

Cisco Performance Routing (PfR) Solution Guides

PfR Basic Load Balancing using BGP

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PfR Solution Used

This solution describes a basic load sharing for an enterprise dual attached to two IP-VPN Service Providers. The load-balancing used here is taking place between external interfaces and will be based on the top talker prefixes.

- Learning phase: automatic. Top talkers based on Netflow reports from the Border Routers
- Measuring phase: mode both, which means passive monitoring based on Netflow and active probes when choosing new exits.
- Policies:

utilization: Link utilization for each exit interface on the Border Routers should not exceed 90% of the defined bandwidth

range: traffic should be load-balanced so that the average bandwidth range between external interfaces should be maintain within 10%.

- Enforcement: load-balancing based on prefixes and BGP used on the uplinks toward the Service Providers. PfR will enforce the path by modifying the BGP local-pref attribute for controlled prefixes.

PfR Features that Enable Load Balancing

Link Utilization

Usage of this policy sets an upper threshold on the amount of traffic a specific link can carry. For example, if the upper threshold for a link is 90 % of total bandwidth, and it is currently running at 95 % of bandwidth, the link is Out-of-Policy (OOP). Cisco PfR will attempt to bring the link back into policy by repeatedly moving prefixes from the over-used link onto other exit links.

Range

Usage of this policy keeps some or all WAN links within a certain utilization range, relative to each other in order to ensure fair load-sharing across all concerned links. The range functionality allows the network administrator to instruct Cisco PfR to keep the usage on a set of exit links with in a certain percentage range of each other. If the difference between the links becomes too great, Cisco PfR will attempt to bring the link back in to policy by distributing data traffic among the available exit links.

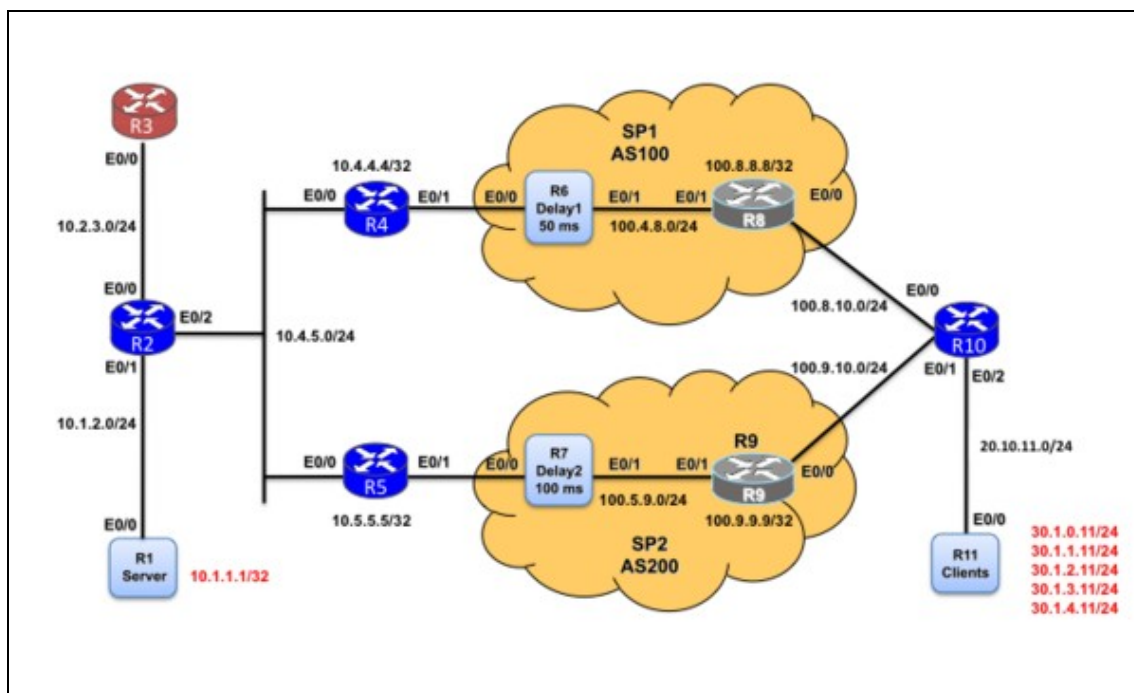
Traffic Class Performance

Usage of this policy enables the customer to define multiple paths that a set of traffic (ie voice traffic) could use as long as all the paths maintain the performance SLA ?s that are needed forth at set of traffic. Hence, a policy that determines voice traffic to have a delay threshold of less than 250 msec can utilize multiple paths in the network if available, as long as all the paths deliver the traffic within its performance bounds.

PfR Network Topology Used

The central site has two Border Routers, connected to two separate Service Providers using eBGP. R2, R4 and R5 are iBGP peers.

- R3 is the Master Controller
- R4 and R5 the Border Routers
- Traffic Simulator tool is used between R1 and R11 to emulate traffic
- R6 and R7 are delay generators that add delay/loss to the path through SP1 and SP2. By default, 100 ms through SP1 and 50 ms through SP2.
- R1 and R11 are packet generators that send/receive traffic (http, ssh, etc).



PfR Components Configuration

Master Controller Configuration	Comments
<pre> ! key chain pfr key 0 key-string cisco ! pfr master max-range-utilization percent 10 logging ! border 10.4.5.5 key-chain pfr interface Ethernet0/1 external max-xmit-utilization percentage 90 interface Ethernet0/0 internal </pre>	<ul style="list-style-type: none"> • max-range-utilization percent 10 : Start Load balancing when exits links utilization differ more than 10%. • logging : Enable PfR Syslogs (can be checked using show logging). • max-xmit-utilization percentage 90 : If utilization on an external link exceeds 90% of the configured bandwidth, PfR will detect a Load OOP condition. • mode route control: PfR control the routes

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<pre> ! border 10.4.5.4 key-chain pfr interface Ethernet0/1 external max-xmit-utilization percentage 90 interface Ethernet0/0 internal ! learn throughput delay periodic-interval 0 monitor-period 1 mode route control periodic 180 resolve range priority 1 resolve utilization priority 5 variance 20 no resolve delay ! </pre>	<ul style="list-style-type: none"> • resolve: Check range then utilization. If utilization on an external link is more than 20% greater than the range across all of the links, PfR will detect a Range OOP condition. • periodic 180: policies are reevaluated every 180s (optional)
---	---

Border Router Configuration	Comments
<pre> ! key chain pfr key 0 key-string cisco ! pfr border local Ethernet0/0 master 10.2.3.3 key-chain pfr ! ! interface Ethernet0/0 description --INTERNAL-- bandwidth 10000 ip address 10.4.5.4 255.255.255.0 ip ospf 100 area 0 load-interval 30 ! interface Ethernet0/1 description --ISP1-- bandwidth 500 ip address 100.4.8.4 255.255.255.0 load-interval 30 ! </pre>	<p>The Master Controller needs to be configured to talk to the border routers. The IP address used is the one referred by the ?local <interface>? configuration on the BR.</p> <p>Netflow configuration on internal and external interfaces is not needed for PfR to operate. Just configure here as a mean to verify flows that are crossing this BR.</p> <p>External interface Don?t forget to configure external interfaces with the contracted bandwidth so that PfR knows how to share load. Also set the load interval to 30 seconds for better accuracy.</p>

Flexible Netflow

While configuring Netflow is not a mandatory task for PfR to work, it allows to have a good understanding of the traffic flows across the border routers. The following configuration is just an example of a flow monitor definition.

Flow Record Definition

```
!
```

Flexible Netflow

```
flow record MYRECORD
 match ipv4 protocol
 match ipv4 source address
 match ipv4 destination address
 match transport source-port
 match transport destination-port
 match interface input
 collect interface output
 collect counter bytes
 collect counter packets
!
```

Flow Monitor Definition

```
flow monitor MYMONITOR
 record MYRECORD
!
```

And then apply the FNF Monitor on the interface

```
interface Ethernet0/0
 ip flow monitor MYMONITOR input
!
```

Master Controller Verification ? show pfr master

Goal:

- Verify that the MC is active
- Verify that the learning process is enabled on the Master Controller
- Display the policy settings as well as the learning parameters and global timers.

```
MC#sh pfr master
OER state: ENABLED and ACTIVE
 Conn Status: SUCCESS, PORT: 3949
 Version: 3.0
 Number of Border routers: 2
 Number of Exits: 2
 Number of monitored prefixes: 6 (max 5000)
 Max prefixes: total 5000 learn 2500
 Prefix count: total 6, learn 6, cfg 0
 PBR Requirements met
 Nbar Status: Inactive
```

Border	Status	UP/DOWN		AuthFail	Version
10.4.5.5	ACTIVE	UP	00:15:21	0	3.0
10.4.5.4	ACTIVE	UP	00:15:16	0	3.0

```
Global Settings:
 max-range-utilization percent 10 recv 0
 mode route metric bgp local-pref 5000
 mode route metric static tag 5000
 trace probe delay 1000
```

Master Controller Verification ? show pfr master

PfR:Solutions:BasicLoadBalancing

```
logging
exit holddown time 60 secs, time remaining 0
```

Default Policy Settings:

```
backoff 300 3000 300
delay relative 50
holddown 300
periodic 180
probe frequency 56
number of jitter probe packets 100
mode route control
mode monitor both
mode select-exit good
loss relative 10
jitter threshold 20
mos threshold 3.60 percent 30
unreachable relative 50
resolve range priority 1 variance 0
resolve utilization priority 5 variance 20
```

Learn Settings:

```
current state : STARTED
time remaining in current state : 77 seconds
throughput
delay
no inside bgp
monitor-period 1
periodic-interval 0
aggregation-type prefix-length 24
prefixes 100 appls 100
expire after time 720
```

MC#

What to check:

- Both Border Routers are up and running
- Number of Monitored Prefixes: 6 are learned
- Global Settings: max-range-utilization is 10 (percentage of bandwidth difference between all exit interfaces)
- All default policy settings are displayed
- Learn is started (current state : STARTED)

The PfR state should be "enabled and active" and the learning state "started". You can also notice that there are a few default values already defined for several thresholds.

Netflow Statistics

As explained before, explicitly enabling Netflow is not required for PfR to run but is a good practice to check active flows crossing the Border Routers, verify the ingress/egress interfaces used (must be internal to external or vice-versa).

In this example, we check if traffic is flowing through the border router R4 (by default R4 is the exit point according to BGP):

R4#

Netflow Statistics

PfR:Solutions:BasicLoadBalancing

```
R4# sh flow monitor MYMONITOR cache format table
Cache type:                Normal
Cache size:                4096
Current entries:          68
High Watermark:          68

Flows added:              73
Flows aged:               5
  - Active timeout        ( 1800 secs) 0
  - Inactive timeout      (   15 secs) 5
  - Event aged            0
  - Watermark aged       0
  - Emergency aged       0
```

IPV4 SRC ADDR	IPV4 DST ADDR	TRNS SRC PORT	TRNS DST PORT	INTF INPUT	IP PROT	int
10.4.5.2	224.0.0.5	0	0	Et0/0	89	NuL
10.4.5.5	224.0.0.5	0	0	Et0/0	89	NuL
10.2.3.3	10.4.5.4	3949	52511	Et0/0	6	NuL
10.1.1.1	30.1.1.11	22	1011	Et0/0	6	EtC
10.2.3.3	10.4.5.4	3949	15621	Et0/0	6	NuL
10.1.1.1	30.1.2.11	25	2008	Et0/0	6	EtC
10.1.1.1	30.1.3.11	21	3002	Et0/0	6	EtC
10.1.1.1	30.1.0.11	262	10	Et0/0	6	EtC
10.1.1.1	30.1.4.11	22	1012	Et0/0	6	EtC
10.1.1.1	30.1.5.11	25	2009	Et0/0	6	EtC
10.1.1.1	30.1.1.11	263	10	Et0/0	6	EtC
10.1.1.1	30.1.2.11	22	1013	Et0/0	6	EtC
10.1.1.1	30.1.0.11	264	10	Et0/0	6	EtC
10.1.1.1	30.1.4.11	22	1014	Et0/0	6	EtC
10.1.1.1	30.1.5.11	22	1015	Et0/0	6	EtC
10.1.1.1	30.1.1.11	265	10	Et0/0	6	EtC
10.1.1.1	30.1.2.11	22	1016	Et0/0	6	EtC
10.1.1.1	30.1.0.11	266	10	Et0/0	6	EtC
10.1.1.1	30.1.4.11	22	1017	Et0/0	6	EtC
10.1.1.1	30.1.5.11	22	1018	Et0/0	6	EtC
10.1.1.1	30.1.3.11	80	3003	Et0/0	6	EtC

[snip]

10.1.1.1	30.1.5.11	205	10	Et0/0	6	EtC
10.1.1.1	30.1.1.11	206	10	Et0/0	6	EtC
10.1.1.1	30.1.5.11	22	1060	Et0/0	6	EtC
10.1.1.1	30.1.2.11	207	10	Et0/0	6	EtC

R4#

We clearly see that traffic is crossing the BR between internal and external interfaces (E0/0 and E0/1). Next step is to check the Traffic Classes on the Master Controller.

Verify Load balancing

As soon as you see:

```
MC#
*Sep  3 16:01:22.924: %OER_MC-5-NOTICE: Prefix Learning WRITING DATA
*Sep  3 16:01:22.966: %OER_MC-5-NOTICE: Prefix Learning STARTED
MC#
```

PfR:Solutions:BasicLoadBalancing

You should be able to see the traffic classes on the Master Controller. You will need a few cycles before having all prefixes in INPOLICY state. You will start getting OOP (out of policy messages) from PfR regarding range, because R4 (10.4.5.4) is currently the only exit point while R5 (10.4.5.5) has no traffic:

MC#

```
*Sep  3 16:01:39.232: %OER_MC-5-NOTICE: Range OOP BR 10.4.5.4, i/f Et0/1, percent 76. Other BR 10.
```

```
*Sep  3 16:01:39.232: %OER_MC-5-NOTICE: Exit 10.4.5.4 intf Et0/1 OOP, Tx BW 383, Rx BW 54, Tx Load
```

MC#

Traffic Classes

On the Master Controller, you have all the Traffic Classes (in this case prefixes) learnt as well as statistics:

Using show oer master traffic-class

MC#sh pfr master traffic-class

OER Prefix Statistics:

Pas - Passive, Act - Active, S - Short term, L - Long term, Dly - Delay (ms),

P - Percentage below threshold, Jit - Jitter (ms),

MOS - Mean Opinion Score

Los - Packet Loss (packets-per-million), Un - Unreachable (flows-per-million),

E - Egress, I - Ingress, Bw - Bandwidth (kbps), N - Not applicable

U - unknown, * - uncontrolled, + - control more specific, @ - active probe all

- Prefix monitor mode is Special, & - Blackholed Prefix

% - Force Next-Hop, ^ - Prefix is denied

DstPrefix	Flags		Appl_ID		Dscp		Prot	SrcPort	Time	SrcPrefix	CurrBR	CurrI/F	Protocol								
	PasSDly	ActSDly	PasLDly	ActLDly	PasSUn	ActSUn								PasLUn	ActLUn	PasSJos	ActSJit	PasLJos	ActPMOS	EBw	IBw
30.1.0.0/24			N	N	N			N			N	N									
									@83		10.4.5.4	Et0/1		U							
	52		52		0		0	0	0	0	0	67		7							
	51		51		0		0	N		N	N	N		N							
30.1.1.0/24			N	N	N			N			N	N									
									@82		10.4.5.5	Et0/1		BGP							
	104		102		0		0	0	0	0	0	55		6							
	102		102		0		0	N		N	N	N		N							
30.1.2.0/24			N	N	N			N			N	N									
									@84		10.4.5.5	Et0/1		BGP							
	104		100		0		0	0	0	0	0	55		6							
	100		100		0		0	N		N	N	N		N							
30.1.3.0/24			N	N	N			N			N	N									
									@82		10.4.5.4	Et0/1		U							
	52		52		0		0	0	0	0	0	66		7							
	51		51		0		0	N		N	N	N		N							
30.1.4.0/24			N	N	N			N			N	N									
									@77		10.4.5.5	Et0/1		BGP							
	104		102		0		0	0	0	0	0	53		6							
	105		105		0		0	N		N	N	N		N							
30.1.5.0/24			N	N	N			N			N	N									
									@76		10.4.5.4	Et0/1		U							
	52		52		0		0	0	0	0	0	67		7							

51 51 0 0 N N N N

MC#

A closer look at the results

If we look at 2 specific prefixes 30.1.0.0/24 and 30.1.1.0/24, we can see that PfR controls one, while the other is under the parent route control.

From the command `?show oer master traffic-class`, let's focus on the prefix 30.1.0.0/24 to understand the interesting values reported here:

```
MC#sh pfr master traffic-class
```

```
OER Prefix Statistics:
```

```
Pas - Passive, Act - Active, S - Short term, L - Long term, Dly - Delay (ms),
P - Percentage below threshold, Jit - Jitter (ms),
MOS - Mean Opinion Score
Los - Packet Loss (packets-per-million), Un - Unreachable (flows-per-million),
E - Egress, I - Ingress, Bw - Bandwidth (kbps), N - Not applicable
U - unknown, * - uncontrolled, + - control more specific, @ - active probe all
# - Prefix monitor mode is Special, & - Blackholed Prefix
% - Force Next-Hop, ^ - Prefix is denied
```

DstPrefix	Flags	Appl_ID	Dscp	Prot	SrcPort	Time	DstPort	SrcPrefix	Protocol	
	PasSDly	PasLDly	PasSUn	PasLUn	PasSLos	PasLLos	CurrBR	CurrI/F	EBw	IBw
	ActSDly	ActLDly	ActSUn	ActLUn	ActSJit	ActPMOS	ActSLos	ActLLos		
30.1.0.0/24			N	N	N	N	N	N		
			INPOLICY*			29	10.4.5.4	Et0/1		U
	52	52	0	0	0	0	0	66	7	
	51	51	0	0	N	N	N	N	N	

[snip]

MC#

In looking at the detail display of the prefix, several items bear notice:

- **Line1:** prefix
- **Line2:** State of INPOLICY*?The asteric (*) indicates this prefix is uncontrolled by PfR (the parent route controls routing) , but is currently inpolicy.
- **Line3: Passive results**
- **Line3 (PasSDly, PasLDly):** short-term and long-term passive delay, measured from the TCP Syn/Ack. As explained previously, TCP Syn/Ack are used to check the reachability of the prefix and to collect the delay and loss information. The delay is around 50 ms, which is the delay through ISP1 (BR R4).
- **Line3 (PasSUn, PasLUn):** short-term and long-term statistics for Unreachable.
- **Line3 (PasSLos, PasLLos):** short-term and long-term statistics for Loss.
- **Line3 (EBw/IBw):** the bandwidth for this prefix in egress and ingress direction.

- **Line4: Active results**
- Line4 (ActSDly, ActLDly): short-term and long-term active delay, measured by active probes that are automatically learned.
- Line4 (ActSUn, ActLUn): short-term and long-term Unreachable results.
- Line4 (ActSLos, ActLLos): short-term and long-term Loss results.

Now, let's focus on the prefix 30.1.1.0/24:

```
MC#sh pfr master traffic-class
OER Prefix Statistics:
Pas - Passive, Act - Active, S - Short term, L - Long term, Dly - Delay (ms),
P - Percentage below threshold, Jit - Jitter (ms),
MOS - Mean Opinion Score
Los - Packet Loss (packets-per-million), Un - Unreachable (flows-per-million),
E - Egress, I - Ingress, Bw - Bandwidth (kbps), N - Not applicable
U - unknown, * - uncontrolled, + - control more specific, @ - active probe all
# - Prefix monitor mode is Special, & - Blackholed Prefix
% - Force Next-Hop, ^ - Prefix is denied

DstPrefix      Appl_ID  Dscp Prot      SrcPort      DstPort  SrcPrefix
      Flags      State      Time      CurrBR      CurrI/F  Protocol
      PasSDly PasLDly PasSUn PasLUn PasSLos PasLLos      EBw      IBw
      ActSDly ActLDly ActSUn ActLUn ActSJit ActPMOS ActSLos ActLLos
-----
[snip]
30.1.1.0/24          N    N    N          N          N N
                   INPOLICY      @37          10.4.5.5 Et0/1          BGP
                   104    103      0      0      0      0      53      6
                   103    103      0      0      N      N      N      N

[snip]
MC#
```

In looking at the detail display of the prefix, several items bear notice:

- Line1: prefix
- Line2: State of INPOLICY?this prefix is controlled by PfR and is currently inpolicy. BGP is used to enforce the path.
- Line2: The ?at sign? (@) on the Time Remaining value means the prefix is being actively probed. The numerical value is a countdown timer indicating when this state will expire.

- **Line3: Passive results**
- Line3 (PasSDly, PasLDly): short-term and long-term passive delay, measured from the TCP Syn/Ack. As explained previously, TCP Syn/Ack are used to check the reachability of the prefix and to collect the delay and loss information. The delay is around 100 ms, which is the delay through ISP2 (BR R5).
- Line3 (PasSUn, PasLUn): short-term and long-term statistics for Unreachable.

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- Line3 (PasSLoS, PasLLoS): short-term and long-term statistics for Loss.
- Line3 (EBw/IBw): the bandwidth for this prefix in egress and ingress direction.

- **Line4: Active results**

- Line4 (ActSDly, ActLDly): short-term and long-term active delay, measured by active probes that are automatically learned.
- Line4 (ActSUn, ActLUn): short-term and long-term Unreachable results.
- Line4 (ActSLoS, ActLLoS): short-term and long-term Loss results.

As the mode in ?both?, active probes are automatically calculated and generated:

```
MC#sh pfr master act
MC#sh pfr master active-probes
      OER Master Controller active-probes
Border   = Border Router running this Probe
State    = Un/Assigned to a Prefix
Prefix   = Probe is assigned to this Prefix
Type     = Probe Type
Target   = Target Address
TPort    = Target Port
How      = Was the probe Learned or Configured
N - Not applicable
```

The following Probes exist:

State	Prefix	Type	Target	TPort	How	Codec
Assigned	30.1.4.0/24	echo	30.1.4.11	N	Lrnd	N
Assigned	30.1.5.0/24	echo	30.1.5.11	N	Lrnd	N
Assigned	30.1.2.0/24	echo	30.1.2.11	N	Lrnd	N
Assigned	30.1.0.0/24	echo	30.1.0.11	N	Lrnd	N
Assigned	30.1.1.0/24	echo	30.1.1.11	N	Lrnd	N
Assigned	30.1.3.0/24	echo	30.1.3.11	N	Lrnd	N

The following Probes are running:

Border	State	Prefix	Type	Target	TPort
10.4.5.4	ACTIVE	30.1.3.0/24	echo	30.1.3.11	N
10.4.5.5	ACTIVE	30.1.3.0/24	echo	30.1.3.11	N
10.4.5.4	ACTIVE	30.1.1.0/24	echo	30.1.1.11	N
10.4.5.5	ACTIVE	30.1.1.0/24	echo	30.1.1.11	N
10.4.5.4	ACTIVE	30.1.2.0/24	echo	30.1.2.11	N
10.4.5.5	ACTIVE	30.1.2.0/24	echo	30.1.2.11	N

MC#

The policy applied to a specific prefix can be seen by the ?show oer master prefix XX policy?:

```
MC#sh pfr master prefix 30.1.1.0/24 policy
Default Policy Settings:
  backoff 300 3000 300
```

A closer look at the results

```

delay relative 50
holddown 300
periodic 180
probe frequency 56
number of jitter probe packets 100
mode route control
mode monitor both
mode select-exit good
loss relative 10
jitter threshold 20
mos threshold 3.60 percent 30
unreachable relative 50
resolve utilization priority 1 variance 20
resolve range priority 2 variance 0
MC#

```

Bandwidth used on exit links

The next step step is to verify the accuracy of the load-balancing scheme on both Border Routers R4 and R5.

```

MC#sh pfr master border detail
Border
10.4.5.4      Status UP/DOWN      AuthFail Version
Et0/0        INTERNAL UP
Et0/1        EXTERNAL UP

External      Capacity      Max BW      BW Used      Load Status      Exit Id
Interface     (kbps)       (kbps)     (kbps)       (%)
-----
Et0/1        Tx           500         450          192           39 UP
              Rx           500         49            9
-----

Border
10.4.5.5      Status UP/DOWN      AuthFail Version
Et0/0        INTERNAL UP
Et0/1        EXTERNAL UP

External      Capacity      Max BW      BW Used      Load Status      Exit Id
Interface     (kbps)       (kbps)     (kbps)       (%)
-----
Et0/1        Tx           500         450          175           33 UP
              Rx           500         0             0
-----
MC#

```

Verify Enforcement

BGP Route Table on R2

R2 is an iBGP peer for both border routers and as such as the BGP route table. PfR being not active, the parent routes are BGP based on R2, R4 and R5 and R4 is the preferred exit point as seen below:

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```
R2#sh ip bgp
BGP table version is 27, local router ID is 10.2.2.2
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
               r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete
```

Network	Next Hop	Metric	LocPrf	Weight	Path
r i10.4.5.0/24	10.5.5.5	0	100	0	i
r>i	10.4.4.4	0	100	0	i
*>i20.10.11.0/24	100.4.8.8	0	100	0	100 20 i
* i	100.5.9.9	0	100	0	200 20 i
*>i20.11.11.11/32	100.4.8.8	0	100	0	100 20 i
* i	100.5.9.9	0	100	0	200 20 i
*>i30.1.0.0/24	100.4.8.8	0	100	0	100 20 i
* i	100.5.9.9	0	100	0	200 20 i
*>i30.1.1.0/24	100.4.8.8	0	100	0	100 20 i
* i	100.5.9.9	0	100	0	200 20 i
*>i30.1.2.0/24	100.4.8.8	0	100	0	100 20 i
* i	100.5.9.9	0	100	0	200 20 i
*>i30.1.3.0/24	100.4.8.8	0	100	0	100 20 i
* i	100.5.9.9	0	100	0	200 20 i
*>i30.1.4.0/24	100.4.8.8	0	100	0	100 20 i
* i	100.5.9.9	0	100	0	200 20 i
*>i30.1.5.0/24	100.4.8.8	0	100	0	100 20 i

Network	Next Hop	Metric	LocPrf	Weight	Path
* i	100.5.9.9	0	100	0	200 20 i
r>i100.4.8.0/24	10.4.4.4	0	100	0	i
r>i100.5.9.0/24	10.5.5.5	0	100	0	i
*>i100.8.10.0/24	100.4.8.8	0	100	0	100 20 i
* i	100.5.9.9	0	100	0	200 20 i
*>i100.9.10.0/24	100.4.8.8	0	100	0	100 20 i
* i	100.5.9.9	0	100	0	200 20 i

R2#

After a few cycles, PfR controls the prefixes and modifies BGP local-pref for prefixes that have to go to R5 instead of R4.

```
R2#sh ip bgp
BGP table version is 52, local router ID is 10.2.2.2
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
               r RIB-failure, S Stale, m multipath, b backup-path, x best-external
Origin codes: i - IGP, e - EGP, ? - incomplete
```

Network	Next Hop	Metric	LocPrf	Weight	Path
r>i10.4.5.0/24	10.4.4.4	0	100	0	i
r i	10.5.5.5	0	100	0	i
*>i20.10.11.0/24	100.4.8.8	0	100	0	100 20 i
* i	100.5.9.9	0	100	0	200 20 i
*>i20.11.11.11/32	100.4.8.8	0	100	0	100 20 i
* i	100.5.9.9	0	100	0	200 20 i
* i30.1.0.0/24	100.5.9.9	0	100	0	200 20 i
*>i	100.4.8.8	0	100	0	100 20 i
*>i30.1.1.0/24	100.5.9.9	0	5000	0	200 20 i
* i30.1.2.0/24	100.5.9.9	0	100	0	200 20 i
*>i	100.4.8.8	0	100	0	100 20 i
*>i30.1.3.0/24	100.5.9.9	0	5000	0	200 20 i
*>i30.1.4.0/24	100.4.8.8	0	100	0	100 20 i
* i	100.5.9.9	0	100	0	200 20 i
*>i30.1.5.0/24	100.5.9.9	0	5000	0	200 20 i

BGP Route Table on R2

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```
r>i100.4.8.0/24      10.4.4.4          0    100    0 i
r>i100.5.9.0/24    10.5.5.5          0    100    0 i
*>i100.8.10.0/24   100.4.8.8         0    100    0 100 20 i
* i                100.5.9.9         0    100    0 200 20 i
*>i100.9.10.0/24  100.4.8.8         0    100    0 100 20 i
* i                100.5.9.9         0    100    0 200 20 i
R2#
```

- The prefix 30.1.0.0/24 uncontrolled by PfR has a default local-preference of 100 (which is the default local-pref) toward exit BR R4.
- The prefix 30.1.1.0/24 controlled by PfR has a local-preference of 5000 (this is the default value assigned by PfR and can be changed in the PfR global configuration) toward exit BR R5.

Border Routers

Let's have a look at the border routers.

Let's begin with R4:

```
R4#sh pfr border routes bgp
BGP table version is 22, local router ID is 10.4.4.4
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
               r RIB-failure, S Stale, m multipath, b backup-path, x best-external
Origin codes: i - IGP, e - EGP, ? - incomplete
OER Flags: C - Controlled, X - Excluded, E - Exact, N - Non-exact, I - Injected

   Network          Next Hop          OER    LocPrf Weight Path
*>i30.1.1.0/24      100.5.9.9        XN      5000     0 200 20 i
*>i30.1.2.0/24      100.5.9.9        XN      5000     0 200 20 i
*>i30.1.4.0/24      100.5.9.9        XN      5000     0 200 20 i
R4#
```

The ?X? under the OER column for the 30.1.1.0/24 route on R4 means that the route is not locally controlled. Meaning that the local preference 5000 is being injected from another router. When the ?X? attribute is set, the exact vs. non-exact is meaningless.

If we look at the route on R5, we can see that it is locally controlled, and the exact route is controlled. The ?exact? means that the 30.1.1.0/24 route was found in the BGP table and there are no more specific subnets underneath:

```
R5#sh pfr border routes bgp
BGP table version is 22, local router ID is 10.5.5.5
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
               r RIB-failure, S Stale, m multipath, b backup-path, x best-external
Origin codes: i - IGP, e - EGP, ? - incomplete
OER Flags: C - Controlled, X - Excluded, E - Exact, N - Non-exact, I - Injected

   Network          Next Hop          OER    LocPrf Weight Path
*> 30.1.1.0/24      100.5.9.9        CE              0 200 20 i
*> 30.1.2.0/24      100.5.9.9        CE              0 200 20 i
```

```
*> 30.1.4.0/24      100.5.9.9      CE      0 200 20 i  
R5#
```

Conclusion

One of the basic solution provided by PfR is to be able to load-balance traffic among multiple exit interface. The configuration is straightforward and very efficient. Based on that, a customer can evolve to a more complex Performance Routing solution based on Traffic Class performance and not only link utilization.