

Radio Aware Routing

Radio-Aware Routing (RAR) is a mechanism that uses radios to interact with the routing protocol OSPFv3 to signal the appearance, disappearance, and link conditions of one-hop routing neighbors.

In a large mobile networks, connections to the routing neighbors are often interrupted due to distance and radio obstructions. When these signals do not reach the routing protocols, protocol timers are used to update the status of a neighbor. Routing protocols have lengthy timer, which is not recommended in mobile networks.

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Benefits of Radio Aware Routing

The Radio Aware Routing feature offers these benefits:

- Provides faster network convergence through immediate recognition of changes.
- Enables routing for failing or fading radio links.
- Allows easy routing between line-of-sight and non-line-of-sight paths.
- Provides faster convergence and optimal route selection so that delay-sensitive traffic, such as voice and video, is not disrupted
- Provides efficient radio resources and bandwidth usage.
- Reduces impact on the radio links by performing congestion control in the router.
- Allows route selection based on radio power conservation.
- Enables decoupling of the routing and radio functionalities.
- Provides simple Ethernet connection to RFC 5578, R2CP, and DLEP compliant radios.

Restrictions and Limitations

The Radio Aware Routing feature has these restrictions and limitations:

- The DLEP and R2CP protocols are not supported on Cisco 8200 Series Secure Routers.
- Multicast traffic is not supported in aggregate mode.
- Cisco High Availability (HA) technology is not supported.

License Requirements

This feature is made available with the AppX license.

System components

The Radio Aware Routing (RAR) feature is implemented using the MANET (Mobile adhoc network) infrastructure comprising of different components such as PPPoE, Virtual multipoint interface (VMI), QoS, routing protocol interface and RAR protocols.

Point-to-Point Protocol over Ethernet or PPPoE

PPPoE is a well-defined communication mechanism between the client and the server. In the RAR implementation, radio takes the role of the PPPoE client and router takes the role of the PPPoE server. This allows a loose coupling of radio and router, while providing a well-defined and predictable communication mechanism.

As PPPoE is a session or a connection oriented protocol, it extends the point-to-point radio frequency (RF) link from an external radio to an IOS router.

PPPoE extensions

PPPoE extensions are used when the router communicates with the radio. In the Cisco IOS implementation of PPPoE, each individual session is represented by virtual access interface (connectivity to a radio neighbor) on which, QoS can be applied with these PPPoE extensions.

RFC5578 provides extensions to PPPoE to support credit-based flow control and session-based real time link metrics, which are very useful for connections with variable bandwidth and limited buffering capabilities (such as radio links).

Virtual Multipoint Interface (VMI)

Though PPPoE Extensions provides the most of the setup to communicate between a router and a radio, VMI addresses the need to manage and translate events that higher layers (example, routing protocols) consume. In addition, VMI operates in the Bypass mode.

In Bypass mode, every Virtual Access Interface (VAI) representing a radio neighbor is exposed to routing protocols OSPFv3 and EIGRP, so that, the routing protocol directly communicates with the respective VAI for both unicast and multicast routing protocol traffic.

In Aggregae mode, VMI is exposed to the routing protocols (OSPF) so that the routing protocols can leverage VMI for their optimum efficiency. When the network neighbors are viewed as a collection of networks on a point-to-multipoint link with broadcast and multicast capability at VMI, VMI helps in aggregating the multiple virtual access interfaces created from PPPoE. VMI presents a single multi access layer 2 broadcast capable interface. The VMI layer handles re-directs unicast routing protocol traffic to the appropriate P2P link (Virtual-Access interface), and replicats any Multicast/Broadcast traffic that needs to flow. Since the routing protocol communicates to a single interface, the size of the topology database is reduced, without impacting the integrity of the network.

QoS Provisioning on PPPoE Extension Session

The following example describes QoS provisioning on PPPoE extension session:

```
policy-map rar_policer
 class class-default
  police 10000 2000 1000 conform-action transmit  exceed-action drop  violate-action drop
policy-map rar_shaper
 class class-default
  shape average percent 1

interface Virtual-Template2
 ip address 192.0.2.7 255.255.255.0
 no peer default ip address
 no keepalive
 service-policy input rar_policer
end
```

Example: Configure the RAR feature in bypass mode

This example is an end-to-end configuration of RAR in the bypass mode:

Note Before you being the RAR configuration, you must first configure the **subscriber authorization enable** command to bring up the RAR session. Without enbaling authorization, the Point-to-Point protocol does not recognize this as a RAR session and may not tag *manet_radio* in presentation of a PPPoE Active Discovery Initiate (PADI). By default, bypass mode does not appears in the configuration. It appears only if the mode is configured as bypass.

Configure a Service for RAR

```
policy-map type service rar-lab
 pppoe service manet_radio //note: Enter the pppoe service policy name as manet_radio
!
```

Configure Broadband

```
bba-group pppoe VMI2
 virtual-template 2
service profile rar-lab
!
interface GigabitEthernet0/0/0
```

```
 description Connected to Client1
  negotiation auto
  pppoe enable group VMI2
!
```

Configure a Service for RAR

```
policy-map type service rar-lab
 pppoe service manet_radio //note: Enter the pppoe service policy name as manet_radio
!
```

Configuration in Bypass Mode

- IP Address Configured under Virtual-Template Explicitly

```
interface Virtual-Template2
ip address 192.0.2.7 255.255.255.0
no ip redirects
peer default ip address pool PPPoEpool2
ipv6 enable
ospfv3 1 network manet
ospfv3 1 ipv4 area 0
ospfv3 1 ipv6 area 0
no keepalive
service-policy input rar_policer Or/And
service-policy output rar_shaper
```

- VMI Unnumbered Configured under Virtual Template

```
interface Virtual-Template2
ip unnumbered vmi2
no ip redirects
peer default ip address pool PPPoEpool2
ipv6 enable
ospfv3 1 network manet
ospfv3 1 ipv4 area 0
ospfv3 1 ipv6 area 0
no keepalive
service-policy input rar_policer Or/And
service-policy output rar_shaper
```

Configure the Virtual Multipoint Interface in Bypass Mode

```
interface vmi2 //configure the virtual multi interface
ip address 192.0.2.5 255.255.255.0
physical-interface GigabitEthernet0/0/0
mode bypass
```

```
interface vmi3//configure the virtual multi interface
 ip address 192.0.2.6 255.255.255.0
 physical-interface GigabitEthernet0/0/1
mode bypass
```

Configure OSPF Routing

```
router ospfv3 1
 router-id 192.0.2.1
```

```
!
 address-family ipv4 unicast
  redistribute connected metric 1 metric-type 1
  log-adjacency-changes
 exit-address-family
 !
 address-family ipv6 unicast
  redistribute connected metric-type 1
  log-adjacency-changes
 exit-address-family
!
ip local pool PPPoEpool2 192.0.2.8 192.0.2.4
```

Example: Configuring the RAR feature in aggregate mode

This example is an end-to-end configuration of RAR in the aggregate mode:



Note Before you being the RAR configuration, you must first configure the **subscriber authorization enable** command to bring up the RAR session. Without enabling authorization, the Point-to-Point protocol does not recognize this as a RAR session and may not tag *manet_radio* in PADI.

Configure a Service for RAR

```
policy-map type service rar-lab
 pppoe service manet_radio //note: Enter the pppoe service policy name as manet_radio
!
```

Configure Broadband

```
bba-group pppoe VMI2
 virtual-template 2
service profile rar-lab

!
interface GigabitEthernet0/0/0
 description Connected to Client1
  negotiation auto
  pppoe enable group VMI2

!
```

Configure a Service for RAR

```
policy-map type service rar-lab
 pppoe service manet_radio //note: Enter the pppoe service policy name as manet_radio
!
```

Configuration in Aggregate Mode

```
interface Virtual-Template2
ip unnumbered vmi2
```

```
no ip redirects
no peer default ip address
ipv6 enable
no keepalive
service-policy input rar_policer Or/And
service-policy output rar_shaper
```

Configure the Virtual Multipoint Interface in Aggregate Mode

```
interface vmi2 //configure the virtual multi interface
ip address 192.0.2.8 255.255.255.0
physical-interface GigabitEthernet0/0/0
mode aggregate
```

```
interface vmi3//configure the virtual multi interface
 ip address 192.0.2.4 255.255.255.0
 no ip redirects
 no ip split-horizon eigrp 1
 physical-interface GigabitEthernet0/0/1
mode aggregate
```

Configure OSPF Routing

```
router ospfv3 1
 router-id 192.0.2.1
!
 address-family ipv4 unicast
  redistribute connected metric 1 metric-type 1
  log-adjacency-changes
 exit-address-family
 !
 address-family ipv6 unicast
  redistribute connected metric-type 1
  log-adjacency-changes
 exit-address-family
!
ip local pool PPPoEpool2 192.0.2.4 192.0.2.8
ip local pool PPPoEpool3 192.0.2.6 192.0.2.2
```

Verify RAR Session Details

To retrieve RAR session details, use these show commands:

```
Router#show pppoe session packets all
Total PPPoE sessions 2

session id: 9
local MAC address: 006b.f10e.a5e0, remote MAC address: 0050.56bc.424a
virtual access interface: Vi2.1, outgoing interface: Gi0/0/0
    1646 packets sent, 2439363 received
    176216 bytes sent, 117250290 received

PPPoE Flow Control Stats
 Local Credits: 65535   Peer Credits: 65535   Local Scaling Value 64 bytes
 Credit Grant Threshold: 28000    Max Credits per grant: 65535
 Credit Starved Packets: 0
 PADG xmit Seq Num: 32928     PADG Timer index: 0
```

```
 PADG last rcvd Seq Num: 17313
 PADG last nonzero Seq Num: 17306
 PADG last nonzero rcvd amount: 2
 PADG Timers: (ms)   [0]-1000    [1]-2000    [2]-3000    [3]-4000    [4]-5000
 PADG xmit: 33308  rcvd: 17313
 PADC xmit: 17313  rcvd: 19709
 In-band credit pkt xmit: 7 rcvd: 2434422
 Last credit packet snapshot
  PADG xmit: seq_num = 32928, fcn = 0, bcn = 65535
  PADC rcvd: seq_num = 32928, fcn = 65535, bcn = 65535
  PADG rcvd: seq_num = 17313, fcn = 0, bcn = 65535
  PADC xmit: seq_num = 17313, fcn = 65535, bcn = 65535
  In-band credit pkt xmit: fcn = 61, bcn = 65533
  In-band credit pkt rcvd: fcn = 0, bcn = 65534
    ==== PADQ Statistics ====
     PADQ xmit: 0  rcvd: 0


session id: 10
local MAC address: 006b.f10e.a5e1, remote MAC address: 0050.56bc.7dcb
virtual access interface: Vi2.2, outgoing interface: Gi0/0/1
    1389302 packets sent, 1852 received
    77869522 bytes sent, 142156 received

PPPoE Flow Control Stats
 Local Credits: 65535   Peer Credits: 65535   Local Scaling Value 64 bytes
 Credit Grant Threshold: 28000    Max Credits per grant: 65535
 Credit Starved Packets: 0
 PADG xmit Seq Num: 18787     PADG Timer index: 0
 PADG last rcvd Seq Num: 18784
 PADG last nonzero Seq Num: 18768
 PADG last nonzero rcvd amount: 2
 PADG Timers: (ms)   [0]-1000    [1]-2000    [2]-3000    [3]-4000    [4]-5000
 PADG xmit: 18787  rcvd: 18784
 PADC xmit: 18784  rcvd: 18787
 In-band credit pkt xmit: 1387764 rcvd: 956
 Last credit packet snapshot
  PADG xmit: seq_num = 18787, fcn = 0, bcn = 65535
  PADC rcvd: seq_num = 18787, fcn = 65535, bcn = 65535
  PADG rcvd: seq_num = 18784, fcn = 0, bcn = 65535
  PADC xmit: seq_num = 18784, fcn = 65535, bcn = 65535
  In-band credit pkt xmit: fcn = 0, bcn = 64222
  In-band credit pkt rcvd: fcn = 0, bcn = 65534
    ==== PADQ Statistics ====
     PADQ xmit: 0  rcvd: 1


Router#show pppoe session packets
Total PPPoE sessions 2

SID     Pkts-In         Pkts-Out        Bytes-In        Bytes-Out
9       2439391         1651            117252098       176714
10      1858            1389306         142580          77869914


Router#show vmi counters
Interface vmi2: - Last Clear Time =

Input Counts:
  Process Enqueue      =          0 (VMI)
  Fastswitch           =          0
  VMI Punt Drop:
       Queue Full      =          0
```

```
Output Counts:
  Transmit:
       VMI Process DQ  =       4280
       Fastswitch VA   =          0
       Fastswitch VMI  =          0
  Drops:
       Total           =          0
       QOS Error       =          0
       VMI State Error =          0
       Mcast NBR Error =          0
       Ucast NBR Error =          0
Interface vmi3: - Last Clear Time =

Input Counts:
  Process Enqueue      =          0 (VMI)
  Fastswitch           =          0
  VMI Punt Drop:
       Queue Full      =          0

Output Counts:
  Transmit:
       VMI Process DQ  =       2956
       Fastswitch VA   =          0
       Fastswitch VMI  =          0
  Drops:
       Total           =          0
       QOS Error       =          0
       VMI State Error =          0
       Mcast NBR Error =          0
       Ucast NBR Error =          0
Interface vmi4: - Last Clear Time =

Input Counts:
  Process Enqueue      =          0 (VMI)
  Fastswitch           =          0
  VMI Punt Drop:
       Queue Full      =          0

Output Counts:
  Transmit:
       VMI Process DQ  =          0
       Fastswitch VA   =          0
       Fastswitch VMI  =          0
  Drops:
       Total           =          0
       QOS Error       =          0
       VMI State Error =          0
       Mcast NBR Error =          0
       Ucast NBR Error =          0
Router#


Router#show vmi neighbor details
1 vmi2 Neighbors
      1 vmi3 Neighbors
      0 vmi4 Neighbors
      2 Total Neighbors

vmi2   IPV6 Address=FE80::21E:E6FF:FE43:F500
       IPV6 Global Addr=::
       IPV4 Address=192.0.2.6, Uptime=05:15:01
       Output pkts=89, Input pkts=0
       No Session Metrics have been received for this neighbor.
       Transport PPPoE, Session ID=9
```

```
       INTERFACE STATS:
          VMI Interface=vmi2,
             Input qcount=0, drops=0, Output qcount=0, drops=0
          V-Access intf=Virtual-Access2.1,
             Input qcount=0, drops=0, Output qcount=0, drops=0
          Physical intf=GigabitEthernet0/0/0,
             Input qcount=0, drops=0, Output qcount=0, drops=0

PPPoE Flow Control Stats
 Local Credits: 65535   Peer Credits: 65535   Local Scaling Value 64 bytes
 Credit Grant Threshold: 28000    Max Credits per grant: 65535
 Credit Starved Packets: 0
 PADG xmit Seq Num: 33038     PADG Timer index: 0
 PADG last rcvd Seq Num: 17423
 PADG last nonzero Seq Num: 17420
 PADG last nonzero rcvd amount: 2
 PADG Timers: (ms)   [0]-1000    [1]-2000    [2]-3000    [3]-4000    [4]-5000
 PADG xmit: 33418  rcvd: 17423
 PADC xmit: 17423  rcvd: 19819
 In-band credit pkt xmit: 7 rcvd: 2434446
 Last credit packet snapshot
  PADG xmit: seq_num = 33038, fcn = 0, bcn = 65535
  PADC rcvd: seq_num = 33038, fcn = 65535, bcn = 65535
  PADG rcvd: seq_num = 17423, fcn = 0, bcn = 65535
  PADC xmit: seq_num = 17423, fcn = 65535, bcn = 65535
  In-band credit pkt xmit: fcn = 61, bcn = 65533
  In-band credit pkt rcvd: fcn = 0, bcn = 65534
    ==== PADQ Statistics ====
     PADQ xmit: 0  rcvd: 0


vmi3   IPV6 Address=FE80::21E:7AFF:FE68:6100
       IPV6 Global Addr=::
       IPV4 Address=192.0.2.10, Uptime=05:14:55
       Output pkts=6, Input pkts=0
       METRIC DATA: Total rcvd=1, Avg arrival rate (ms)=0
          CURRENT: MDR=128000 bps, CDR=128000 bps
                   Lat=0 ms, Res=100, RLQ=100, load=0
          MDR      Max=128000 bps, Min=128000 bps, Avg=128000 bps
          CDR      Max=128000 bps, Min=128000 bps, Avg=128000 bps
          Latency  Max=0, Min=0, Avg=0 (ms)
          Resource Max=100%, Min=100%, Avg=100%
          RLQ      Max=100, Min=100, Avg=100
          Load     Max=0%, Min=0%, Avg=0%
       Transport PPPoE, Session ID=10
       INTERFACE STATS:
          VMI Interface=vmi3,
             Input qcount=0, drops=0, Output qcount=0, drops=0
          V-Access intf=Virtual-Access2.2,
             Input qcount=0, drops=0, Output qcount=0, drops=0
          Physical intf=GigabitEthernet0/0/1,
             Input qcount=0, drops=0, Output qcount=0, drops=0

PPPoE Flow Control Stats
 Local Credits: 65535   Peer Credits: 65535   Local Scaling Value 64 bytes
 Credit Grant Threshold: 28000    Max Credits per grant: 65535
 Credit Starved Packets: 0
 PADG xmit Seq Num: 18896     PADG Timer index: 0
 PADG last rcvd Seq Num: 18894
 PADG last nonzero Seq Num: 18884
 PADG last nonzero rcvd amount: 2
 PADG Timers: (ms)   [0]-1000    [1]-2000    [2]-3000    [3]-4000    [4]-5000
 PADG xmit: 18896  rcvd: 18894
 PADC xmit: 18894  rcvd: 18896
```

```
 In-band credit pkt xmit: 1387764 rcvd: 961
 Last credit packet snapshot
  PADG xmit: seq_num = 18896, fcn = 0, bcn = 65535
  PADC rcvd: seq_num = 18896, fcn = 65535, bcn = 65535
  PADG rcvd: seq_num = 18894, fcn = 0, bcn = 65535
  PADC xmit: seq_num = 18894, fcn = 65535, bcn = 65535
  In-band credit pkt xmit: fcn = 0, bcn = 64222
  In-band credit pkt rcvd: fcn = 0, bcn = 65534
    ==== PADQ Statistics ====
     PADQ xmit: 0  rcvd: 1


Router#show vmi neighbor details vmi 2
              1 vmi2 Neighbors

vmi2   IPV6 Address=FE80::21E:E6FF:FE43:F500
       IPV6 Global Addr=::
       IPV4 Address=192.0.2.4, Uptime=05:16:03
       Output pkts=89, Input pkts=0
       No Session Metrics have been received for this neighbor.
       Transport PPPoE, Session ID=9
       INTERFACE STATS:
          VMI Interface=vmi2,
             Input qcount=0, drops=0, Output qcount=0, drops=0
          V-Access intf=Virtual-Access2.1,
             Input qcount=0, drops=0, Output qcount=0, drops=0
          Physical intf=GigabitEthernet0/0/0,
             Input qcount=0, drops=0, Output qcount=0, drops=0

PPPoE Flow Control Stats
 Local Credits: 65535   Peer Credits: 65535   Local Scaling Value 64 bytes
 Credit Grant Threshold: 28000    Max Credits per grant: 65535
 Credit Starved Packets: 0
 PADG xmit Seq Num: 33100     PADG Timer index: 0
 PADG last rcvd Seq Num: 17485
 PADG last nonzero Seq Num: 17449
 PADG last nonzero rcvd amount: 2
 PADG Timers: (ms)   [0]-1000    [1]-2000    [2]-3000    [3]-4000    [4]-5000
 PADG xmit: 33480  rcvd: 17485
 PADC xmit: 17485  rcvd: 19881
 In-band credit pkt xmit: 7 rcvd: 2434460
 Last credit packet snapshot
  PADG xmit: seq_num = 33100, fcn = 0, bcn = 65535
  PADC rcvd: seq_num = 33100, fcn = 65535, bcn = 65535
  PADG rcvd: seq_num = 17485, fcn = 0, bcn = 65535
  PADC xmit: seq_num = 17485, fcn = 65535, bcn = 65535
  In-band credit pkt xmit: fcn = 61, bcn = 65533
  In-band credit pkt rcvd: fcn = 0, bcn = 65534
    ==== PADQ Statistics ====
     PADQ xmit: 0  rcvd: 0


Router#show platform hardware qfp active feature ess session
Current number sessions: 2
Current number TC flow: 0
Feature Type: A=Accounting D=Policing(DRL) F=FFR M=DSCP Marking L=L4redirect P=Portbundle
T=TC

   Session    Type      Segment1      SegType1      Segment2      SegType2 Feature Other
-------------------------------------------------------------------------------------
        21     PPP 0x0000001500001022    PPPOE 0x0000001500002023    LTERM -------
        24     PPP 0x0000001800003026    PPPOE 0x0000001800004027    LTERM -------
```

```
Router#show platform software subscriber pppoe_fctl evsi 21
PPPoE Flow Control Stats
 Local Credits: 65535   Peer Credits: 65535   Local Scaling Value 64 bytes
 Credit Grant Threshold: 28000    Max Credits per grant: 65535
 Credit Starved Packets: 0
 PADG xmit Seq Num: 33215     PADG Timer index: 0
 PADG last rcvd Seq Num: 17600
 PADG last nonzero Seq Num: 17554
 PADG last nonzero rcvd amount: 2
 PADG Timers: (ms)   [0]-1000    [1]-2000    [2]-3000    [3]-4000    [4]-5000
 PADG xmit: 33595  rcvd: 17600
 PADC xmit: 17600  rcvd: 19996
 In-band credit pkt xmit: 7 rcvd: 2434485
 Last credit packet snapshot
  PADG xmit: seq_num = 33215, fcn = 0, bcn = 65535
  PADC rcvd: seq_num = 33215, fcn = 65535, bcn = 65535
  PADG rcvd: seq_num = 17600, fcn = 0, bcn = 65535
  PADC xmit: seq_num = 17600, fcn = 65535, bcn = 65535
  In-band credit pkt xmit: fcn = 61, bcn = 65533
  In-band credit pkt rcvd: fcn = 0, bcn = 65534

BQS buffer statistics
 Current packets in BQS buffer: 0
 Total en-queue packets: 0 de-queue packets: 0
 Total dropped packets: 0

Internal flags: 0x0


Router#show platform hardware qfp active feature ess session id 21
Session ID: 21

  EVSI type: PPP
  SIP Segment ID: 0x1500001022
  SIP Segment type: PPPOE
  FSP Segment ID: 0x1500002023
  FSP Segment type: LTERM
  QFP if handle: 16
  QFP interface name: EVSI21
  SIP TX Seq num: 0
  SIP RX Seq num: 0
  FSP TX Seq num: 0
  FSP RX Seq num: 0
  Condition Debug: 0x00000000
    session


Router#show ospfv3 neighbor

          OSPFv3 1 address-family ipv4 (router-id 192.0.2.3)

Neighbor ID     Pri   State           Dead Time   Interface ID    Interface
192.0.2.1           0   FULL/  -        00:01:32    19              Virtual-Access2.1

          OSPFv3 1 address-family ipv6 (router-id 192.0.2.3)

Neighbor ID     Pri   State           Dead Time   Interface ID    Interface
192.0.2.1           0   FULL/  -        00:01:52    19              Virtual-Access2.1
Router#
```

```
Router#sh ip route

Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
ia - IS-IS inter area, * - candidate default, U - per-user static route
o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
a - application route
+ - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      192.0.2.8/8 is variably subnetted, 3 subnets, 2 masks
C        192.0.2.5/24 is directly connected, Virtual-Access2.1
O        192.0.2.6/32 [110/1] via 192.0.2.22, 00:00:03, Virtual-Access2.1
L        192.0.2.7/32 is directly connected, Virtual-Access2.1
      192.0.2.12/32 is subnetted, 1 subnets
C        192.0.2.20 is directly connected, Virtual-Access2.1
```

Troubleshoot Radio Aware Routing

To troubleshoot the RAR, use these debug commands:

- **debug pppoe errors**
- **debug pppoe events**
- **debug ppp error**
- **debug vmi error**
- **debug vmi neighbor**
- **debug vmi packet**
- **debug vmi pppoe**
- **debug vmi registries**
- **debug vmi multicast**
- **debug vtemplate cloning**
- **debug vtemplate event**
- **debug vtemplate error**
- **debug plat hard qfp ac feature subscriber datapath pppoe detail**