ROUTING CONSORTIUM

Virtual Router Redundancy Protocol
Operations Test Suite

Technical Document

Revision 2.5

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MODIFICATION RECORD

Version 2.5	December 8, 2006	
	Fixed timing calculations on test 3.3.	

Version 2.4   February 25, 2005
       Edited typos
       More specific priority in tests 2.2 through 2.4.
    August 30, 2005
       Created Parts A and B in test 3.3
       Modified test 4.1 so that TR1 is not the owner of the virtual router
       address.

Version 2.3   April 16, 2004
       Updated the test suite with the new VRRP RFC (3768)
       Removed Resource Requirements
       Added diagrams to all tests
       Separated tests in section 4
    June 25, 2004
       Edited typos
       Updated tests to make them more comprehensible

Version 2.2   February 9, 2001
       Added test 2.2, changed small grammatical and numbering errors

Version 2.1   February 7, 2001
       Reworked introduction, test layout and section layout
       Modified each test to conform to new layout
    Substantive changes to tests 1.1, 2.5, 2.7, 3.4, 4.1and 5.1

Version 2.0   February 2, 2001
       Restructured test labels and added test numbers
       Added tests for Type Field and the Backup state

Version 1.0   February 3, 1999
       Added simple_authentication.vrrp.v4.ip

Draft Version   December 8, 1998
       Initial Release
          multicast_address.vrrp.v4.ip
          initialize.vrrp.v4.ip
          backup.vrrp.v4.ip
          master.vrrp.v4.ip
          receiving.vrrp.v4.ip
          transmitting.vrrp.v4.ip

University of New Hampshire
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INTRODUCTION

Overview

The University of New Hampshire's InterOperability Laboratory (IOL) is an institution designed to improve the interoperability of standards based products by providing an environment where a product can be tested against other implementations of a standard. This suite of tests has been developed to help implementers evaluate the functioning of their Virtual Router Redundancy Protocol implementations. The tests do not determine if a product conforms to the specifications, nor are they purely interoperability tests. Rather, they provide a method to isolate problems within a device. Successful completion of all tests contained in this suite does not guarantee that the tested device will operate with other VRRP devices. However, these tests provide a reasonable level of confidence that the Router Under Test will function well in most multi-vendor VRRP environments.

Test Software

The UNH IOL Testing Software is not a full VRRP implementation; it is simply a packet generator that can transmit and receive packets. This allows the Testing Router to generate invalid packets and to simulate parts of the Virtual Router Redundancy Protocol. The Testing Software is not currently available to the public.

Acronyms

Acronyms used in this Test Suite:

TR: **T**esting **R**outer
RUT: **R**outer **U**nder **T**est
N: **N**etwork
VRID: **V**irtual **R**outer **ID**

When several entities of the same type are present in a test configuration, a number is appended to the acronym to yield a label for each entity. For example, if there were three testing routers in the test configuration, they would be labeled TR1, TR2 and TR3.

TEST ORGANIZATION

This document organizes tests by group based on related test methodology or goals. Each group begins with a brief set of comments pertaining to all tests within that group. This is followed by a series of description blocks; each block describes a single test. The format of the description block is as follows:

Test Label: The test label and title comprise the first line of the test block. The test label is composed by concatenating the short test suite name, the group number, and the test number within the group, separated by periods. The **Test Number** is the group and test number, also separated by a period. So, test label **VRRP.1.2** refers to the second test of the first test group in the VRRP suite. The test number is 1.2.

Purpose: The Purpose is a short statement describing what the test attempts to achieve. It is usually phrased as a simple assertion of the feature or capability to be tested.

References: The References section lists cross-references to the specifications and documentation that might be helpful in understanding and evaluating the test and results.

Discussion: The Discussion is a general discussion of the test and relevant section of the specification, including any assumptions made in the design or implementation of the test as well as known limitations.

Test Setup: The Test Setup describes the configuration of all devices prior to the start of the test. Different parts of the procedure may involve configuration steps that deviate from what is given in the test setup. If a value is not provided for a protocol parameter, then the protocol's default is used for that parameter.

Procedure: The Procedure of the test description contains the step-by-step instructions for carrying out the test. These steps include such things as enabling interfaces, unplugging devices from the network, or transmitting a packet from a test station. The test procedure also cues the tester to make observations, which are interpreted in accordance with the observable results given for that test part.

Observable Results: The Observable Results lists observable results that can be examined by the tester to verify that the RUT is operating properly. When multiple observable results are possible, this section provides a short discussion on how to interpret them. The determination of a pass or fail for each test is usually based on how the RUT's behavior compares to the results described in this section.

Possible Problems: The Possible Problems contains a description of known issues with the test procedure, which may affect test results in certain situations.

REFERENCES

The following documents are referenced in this text:

- [2338] S. Knight, et all., Virtual Router Redundancy Protocol (VRRP), April 1998

- [3768] R. Hinden, Ed., Virtual Router Redundancy Protocol (VRRP), April 2004

ABSTRACT

The following tests cover the operation of the Virtual Router Redundancy Protocol (VRRP). VRRP specifies an election protocol that dynamically assigns responsibility for a virtual router to one of the VRRP routers on a LAN. The VRRP router controlling the IP address(es) associated with a virtual router is called the Master, and forwards packets transmitted to these IP addresses. The election process provides dynamic fail over in the forwarding responsibility should the Master become unavailable. This allows any of the virtual router IP addresses on the LAN to be used as the default first hop router by end-hosts. The advantage gained from using VRRP is a higher availability default path without requiring configuration of dynamic routing or router discovery protocols on every end-host.

GROUP 1: Interoperability

Scope:

The following tests verify the general operation of a VRRP router and are not specific to any single section of the specification.

Overview:

These tests have been designed to test the Interoperability of the RUT with other VRRP capable devices. This test group focuses on testing configurations of the network that could cause problems when deployed if the RUT does not operate properly with the devices that it is connected to. The tests in this group do not determine if a product conforms to the VRRP standard but they are designed as interoperability tests. The test routers in this section are complete implementations of VRRP.

Test VRRP.1.1: Basic VRRP Interoperability

Purpose: To verify that a router can interoperate with other VRRP implementations in a setup with a single virtual router.

References: [3768] – Sections 3, 4 and 5

Discussion: This test verifies that the RUT can successfully exchange packets and develop a proper VRRP configuration when directly connected to other VRRP implementations on the same subnet.

Test Setup: Test Station A has a route to network 1 through the address of the virtual router with VRID 1 that is in the Master state on network 0. Test Station B has a route to network 0 through the address of the RUT's interface 2. All of the devices on network 0 and network 1 are connected by repeaters.

Device	Interface	Network	VRID
RUT	1	0	1
RUT	2	1	2
TR1	1	0	1
TR1	2	1	2
TR2	1	0	1
TR2	2	1	2
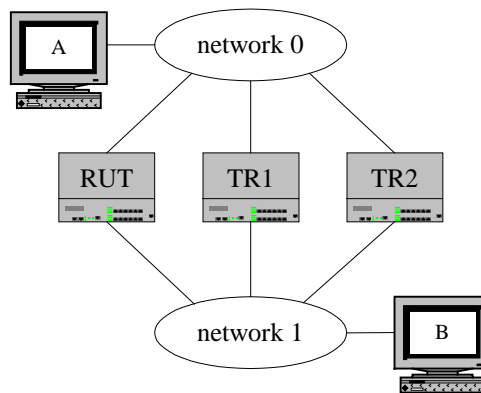
Procedure:
Part A: The RUT in the Backup state
1. Configure TR1 to associate a virtual router {VRID = 1} with the IP address of its first interface. TR1's Priority is 255; it owns the IP address of the virtual router.
2. Configure the RUT as backup, Priority 100, for the virtual router created in step 1. Configure TR2 to also backup the virtual router created in step1 and to have a Priority of 99.
3. Enable VRRP on the RUT, TR1 and TR2.
4. Ping station B from station A.
5. Observe the packets transmitted on network 0 and network 1.

Part B: Master Down
6. Disconnect TR1's interface 1 on network 0.
7. Ping station B from station A.
8. Observe the packets transmitted on network 0 and network 1.

Part C: The RUT preempted by TR2
9. Configure TR2 as backup, with a Priority of 101, for the virtual router created in step 1.
10. Ping station B from station A.
11. Observe the packets transmitted on network 0 and network 1.

Part D: The RUT owns the virtual router IP
12. Disable VRRP on TR1, TR2 and the RUT. Return the network configuration to that given in the Test Setup section.
13. Configure TR1 and TR2 to backup a virtual router {VRID = 1} with the virtual router IP address equal to the IP address of the RUT's first interface. The Priority on TR1 is set to 100 and the Priority on TR2 is set to 99.
14. Configure the RUT to associate the virtual router {VRID = 1} with the IP address of its first interface. Its Priority is 255.
15. Enable VRRP on the RUT, TR1 and TR2.
16. Ping station B from station A.
17. Observe the packets transmitted on network 0 and network 1.

Part E: Power failure
18. Power down the RUT.
19. Ping station B from station A.
20. Observe the packets transmitted on network 0 and network 1.

Observable Results:
- In Part A, the RUT remained in the Backup state. IP packets transmitted by station A destined for station B were forwarded onto network 1 by TR1.
- In Part B, after a delay of no more than 4 seconds, the RUT transitioned into the Master state. IP packets transmitted by station A destined for station B were forwarded onto network 1 by the RUT. TR2 remained in the Backup state.
- In Part C, after a delay of no more than 4 seconds, TR2 transitioned into the Master state, preempting the RUT. IP packets transmitted by station A destined for station B were forwarded onto network 1 by TR2.
- In Part D, the RUT entered into the Master state. IP packets transmitted by station A destined for station B were forwarded onto network 1 by the RUT
- In Part E, after a delay of no more than 4 seconds, TR1 transitioned into the Master state. IP packets transmitted by station A destined for station B were forwarded onto network 1 by TR1. The ping failed because the reverse path from B to A failed once the RUT is down.

Possible Problems: Please note that this test is an interoperability test. Therefore, failure against any one router does not necessarily indicate nonconformance. Rather, it indicates that the two routers are unable to work "properly" together and that further work should be done to isolate the cause of the failure.

Test VRRP.1.2: Advanced VRRP Interoperability

Purpose: To verify that a router can interoperate with other VRRP implementations on multiple subnets.

References: [3768] – Sections 3, 4 and 5

Discussion: This test verifies that the RUT can successfully exchange packets and develop a proper VRRP configuration when directly connected to other VRRP implementations on multiple subnets.

Test Setup:

Device	Interface	Network	VRID	Priority
RUT	1	0	1	100
RUT	2	1	2	100
RUT	3	2	3	100
TR1	1	0	1	255
TR1	2	1	2	99
TR2	1	0	1	99
TR2	3	2	3	255
TR3	2	1	2	255
TR3	3	2	3	101
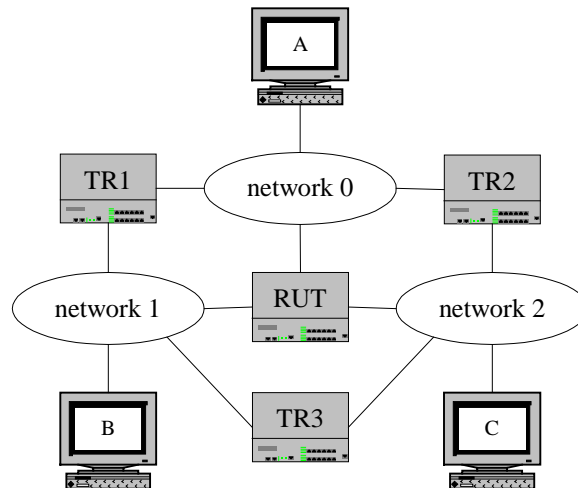
Procedure:

Part A: The RUT in the Backup state
1. Configure TR1 as the Master on network 0, TR3 as the Master on network 1 and TR2 as the Master on network 2.
2. Enable VRRP on the RUT, TR1, TR2 and TR3.
3. Pass valid IP packets between stations A, B and C.
4. Observe the packets transmitted on network 0, network 1 and network 2.

Part B: The RUT in transition
5. Disconnect TR1 from network 0 and TR2 from network 2.
6. After Master_Down_Interval, pass valid IP packets between stations A, B and C.
7. Observe the packets transmitted on network 0, network 1 and network 2.

Part C: Preemption
8. Configure the interface to network 0 on TR1 to a Priority of 100 and that IP address to a value higher than that of the RUT. Configure the interface to network 2 on TR2 to a Priority of 100 and that IP address to a value higher than that of the RUT.
9. Reconnect TR1 to network 0 and TR2 to network 2.
10. After Master_Down_Interval, pass valid IP packets between stations A, B and C.
11. Observe the packets transmitted on network 0, network 1 and network 2.

Observable Results:
- In Part A, the RUT remained in the Backup state. Packets transmitted from each station were observed by the stations as follows:

  B → C via TR3
  A → B via TR1
  C → A via TR2

  Packets were not observed on any other stations or via any other routes.

- In Part B, the RUT transitioned to the Master state for network 0. TR3 was the Master on both networks 1 and 2. Packets transmitted from each station were observed by the stations as follows:

  A → B via the RUT (all replies were dropped)
  A → C via the RUT (all replies were dropped)
  B → C via TR3
  C → B via TR3

  Packets were not observed on any other stations or via any other routes.

- In Part C, the RUT transitioned to Backup state on network 0. Packets transmitted from each station were observed by all the stations as follows:

  A → B via TR1
  B → C via TR3
  C → B via TR3

  Packets were not observed on any other stations or via any other routes.

Possible Problems: Please note that this test is an interoperability test. Therefore, failure against any one router does not necessarily indicate nonconformance. Rather, it indicates that the two routers are unable to work "properly" together and that further work should be done to isolate the cause of the failure.

GROUP 2: State Transition Diagram

Scope:

The following tests cover the State Transition Diagram in section 6.3.

Overview:

These tests are designed to verify that the RUT behaves properly by conforming to the Initialize, Master and Backup states. The test router in this group of tests consists of an analyzer that can transmit and receive frames.

Test VRRP.2.1: The Initialize State

Purpose: To verify that a router operates properly while in the Initialize state.

References: [3768] – Sections 6.1, 6.2, 6.3 and 6.4.1

Discussion: The purpose of the Initialize state is to wait for a Startup event. If the Router owns the IP addresses associated with the virtual router (a Priority value of 255), it should transmit an ADVERTISEMENT and transmit a gratuitous ARP request containing the virtual router MAC address for each IP address. It should then set the Adver_Time to Advertisement_Interval before transitioning to the Master state.   If the Router has a Priority value of less than 255, it should set the Master_Down_Timer to Master_Down_Interval before transitioning to the Backup state. When Master_Down_Timer fires, the router should transmit an ADVERTISEMENT and transmit a gratuitous ARP request containing the virtual router MAC address for each IP address. It should then set the Adver_Time to Advertisement_Interval before transitioning to the Master state.

Test Setup: Configure the RUT to be in the Initialize state.
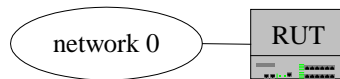
Procedure:
Part A: The RUT with a Priority of 255
1. Enable VRRP on the RUT with a Priority of 255. The RUT is owner of the virtual router IP address.
2. Observe the packets transmitted on network 0.
Part B: The RUT with a Priority of 254
3. Enable VRRP on the RUT with a Priority of 254. The RUT is not the owner of the virtual router IP address.
4. Observe the packets transmitted on network 0.

Observable Results:
- In Part A, the RUT transmitted an ADVERTISEMENT and broadcasted a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router.
- In Part B, the RUT waited approximately Master_Down_Interval (3.0078125 seconds) before it transmitted an ADVERTISEMENT and broadcasted a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router.

Possible Problems: None.

Test VRRP.2.2: Packet Reception in the Backup State

Purpose: To verify that a router properly discards frames destined to the virtual router while in the Backup state.

References: [3768] – Sections 6.1, 6.2, 6.3 and 6.4.2

Discussion: The purpose of the Backup state is to monitor the availability and state of the Master Router. A router in the Backup state MUST NOT respond to ARP requests for the IP addresses associated with the virtual router. A router in the Backup state MUST discard packets with a destination link layer MAC address equal to the virtual router MAC address. A router in the Backup state MUST NOT accept packets addressed to the IP address(es) associated with the virtual router.

Test Setup: Enable VRRP on the RUT with the Priority set to 100. TR1 is a packet generator simulating a router.
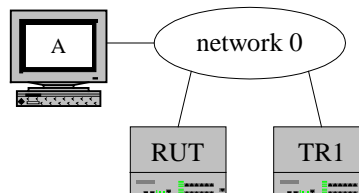
Procedure:
Part A: Reception of ARP requests
1. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
2. Properly formatted ARP packets are transmitted for the IP address associated with the virtual router.
3. Observe the packets transmitted on network 0.
Part B: Reception of packets with the MAC address of the virtual router
4. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
5. Properly formatted IP packets are transmitted with a destination link layer MAC address equal to the virtual router MAC address, to destination IP address on one of the RUT's directly connected networks.
6. Observe the packets transmitted on network 0.
Part C: Reception of packets with the IP address of the virtual router
7. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
8. An Echo Request is transmitted to the IP address associated with the virtual router.
9. Observe the packets transmitted on network 0.

Observable Results:
- In Part A, the RUT did not respond to the ARP packets.
- In Part B, the RUT did not forward the packets with a destination link layer MAC address equal to the virtual router MAC address.
- In Part C, the RUT did not respond to the Echo Request.

Possible Problems: None.

Test VRRP.2.3: Master Down in the Backup State

Purpose: To verify that a router operates properly while in the Backup state.

References: [3768] – Sections 6.1, 6.2, 6.3 and 6.4.2

Discussion: The purpose of the Backup state is to monitor the availability and state of the Master Router. If the Master_Down_Timer fires while a router is in the Backup state, the router should transmit an ADVERTISEMENT and broadcast a gratuitous ARP request for each IP address associated with the virtual router. The router should then set the Adver_Time to Advertisement_Interval before transitioning to the Master state.

Test Setup: Configure the RUT with an Adv_Interval of 5 seconds. Enable VRRP on the RUT with the Priority set to 100. TR1 is a packet generator simulating a router.
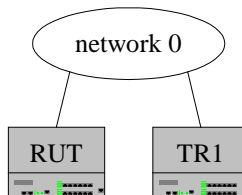
Procedure:
Part A: Master Down in the Backup State
1. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
2. TR1 ceases transmission of ADVERTISEMENTS (without transmitting a last ADVERTISEMENT with Priority equal to zero).
3. Observe the packets transmitted on network 0.

Observable Results:
- In Part A, approximately 16 seconds from when TR1 transmitted its last VRRP ADVERTISEMENT, the RUT transmitted an ADVERTISEMENT, broadcasted a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router and transitioned to the Master state.

Possible Problems: None.

Test VRRP.2.4: Advertisement Reception in the Backup State

Purpose: To verify that a router properly receives ADVERTISEMENTS while in the Backup state.

References: [3768] – Sections 6.1, 6.2, 6.3 and 6.4.2

Discussion: The purpose of the Backup state is to monitor the availability and state of the Master Router. If a router in the Backup state receives an ADVERTISEMENT with a Priority of higher or equal value, it should reset the Master_Down_Timer and remain in the Backup state. If a router in the Backup state receives an ADVERTISEMENT with a Priority of zero, it should set the Master_Down_Timer to Skew_Time and eventually transition to the Master state. If a router in the Backup state receives an ADVERTISEMENT with a Priority of lower value, it should discard the ADVERTISEMENT and not reset the Master_Down_Timer, eventually transitioning to the Master state.

Test Setup: Enable VRRP on the RUT with the Priority set to 100. TR1 is a packet generator simulating a router.
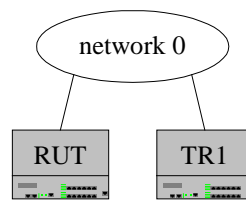
Procedure:
Part A: ADVERTISEMENT reception with a higher Priority value
1. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
2. TR1 transmits ADVERTISEMENTS with a Priority higher than that of the RUT.
3. Observe the packets transmitted on network 0.
Part B: ADVERTISEMENT reception with an equal Priority value
4. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
5. TR1 transmits ADVERTISEMENTS with a Priority equal to that of the RUT.
6. Observe the packets transmitted on network 0.
Part C: ADVERTISEMENT reception with a Priority of zero
7. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
8. TR1 stops transmitting ADVERTISEMENTS via a Shutdown Event (transmitting a last ADVERTISEMENT with Priority equal to zero).
9. Observe the packets transmitted on network 0.
Part D: ADVERTISEMENT reception with a lower Priority value
10. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
11. TR1 transmits ADVERTISEMENTS with a Priority lower than that of the RUT.
12. Observe the packets transmitted on network 0.

Observable Results:
- In Parts A and B, the RUT did not transmit any ADVERTISEMENTS.

- In Part C, the RUT set Master_Down_Timer to Skew_Time. When Master_Down_Timer fires, the RUT transmitted an ADVERTISEMENT and broadcast a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router before it transitioned to the Master state.
- In Part D, the RUT discarded the ADVERTISEMENT upon reception. After Master_Down_Interval, the Master_Down_Timer expires, the RUT transmitted an ADVERTISEMENT, broadcasted a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router and transitioned to the Master state.

Possible Problems: None.

Test VRRP.2.5: Packet Reception in the Master State

Purpose: To verify that a router properly discards frames destined to the virtual router while in the Master state.

References: [3768] – Sections 6.1, 6.2, 6.3 and 6.4.3

Discussion: While in the Master state, the router functions as the forwarding router for the IP address(es) associated with the virtual router. A router in the Master state MUST respond to ARP requests for the IP addresses associated with the virtual router. A router in the Master state MUST forward packets with a destination link layer MAC address equal to the virtual router MAC address. A router in the Master state MUST NOT accept packets addressed to the IP address(es) associated with the virtual router if it is not the owner. A router in the Master state MUST accept packets addressed to the IP address(es) associated with the virtual router if it is the owner.

Test Setup: Enable VRRP on the RUT with the Priority set to 100.   TR1 is a packet generator simulating a router.
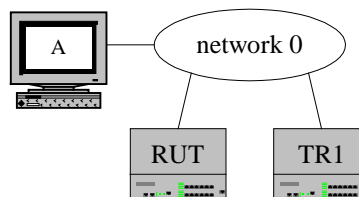
Procedure:
Part A: Reception of ARP requests
1. The RUT transitions to the Master state.
2. Properly formatted ARP packets are transmitted for the IP address associated with the virtual router.
3. Observe the packets transmitted on network 0.
Part B: Reception of packets with the MAC address of the virtual router
4. The RUT transitions to the Master state.
5. An IP packet is transmitted with destination link layer MAC address equal to the virtual router MAC address to a destination IP address on one of the RUT's directly connected networks.
6. Observe the packets transmitted on network 0.
Part C: Reception of packets with the IP address of a different virtual router
7. The RUT transitions to the Master state.
8. Configure the RUT so that it is not the owner of the IP address associated with the virtual router.
9. An ICMP echo request is transmitted to the MAC address and destination IP address of the virtual router.
10. Observe the packets transmitted on network 0.

Part D: Reception of packets with the IP address of the virtual router
11. The RUT transitions to the Master state.
12. Configure the RUT so that it is the owner of the IP address associated with the virtual router.
13. An ICMP echo request is transmitted to the MAC address and destination IP address of the virtual router.
14. Observe the packets transmitted on network 0.

Observable Results:
- In Part A, the RUT responded to the ARP packet for the IP address associated with the virtual router. The MAC address given in the reply was the MAC address of the virtual router.
- In Part B, the RUT forwarded the packets with a destination link layer MAC address equal to the virtual router MAC address onto the appropriate network for the destination IP address.
- In Part C, the RUT did not reply to the ICMP echo request.
- In Part D, the RUT replied to the ICMP echo request.

Possible Problems: If the RUT does not have an ARP entry for the Virtual Router IP address, part D may fail. If this occurs, add an ARP entry for the IP Address associated with the Virtual Router, and retry part D.
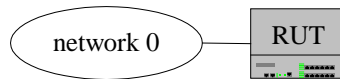
Test VRRP.2.6: Shutdown Event in the Master State

Purpose: To verify that a router properly handles a shutdown event while in the Master state.

References: [3768] – Sections 6.1, 6.2, 6.3 and 6.4.3

Discussion: While in the Master state, the router functions as the forwarding router for the IP address(es) associated with the virtual router. Upon reception of a shutdown event, a router in the Master state immediately cancels the Adver_Timer, transmits an ADVERTISEMENT with a Priority of zero, and transitions to the Initialize state.

Test Setup: Enable VRRP on the RUT. Allow time for the RUT to transition to the Master state.

Procedure:
Part A: Shutdown event in the Master state
1. Shutdown VRRP on the RUT.
2. Observe the packets transmitted on network 0.

Observable Results:
- In Part A, the RUT transmitted an ADVERTISEMENT with Priority equal to zero.

Possible Problems: None.

Test VRRP.2.7: Advertisement Reception in the Master State

Purpose: To verify that a router properly receives ADVERTISEMENTS while in the Master state.

References: [3768] – Sections 6.1, 6.2, 6.3 and 6.4.3

Discussion: While in the Master state, the router functions as the forwarding router for the IP address(es) associated with the virtual router. If a router in the Master state receives an ADVERTISEMENT with a Priority of higher or equal value, it should cancel Adver_Timer, set the Master_Down_Timer to Master_Down_Interval and transition to the Backup state. If a router in the Master state receives an ADVERTISEMENT with a Priority of lower value, it should discard the ADVERTISEMENT and not reset the Master_Down_Timer, remaining in the Master state. If a router in the Master state receives an ADVERTISEMENT with a Priority of zero, it should transmit an ADVERTISEMENT and reset Adver_Timer to Advertisement_Interval. If a router in the Master state receives an ADVERTISEMENT with a Priority of equal value and the primary IP Address of the sender is higher than the local primary IP Address, the router should cancel Adver_Timer, set the Master_Down_Timer to Master_Down_Interval and transition to the Backup state. If a router in the Master state receives an ADVERTISEMENT with a Priority of equal value and the primary IP Address of the sender is less than or equal to the local primary IP Address, the router should discard the ADVERTISEMENT and remain in the Master state.

Test Setup: Enable VRRP on the RUT. TR1 is a packet generator simulating a router.
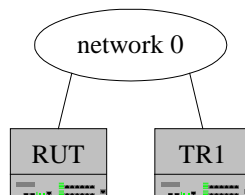
Procedure:
Part A: Reception of an ADVERTISEMENT with a higher Priority value
1. The RUT transitions to the Master state.
2. TR1 transmits an ADVERTISEMENT with Priority higher than that of the RUT.
3. Observe the packets transmitted on network 0.
Part B: Reception of an ADVERTISEMENT with a lower Priority value
4. The RUT transitions to the Master state.
5. TR1 transmits an ADVERTISEMENT with Priority lower than that of the RUT.
6. Observe the packets transmitted on network 0.
Part C: Reception of an ADVERTISEMENT with a Priority of zero
7. The RUT transitions to the Master state.
8. TR1 transmits an ADVERTISEMENT with Priority equal to zero.
9. Observe the packets transmitted on network 0.

Part D: Reception of an ADVERTISEMENT with an equal Priority value and a higher primary IP address
10. The RUT transitions to the Master state.
11. TR1 transmits an ADVERTISEMENT with Priority equal to that of the RUT and primary IP Address higher than the primary IP Address of the RUT.
12. Observe the packets transmitted on network 0.

Part E: Reception of an ADVERTISEMENT with an equal Priority value and an equal primary IP address
13. The RUT transitions to the Master state.
14. TR1 transmits an ADVERTISEMENT with Priority equal to that of the RUT and primary IP Address equal to the primary IP Address of the RUT.
15. Observe the packets transmitted on network 0.

Part F: Reception of an ADVERTISEMENT with an equal Priority value and lower primary IP address
16. The RUT transitions to the Master state.
17. TR1 transmits an ADVERTISEMENT with Priority equal to that of the RUT and primary IP Address less than the primary IP Address of the RUT.
18. Observe the packets transmitted on network 0.

Observable Results:
- In Part A, the RUT canceled the Adver_Timer, set Master_Down_Timer to Master_Down Interval and transitioned to the Backup state. The RUT ceased transmission of ADVERTISMENTS.
- In Parts B, E and F, the RUT discarded the ADVERTISEMENT transmitted by TR1 and remained in the Master state.
- In Part C, the RUT transmitted an ADVERTISEMENT and reset the Adver_Timer to Advertisement_Interval and remained in the Master state.
- In Part D, the RUT canceled the Adver_Timer, set Master_Down_Timer to Master_Down Interval and transitioned to the Backup state.

Possible Problems: In order to determine part E has passed or failed, observe the packets when TR1 ceases transmission. If the RUT transmits a gratuitous ARP request the test fails, as this indicates that it had to transition into the Master State.

GROUP 3: Parameters Per Virtual Router

Scope:

The following tests cover the values discussed in section 6.1.

Overview:

These tests are designed to verify that the RUT properly implements the timer values described in section 6.1. These tests assume that the RUT has properly implemented the State Transition Diagram described in section 6.3. The test router in this group of tests consists of an analyzer that can transmit and receive frames.
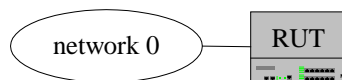
Test VRRP.3.1: Advertisement_Interval

Purpose: To observe the Advertisement_Interval value.

References: [3768] – Sections 5.3.7 and 6.1

Discussion: The Advertisement_Interval indicates the time interval (in seconds) between ADVERTISEMENTS. The default is one second. This field is used for troubleshooting misconfigured routers.

Test Setup: Reset factory defaults and enable VRRP on the RUT. Configure the RUT to be the Master.

Procedure:
Part A: Default Value
1. Observe and record the time interval between the ADVERTISEMENTS that the RUT transmits.
Part B: Configured Value
2. Configure the value of Advertisement_Interval on the RUT to have a different value than that of one second.
3. Observe and record the time interval between the ADVERTISEMENTS that the RUT transmits.

Observable Results:
- In Part A, the time interval between the ADVERTISEMENTS that the RUT transmitted was one second.
- In Part B, the time interval between the ADVERTISEMENTS that the RUT transmitted was equivalent to the value configured in step 2.

Possible Problems: Some routers may not allow the Advertisement_Interval value to be configured.

Test VRRP.3.2: Skew_Time

Purpose: To observe the Skew_Time value.

References: [3768] – Sections 6.1 and 6.4.2

Discussion: Skew_Time is the time to skew Master_Down_Interval in seconds. Skew_Time is calculated as [(256 – Priority) / 256] where Priority is the Priority value to be used by the VRRP router in Master election.

Test Setup: Enable VRRP on the RUT with an Adv_Interval of 5 seconds. TR1 is a packet generator simulating a router.
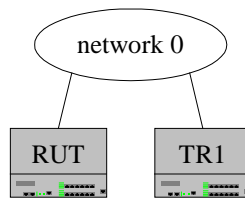
Procedure:
Part A: Skew_Time with a Priority of 1
1. Configure the RUT with a Priority value of 1.
2. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
3. TR1 transmits a final ADVERTISEMENT with Priority equal to zero.
4. Observe the packets transmitted on network 0.

Part B: Skew_Time with a Priority of 254
5. Configure the RUT with a Priority value of 254.
6. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
7. TR1 transmits a final ADVERTISEMENT with Priority equal to zero.
8. Observe the packets transmitted on network 0.

Part C: Skew_Time with a Priority of 100
9. Configure the RUT with a Priority value of 100.
10. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
11. TR1 transmits a final ADVERTISEMENT with Priority equal to zero.
12. Observe the packets transmitted on network 0.

Observable Results:
- In Parts A, B and C, Upon Reception of an ADVERTISEMENT with a Priority equal to zero, the RUT set Master_Down_Timer to Skew_Time. The RUT then transmitted an ADVERTISEMENT when Master_Down_Timer fires.
- In Part A, the time between the last ADVERTISEMENT transmitted from TR1 and the first ADVERTISEMENT transmitted from the RUT was 255/256 second (approximately one second).
- In Part B, the time between the last ADVERTISEMENT transmitted from TR1 and the first ADVERTISEMENT transmitted from the RUT was 2/256 second (approximately 7.8 ms).
- In Part C, the time between the last ADVERTISEMENT transmitted from TR1 and the first ADVERTISEMENT transmitted from the RUT was 156/256 second (approximately 609 ms).

Possible Problems: If any of the parts fail, retest at least 6 times and record the results.
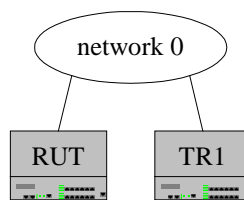
Test VRRP.3.3: Master_Down_Interval

Purpose: To observe the Master_Down_Interval value.

References: [3768] – Sections 6.1 and 6.4.2

Discussion: Master_Down_Interval is the time interval for Backup to declare Master down in seconds. It is calculated as (3 * Advertisement_Interval) + Skew_Time

Test Setup: Enable VRRP on the RUT with a Priority of 254. TR1 is a packet generator simulating a router.

Procedure:
Part A: Default Master_Down_Interval
1. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
2. TR1 ceases transmission of ADVERTISEMENTS (without transmitting a last ADVERTISEMENT with Priority equal to zero).
3. Observe the packets transmitted on network 0.
Part B: Configured Master_Down_Interval
4. Configure the RUT with an Advertisement_Interval of 4 seconds.
5. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
6. TR1 ceases transmission of ADVERTISEMENTS (without transmitting a last ADVERTISEMENT with Priority equal to zero).
7. Observe the packets transmitted on network 0.

Observable Results:
- In Part A, ADVERTISEMENTS were not received during Master_Down_Interval causing the Master_Down_Timer to fire. The RUT transmitted an ADVERTISEMENT, broadcasted a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router and transitioned to the Master state. (Master_Down_Interval was calculated as (3x1) + Skew-Time (approximately 0 seconds) = 3 seconds.)
- In Part B, ADVERTISEMENTS were not received during Master_Down_Interval causing the Master_Down_Timer to fire. The RUT transmitted an ADVERTISEMENT, broadcasted a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router and transitioned to the Master state. (Master_Down_Interval was calculated as (3x4) + Skew-Time (approximately 0 second) = 12 seconds.)

Possible Problems: Some routers may not allow the Advertisement_Interval value to be configured.

Test VRRP.3.4: Preempt_Mode

Purpose: To verify that a router properly implements Preempt_Mode.

References: [3768] – Sections 6.1, 6.4.1, 6.4.2 and 6.4.3

Discussion: Preempt_Mode controls whether a higher Priority Backup router preempts a lower Priority Master. The default value is True. When Preempt_Mode is disabled, a higher Priority router will not transmit ADVERTISEMENTS when it detects that a lower Priority router is already the virtual router master.

Test Setup: Enable VRRP on the RUT. Neither the RUT nor TR1 owns the IP address associated with the virtual router. TR1 is a packet generator simulating a router.
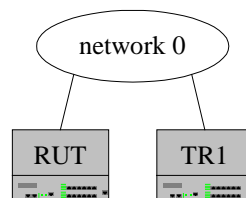
Procedure:
Part A: Preempt_Mode True
1. Configure Preempt_Mode to True on the RUT.
2. While the RUT is in the INITIALIZE state, TR1 transmits ADVERTISEMENTS with a Priority less than that of the RUT.
3. Observe the packets transmitted on network 0.
Part B: Preempt_Mode False
4. Configure Preempt_Mode to False on the RUT.
5. While the RUT is in the INITIALIZE state, TR1 transmits ADVERTISEMENTS with a Priority less than that of the RUT.
6. Observe the packets transmitted on network 0.

Observable Results:
- In Part A, the RUT preempted TR1 and transitioned to the Master state. The RUT then transmitted an ADVERTISEMENT, broadcasted a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router and transitioned to the Master state.
- In Part B, the RUT remained in the Backup state. The RUT did not originate any ADVERTISMENTS.

Possible Problems: Some routers may not allow Preempt_Mode to be configured.

GROUP 4: VRRP Transmission and Reception

Scope:

The following tests cover the transmission and reception of VRRP packets.

Overview:

Section 7 describes the proper behavior that a device must display when transmitting and receiving VRRP packets. These tests are designed to verify that the RUT properly transmits and receives VRRP packets. The test router in this group of tests consists of an analyzer that can transmit and receive frames.
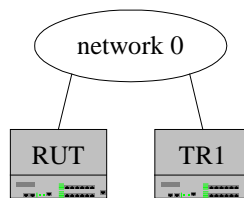
Test VRRP.4.1: Reception of Invalid TTL field

Purpose: To verify that a router discards VRRP ADVERTISEMENTS with an invalid TTL field value.

References: [3768] – Sections 5, 5.2.3, 6.4.2 and 7.1

Discussion: A VRRP router must perform checks on VRRP packets received to determine their validity. VRRP packets are sent encapsulated in IP packets with the IP TTL must be set to 255. If a VRRP packet is received with the IP TTL value other than 255, a router must discard the packet.

Test Setup: TR1 is a packet generator simulating a router.

Procedure:
Part A: Reception of an invalid TTL field
1. Enable VRRP on the RUT.
2. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
3. TR1 transmits VRRP packets with the IP TTL field value set to 255.
4. TR1 transmits VRRP packets with the IP TTL field with a value less than 255.
5. Observe the packets transmitted by the RUT.

Observable Results:
- In Part A, the RUT discarded the VRRP packets with the IP TTL not equal to 255. Within 4 seconds of TR1's last valid VRRP ADVERTISEMENT, the RUT transmitted an ADVERTISEMENT, broadcasted a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router and transitioned to the Master state.

Possible Problems: None.

Test VRRP.4.2: Reception of Invalid Version field

Purpose: To verify that a router properly discards VRRP ADVERTISEMENTS containing an invalid version field.

References: [3768] – Sections 5, 5.3.1 and 7.1

Discussion: A VRRP router must perform checks on VRRP packets received to determine their validity. The version field specifies the VRRP protocol version of the packet. The version is set to 2. If a router receives a VRRP packet with the version set to a value other than 2, it must discard the packet.

Test Setup: TR1 is a packet generator simulating a router.
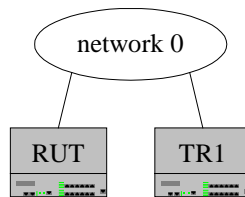
Procedure:
Part A: Reception of invalid version field
1. Enable VRRP on the RUT.
2. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
3. TR1 transmits VRRP packets with the VRRP version field equal to 2.
4. TR1 transmits VRRP packets with the VRRP version field not equal to 2.
5. Observe the packets transmitted by the RUT.

Observable Results:
- In Part A, the RUT discarded the VRRP packets with the version field not equal to 2. Within 4 seconds of TR1's last valid ADVERTISEMENT, the RUT transmitted an ADVERTISEMENT, broadcasted a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router and transitioned to the Master state.

Possible Problems: None.

Test VRRP.4.3: Reception of Invalid Complete VRRP Packet length

Purpose: To verify that a router properly discards VRRP ADVERTISEMENTS containing an invalid complete VRRP packet length.

References: [3768] – Sections 5, 6.4.2 and 7.1

Discussion: A VRRP router must perform checks on VRRP packets received to determine their validity. The received packet must contain the complete VRRP packet (including fixed fields, IP Address(es) and Authentication Data). If a router receives a packet that does not contain the complete packet, it must be discarded.

Test Setup: TR1 is a packet generator simulating a router.
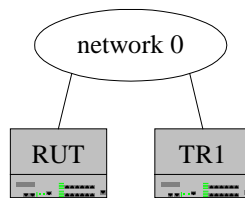
Procedure:
Part A: Reception of illegal complete VRRP packet length
1. Enable VRRP on the RUT.
2. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
3. TR1 transmits VRRP packets with the complete VRRP packet length of 40.
4. TR1 transmits VRRP packets with the complete VRRP packet length less 40.
5. Observe the packets transmitted by the RUT.

Observable Results:
- In Part A, the RUT discarded the VRRP packets with a complete VRRP packet length less than 40. Within 4 seconds of TR1's last valid ADVERTISEMENT, the RUT transmitted an ADVERTISEMENT, broadcasted a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router and transitioned to the Master state.

Possible Problems: None.

Test VRRP.4.4: Reception of Invalid checksum field

Purpose: To verify that a router properly discards datagrams containing an invalid checksum.

References: [3768] – Sections 5, 5.3.8, 6.4.2 and 7.1

Discussion: A VRRP router must perform checks on VRRP packets received to determine their validity. The checksum field is used to detect data corruption in the VRRP message. The checksum is the 16-bit one's complement of the one's complement sum of the entire VRRP message starting with the version field. For computing the checksum, the checksum field is set to zero. If a VRRP router receives a packet with an incorrect checksum, the packet must be discarded.

Test Setup: TR1 is a packet generator simulating a router.
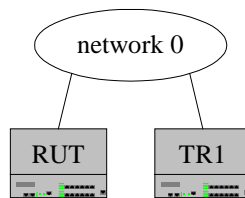
Procedure:
Part A: Reception of invalid checksum
1. Enable VRRP on the RUT.
2. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
3. TR1 transmits VRRP packets with a valid VRRP checksum.
4. TR1 transmits VRRP packets with an invalid VRRP checksum.
5. Observe the packets transmitted by the RUT.

Observable Results:

*   In Part A, the RUT discarded the VRRP packets with an invalid checksum. Within 4 seconds of TR1's last valid ADVERTISEMENT, the RUT transmitted an ADVERTISEMENT, broadcasted a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router and transitioned to the Master state.

Possible Problems: None.

Test VRRP.4.5: Reception of Invalid VRID field

Purpose: To verify that a router properly discards datagrams containing an invalid VRID field.

References: [3768] – Sections 5, 5.3.3, 6.1, 6.4.2 and 7.1

Discussion: A VRRP router must perform checks on VRRP packets received to determine their validity. The Virtual Router Identifier (VRID) field identifies the virtual router this packet is reporting status for. It is a configurable item in the range 1-255 (decimal). The router must check that the VRID is configured on the receiving interface and the local router is not the IP Address owner (Priority equals 255 (decimal)). If a VRRP router receives a packet with an invalid VRID, the packet must be discarded.

Test Setup: TR1 is a packet generator simulating a router.
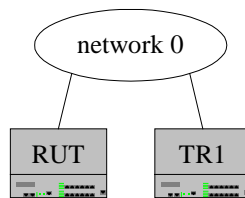
Procedure:

Part A: Reception of invalid VRID
1. Enable VRRP on the RUT.
2. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
3. TR1 transmits VRRP packets with a valid VRID.
4. TR1 transmits VRRP packets with an invalid VRID.
5. Observe the packets transmitted by the RUT.

Observable Results:

- In Part A, the RUT discarded the VRRP packets with an invalid VRID. Within 4 seconds of TR1's last valid ADVERTISEMENT, the RUT transmitted an ADVERTISEMENT, broadcasted a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router and transitioned to the Master state.

Possible Problems: None.

Test VRRP.4.6: Reception of Invalid Auth Type Information

Purpose: To verify that a router properly discards datagrams containing Auth Type that conflict with the local configuration.

References: [3768] – Sections 5, 5.3.6, 6.1, 6.4.2 and 7.1

Discussion: A VRRP router must perform checks on VRRP packets received to determine their validity. A VRRP router must verify that the Auth Type matches the locally configured authentication method for the virtual router and perform that authentication method. The authentication type field identifies the authentication method being utilized. Authentication type is unique on a Virtual Router basis. The authentication type field is an 8 bit unsigned integer. A packet with unknown authentication type or that does not match the locally configured authentication method must be discarded. The authentication methods currently defined are 0 – No Authentication, 1 – Reserved 2 – Reserved. The use of authentication type 0 means that VRRP protocol exchanges are not authenticated. The contents of the Authentication Data field should be set to zero on transmission and ignored on reception. The use of authentication type 1 and type 2 are reserved to maintain backwards compatibility with RFC 2338.

Test Setup: Configure the RUT with authentication type 0. TR1 is a packet generator simulating a router.
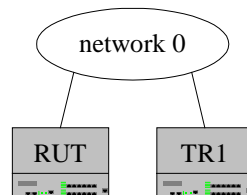
Procedure:
Part A: Reception of conflicting Authentication information
1.   Enable VRRP on the RUT.
2.   TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
3.   TR1 transmits VRRP packets with a VRRP authentication type 0.
4.   TR1 transmits VRRP packets with a VRRP authentication type 1.
5.   Observe the packets transmitted by the RUT.

Observable Results
- In Part A, the RUT discarded the VRRP packets with an authentication type 1. Within 4 seconds of TR1's last non-conflicting ADVERTISEMENT, the RUT transmitted an ADVERTISEMENT, broadcasted a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router and transitioned to the Master state.

Possible Problems: None.

Test VRRP.4.7: Reception of Invalid Adver Interval Information

Purpose: To verify that a router properly discards datagrams containing Adver Interval fields that conflict with the local configuration.

References: [3768] – Sections 5, 5.3.7, 6.1, 6.4.2 and 7.1

Discussion: A VRRP router must perform checks on VRRP packets received to determine their validity. A VRRP router must verify that the Adver Interval in the packet is the same as the locally configured for the virtual router. If the interval is different, the receiver must discard the packet. The advertisement interval indicates the time interval (in seconds) between ADVERTISEMENTS. The default is 1 second. This field is used for troubleshooting misconfigured routers.

Test Setup: Configure the RUT with an Adver Interval set to 1 second. TR1 is a packet generator simulating a router.
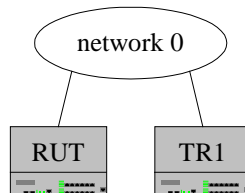
Procedure:
Part A: Reception of conflicting Advertisement Interval information
1. Enable VRRP on the RUT.
2. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
3. TR1 transmits VRRP packets with an Adver Interval of 1 second.
4. TR1 transmits VRRP packets with an Adver Interval of 7 seconds.
5. Observe the packets transmitted by the RUT.

Observable Results
- In Part A, the RUT discarded the VRRP packets with an Adver Interval of 7 seconds. Within 4 seconds of TR1's last non-conflicting ADVERTISEMENT, the RUT transmitted an ADVERTISEMENT, broadcasted a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router and transitioned to the Master state.

Possible Problems: None.

Test VRRP.4.8: Reception of Invalid Unknown Type Field

Purpose: To verify that a router properly discards datagrams containing an unknown type field.

References: [3768] – Sections 5, 5.3.2 and 6.4.2

Discussion: VRRP routers must transmit VRRP packets with the packet fields set appropriately. The type field specifies the type of VRRP packet. The only type defined in this version of the protocol is ADVERTISEMENT, which has a type value of one. A packet with an unknown type MUST be discarded.

Test Setup: TR1 is a packet generator simulating a router.
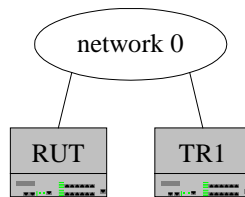
Procedure:
Part A: Reception of Invalid Unknown Type Field
1. Enable VRRP on the RUT.
2. TR1 transmits ADVERTISEMENTS to put the RUT in the Backup state.
3. TR1 transmits VRRP packets with the Type field set to 1.
4. TR1 transmits VRRP packets with the Type field set to an unknown value.
5. Observe the packets transmitted by the RUT.

Observable Results:
- In Part A, the RUT discarded the VRRP packets with the unknown Type fields. Within 4 seconds of TR1's last ADVERTISEMENT with type 1, the RUT transmitted an ADVERTISEMENT, broadcasted a gratuitous ARP request containing the virtual router MAC address for each IP address associated with the virtual router and transitioned to the Master state.
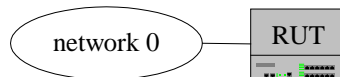
Possible Problems: None.

Test VRRP.4.9: Proper Transmission of VRRP packets

Purpose: To verify that a router transmits VRRP packets with the correct field values.

References: [3768] – Sections 5, 6, 6.4.3 and 7.1

Discussion: VRRP routers must transmit VRRP packets with the packet fields set appropriately.

Test Setup: Enable VRRP on the RUT.

Procedure:
Part A: Proper field values
1. The RUT transitions to the Master state.
2. Observe the packets transmitted by the RUT.

Observable Results:
- In Part A, the RUT transmitted VRRP packets with the following field values:
    - TTL equal to 255
    - IP protocol number equal to 112
    - Type field equal to 1
    - VRRP version equal to 2
    - Priority field equal to 255 (when the RUT owns the IP address associated with the virtual router)
    - Source IP address equal to the interface primary IP address
    - Destination IP address equal to the VRRP multicast address (224.0.0.18)
    - Source MAC address equal to the virtual router MAC address (0:0:5e:0:1:1)
    - Destination Link Layer address equal to the VRRP link layer multicast address (1:0:5e:0:0:12)
    - The correct VRRP checksum

Possible Problems: None.