Cisco Learning Network CCIE SP series

IOS XR RPL – Route Policy Language

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Cisco Learning Network CCIE SP Series

Agenda

- Are [route-maps|prefix-lists|access-lists|filter-list|distribute-list|offset-lists|...] not enough?
- RPL introduction
- RPL basic usage & constructs
- RPL in specific use cases and troubleshooting RPL
- Q&A

Route Policy Language
Introduction

RPL brings clarity to Route-Maps

```
router bgp 100
   bgp log-neighbor-changes
   neighbor 100.64.1.1 remote-as 101
   neighbor 100.64.1.1 password CLN-WEBINARS-RULEZ
   neighbor 100.64.1.1 remove-private-as
   neighbor 100.64.1.1 soft-reconfiguration inbound
   neighbor 100.64.1.1 prefix-list INTERNET-IN in
   neighbor 100.64.1.1 prefix-list INTERNET-OUT out
   neighbor 100.64.1.1 route-map INTERNET-IN in
   neighbor 100.64.1.1 route-map INTERNET-OUT out
   neighbor 100.64.1.1 filter-list 3 in
   neighbor 100.64.1.1 filter-list 7 out
```

What is the order of processing?

Filtering order of operations – IOS/IOS-XE

- For inbound updates the order of preference is:

  route-map

  filter-list

  prefix-list, distribute-list

- For outbound updates the order of preference is:

  filter-list

  route-map | unsuppress-map

  advertise-map (conditional-advertisement)

  prefix-list|distribute-list

  ORF prefix-list (a prefix-list the neighbor sends us)

- **Note: The attributes prefix-list and distribute-list are mutually exclusive, and only one command (neighbor prefix-list or neighbor distribute-list) can be applied to each inbound or outbound direction for a particular neighbor.**

So…. new routing policy tool is needed!

- RPL developed along the IOS XR (1997-)
- Main building principles:

  exploit modularity (think SPs, think IXPs, scale, SCALE!)

  parametrization (SCALE again!)

  clarity (one default, no hidden steps, explicit logic)
- Incremental changes in new releases

Let’s compare live policy – SRD in action

IOS/IOS XE/NX OS

```
!
route-map BGP-BH-IPv4 deny 10
 match ip address prefix-list GOLDEN-NETS
!
route-map BGP-BH-IPv4 permit 100
 match community bgpbh-bogons
 set local-preference 6666
 set weight 6666
 set origin igp
 set community no-advertise additive
 set ip next-hop 192.0.2.1
!
route-map BGP-BH-IPv4 permit 200
 match community bgpbh-bogons-self
 set local-preference 6666
 set weight 6666
 set origin igp
 set community no-advertise additive
 set ip next-hop 192.0.2.1
!
```

IOS XR

```
!
route-policy BGP-BH-IPv4
  if destination in GOLDEN-NETS then
    drop
  endif
  if community matches-within \
     (bgpbh-bogons, bgpbh-bogons-self) then
    set local-preference 6666
    set weight 6666
    set origin igp
    set community (no-advertise) additive
    set next-hop discard
  endif
!
```

1. Do not program into FIB anything pointing to „Golden prefixes” (root DNS/NTP/local)
2. Install in FIB any routes matching communities bgpbh-bogons & bgpbh-bogons-self and set proper attributes to drop/discard them

My BGP edge policies simplified!

IOS XR

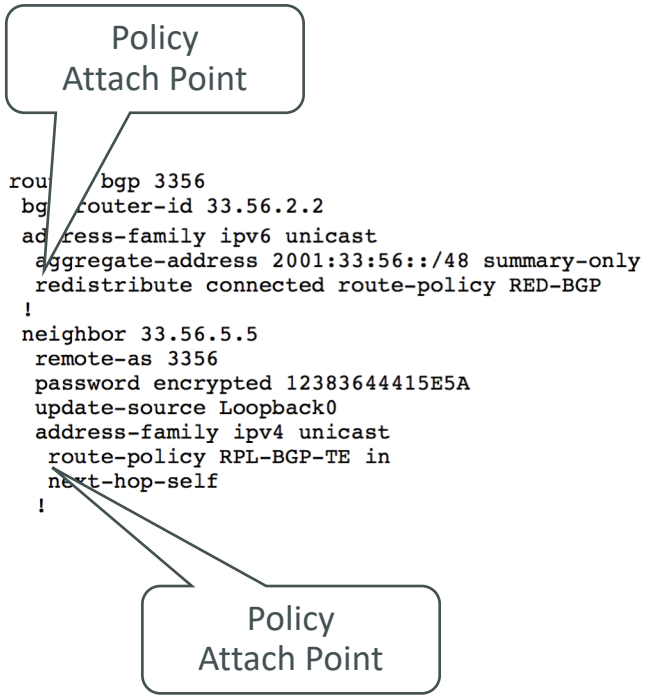
```
!
route-policy BGP-EDGE-ORANGE
  apply BGP-F-BOGONS
  apply BGP-BP-COMMON
  apply BGP-BP-ORANGE-PREF
end-policy
!
route-policy BGP-EDGE-TMOBILE
  apply BGP-F-BOGONS
  apply BGP-BP-COMMON
  apply BGP-BP-TMOBILE-PREF
!
router bgp
 neighbor x.x.x.x
  address-family ipv4
   route-policy BGP-EDGE-ORANGE in
 neighbor x.x.y.y
 address-family ipv4
   route-policy BGP-EDGE-TMOBILE in
```

```
prefix-set PFX-BOGONS
 0.0.0.0/8 le 32,
 10.0.0.0/8 le 32,
 [...]
end-set
!
route-policy BGP-F-BOGONS
  if destination in ( PFX-BOGONS ) then
   drop
  endif
end-policy
```

```
route-policy BGP-BP-COMMON
   set origin igp
   set local-preference 500
   set med 100
   delete community all
end-policy
```

```
route-policy BGP-BP-ORANGE-PREF
   if destination in ( PFX-ORANGE ) then
    set local-preference 200
   else
    set local-preference 90
   endif
end-policy
```

RPL keywords



Protocol Attribute(s)	RPL Attribute(s)	RPL Operation(s)
next-hop	source	pass / drop
weight	destination	suppress-route
local-preference	route-type	unsuppress-route
med	rib-has-route	length, unique-length
origin	traffic-index	set
as-path	dampening	apply
community	label	If, then
ext community	tag	else, elseif
rd		and, or, not
		eq, neq, le, gt
		in, is
		ios-regex

Actions in a RPL

Define action (default is drop) and may affect control flow

There is an implicit drop at the end of RPL processing.
A route must be given a '**ticket**' to ensure that it has been inspected by the RPL

Pass – prefix allowed if not later dropped

`pass` grants a ticket to defeat default drop

Execution continues after pass

Set – value changed, prefix allowed if not later dropped

Any `set` at any level grants a ticket

Execution continues after `set`

Values can be set more than once

Drop – prefix is discarded

Explicit drop stops policy execution

Implicit drop (if policy runs to end without getting a ticket)

Done – accepts prefix and stops processing

Things to remember when working with RPL:
Default eBGP policy (a.k.a. RFC 8212)

- eBGP sessions by default won't exchange any prefixes unless policy is configured
- There's a knob:

```
bgp unsafe-ebgp-policy
```

- https://tools.ietf.org/html/rfc8212

Things to remember when working with RPL:
Original value is stored until end of policy

- A conditional match does not occur on intermediary values during the route policy processing.

Conditional Matches on Original Value

```
route-policy ORGINAL-VALUES
  if med eq 100 then
    set med 200
  endif
  if med eq 200 then
    drop
  endif
end-policy
```

- In the example, only the original routes with a MED of 200 are dropped and the routes with values set to 200 are not dropped.

Basic RPL Examples

- Basic Pass Policy

Example Configuration

```
route-policy PASS-ALL
  pass
end-policy
```

- Basic Drop Policy

Example Configuration

```
route-policy DROP-ALL
  drop
end-policy
```

Somewhat redundant due to implicit drop

RPL Examples

- Basic conditional statement

Logic	Example Configuration

if **Match-Condition-One** then
Action-One
end-if
	`if med eq 150 then`
	`pass`
	`endif`

Conditional Match

Action

- Branching options

Logic	Example Configuration

if **Match-Condition-One** then
Action-One
else
Action-Two
end-if
	if destination in (10.0.0.0/8 ge 8) then
	pass
	else
	drop
	endif

Comparison operator

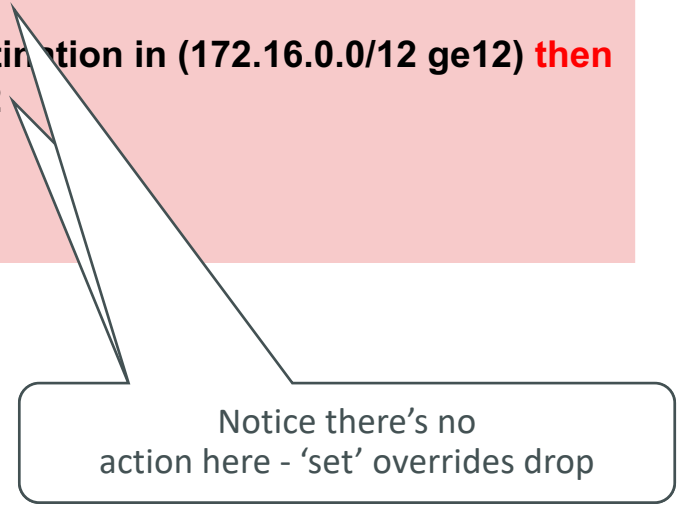
Notice we are matching networks directly in the RPL.
Supports Prefix Matching or Wildcard

RPL Examples (continued)

- Multiple branching options

Logic	Example Configuration

if **Match-Condition-One** then
Action-One
elseif **Match-Condtion-Two** then
Action-Two
else
Action-Three
end-if
	if destination in (10.0.0.0/8 ge 8) then
	set tag 1
	elseif destination in (172.16.0.0/12 ge12) then
	set tag 2
	else
	drop
	endif



Nested Conditions

- If statements within other if/elseif/else statements

  Method or placing multiple conditions

- Nesting can be any depth

Logic	Example Configuration

if **MATCHING-CONDITION-ONE** then
  if **MATCHING-CONDITION-TWO** then
  ACTION-ONE
  end-if
end-if
	if as-path passes-through '100' then
	  if destination in PREFIX-SET-RFC1918 then
	  pass
	  endif
	endif

Simplifying BGP AS-Path Conditions

AS Path Selection Criteria	Route-Map AS-Path ACL Logic *(ip as-path access-list 1)*	RPL Logic
Local Routes	`permit ^$`	`if as-path is-local`
Only Routes From Neighbor AS 200	`permit ^200_`	`if as-path neighbor-is '200'`
Only Routes Originating From AS 200	`permit _200$`	`if as-path originates-from '200'`
Passes Through AS200	`permit  _200_`	`if as-path passes-through '200'`
Routes From 3 ASes or less away	`permit ^[0-9]+ [0-9]+ [0-9]+?`	`if as-path length le 3`

RPL Examples

Bad RPL Logic

```
route-policy METRIC-MODIFICATION
  if destination in (192.168.0.0/16 ge 16) then
    set med 100
  endif
  set med 200
end-policy
```

Overwrites setting

Good RPL Logic Option #1

```
route-policy METRIC-MODIFICATION
  if destination in (10.0.0.0/8 ge 8) then
    set med 100
    pass
  else
    set med 200
    pass
  endif
end-policy
```

Option #2

```
route-policy METRIC-MODIFICATION
  if destination in (10.0.0.0/8 ge 8) then
    set med 100
    done
  endif
  set med 200
end-policy
```

Stops all processing on matched prefixes

Route Policy Language

Sets, nesting policies and parametrization

RPL Policy Sets

- Prefix-lists, ACLs, AS_PATH ACLs can be confusing because of permit/deny actions
- IOS XR uses policy sets to store the same information:
  Prefix set, Community set, Extended Community set, AS_PATH set, RD set
- There is no ‘deny’ in a Policy set
- Processing occurs until the first match is made

Named and Inline Set (same behavior)

Inline Example Configuration

```
if destination in (10.0.0.0/8 ge 8, 172.16.0.0/12 ge 12, 192.168.0.0/16 ge 16) then
    pass
  else
    drop
  endif
```

Set Example Configuration

```
route-policy RFC1918-PREFIX-SET
  if destination in PREFIX-SET-RFC1918 then
    pass
  endif
end-policy
!
prefix-set PREFIX-SET-RFC1918
  10.0.0.0/8 ge 8,
  172.16.0.0/12 ge 12,
  192.168.0.0/16 ge 16
end-set
```

Viewing Set Based RPLS

Keyword required to see sets in the RPL

Inline Example Configuration

```
RP/0/0/CPU0:XR1#show rpl route-policy RFC1918-PREFIX-SET inline

route-policy RFC1918-PREFIX-SET
  if destination in (10.0.0.0/8 ge 8, 172.16.0.0/12 ge 12, 192.168.0.0/16 ge 16) then
    pass
  endif
end-policy
```

Parameter Passing

Single Parameter

```
route-policy PARAM ($MED)
 set med $MED
end-policy

router bgp 300
 […]
 neighbor 33.56.5.1
  remote-as 49.12
  address-family ipv4 unicast
   route-policy PARAM (50) in
   route-policy PASS-ALL out
```

List of policy parameters

Accessing the passed parameter

Calling policy and passing parameter

Using Multiple Parameters

Multiple Parameters

```
route-policy SP-PEER ($AS, $PREFIX)
 if destination in $PREFIX and as-path originates-from '$AS' then
   pass
 endif
end-policy

router bgp 300
 […]
 neighbor 33.56.5.1
  remote-as 49.12
  address-family ipv4 unicast
   route-policy SP-PEER (50, CUST1-PREFIX-SET) in
   route-policy PASS-ALL out
```

Can reference a policy-set

Nesting in RPL

- By nesting policies we can scale RPL out

Example Configuration

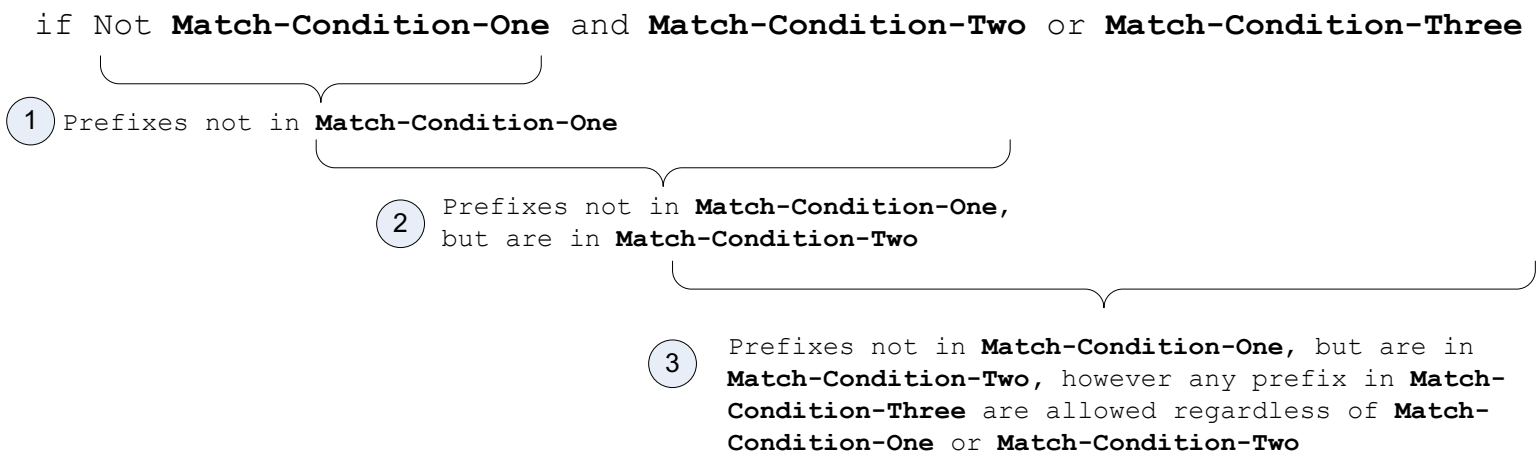
```
route-policy PARENT
    apply CHILD-ONE
    apply CHILD-TWO
    pass
end-policy

route-policy CHILD-ONE
     set weight 100
end-policy

route-policy CHILD-TWO
     set community (2:1234) additive
end-policy
```

Boolean (Logical) Operations

- Comparison operators are context sensitive

  Semantic check not done until RPL policy use is committed

- Supported Operators - Not, And, & Or (in order of precedence)



Boolean (Logical) Operations

- Conditional match that requires a route to not pass through AS 100 or AS 200, and must be within the 192.168.0.0/16 network range

```
if (((Not Match-Condition-One) and Match-Condition-Two) or Match-Condition-Three)
```

Use of parentheses

if not (as-path passes-through '100' or as-path passes-through '200') and destination in (192.168.0.0/16 ge 16)

Boolean Operators

Negation

```
if not destination in PREFIX-SET-RFC1918 then
    pass
endif
```

Conjunction

```
if destination in PREFIX-SET-RFC1918 and as-path passes-through '100' then
    pass
endif
```

Disjunction

```
if destination in PREFIX-SET-RFC1918 or as-path passes-through '100' then
    pass
endif
```

Route Policy Language

Corner cases, comments and troubleshooting

Community matching and manipulation

Matching specific community(-ies)

```
!
route-policy AS100-TE
  if community matches-any (100:748) then
    delete community in (internet)
  endif
  pass
end-policy
!
```

Deleting / modifying communities

```
!
route-policy AS100-TE
  if […]
   delete community in (100:*)
  endif
  pass
end-policy
!
```

Nested policies in ‚if' statement

- What is the behavior of policies if nested at ‚if' statement?

```
!
route-policy CHECK-MULTIPLE-OPTIONS
  if apply CHECK-FIRST and apply CHECK-SECOND then
   set community 3356:666
  else
   drop
  endif
  pass
end-policy
!
```

Remarks in policies (that survive reboot)
(and upgrade... and in order defined originally ;))

```
!
route-policy CLN71
  # this is specific policy for
  # testing the ordered remarks
  # for CLN session slides
  #
  # welcome
  set med 6
end-policy
!
```

Profiling of RPL runs – use with care!

- ”Everybody has a testing environment. Some people are lucky enough enough to have a totally separate environment to run production in.”

DevOptimist.
@stahnma

```
!
RP/0/0/CPU0:SP1R2#debug pcl profile detail
!
(wait)
!
RP/0/0/CPU0:SP1R2#sh pcl protocol bgp speaker-0 neighbor-in-dflt default-IPv4-40.67.1.1 policy profile
Policy profiling data
Policy : AS100-TE
Pass : 4
Drop : 0
# of executions : 4
Total execution time : 0msec

Node Id    Num visited      Exec time  Policy engine operation
------------------------------------------------------------------------------
PXL_0_1                                community delete-in
                                       <end-policy/>
```

Route Policy Language

Migration hints

Migrating route-maps to RPL

- Do a simple syntax translation
- Nest conditionals to reduce repetitions & comparisions
- Use inline sets to remove small indirect set references
- Parameterize to reuse common structures

Step 1: Direct syntax translation

- Each route-map becomes a route-policy
- Each clause in a route-map becomes a clause in an if-then-else sequence.
- For each clause:

  Map each ‘match’ to the corresponding conditional.

  Map each ‘set’ to the corresponding ‘action’.

```
route-map PROCESS_INBOUND deny 5
 match as-path 150
!
route-map PROCESS_INBOUND permit 10
 match as-path 10
 match community 1
 set local-preference 70
 set community 100:500 100:505 100:999 additive
!
route-map PROCESS_INBOUND permit 20
 match as-path 10
 match community 2
 set local-preference 80
 set community 100:500 100:505 100:999 additive
!
route-map PROCESS_INBOUND permit 30
 set local-preference 90
 set community 100:500 100:505 100:999 additive
!
```

```
route-policy PROCESS_INBOUND
 if (as-path in aspath_150) then
   drop
 elseif ((community matches-any comm_1) and (as-path in aspath_10)) then
   set local-preference 70
   set community (100:500, 100:505, 100:999) additive
 elseif ((community matches-any comm_2) and (as-path in aspath_10)) then
   set local-preference 80
   set community (100:500, 100:505, 100:999) additive
 else
  set local-preference 90
  set community (100:500, 100:505, 100:999) additive
 endif
end-policy
```

Step 2: Nest Conditionals

- Collect similar conditions into nested ‘if’ statements.

```
route-policy PROCESS_INBOUND
 if (as-path in as_path_150) then
  drop
 elseif (as-path in as_path_10) then
   if (community matches-any comm_1) then
     set local-preference 70
     set community (100:500, 100:505, 100:999) additive
   elseif (community matches-any comm_2) then
     set local-preference 80
     set community (100:500, 100:505, 100:999) additive
  endif
 else
  set local-preference 90
  set community (100:500, 100:505, 100:999) additive
 endif
end-policy
```

Step 3: Use inline sets (when it makes sense)

- Small sets (AS-Path set, Community set, etc.) can be replaced with inline sets.

```
route-policy PROCESS_INBOUND
 if (as-path in '_701_', '_3561_') then
   drop
 elseif (as-path in '^21409_') then
   if (community matches-any ‘5511:70’) then
     set local-preference 70
     set community (100:500, 100:505, 100:999) additive
   elseif (community matches-any ‘5511:80’) then
     set local-preference 80
     set community (100:500, 100:505, 100:999) additive
  endif
 else
  set local-preference 90
  set community (100:500, 100:505, 100:999) additive
 endif
end-policy
```

Step 4: Parameterize

- Similar actions can be grouped into a common policy with parameters.

```
route-policy set_attributes ($pref)
   set local-preference $pref
   set community (100:500:, 100:505, 100:999) additive
end-policy
!
route-policy PROCESS_INBOUND
 if (as-path in '_701_', '_3561_') then
   drop
 elseif (as-path in '^21409_') then
   if (community matches-any '5511:70') then
      apply set_attributes (70)
    elseif (community matches-any '5511:80') then
      apply set_attributes (80)
   endif
 else
      apply set_attributes (90)
 endif
end-policy
```

Policy Lists with mixed entries.

- Recall, that sets within RPL do not convey the concept of permit or deny - only membership.
- So, how does the following policy get converted ?

```
ip prefix-list martians seq 10 permit 0.0.0.0/0
ip prefix-list martians seq 20 permit 127.0.0.0/8 le 32
ip prefix-list martians seq 30 deny 10.192.0.0/10 ge 12 le 21
ip prefix-list martians seq 40 permit 10.0.0.0/8 le 32
ip prefix-list martians seq 50 permit 172.16.0.0/12 le 32
ip prefix-list martians seq 60 permit 192.168.0.0/16 le 32
ip prefix-list martians seq 70 permit 128.0.0.0/16 le 32
ip prefix-list martians seq 80 permit 192.0.0.0/24 le 32
ip prefix-list martians seq 90 permit 223.255.255.0/24 le 32
ip prefix-list martians seq 100 permit 224.0.0.0/3 le 32
ip prefix-list martians seq 110 permit 192.157.69.0/24 le 32
!
route-map CUST-FACE deny 10
 match ip address prefix-list martians
```

Policy Lists with mixed entries.

Keep all of the ‘permit’s ?

```
prefix-set pfx_martians
 0.0.0.0/0,
 127.0.0.0/8 le 32,
 10.0.0.0/8 le 32,
 172.16.0.0/12 le 32,
 192.168.0.0/16 le 32,
 128.0.0.0/16 le 32,
 192.0.0.0/24 le 32,
 223.255.255.0/24 le 32,
 224.0.0.0/3 le 32,
 192.157.69.0/24 le 32
end-set
!
route-policy CUST_FACE
 if (destination in pfx_martians)  then
   drop
 else
   pass
 endif
end-policy
!
```

Keep all of the ‘deny’s ?

```
prefix-set pfx_martians
 10.192.0.0/10 ge 12 le 21,
end-set
!
route-policy CUST_FACE
 if (destination in pfx_martians) then
   pass
 else
   drop
 endif
end-policy
!
```

Policy Lists with mixed entries.

The answer is: BOTH !

1) Partition the prefix-list into separate sections - each containing a string of ‘permit’ or ‘deny’ entries.

2) Create a prefix-set to correspond to each section.

3) Adjust the route-policy to process each partition in turn.

   Keeping the partitions in order is important to preserve the original logic with respect to overlapping entries.

   The same process can be applied to as-path-set(s) & community-set(s)

```
prefix-set pfx_martians_p1_permit
 0.0.0.0/0
 127.0.0.0/8 le 32
end-set
!
prefix-set pfx_martians_p2_deny
 10.192.0.0/10 ge 12 le 21
end-set
!
prefix-set pfx_martians_p3_permit
 10.0.0.0/8 le 32,
 172.16.0.0/12 le 32,
 192.168.0.0/16 le 32,
 128.0.0.0/16 le 32,
 191.255.0.0/16 le 32,
 192.0.0.0/24 le 32,
 223.255.255.0/24 le 32,
 224.0.0.0/3 le 32,
 192.157.69.0/24 le 32
end-set
!
route-policy CUST_FACE
 if (destination in pfx_martians_p1_permit) then
   drop
 elseif (destination in pfx_martians_p2_deny) then
   pass
 elseif (destination in pfx_martians_p3_permit) then
   drop
 endif
end-policy
```

Route Policy Language

Follow up – where to look for information

Resources

- Understanding and using IOS XR RPL: https://supportforums.cisco.com/t5/service-providers-documents/asr9000-xr-understanding-and-using-rpl-route-policy-language/ta-p/3117050
- Using IOS XR RPL for BGP: https://learning.nil.com/assets/Tips-/Using-the-IOS-XR-Routing-Policy-Language-for-BGP.pdf
- Great site for IOS XR geeks: https://xrdocs.github.io/
- Cisco Press IOS XR fundamentals book: http://www.ciscopress.com/store/cisco-ios-xr-fundamentals-9781587052712
- Cisco Press IP routing on IOS, IOS XE and IOS XR book: http://www.ciscopress.com/store/ip-routing-on-cisco-ios-ios-xe-and-ios-xr-an-essential-9781587144233
- CCIE SP Study Group home page: https://learningnetwork.cisco.com/groups/ccie-sp-study-group

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Thank You!

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