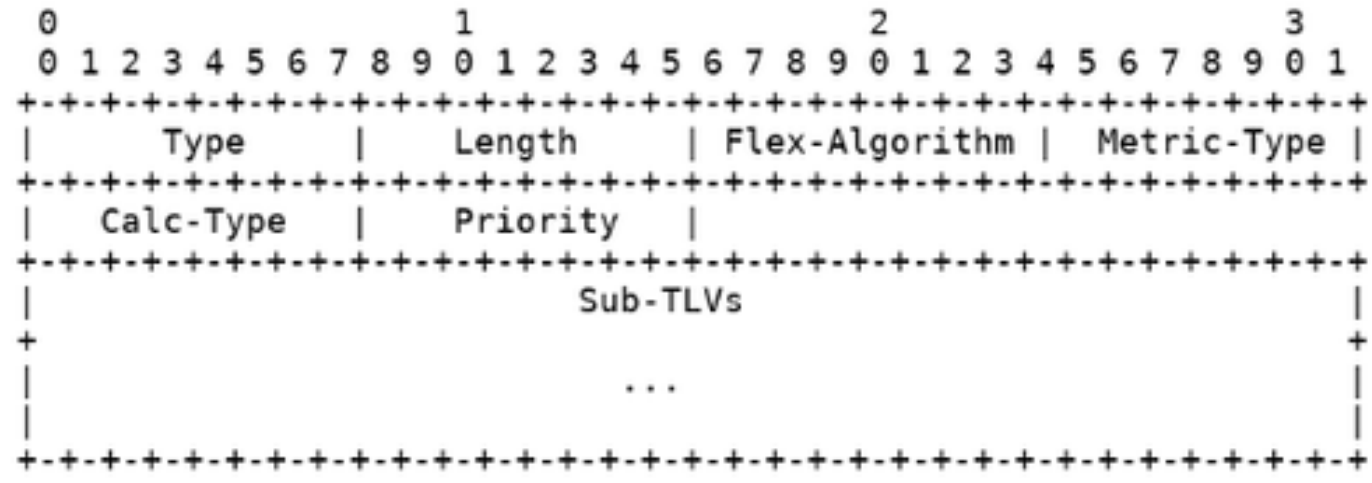


圖 2:Flex-Algo定義(FAD)TLV格式

網路拓撲

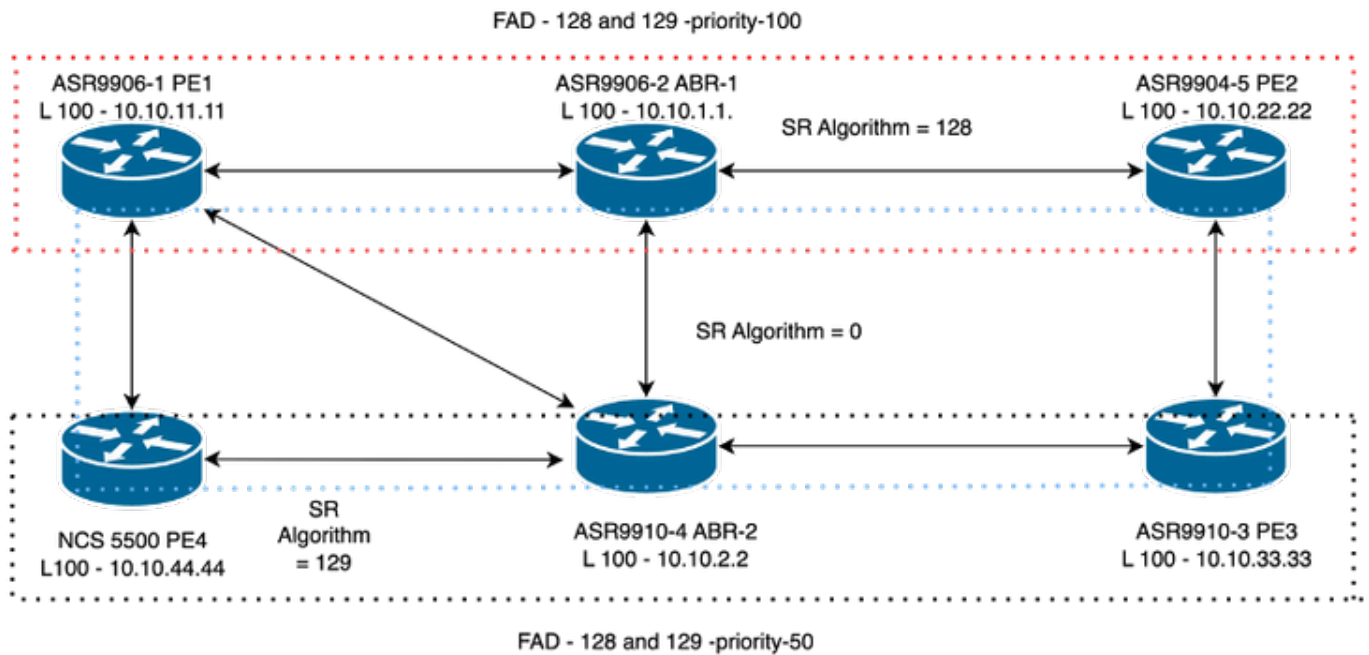


圖 3:網路拓撲圖

網路

- 演算法128 →定義延遲最佳化切片。
- 演算法129 →定義TE最佳化切片。
- ABR1和ABR2在IS-IS連結狀態通訊協定資料單元(LSP)中通告其Flex-Algo定義(FAD TLV)。
- FAD發起方可以是IS-IS域中的任何路由器；路由器無需參與每個Flex-Algo即可通告其定義。

Flex-Algo配置

```
<#root>
```

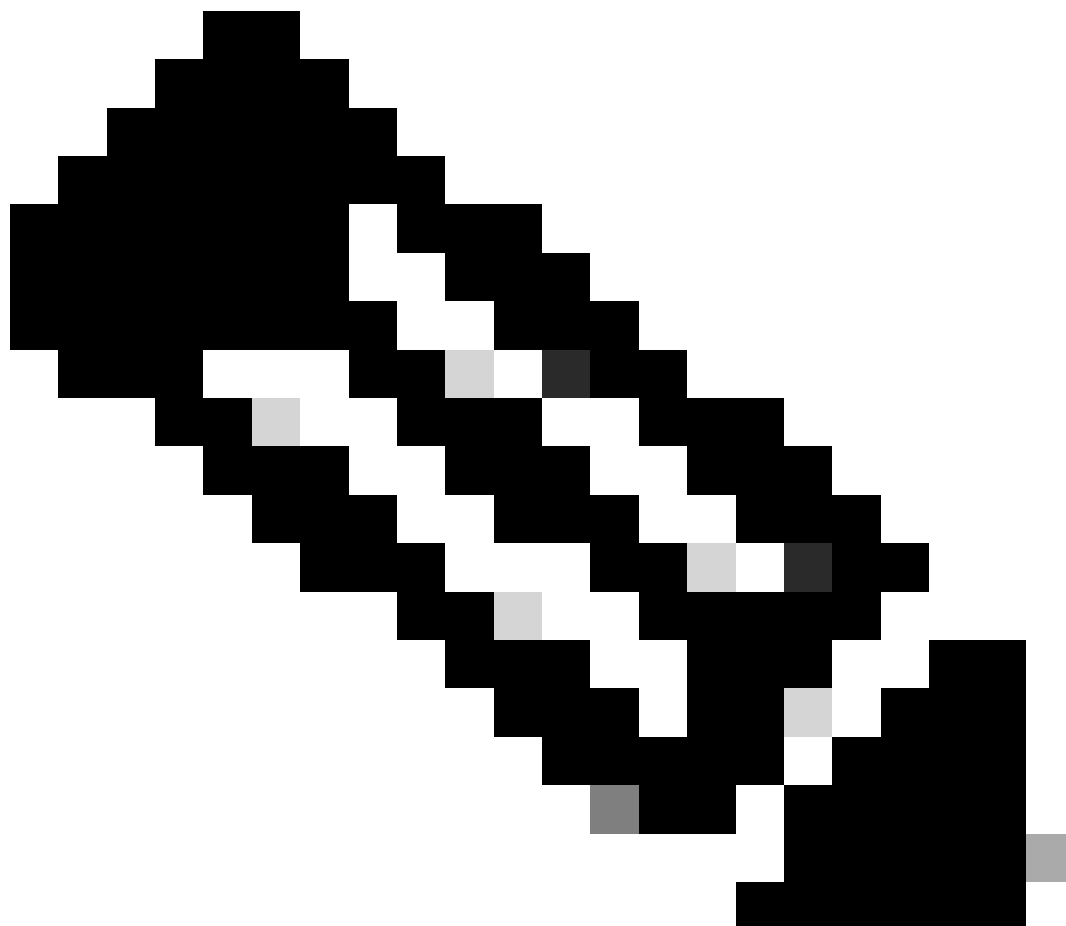
```
router isis core
flex-algo 128
  interface Loopback100
    passive
    address-family ipv4 unicast
```

```
prefix-sid index 11
```

```
explicit-null
```

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

```
explicit-null
```



附註：

- 索引11 — 繫結到Flex-Algo 0(預設最短路徑優先(SPF))的字首SID。
- 索引811 — 繫結到Flex-Algo 128的字首SID。
- Flex-Algo Prefix-SID啟用網路切片，對於給定的字首（例如Loopback100），可以通告多個字首SID，每個字首都繫結到特定的Flex-Algo。
- 第一個Prefix-SID（索引11）自動與Flex-Algo 0（預設IGP最短路徑演算法）相關聯。
- 第二個字首SID（索引811）與Flex-Algo 128（使用者定義的演算法）顯式關聯。

Flex-Algo 129由度量型別TE定義

組態

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

驗證

<#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
-----------------	-----------	--------	-------------------------

Flex-Algorithm 128由度量型別延遲定義

組態

<#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-Algorithm 128

!>>>
interface HundredGigE0/1/0/3
delay-measurement

驗證

<#root>

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

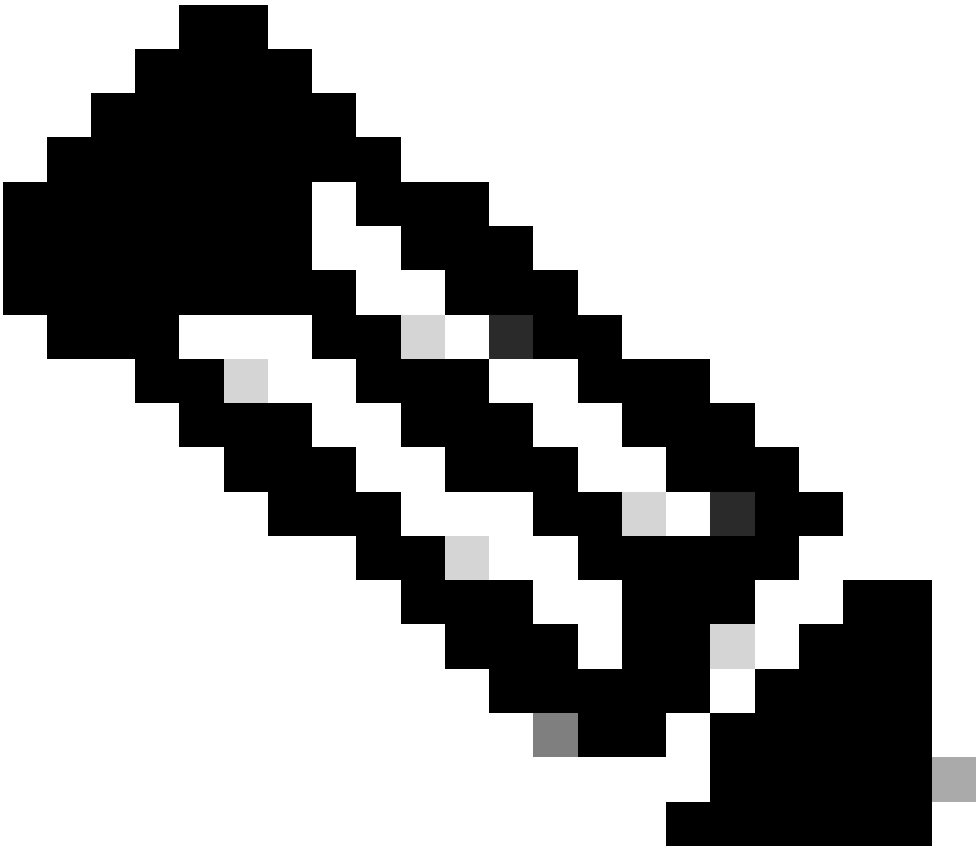
Definition Priority: 100

Definition Source: ASR9906-2-ABR-1.00

Definition Equal to Local: No

Definition Metric Type: Delay

Definition Flex-Algo Prefix Metric: No



附註：在PE2上，靜態配置PE2和ABR 1之間的效能測量介面HundredGigE0/1/0/1
>>鏈路delay-measurement advertise-delay 100 >>延遲。這會將從PE2到PE1的延
遲度量增加+100，因此從PE2到ABR 1的延遲為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*

如果介面上未配置手動通告 — 延遲，並且使用介面上啟用的預設延遲測量配置檔案，則會在鏈路上傳送探測器，以測量介面上的延遲。

<#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

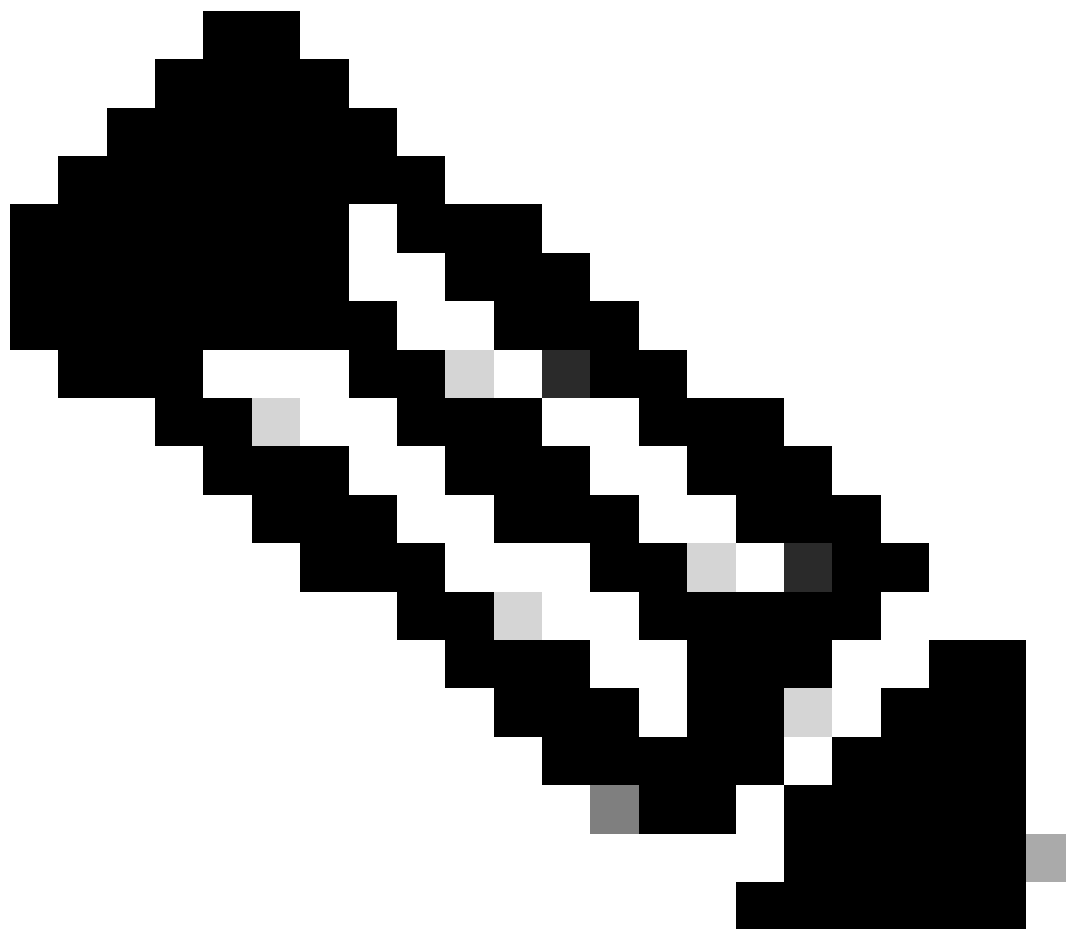
System Id	Metric	Next-Hop	Interface	SNPA
ASR9906-2-ABR-1				

12

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

24

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



附註：

- 從PE1到ABR 1，只有12個使用者延遲
- 從PE1到PE2，存在24個使用者延遲

FLEX-ALGO 129上的拓撲無關無環交換(TI-LFA)和微環規避(MLA)

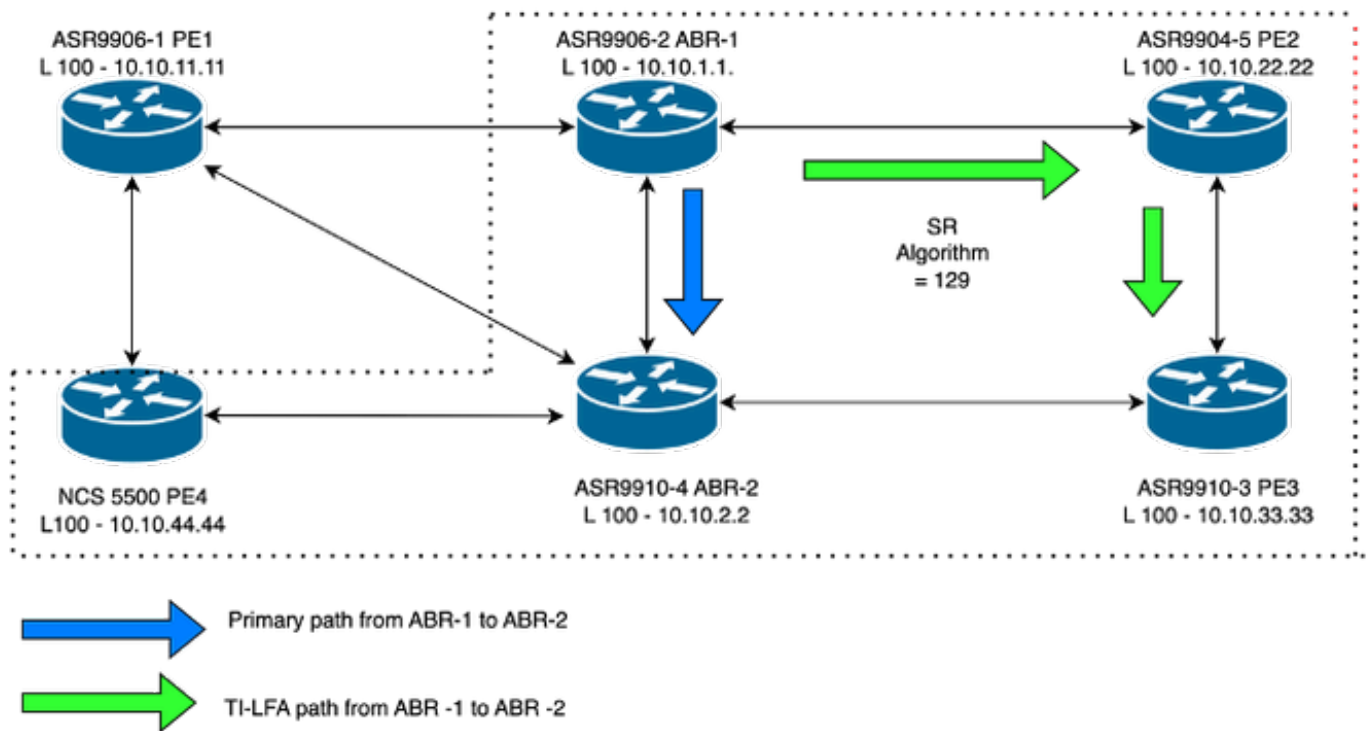


圖 4:用於演示Flex- Algo 129的TI-LFA和MLA的網路拓撲圖

<#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

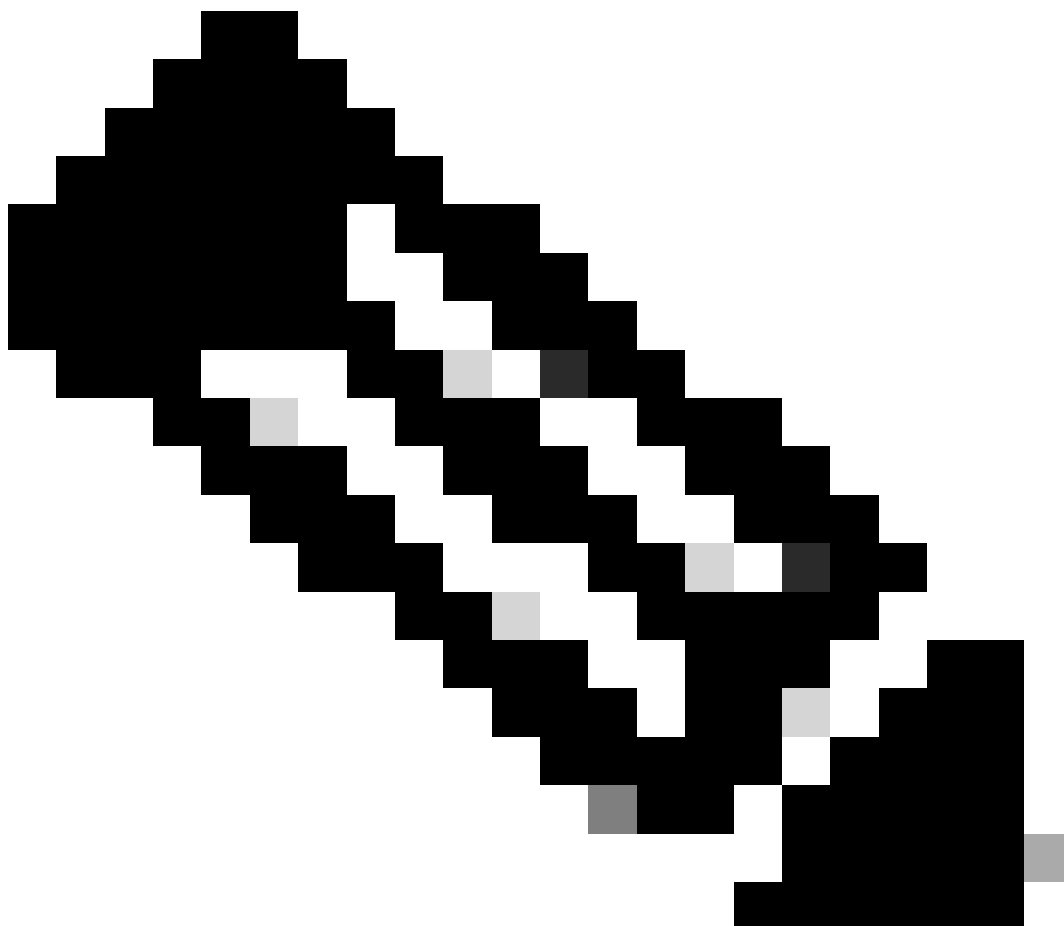
P node: ASR9910-3-PE3.00 [10.10.33.33], Label: 16933 >>>>>>>> TI-LFA precomputed path for FRR

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



附註：

- 16933 PE3 Flex-Algo 129標籤
- 16092 ABR -2 Flex-Algo 129標籤
- TI-LFA路徑也受flex algo 129的邏輯網路片限制

在ABR-1上，當ABR 1和2之間的鏈路關閉時，會觸發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運行自己的約束SPF，預計算尊重Algo 129約束的快速重路由隧道，僅使用FLEX-ALGO 129標籤。

鏈路關聯對映約束

- 關聯性是與IGP鏈路關聯的32位屬性，由操作員管理分配。
- 每個位位置對應於由運算子定義的語義含義。
- 這些關聯位作為鏈路TE屬性的一部分在IGP(OSPF/IS-IS)中通告。

當Flex-Algo計算其最短路徑樹(SPF)時，它在路徑選擇期間應用關聯約束：

- Include-Any(IA):計算出的路徑必須至少遍歷一個已設定任何指定關聯位元的連結。
- Include-All(IAI):計算出的路徑必須僅遍歷包含所有指定關聯位的鏈路。
- Exclude-Any(EA):計算出的路徑必須避免包含任何指定關聯位的所有鏈路。

組態

在ABR 1和2上：

```
<#root>
```

```
On ABR 1 and 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上發佈此配置。

驗證

```
<#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
```

未在任何鏈路上配置鏈路親合圖時，從PE4到PE3的路徑：

```
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
```

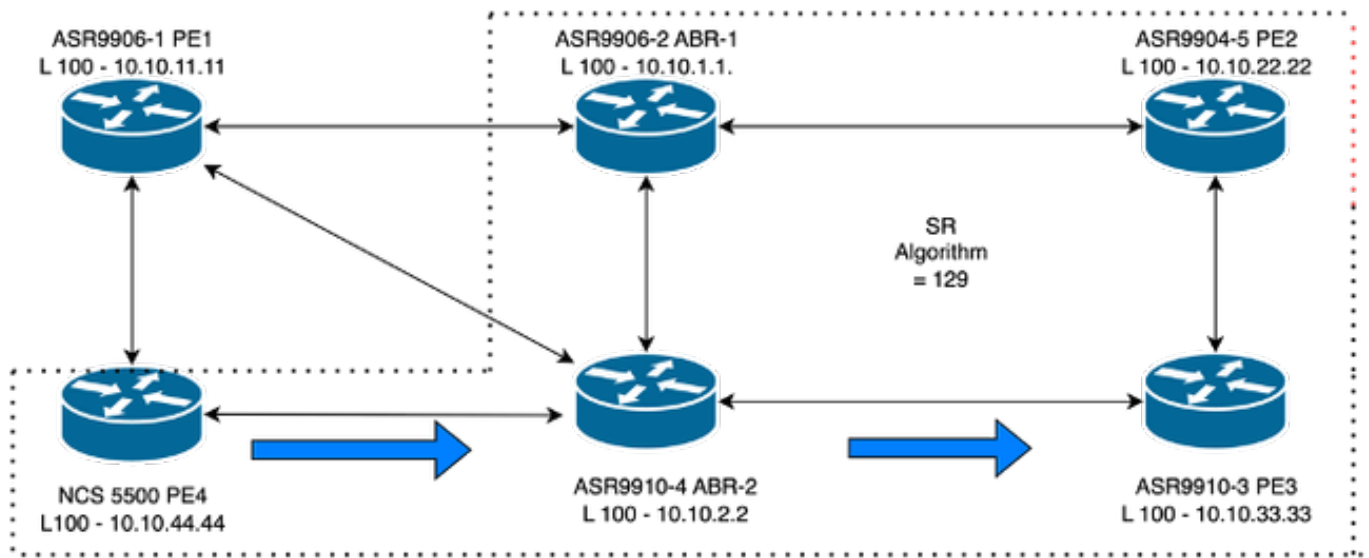


圖 5:未定義關聯對映的PE4到PE3之間的Traceroute

在ABR-2上配置關聯對映

<#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
  
```

驗證

<#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

根據Flex Algo 129從PE4到PE3的FAD，它需要排除任何具有關聯對映位位置6的鏈路。

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

[illegible]

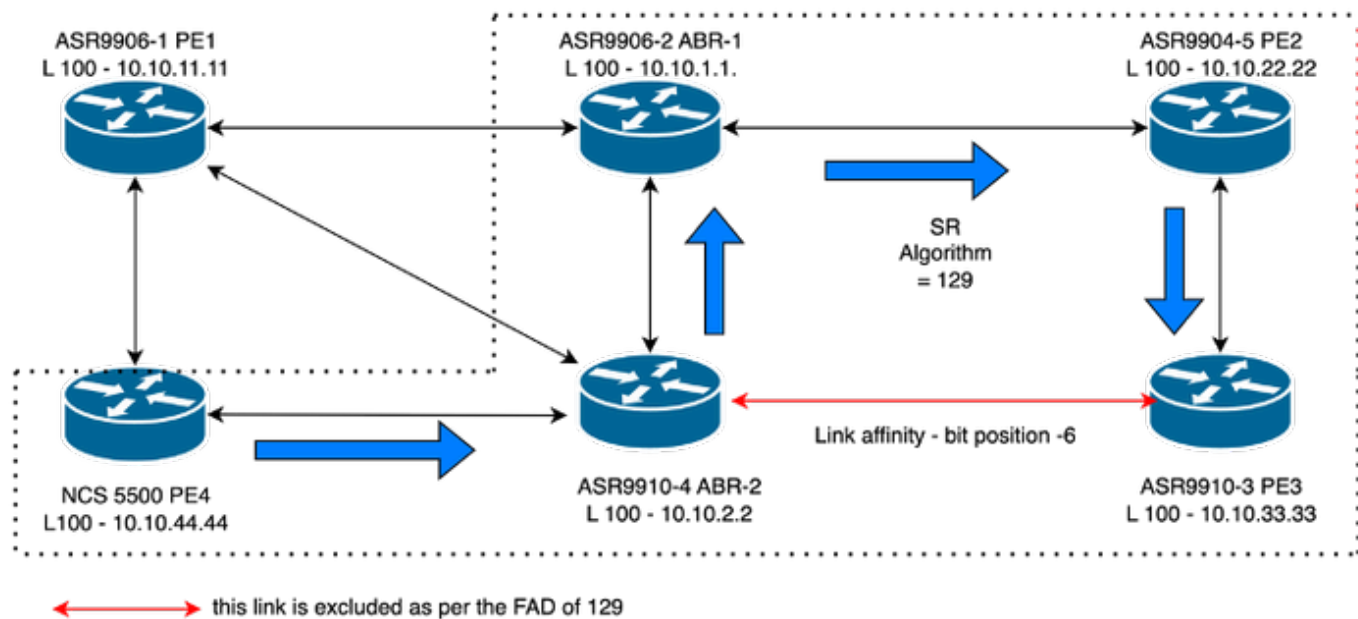
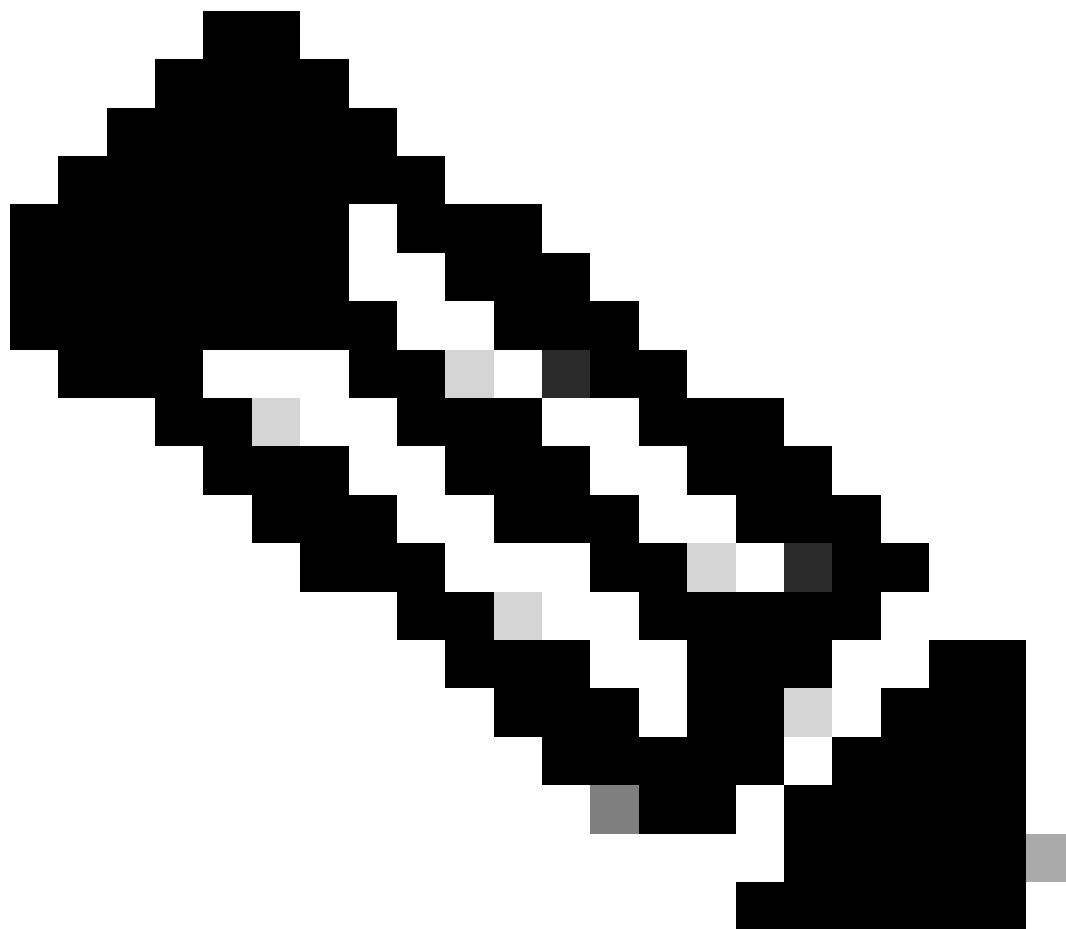


圖 6:配置關聯對映後從PE4到PE3的路徑



附註：同樣，在撓曲演算法的FAD中使用「包括any」和「包括all」，我們可以影響從頭端到尾端的路徑計算。

結論

本文檔介紹使用Flexible Algorithm(Flex-Algo)將IS-IS域邏輯切成多個網路切片。每個片可以定義自己的路徑計算規則和約束，從而能夠根據SLA要求或流量敏感性對流量流進行區別處理。

指令

```
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
```

關於此翻譯

思科已使用電腦和人工技術翻譯本文件，讓全世界的使用者能夠以自己的語言理解支援內容。請注意，即使是最佳機器翻譯，也不如專業譯者翻譯的內容準確。Cisco Systems, Inc. 對這些翻譯的準確度概不負責，並建議一律查看原始英文文件（提供連結）。