

IPv6 CONSORTIUM TEST SUITE

Protocol Independent Multicast – Sparse Mode
(PIM-SM) Operations Test Suite

Technical Document

Revision 1.0



**University of New Hampshire
InterOperability Laboratory
IPv6 Consortium
<http://www.iol.unh.edu>**

**121 Technology Drive, Suite 2
Durham, NH 03824
Phone: +1-603-862-2804
Fax: +1-603-862-0898**

TABLE OF CONTENTS

MODIFICATION RECORD	4
ACKNOWLEDGEMENTS	5
INTRODUCTION	6
TIMERS AND DEFAULT VALUES	8
TEST ORGANIZATION.....	9
REFERENCES	10
GROUP 1: Hello Messages and Designated Router Election	11
Test PIM_SM.1.1: Sending Hello Messages.....	12
Test PIM_SM.1.2: Triggered Hello Messages.....	13
Test PIM_SM.1.3: DR Election	15
Test PIM_SM.1.4: Change of DR.....	18
Test PIM_SM.1.5: Generation ID in DR Election	21
Test PIM_SM.1.6: HoldTime in Hello Messages	22
GROUP 2: Multicast Forwarding	24
Test PIM_SM.2.1: Forwarding Packets	25
Test PIM_SM.2.2: Encapsulate Packets	27
Test PIM_SM.2.3: Forwarding Encapsulated Data Packets	28
Test PIM_SM.2.4: Encapsulation for Multiple RP's	29
Test PIM_SM.2.5: Source Packets.....	30
Test PIM_SM.2.6: Forwarding Encapsulated and Decapsulated Data Packets	31
Test PIM_SM.2.7: RegisterStop (S,G).....	32
Test PIM_SM.2.8: RegisterStop (*,G).....	33
Test PIM_SM.2.9: Data Forwarding to Several Links.....	34
Test PIM_SM.2.10: Multiple Sources.....	36
Test PIM_SM.2.11: Forwarding From Multiple RPs.....	38
Test PIM_SM.2.12: PIM Tree Receiver	39
Test PIM_SM.2.13: PIM Tree - Source	41
GROUP 3: Reception of Join and Prune Messages.....	43
Test PIM_SM.3.1: Unknown Join Messages	44
Test PIM_SM.3.2: Join Messages Destination Address	46
Test PIM_SM.3.3: Transitions from (*,*,RP) NoInfo State	48
Test PIM_SM.3.4: Transitions from Join (*,*,RP) State	49
Test PIM_SM.3.5: Transitions from (*,*,RP) Prune Pending State	51
Test PIM_SM.3.6: Transitions from (*,G) NoInfo State	53
Test PIM_SM.3.7: Transitions from (*,G) Join State	54
Test PIM_SM.3.8: Transitions from (*,G) Prune-Pending State	56
Test PIM_SM.3.9: Transitions from (S,G) NoInfo State	58

*University of New Hampshire
InterOperability Laboratory*

Test PIM_SM.3.10: Transitions from (S,G) Join State	59
Test PIM_SM.3.11: Transitions from (S,G) Prune Pending State	61
GROUP 4: Transmission of Join and Prune Messages	63
Test PIM_SM.4.1: Transitions from (*,*,RP) NotJoined State	64
Test PIM_SM.4.2: Transitions from (*,*,RP) Joined State, Setup 1	65
Test PIM_SM.4.3: Suppression and Override in (*,*,RP) Joined State.....	66
Test PIM_SM.4.4: Transitions from (*,*,RP) Joined State, Setup 2	68
Test PIM_SM.4.5: Transitions from (*,G) NotJoined State	70
Test PIM_SM.4.6: Transitions from (*,G) Joined State, Setup 1	71
Test PIM_SM.4.7: Suppression and Override in (*,G) Joined State.....	72
Test PIM_SM.4.8: Transitions from (*,G) Joined State, Setup 2	74
Test PIM_SM.4.9: Transitions (S,G) NotJoined State	76
Test PIM_SM.4.10: Transitions from (S,G) Joined State, Setup 1	77
Test PIM_SM.4.11: Suppression and Override in (S,G) Joined State	78
Test PIM_SM.4.12: Transitions from (S,G) Joined State, Setup 2	80
Test PIM_SM.4.13: Transitions from (S,G,rpt) NotPruned State.....	82
GROUP 5: Assert Messages	84
Test PIM_SM.5.1: Unknown Assert	85
Test PIM_SM.5.2: Upstream Assert	87
Test PIM_SM.5.3: Unknown Upstream Assert.....	89
Test PIM_SM.5.4: Transitions from (S,G) NoInfo State	91
Test PIM_SM.5.5: Transitions from (S,G) “I am Assert Winner” State.....	94
Test PIM_SM.5.6: AssertCancel Message Transmission	97
Test PIM_SM.5.7: (S,G) “I am Assert Loser” State Transition, Message Reception.....	99
Test PIM_SM.5.8: (S,G) “I am Assert Loser” State Transition, Internal Event	102
Test PIM_SM.5.9: (*,G) NoInfo State Transition.....	104
Test PIM_SM.5.10: (*,G) “I am Assert Winner” State Transition, Message Reception	107
Test PIM_SM.5.11: (*,G) “I am Assert Winner” State Transition, Internal Event.....	110
Test PIM_SM.5.12: Transitions from (*,G) “I am Assert Loser” State, (S,G) NoInfo.....	113
Test PIM_SM.5.13: Transitions from (*,G) “I am Assert Loser” State.....	116

MODIFICATION RECORD

Version 1.0

September 23, 2004

ACKNOWLEDGEMENTS

The University of New Hampshire would like to acknowledge the efforts of the following individuals in the development of this test suite.

Chris Burke	University of New Hampshire
Joel Daniels	University of New Hampshire
Chris Nelson	University of New Hampshire
Kari Revier	University of New Hampshire
Ben Schultz	University of New Hampshire
Timothy Winters	University of New Hampshire

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 Protocol Independent Multicast – Sparse Mode 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 PIM-SM devices. However, these tests provide a reasonable level of confidence that the Router Under Test will function well in most multi-vendor PIM-SM environments.

Test Software

The UNH IOL Testing Software is not a full PIM-SM implementation; it is simply a packet generator that can transmit and receive packets. This allows the Testing Node to generate invalid packets and to simulate parts of the Protocol Independent Multicast – Sparse Mode. The Testing Software is not currently available to the public. This software is unused in Section 1, as these are interoperability tests. This software emulates test routers in the other sections, thus when configurations are present, these are merely virtual configurations to test the conformance to PIM-SM.

Acronyms

RUT: Router Under Test

TR: Testing Router

RP: Rendezvous Point

DR: Designated Router

MLD: Multicast Listener Discovery

MRIB: Multicast Routing Information Base

RPF: Reverse Path Forwarding

TIB: Tree Information Base

MFIB: Multicast Forwarding Information Base

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.

Definitions

Rendezvous Point (RP):

An RP is a router that has been configured to be used as the root of the non-source-specific distribution tree for a multicast group. Join messages from receivers for a group are sent towards

the RP, and data from senders is sent to the RP so that receivers can discover who the senders are, and start to receive traffic destined for the group.

Designated Router (DR):

A shared-media LAN like Ethernet may have multiple PIM-SM routers connected to it. If the LAN has directly connected hosts, then a single one of these routers, the DR, will act on behalf of those hosts with respect to the PIM-SM protocol. A single DR is elected per interface (LAN or otherwise) using a simple election process.

MRIB Multicast Routing Information Base:

This is the multicast topology table, which is typically derived from the unicast routing table, or routing protocols such as MBGP that carry multicast-specific topology information. In PIM-SM, the MRIB is used to decide where to send Join/Prune messages. A secondary function of the MRIB is to provide routing metrics for destination addresses, these metrics are used when sending and processing Assert messages.

RPF Neighbor:

RPF stands for "Reverse Path Forwarding". The RPF Neighbor of a router with respect to an address is the neighbor that the MRIB indicates should be used to forward packets to that address. In the case of a PIM-SM multicast group, the RPF neighbor is the router that a Join message for that group would be directed to, in the absence of modifying Assert state.

TIB Tree Information Base:

This is the collection of state at a PIM router that has been created by receiving PIM Join/Prune messages, PIM Assert messages, and IGMP or MLD information from local hosts. It essentially stores the state of all multicast distribution trees at that router.

MFIB Multicast Forwarding Information Base:

The TIB holds all the state that is necessary to forward multicast packets at a router. However, although this specification defines forwarding in terms of the TIB, to actually forward packets using the TIB is very inefficient. Instead a real router implementation will normally build an efficient MFIB from the TIB state to perform forwarding. How this is done is implementation-specific, and is not discussed in this document.

Upstream

Towards the root of the tree. The root of tree may either be the source or the RP depending on the context.

Downstream

Away from the root of the tree.

TIMERS AND DEFAULT VALUES

PIM-SM defines several timers and default values. For the purpose of testing, all configurable timers and values are set to their defaults, unless otherwise noted in the test description. These defaults are given here for reference, taken or calculated from draft-ietf-pim-sm-v2-new-05, section 4.12:

Hello_Period:	30 Seconds
Triggered_Hello_Delay:	5 Seconds
Holdtime:	105 Seconds
Assert_Time:	180 Seconds
Assert_Override_Interval:	3 Seconds
Register_Suppression_Time:	60 Seconds
t_override:	2.5 Seconds
t_periodic:	60 Seconds

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 PIM.1.2 refers to the second test of the first test group in the PIM-SM Conformance 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 section 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:** This section 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 link, or transmitting 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:** This section 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:** This section 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:

- draft-ietf-pim-sm-v2-new-10 – Protocol Independent Multicast – Sparse Mode (PIM-SM): protocol specification.

GROUP 1: Hello Messages and Designated Router Election

Scope:

These tests are designed to verify conformance with Hello Messaging and DR Election for PIM-SM.

Overview:

PIM routers transmit Hello Messages to notify other PIM-SM routers of their presence on a link. Designated Router Election is performed in order to elect a router to forward multicast data on a given subnet. Hello messages are also the way that option negotiation takes place in PIM, so that additional functionality can be enabled, or parameters tuned.

Test Implementation:

In each test in this section, a test tool is used to transmit and receive PIM-SM packets. This simulates all test routers involved in the test procedure.

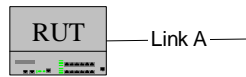
Test PIM_SM.1.1: Sending Hello Messages

Purpose: To verify that a router properly transmits Hello messages.

References: [draft-ietf-pim-sm-v2-new-10] Sections 4.3.1 and 4.12

Discussion: PIM-SM-Hello messages are sent periodically on each PIM-enabled interface. Hello messages **MUST** be sent on all active interfaces, including physical point-to-point links, and are multicast to address ff02::d (the ALL-PIM-ROUTERS group). A per interface hello timer (HT(I)) is used to trigger sending Hello messages on each active interface. Hello messages must be sent every Hello_Period seconds. The hello timer should not be reset except when it expires.

Test Setup: The RUT should not be running PIM-SM on link A.



Procedure:

Part A: Default Hello_Period

1. Reset the RUT to factory defaults.
2. Enable PIM-SM on the RUT.
3. Observe the packets transmitted by the RUT on link A.

Part B: Configured Hello_Period

4. Configure the Hello_Period to a value of 90 seconds.
5. Restart PIM-SM on the RUT.
6. Observe the packets transmitted by the RUT on link A.

Observable Results:

- *In Part A,*
Step 3: The RUT must transmit a Hello Message to the ALL-PIM-ROUTERS multicast address ff02::d on link A every 30 seconds (Hello_Period).
- *In Part B,*
Step 6: The RUT must transmit a Hello Message to the ALL-PIM-ROUTERS multicast address ff02::d on link A every 90 seconds (Hello_Period).

Possible Problems:

- The RUT may not allow the Hello_Period value to be configured.

Test PIM_SM.1.2: Triggered Hello Messages

Purpose: To verify that a router properly transmits a triggered Hello Message.

References: [draft-ietf-pim-sm-v2-new-05] Sections 4.3.1 and 4.12

Discussion: When PIM is enabled on an interface or a router first starts, the hello timer of that interface is set to a random value between 0 and Triggered_Hello_Delay. This prevents synchronization of Hello messages if multiple routers are powered on simultaneously. After the initial randomized interval, Hello messages must be sent every Hello_Period seconds. To allow new or rebooting routers to learn of PIM neighbors quickly, when a Hello message is received from a new neighbor, or a Hello message with a new GenID is received from an existing neighbor, a new Hello message should be sent on this interface after a randomized delay between 0 and Triggered_Hello_Delay. Triggered_Hello_Delay is set to a default of 5 seconds.

Test Setup: Ensure that the RUT is running PIM-SM on Link A. TR1 should not be running PIM-SM on link A.



Procedure:

Part A: Message Reception from New Neighbor

1. TR1 transmits Hello messages from TR1 every 30 seconds.
2. Observe packets transmitted by the RUT on link A.

Part B: New GenID Reception

3. TR1 transmits Hello messages on link A.
4. Observe packets transmitted by the RUT on link A.
5. TR1 transmits Hello message with a new GenID on link A.
6. Observe packets transmitted by the RUT on link A.

Part C: Default Initial Hello Message Transmission

7. Disable PIM-SM and reset the RUT to factory defaults.
8. Enable PIM-SM on the RUT.
9. Observe the packets transmitted by the RUT on link A.

Part D: Configured Initial Hello Message Transmission

10. Disable PIM-SM and configure the Hello_Period to a value of 10 seconds on the RUT.
11. Enable PIM-SM on the RUT.
12. Observe the packets transmitted by the RUT on link A.

Observable Results:

- In Part A,
Step 2: The RUT must transmit a triggered Hello Message in less than Triggered_Hello_Delay (5) seconds.
- In Part B,

*University of New Hampshire
InterOperability Laboratory*

Step 4: The RUT must transmit a triggered Hello Message in less than Triggered_Hello_Delay (5) seconds.

Step 6: The RUT must transmit a triggered Hello Message in less than Triggered_Hello_Delay (5) seconds.

- *In Parts C,*
Step 9: The RUT should transmit the first Hello between 0 and the Trigger_Hello_Delay (5) seconds after PIM is enabled.
- *In Part D,*
Step 12: The RUT should transmit the first Hello between 0 and the Triggered_Hello_Delay seconds after PIM is enabled.

Possible Problems:

- The RUT may not allow the Triggered_Hello_Delay value to be configured.

Test PIM_SM.1.3: DR Election

Purpose: To verify that a router properly performs DR Election.

References: [draft-ietf-pim-sm-v2-new-10] Sections 4.3.1 and 4.3.2

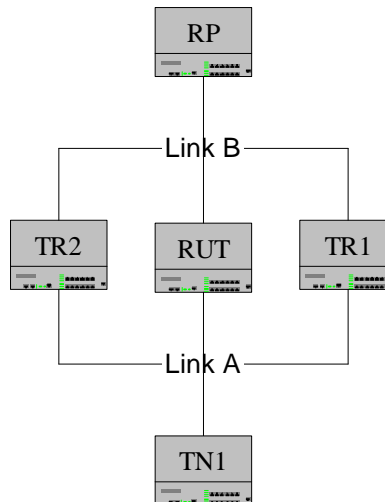
Discussion: The DR_Election_Priority Option allows the link administrator to allow a particular router to win the DR election process by giving it a numerically larger DR Election Priority. The DR_Election_Priority Option SHOULD be included in every Hello message, even if no DR election priority is explicitly configured on that interface. This is necessary because priority-based DR election is only enabled when all neighbors on an interface advertise that they are capable of using the DR Election Priority Option. The default priority is 1.

The router with the highest DR Priority becomes the DR for the subnet. The router with the highest IP address becomes DR if there is a tie in DR Priority, the DR Priority is not configured, or the DR option is not present. Priority based DR election is only enabled when all neighbors on an interface advertise they are capable of using DR Election Priority Option.

The DR election priority is a 32-bit unsigned number and the numerically larger priority is always preferred. A router's idea of the current DR on an interface can change when a PIM-Hello message is received, when a neighbor times out, or when a router's own DR priority changes. If the router becomes the DR or ceases to be the DR, this will normally cause the DR Register state-machine to change state. Subsequent actions are determined by that state-machine.

Test Setup: Unless otherwise noted:

- The RP is statically configured on the RUT for the multicast group ff1e::1:2.
- The RUT is configured to have a DR Priority of 1.
- TR1 is configured to have a DR Priority of 2 and an IP address lower than that of TR2 and the RUT.
- TR2 is configured to have a DR Priority of 1 and an IP address higher than that of TR1 and the RUT.



Procedure:

*University of New Hampshire
InterOperability Laboratory*

Part A: RUT has lower DR Priority

1. On link A, TR1 and TR2 transmit Hello messages.
2. On link B, TR1, TR2 and the RP transmit Hello messages.
3. On link A, the TN1 transmits data packets with a multicast destination of ff1e::1:2.
4. Observe packets transmitted by the RUT on link B.

Part B: RUT has equivalent priority and lower IP Address

5. Configure the RUT to have a DR Priority of 2 and an IPv6 address lower than that of TR1.
6. On link A, TR1 and TR2 transmit Hello messages.
7. On link B, TR1, TR2 and RP transmit Hello messages.
8. On link A, TN1 transmits data packets with a multicast destination of ff1e::1:2.
9. Observe packets transmitted by the RUT on link B.

Part C: RUT has higher DR Priority

10. Configure the RUT to have a DR Priority of 3.
11. On link A, TR1 and TR2 transmit Hello messages.
12. On link B, TR1, TR2 and the RP transmit Hello messages.
13. On link A, TN1 transmits data packets with a multicast destination of ff1e::1:2.
14. Observe packets transmitted by the RUT on link B.

Part D: RUT has equivalent priority and higher IP address

15. Configure RUT to have a DR Priority of 2.
16. TR1 and TR2 have an IP address lower than that of the RUT.
17. On link A, TR1 and TR2 transmit Hello messages.
18. On link B, TR1, TR2, and the RP transmit Hello messages.
19. On link A, TN1 transmits data packets with a multicast destination of ff1e::1:2.
20. Observe the packets transmitted by the RUT on link B.

Part E: No DR Priority, RUT has higher IP address

21. TR1 and TR2 have an IP address lower than that of the RUT.
22. On link A, TR1 transmit Hello messages.
23. On link B, TR1, TR2, and the RP transmit Hello messages.
24. On link A, TR2 transmits Hello Messages without the DR_Election_Priority Option.
25. On link A, TN1 transmits data packets with a multicast destination of ff1e::1:2.
26. Observe the packets transmitted by the RUT on link B.

Part F: No DR Priority, RUT has lower IP address

27. TR1 has an IP address higher than that of the RUT.
28. TR2 has an IP address lower than that of the RUT.
29. On link A, TR1 transmit Hello messages.
30. On link B, the RP, TR1 and TR2 transmit Hello messages.
31. On link A, TR2 transmits Hello Messages without the DR_Election_Priority Option.
32. On link A, TN1 transmits data packets with a multicast destination of ff1e::1:2.
33. Observe the packets transmitted by the RUT on link B.

Observable Results:

- *In Part A,*
Step 4: TR1 must be elected DR. The RUT must not forward the multicast data received on link A.

*University of New Hampshire
InterOperability Laboratory*

- *In Part B,*
Step 9: TR1 must be elected DR. The RUT must not forward the multicast data received on link A.
- *In Part C,*
Step 14: The RUT must be elected DR. The RUT must not forward the multicast data received on link A.
- *In Part D,*
Step 19: The RUT must be elected DR. The RUT must encapsulate the multicast data received on link A and forward them to the RP on link B.
- *In Part E,*
Step 25: The RUT must be elected DR. The RUT must encapsulate the multicast data received on link A and forward them to the RP on link B.
- *In Part F,*
Step 32: TR1 must be elected DR. The RUT must not forward the multicast data received on link A.

Possible Problems:

- The RUT may not implement the DR_Election_Priority Option.

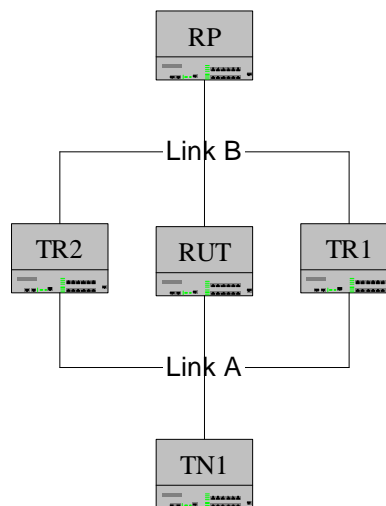
Test PIM_SM.1.4: Change of DR

Purpose: To verify that a router properly changes Designated Routers.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.3.2

Discussion: The information a router contains about the current DR on an interface can change when a PIM-Hello message is received, when a neighbor time out, or when a router's own DR changes. If the router becomes the DR or ceases to be the DR, this will normally cause the DR Register state-machine to change state. Subsequent actions are determined by that state-machine.

Test Setup: Ensure that the RUT is running PIM-SM on link A. TR2 is only needed in Part E.



Procedure:

Part A: DR priority increase transmission

1. Configure the RUT to have a DR priority of 2.
2. On link B, the RP and TR1 transmit Hello messages.
3. On link A, TR1 transmits a Hello message with a DR priority of 3.
4. On link A, TN1 transmits data packets with a multicast destination of ff1e::1:2.
5. Observe the packets transmitted by the RUT on all links.
6. Configure the RUT to have a DR priority of 5.
7. On link A, TN1 transmits data packets with a multicast destination of ff1e::1:2.
8. Observe the packets transmitted by the RUT on all links.

Part B: DR priority decrease transmission

9. Configure the RUT to have a DR priority of 4.
10. On link B, the RP and TR1 transmit Hello messages.
11. On link A, TR1 transmits a Hello message with a DR priority of 2.
12. On link A, TN1 transmits data packets with a multicast destination of ff1e::1:2.
13. Observe the packets transmitted by the RUT on all links.
14. Configure the RUT to have a DR priority of 1.
15. On link A, TN1 transmits data packets with a multicast destination of ff1e::1:2.

*University of New Hampshire
InterOperability Laboratory*

16. Observe the packets transmitted by the RUT on all links.

Part C: DR priority increase reception

17. Configure the RUT to have a DR priority of 4.
18. On link A, TR1 transmits a Hello message with a DR priority of 2.
19. On link B, the RP and TR1 transmit Hello messages.
20. On link A, TN1 transmits data packets with a multicast destination of ff1e::1:2.
21. Observe the packets transmitted by the RUT on all links.
22. On link A, TR1 transmits a Hello message with a DR priority of 5.
23. On link A, TN1 transmits data packets with a multicast destination of ff1e::1:2.
24. Observe the packets transmitted by the RUT on all links.

Part D: DR priority decrease reception

25. Configure the RUT to have a DR priority of 3.
26. On link A, TR1 transmits a Hello message with a DR priority of 5.
27. On link B, the RP and TR1 transmit Hello messages.
28. On link A, TN1 transmits data packets with a multicast destination of ff1e::1:2.
29. Observe the packets transmitted by the RUT on all links.
30. On link A, TR1 transmits a Hello message with a DR priority of 2.
31. On link A, TN1 transmits data packets with a multicast destination of ff1e::1:2.
32. Observe the packets transmitted by the RUT on all links.

Part E: DR Timeout

33. Configure the RUT to have a DR priority of 4.
34. On link B, RP and TR1 transmit Hello messages.
35. On link A, TR1 transmits a Hello message with a DR priority of 3.
36. On link A, TR2 transmits a Hello message with a DR priority of 9.
37. On link A, TN1 transmits data packets with a multicast destination of ff1e::1:2.
38. Observe the packets transmitted by the RUT on all links.
39. On link A, TR2 ceases transmission of Hello messages.
40. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
 - Step 5:** TR1 must be elected DR. The RUT must not forward multicast data received on link A.
 - Step 8:** The RUT must be elected DR. The RUT must encapsulate and transmit the data received on link A onto link B.
- *In Part B,*
 - Step 13:** The RUT must be elected the DR. The RUT must encapsulate and transmit the data received on link A to link B.
 - Step 16:** TR1 must be elected DR. The RUT must not forward multicast data received on link A.
- *In Part C,*
 - Step 21:** The RUT must be elected the DR. The RUT must encapsulate and transmit the data received on link A to link B.
 - Step 24:** TR1 must be elected DR. The RUT must not forward multicast data received on link A.
- *In Part D,*

*University of New Hampshire
InterOperability Laboratory*

Step 29: TR1 must be elected DR. The RUT must not forward multicast data received on link A.

Step 32: The RUT must be elected DR. The RUT must encapsulate and transmit the data received on link A onto link B.

- *In Part E,*

Step 38: TR1 must be elected DR. The RUT must not forward multicast data received on link A.

Step 40: The RUT must be elected DR. The RUT must encapsulate and transmit the data received on link A onto link B.

Possible Problems:

None.

Test PIM_SM.1.5: Generation ID in DR Election

Purpose: To verify that a router properly handles the Generation ID Option when present.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.3.1

Discussion: The Generation_Identifier (GenID) Option SHOULD be included in all Hello messages. The GenID option contains a randomly generated 32-bit value that is regenerated each time PIM forwarding is started or restarted on the interface. When a Hello message with a new GenID is received from a neighbor, any old Hello information about that neighbor SHOULD be discarded and superseded by the information from the new Hello message. This may cause a new DR to be chosen on that interface.

Test Setup: Ensure that the RUT is running PIM-SM on link A.



Procedure:

Part A: New GenID for RUT

1. Observe value of Generation_Identifier transmitted by the RUT on link A.
2. Restart PIM-SM on the RUT.
3. Observe the packets transmitted by the RUT on link A.

Part B: New GenID for RP

4. On link A and B, TR1 and the RP transmit Hello messages.
5. On link A, TR1 transmits a (*,G) Join message for group ff1e::1:2.
6. Observe the packets transmitted by the RUT on link A.
7. On link B, the RP transmits a Hello message with a new GenID.
8. Observe the packets transmitted by the RUT on link A.

Observable Results:

- *In Part A,*
Step 3: The RUT should advertise a new Generation_Identifier each time it is restarted.
- *In Part B,*
Step 6: The RUT must send a join message to the RP for group ff1e::1:2.
Step 8: The RUT should send another join message to the RP.

Possible Problems:

- The RUT may not include the Generation_Identifier Option in its Hello Messages.

Test PIM_SM.1.6: HoldTime in Hello Messages

Purpose: To verify that a router properly handles the Hello HoldTime Option.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.3.1, Sections 4.3.1, 4.3.2, 4.10.2 and 4.12

Discussion: The Neighbor Liveness Timer (NLT(N,I)) is reset to Hello_Holdtime (from the Hello Holdtime option) whenever a Hello message is received containing a Holdtime option, or to Default_Hello_Holdtime if the Hello message does not contain the Holdtime option. Holdtime is the amount of time a receiver must keep the neighbor reachable, in seconds. If the Holdtime is set to '0xffff', the receiver of this message never times out the neighbor. This may be used with dial-on-demand links, to avoid keeping the link up with periodic Hello messages.

Before an interface goes down or changes IP address, a Hello message with a zero HoldTime should be sent immediately (with the old IP address if the IP address changed). This will cause PIM neighbors to remove this neighbor (or its old IP address) immediately. The Holdtime in a Hello Message should be set to (3.5 * Hello_Period), giving a default value of 105 seconds.

Test Setup:



Procedure:

Part A: Default Holdtime transmission

1. Reset the RUT to factory defaults.
2. Enable PIM-SM on the RUT.
3. Observe the packets transmitted by the RUT on link A.

Part B: Default Holdtime reception

4. TR1 transmits 2 Hello Messages with a Holdtime of 0x8C.
5. TR1 stops transmitting Hello messages.
6. Observe the packets transmitted by the RUT on link A.

Part C: Default Holdtime, Holdtime not present in received messages

7. TR1 transmits 2 Hello Messages not containing Hello Holdtime Option.
8. TR1 stops transmitting Hello messages.
9. Observe packets transmitted by the RUT on link A.

Part D: Non-Default Holdtime, Holdtime not present in received messages

10. Configure Hold_period to 56 on the RUT.
11. Enable PIM-SM on the RUT.
12. Observe the packets transmitted by the RUT on link A.

Part E: Reception of zero Holdtime Value

13. TR1 transmits several properly formatted Hello messages. TR1 then transmits a Hello message with a Holdtime containing a zero value.
14. TR1 ceases Hello message transmission.
15. Observe packets transmitted by the RUT on link A.

Part F: Interface on RUT disabled

*University of New Hampshire
InterOperability Laboratory*

16. TR1 transmits several properly formatted Hello messages.
17. Disable the RUT's interface to link A.
18. Observe packets transmitted by the RUT on link A.

Part G: IP Address of Interface Changed

19. TR1 transmits several properly formatted Hello messages.
20. Change the IP address of the RUT's interface to link A.
21. Observe packets transmitted by the RUT on link A.

Observable Results:

- *In Part A,*
Step 3: The RUT should transmit Hello messages with a value of 105 in the Holdtime field.
- *In Part B,*
Step 6: The RUT must wait 140 seconds before removing TR1 from its neighbor list.
- *In Part C,*
Step 9: The RUT must wait 105 seconds before removing TR1 from its neighbor list.
- *In Part D,*
Step 12: The RUT must wait 56 seconds before removing TR1 from its neighbor list.
- *In Part E,*
Step 15: The RUT must immediately remove TR1 from its neighbor list.
- *In Parts F,*
Step 18: The RUT should transmit a Hello message with a zero Holdtime.
- *In Parts G,*
Step 21: The RUT should transmit a Hello message with a zero Holdtime.

Possible Problems:

- The RUT may not support dynamically changing an interface's IP address.

GROUP 2: Multicast Forwarding

Scope:

These tests are designed to verify conformance of multicast forwarding in PIM-SM.

Overview:

When a router is connected to a multicast link, PIM-SM must make certain decisions to ensure forwarding of data is properly accomplished.

Test Implementation:

In each test in this section, a test tool is used to transmit and receive PIM-SM packets. This simulates all test routers involved in the test procedure.

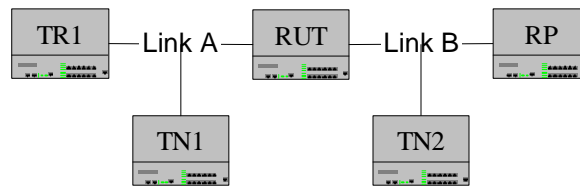
Test PIM_SM.2.1: Forwarding Packets

Purpose: To verify that a router properly forward multicast data packets.

References: [draft-ietf-pim-sm-v2-new-10] Sections 3 and 4.2

Discussion: The RP receives encapsulated data packets, decapsulates them, and forwards them onto the shared tree. The packets follow the (*,G) multicast tree state in the routers on the RP Tree, being replicated whenever the RP tree branches, and eventually reaching all the receivers for the multicast routers.

Test Setup: The RP should be statically configured for group ff1e::1:2. The RUT is the DR for link A and link B.



Procedure:

Part A: Join (,G) Received on downstream link.*

1. On link A and B, the RP and TR1 transmit Hello messages.
2. On link A, TR1 transmits a (*,G) Join message for the group ff1e::1:2.
3. On link B, the RP forwards data packets from the multicast group ff1e::1:2.
4. Observe the packets transmitted by the RUT on all links.

Part B: MLD report received on downstream link.

5. On link B, the RP transmits Hello messages.
6. On link A, transmit MLD Reports for ff1e::1:2.
7. Observe the packets transmitted by the RUT on all links.
8. On link B, the RP forwards data packets from the multicast group ff1e::1:2.
9. Observe the packets transmitted by the RUT on all links.

Part C: MLD reports on upstream and downstream links.

10. On link B, the RP transmits Hello messages.
11. On link A, transmit MLD Reports for ff1e::1:2.
12. On link B, transmit MLD Reports for ff1e::1:2.
13. On link B, the RP forwards data packets from the multicast group ff1e::1:2.
14. Observe the packets transmitted by the RUT on all links.
15. On link A, transmit an MLD Done message.
16. Observe the packets transmitted by the RUT on all links.

Observable Results:

- In Parts A,
Step 4: The RUT must forward the data packets onto link A.
- In Parts B,

*University of New Hampshire
InterOperability Laboratory*

Step 7: The RUT must transmit a Join (*,G) for the multicast group ff1e::1:2 on link A.

Step 9: The RUT must forward the data packets onto link A.

- *In Part C,*

Step 14: The RUT must forward the data onto link A.

Step 16: The RUT must not forward the data onto link A.

Possible Problems:

- None.

Test PIM_SM.2.2: Encapsulate Packets

Purpose: To verify that a router properly encapsulates data packets.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.4.1

Discussion: A multicast data sender just starts sending data destined for a multicast group. The sender's local router (DR) takes those data packets, unicast-encapsulates them, and sends them directly to the RP.

Test Setup: The RUT should be the DR for link A. The RP should be statically configured for multicast group ff1e::1:2.



Procedure:

1. On link B, the RP transmits Hello messages.
2. On link A, TN1 transmits data packets with a multicast destination of ff1e::1:2.
3. Observe the packets transmitted by the RUT on all links.

Observable Results:

- The RUT must encapsulated the data packets and forward the packets upstream to link B for the RP.

Possible Problems:

- None.

Test PIM_SM.2.3: Forwarding Encapsulated Data Packets

Purpose: To verify that a router properly forwards encapsulated data packets.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.2

Discussion: A multicast data sender just starts sending data destined for a multicast group. The sender's local router (DR) takes those data packets, unicast-encapsulates them, and sends them directly to the RP. A router that is upstream from a DR should forward the data packet upstream towards the RP.

Test Setup: The RUT should be the DR for link A and link B. The RP should be statically configured for multicast group ff1e::1:2.



Procedure:

1. On link A and link B, TR1 and the RP transmit Hello messages.
2. On link A, TR1 transmits encapsulated data packets for multicast group ff1e::1:2.
3. Observe the packets transmitted by the RUT on all links.

Observable Results:

Step 3: The RUT must forward the encapsulated data packets from link A onto link B for the RP.

Possible Problems:

- None.

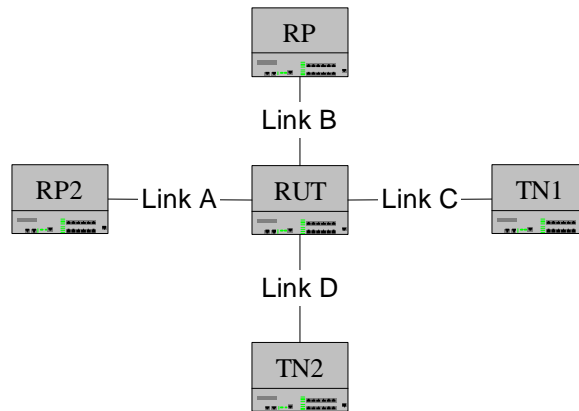
Test PIM_SM.2.4: Encapsulation for Multiple RP's

Purpose: To verify that a router properly encapsulates and transmits data packets to the proper RP.

References: [draft-ietf-pim-sm-v2-new-10] Section 3

Discussion: A multicast data sender just starts sending data destined for a multicast group. The sender's local router (DR) takes those packets, unicast-encapsulate them, and sends them directly to the RP.

Test Setup: RP is statically configured for the multicast group ff1e::1:2 and RP2 is statically configured for the multicast group ff1e::1:3. The RUT is the DR for all links.



Procedure:

1. On link B and A, RP and RP2 transmit Hello messages.
2. On link C, TN1 transmits data with a multicast destination address of ff1e::1:2.
3. On link D, TN2 transmits data with a multicast destination address of ff1e::1:3.
4. Observe the packets transmitted by the RUT on all links.

Observable Results:

Step 4: The RUT must encapsulate the data packets from link C and transmit them onto link B. The RUT must encapsulate the data packets from link D and transmit them onto link A.

Possible Problems:

- None.

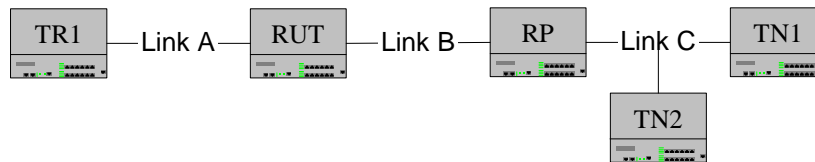
Test PIM_SM.2.5: Source Packets

Purpose: To verify that a router properly forwards source packets.

References: [draft-ietf-pim-sm-v2-new-10] Section 3

Discussion: The RP receives encapsulated data packets, decapsulates them, and forwards them onto the shared tree. The packets follow the (*,G) multicast tree state in the routers on the RP Tree, being replicated whenever the RP tree branches, and eventually reaching all the receivers for that multicast routers.

Test Setup: The RP should be statically configured for group ff1e::1:2. RUT is the DR for link A and B.



Procedure:

1. On link A and B, TR1 and RP transmit Hello messages.
2. On link A, TR1 transmits a (S,G) Join message with a group address ff1e::1:2 and a source address of TN1.
3. On link B, the RP transmits data packets from the multicast group ff1e::1:2 with a source address of TN1.
4. On link B, the RP transmits data packets from the multicast group ff1e::1:2 with a source address of TN2.
5. Observe the packets transmitted by the RUT on all links.

Observable Results:

Step 5: The RUT must forward the data with a source address of TN1 onto link A. The RUT must not forward the data with a source address of TN2 onto link A.

Possible Problems:

- None.

Test PIM_SM.2.6: Forwarding Encapsulated and Decapsulated Data Packets

Purpose: To verify that a router properly forwards both encapsulated and decapsulated data packets.

References: [draft-ietf-pim-sm-v2-new-10] Section 3

Discussion: When the RP receives a register-encapsulated data packet from source S on group G, it will normally initiate an (S,G) source-specific Join towards S. This Join message will travel hop-by-hop towards S, instantiating (S,G) multicast tree state in the routers along the path. (S,G) multicast tree state is used only to forward packets for group G if those packets come from source S. While the RP is in the process of joining the source-specific tree for S, the data packets will continue being encapsulated to the RP. When packets from S also start to arrive natively at the RP, the RP will be receiving two copies of each of these packets.

Test Setup: The RP should be statically configured for group ff1e::1:2. The RUT is the DR for link A.



Procedure:

1. On link B, the RP transmits Hello messages.
2. On link A, TN1 transmits data packets with a group address of ff1e::1:2.
3. Observe the packets transmitted by the RUT on all links.
4. The RP transmits a Join (S,G) with the source address of TN1 and the group address of ff1e::1:2.
5. Observe the packets transmitted by the RUT on all links.

Observable Results:

Step 3: The RUT must forward encapsulated data packets onto link B.

Step 5: The RUT must forward encapsulated and native data packets onto link B.

Possible Problems:

- None.

Test PIM_SM.2.7: RegisterStop (S,G)

Purpose: To verify that a router properly accepts a RegisterStop message

References: [draft-ietf-pim-sm-v2-new-10] Section 3

Discussion: When the RP receives a register-encapsulated data packet from source S on group G, it will normally initiate an (S,G) source-specific Join towards S. This Join message will travel hop-by-hop towards S, instantiating (S,G) multicast tree state in the routers along the path. (S,G) multicast tree state is used only to forward packets for group G to those packets that come from source S. While the RP is in the process of joining the source-specific tree for S, the data packets will continue being encapsulated to the RP. When packets from S also start to arrive natively at the RP, the RP will be receiving two copies of each of these packets. At this point, the RP starts to discard the encapsulated copy of these packets, and it sends a RegisterStop message back to S's DR to prevent the DR unnecessarily encapsulating the packets.

Test Setup: The RP should be statically configured for group ff1e::1:2. The RUT is the DR for the source. The RUT is the DR for link A.



Procedure:

1. On link B, the RP transmits Hello messages.
2. On link A, TN1 transmits data packets with a group address of ff1e::1:2.
3. Observe the packets transmitted by the RUT on all links.
4. The RP transmits a Join (S,G) with the source of TN1 and the group address of ff1e::1:2.
5. Observe the packets transmitted by the RUT on all links.
6. The RP transmits a RegisterStop to the RUT on link B.
7. Observe the packets transmitted by the RUT on all links.

Observable Results:

Step 3: The RUT must forward encapsulated data packets onto link B.

Step 5: The RUT must forward encapsulated and native data packets onto link B.

Step 7: The RUT must stop forwarding the encapsulated data packets. The native data packets should continue to be forwarded onto link B.

Possible Problems:

- None.

Test PIM_SM.2.8: RegisterStop (*,G)

Purpose: To verify that a router properly accepts RegisterStop (*,G) from the DR.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.4.1

Discussion: An RP compliant to RFC 2326 may send a RegisterStop message with the source address set to all-zeros. This was the normal course of action in RFC 2326 when the Register message matched against (*,G) state at the RP, and was defined as meaning “Stop encapsulating all sources for this group”. However the behavior of such a RegisterStop (*,G) is ambiguous or incorrect in some circumstances. In the newly revised PIM-SM specification, an RP should not send RegisterStop (*,G) message, but for compatibility, a DR should be able to accept one if it is received.

Test Setup: The RP should be statically configured for the multicast group ff1e::1:2. The RUT should be the DR for link A.



Procedure:

1. On link B, the RP transmits Hello messages.
2. On link A, TN1 transmit data packets with a destination of ff1e::1:2.
3. Observe the packets transmitted by the RUT on all links.
4. On link B, the RP transmits a Join (S,G) for group ff1e::1:2 and a source of TN1.
5. Observe the packets transmitted by the RUT on all links.
6. The RP transmits a RegisterStop (*,G) for the multicast group ff1e::1:2 containing a source address set to a value of all zeros.
7. Observe the packets transmitted by the RUT on all links.

Observable Results:

Step 3: The RUT must forward encapsulated data packets onto link B.

Step 5: The RUT must forward encapsulated and native data packets onto link B.

Step 7: The RUT must not forward encapsulated data and must forward native data packets onto link B.

Possible Problems:

- None.

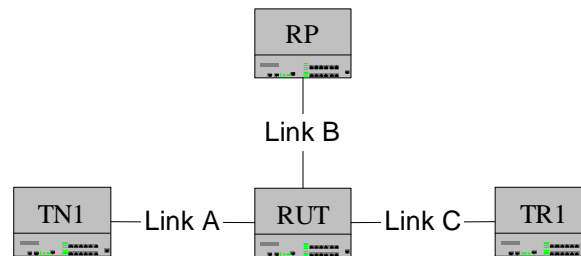
Test PIM_SM.2.9: Data Forwarding to Several Links

Purpose: To verify that a router properly forwards data packets onto the correct link.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.3

Discussion: The RP receives encapsulated data packets, decapsulates them, and forwards them onto the shared tree. The packets follow the (*,G) multicast tree state in the routers on the RP Tree, being replicated whenever the RP tree branches, and eventually reaching all the receivers for that multicast routers.

Test Setup: The RP should be statically configured for group ff1e::1:2. The RUT is the DR for link A, link B and link C.



Procedure:

Part A: Received (,G) Join*

1. On link B and C, The RP and TR1 transmit Hello messages.
2. On link C, TR1 transmits a (*,G) Join message for the group ff1e::1:2.
3. On link A, TN1 transmits MLD reports for ff1e::1:3.
4. On link B, the RP forwards data packets from the multicast group ff1e::1:2.
5. Observe the packets transmitted by the RUT on all links.

Part B: Received MLD report

6. On link B and C, The RP and TR1 transmit Hello messages.
7. On link C, TR1 transmits a (*,G) Join message for the group ff1e::1:2.
8. On link A, transmit MLD Report for ff1e::1:2.
9. On link B, the RP forwards data packets from the multicast group ff1e::1:2.
10. Observe the packets transmitted by the RUT on all links.

Part C: MLD Done Message

11. On link B and C, The RP and TR1 transmit Hello messages.
12. On link C, TR1 transmits a (*,G) Join message for the group ff1e::1:2.
13. On link A, transmit MLD reports for ff1e::1:2.
14. On link B, the RP forwards data packets from the multicast group ff1e::1:2.
15. Observe the packets transmitted by the RUT on all links.
16. On link A, transmit MLD Done message for ff1e::1:2.
17. Observe the packets transmitted by the RUT on all links.

Observable Results:

*University of New Hampshire
InterOperability Laboratory*

- *In Part A,*
Step 5: The RUT must forward the data packets from link B to link C.
- *In Part B,*
Step 10: The RUT must forward the data packets from link B to links A and C.
- *In Part C,*
Step 15: The RUT must forward the data packets from link B to links A and C.
Step 17: The RUT must not forward the data packets from link B to link A. The RUT must forward the data packets from link B to link C.

Possible Problems:

- None.

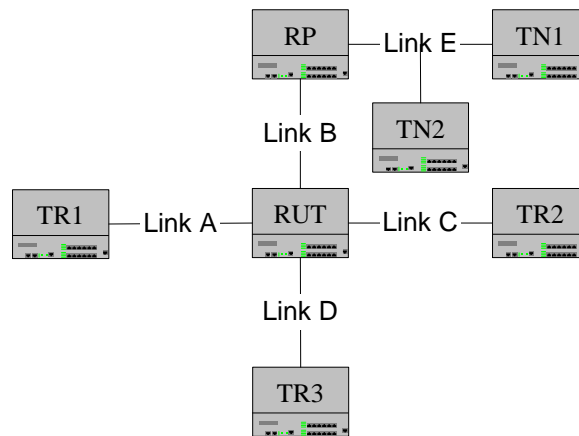
Test PIM_SM.2.10: Multiple Sources

Purpose: To verify that a router properly transmits data packets from several sources.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.3

Discussion: When the RP receives a register-encapsulated data packets from source S on group G, it will normally initiate an (S,G) source-specific Join towards S. This Join message travels hop-by-hop towards S, instantiating (S,G) multicast tree state in the routers along the path.

Test Setup: The RP should be statically configured for group ff1e::1:2. The RUT has a static route to Link E through the RP.



Procedure:

1. On link A, B, C, and D, TR1, RP, TR2, and TR3 transmit Hello messages.
2. On link C, TR1 transmits a (S,G) Join for the multicast group ff1e::1:2 containing a source of TN1.
3. On links A, TR2 transmits a (S,G) Join for the multicast group ff1e::1:2 containing a source of TN2.
4. On link D, TR3 transmits a (*,G) Join for the multicast group ff1e::1:2.
5. On link B, the RP transmits data packets from the multicast group ff1e::1:2 from the source TN1.
6. On link B, the RP transmits data packets from the multicast group ff1e::1:2 from the source TN2.
7. Observe the packets transmitted by the RUT on all links.

Observable Results:

Step 6: The RUT must forward the multicast data with a source address of 3005::1 from link B to link C and link D. The RUT must forward the multicast data with a source address of 3005::4 from link B to link A and link D.

Possible Problems:

- None.

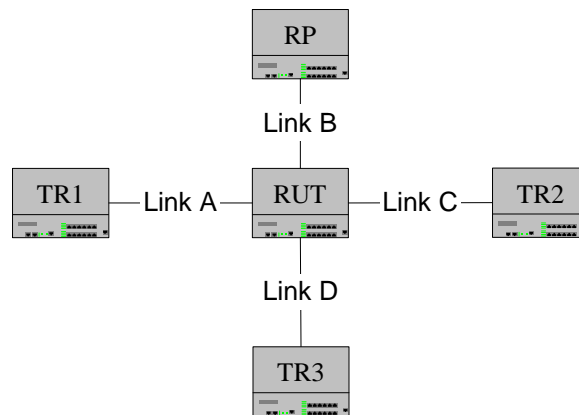
Test PIM_SM.2.11: Forwarding From Multiple RPs

Purpose: To verify that a router properly forwards encapsulated data packets to the correct RP.

References: [draft-ietf-pim-sm-v2-new-10] Section 2.1

Discussion: An RP is a router that is configured as the root of the non-source-specific distribution tree for a multicast group. Join messages from receivers for a group are sent towards the RP, and data from senders is sent to the RP so that receivers can discover who the senders are, and start to receive traffic destined for the group.

Test Setup: RP is statically configured for the multicast group ff1e::1:2 and RP2 is statically configured for the multicast group ff1e::1:3.



Procedure:

1. On link A, B, C, and D, RP2, RP, TR1, and TR2 transmit Hello messages.
2. On link C, TR2 transmits a (*,G) Join for the multicast group ff1e::1:2.
3. On link D, TR3 transmits a (*,G) Join for the multicast group ff1e::1:3.
4. On link B, RP transmits data packets from the multicast group ff1e::1:2.
5. On link A, TR1 transmits data packets from the multicast group ff1e::1:2.
6. Observe the packets transmitted by the RUT on all links.

Observable Results:

Step 5: The RUT must forward the data packets with a multicast destination of ff1e::1:2 from link B onto link C. The RUT must forward the data packets with a multicast destination of ff1e::1:3 from link A onto link D.

Possible Problems:

- The RUT may only support one RP.

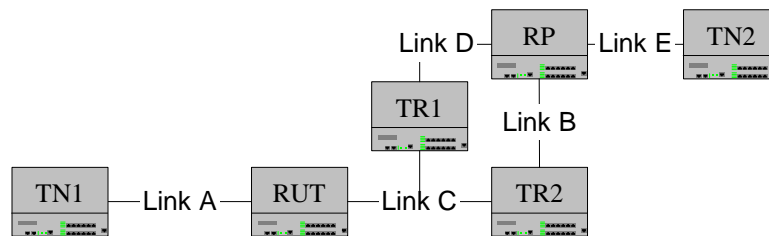
Test PIM_SM.2.12: PIM Tree Receiver

Purpose: To verify that a router properly creates a PIM tree.

References: [draft-ietf-pim-sm-v2-new-10] Section 3

Discussion: A router should be able to initiate a PIM tree when multicast members downstream need information. When a router detects that there is a more optimal path to the source, it should properly send a (S,G) Join upstream and form the shortest-path tree.

Test Setup: RP should be statically configured to be ff1e::1:2. The RUT is the DR for link A. RUT has a route to the RP through TR2. The RUT has a route to the link D through TR1.



Procedure:

Part A: RP Tree Initialization

1. On link C, TR1 and TR2 transmit Hello messages.
2. On link A, transmit MLD Reports for ff1e::1:2.
3. Observe the packets transmitted by the RUT on all links.
4. On link B, the RP will transmit the data packets with a destination address of ff1e::1:2 and a source address of TN2. TR2 will forward the data packets on to link B.
5. Observe the packets transmitted by the RUT on all links.

Part B: Register Stop and SPT

6. On link C, the RUT transmits a Join (S,G) with the source address of TN1 and a group address of ff1e::1:2.
7. On link C, TR1 transmits multicast data packets to TR1.
8. Both TR1 and TR2 are transmitting multicast data packets with a source address of 3005::1 with a group address of ff1e::1:2.
9. Observe the packets transmitted by the RUT on all links.

Observable Results:

- In Part A,
Step 5: The RUT must forward multicast data packets from link C to link A.
- In Part B,
Step 9: On link A the RUT should continue to forward the data packets from link C.

Possible Problems:

*University of New Hampshire
InterOperability Laboratory*

- The RUT may not implement the shortest-path tree and may never send the (S,G) Join towards the source.

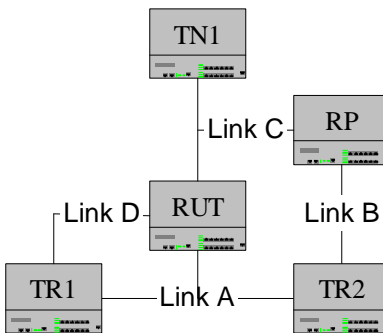
Test PIM_SM.2.13: PIM Tree - Source

Purpose: To verify that a router properly creates a PIM tree when connected to the source link.

References: [draft-ietf-pim-sm-v2-new-10] Section 3

Discussion: When connected to the source link in a PIM topology, a router should be able to initialize the RPT and SPT. The router should also be able to transmit data packets properly to the RP-tree and the shortest-path tree.

Test Setup: RP is statically configured for the multicast group ff1e::1:2, the RP address is on link B. The RUT is the DR for link C. TR1's route to the RP is through TR2. TR1's route to link C is through the RUT. RUT's route to the RP is through link C.



Procedure:

Part A: RP Tree

1. On link B, the RP transmits Hello messages.
2. On link A, TR1 and TR2 transmit Hello messages.
3. On link C, TN1 transmits multicast data packets for the multicast group ff1e::1:2.
4. On link A, TR1 transmits a (*,G) Join with a group address of ff1e::1:2.
5. Observe the packets transmitted by the RUT on all links.

Part B: Register Stop

6. On link C, RP transmits a Join (S,G) with the source address of TN1 and a group address of ff1e::1:2.
7. The RP transmits a Register-Stop message on link C to the RUT.
8. Observe the packets transmitted by the RUT on all links.

Part C: shortest-path tree

9. On link D, TR1 transmits a (S,G) Join with the source address of TN1 and a group address of ff1e::1:2.
10. Observe the packets transmitted by the RUT on all links.

Observable Results:

- In Part A,

*University of New Hampshire
InterOperability Laboratory*

Step 4: The RUT must encapsulate the data packets from TN1 and forward them to the RP on link C.

- *In Part B,*

Step 8: The RUT must stop encapsulating the data. No data should be forwarded by the RUT.

- *In Part C,*

Step 10: The RUT must forward data packets from link C to link A.

Possible Problems:

- None.

GROUP 3: Reception of Join and Prune Messages

Scope:

These tests are designed to verify conformance with the receiving of Join and Prune messages in PIM-SM.

Overview:

Receiving of Join and Prune messages is dependent upon a per-interface state machine kept by a router. A state machine is kept for (*,*,RP), (*,G), (S,G) and (S,G,rpt) states on each interface.

Test Implementation:

In each test in this section, a test tool is used to transmit and receive PIM-SM packets. This simulates all test routers involved in the test procedure.

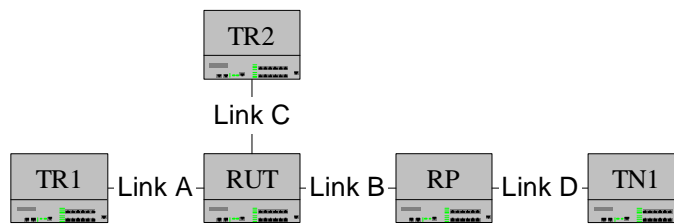
Test PIM_SM.3.1: Unknown Join Messages

Purpose: To verify that a router properly ignores PIM Join messages from unknown neighbors.

References: [draft-ietf-pim-sm-v2-new-10] Sections 4.5, Section 4.3.1

Discussion: If a router receives a Join message from a particular IP source address and it has not seen a PIM Hello message from that source address, then the Join message should be discarded without further processing.

Test Setup: The RP should be statically configured for group ff1e::1:2.



Procedure:

Part A: Join (,*,RP) from Unknown Neighbor*

1. On link A and B, TR1 and the RP transmit Hello messages.
2. On link A, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
3. On link C, TR2 transmits a Join (*,*,RP) message with a source address of the RP.
4. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
5. Observe the packets transmitted by the RUT on all links.

Part B: Join (,G) from Unknown Neighbor*

6. On links A and B, TR1 and the RP transmit Hello messages.
7. On link A, TR1 transmits a Join (*,G) message for the multicast group ff1e::1:2.
8. On link C, TR2 transmits a Join (*,G) message for the multicast group ff1e::1:2.
9. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
10. Observe the packets transmitted by the RUT on all links.

Part C: Join (S,G) from Unknown Neighbor

11. On link A and B, TR1 and the RP transmit Hello messages.
12. On link A, TR1 transmits a Join (S,G) message with a source address of TN1 for the multicast group ff1e::1:2.
13. On link C, TR2 transmits a Join (S,G) message with a source address of TN1 for the multicast group ff1e::1:2.
14. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
15. Observe the packets transmitted by the RUT on all links.

Part D: Join Message from Neighbor

16. On link A, B and C, the TR1, RP and TR2 transmit Hello messages.
17. On link A, TR1 transmits a Join (*,G) message for the multicast group ff1e::1:2.
18. On link C, TR2 transmits a Join (*,G) message for the multicast group ff1e::1:2.
19. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
20. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Parts A,*
Step 5: The RUT must not forward the multicast data onto link C.
- *In Part B,*
Step 10: The RUT must not forward the multicast data onto link C.
- *In Part C,*
Step 15: The RUT must not forward the multicast data onto link C.
- *In Part D,*
Step 20: The RUT must forward the multicast data onto link A and C.

Possible Problems:

- None.

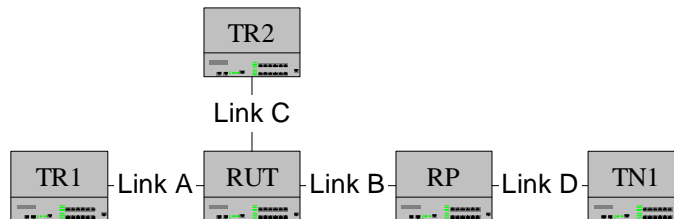
Test PIM_SM.3.2: Join Messages Destination Address

Purpose: To verify that a router properly processes destination addresses.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.1

Discussion: The transition events imply receiving a Join or Prune targeted to this router's address on the received interface. If the destination address is not correct, these state transitions in this state machine must not occur, although seeing such a packet may cause state transitions in other machines.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. 3005:: prefix must not be used on any link.



Procedure:

Part A: Unknown Destination in Join (,*,RP)*

1. On links A, B, and C, TR1, RP and TR2 transmit Hello messages.
2. On link A, TR1 transmits a Join (*,*,RP) message with a source address of the RP. The upstream neighbor address field should contain the address of RUT.
3. On link C, TR2 transmits a (*,G) Join message with a source address of the RP. The upstream neighbor address field should contain the address of the TR2.
4. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
5. Observe the packets transmitted by the RUT on all links.

Part B: Unknown Destination in Join (,G)*

6. On link A, B, and C, TR1, RP and TR2 transmit Hello messages.
7. On link A, TR1 transmit a Join (*,G) message with a group address of ff1e::1:2. The upstream neighbor address field should contain the address of RUT.
8. On link C, TR2 transmit a Join (*,G) message with a source address of the RP. The upstream neighbor address field should contain the address of the TR1.
9. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
10. Observe the packets transmitted by the RUT on all links.

Part C: Unknown Destination in Join (S,G)

11. On links A, B and C, RP, the TR1 and TR2 transmit Hello messages.
12. On link A, TR1 transmits a Join (S,G) message with a source address of TN1 and a group address of ff1e::1:2. The upstream neighbor address field should contain the address of RUT.
13. On link C, TR2 transmits a Join (S,G) message with a source address of TN1 and a group address of ff1e::1:2. The upstream neighbor address field should contain the address of TR1.

*University of New Hampshire
InterOperability Laboratory*

14. On link B, data with a source address of 3005::1 for multicast group ff1e::1:2 is forwarded by the RP.
15. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 5: The RUT must forward all the multicast data packets from link B to link A.
- *In Part B,*
Step 10: The RUT must forward all the multicast data packets from link B to link A.
- *In Part C,*
Step 15: The RUT must forward all the multicast data packets from link B to link A.

Possible Problems:

- None.

Test PIM_SM.3.3: Transitions from (*,*,RP) NoInfo State

Purpose: To verify that a router properly transitions from the NoInfo State when receiving a (*,*,RP) message.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.1

Discussion: When in NoInfo state a Join (*,*,RP) will cause a transition in state. The downstream state machine should transition to the Join state. The Expiry Timer (ET) is set to the Hold Timer and started.

Test Setup: RP is statically configured for multicast group ff1e::1:2. The RUT should be in NoInfo State at the beginning of each part.



Procedure:

Part A: Receiving a Join (,*,RP)*

1. On link A and B, TR1 and the RP transmit Hello messages.
2. On link A, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
3. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
4. Observe the packets transmitted by the RUT on all links.

Part B: Receiving a Prune (,*,RP)*

5. TR1 and RP transmit Hello messages on link A and link B respectively.
6. On link A, TR1 transmits a Prune (*,*,RP) message with a source address of the RP.
7. Multicast data for multicast group ff1e::1:2 is forwarded by the RP on link B.
8. On link A, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
9. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 4: The RUT must forward the multicast data packets onto link A.
- *In Part B,*
Step 9: The RUT must not forward the multicast data packets onto link A until after having received a Join (*,*,RP).

Possible Problems:

- None.

Test PIM_SM.3.4: Transitions from Join (*,*,RP) State

Purpose: To verify that a router properly transitions from the Join State when receiving a (*,*,RP) message.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.1

Discussion: When in Join State, the following many events will trigger a transition:

- Receiving a Join (*,*,RP) will cause the Expiry Timer (ET) is reset. The ET timer's value should be set to the Hold Time included within the Join message. When the ET expires the downstream state machine should transition to the NoInfo State.
- Expiry Timer for the (*,*,RP) downstream state machine expires. The downstream interface should transition to the NoInfo State.
- Receiving a Prune (*,*,RP) should cause the downstream state machine to transition to the Prune-Pending state from the Join State. If there are more than one neighbors the Prune-Pending Timer should be set, when it expires a Prune Echo should be transmitted. If there is only one PIM neighbor a Prune Echo need not be sent on an interface containing only one PIM neighbor.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. The RUT should be in NoInfo State at the beginning of each test.



Procedure:

Part A: Join(,*,RP) Message*

1. On link A and B, TR1 and the RP transmit Hello messages.
2. On link A, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
3. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
4. After 30 seconds, a second Join (*,*,RP) message is transmitted on link A with a source address of the RP.
5. Observe the packets transmitted by the RUT on all links.

Part B: Prune(,*,RP) Message*

6. On link A and B, TR1 and the RP transmit Hello messages.
7. On link A, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
8. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
9. On link A, TR1 transmits a Prune (*,*,RP) message with a source address of ff1e::1:2.
10. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 5: The RUT must continue to forward the data 105 seconds after the second Join message was sent. After 105 seconds the RUT must stop sending data onto link A.

*University of New Hampshire
InterOperability Laboratory*

- *In Part B,*
Step 10: The RUT must stop forwarding data onto link A after the Prune is received.

Possible Problems:

- None.

Test PIM_SM.3.5: Transitions from (*,*,RP) Prune Pending State

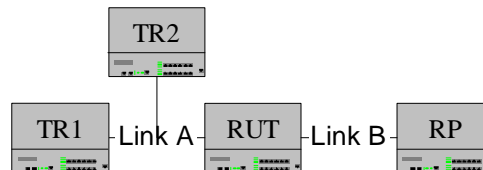
Purpose: To verify that a router properly transitions from the Prune Pending State when receiving a (*,*,RP) message.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.1

Discussion: When in Prune Pending State the following events will trigger a transition:

- Receiving a Join (*,*,RP) will cause the downstream state machine to transition to the Join State. The Expiry Timer (ET) should be reset to the Hold Time included in the Join message.
- Expiry Timer for the (*,*,RP) downstream state machine expires. The downstream interface should transition to the NoInfo State.
- Receiving a Prune (*,*,RP) will cause the downstream state machine to stay in Prune-Pending State. The Prune-Pending Timer is not reset.
- The Prune-Pending Timer (PPT) for the (*,*,RP) downstream state machine expires. The downstream interface should transition to the NoInfo State. When the PPT has expired a Prune Echo should be transmitted unless that interface only contains one PIM neighbor.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. The RUT should be in NoInfo State at the beginning of each part.



Procedure:

Part A: Join (,*,RP)*

1. On link A, TR1 and TR2 transmit Hello messages.
2. On link B, RP transmit Hello messages.
3. On link A, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
4. On link A, TR2 transmits a Join (*,*,RP) message with a source address of the RP.
5. On link B, multicast data for multicast group ff1e::1:2 is forwarded by the RP.
6. On link A, TR1 transmits a Prune (*,*,RP) message with a source address of the RP.
7. On link A, wait 2.5 seconds, then TR2 transmits a Join (*,*,RP) message with a source address of the RP.
8. Observe the packets transmitted by the RUT on all links.

Part B: Single Prune (,*,RP)*

9. On link A, TR1 and TR2 transmit Hello messages.
10. On link B, the RP transmit Hello messages.
11. On link A, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
12. On link A, TR2 transmits a Join (*,*,RP) message with a source address of the RP.
13. On link B, multicast data for multicast group ff1e::1:2 is forwarded by the RP.

*University of New Hampshire
InterOperability Laboratory*

14. Observe the packets transmitted by the RUT on all links.
15. On link A, TR1 transmits a Prune (*,*,RP) message with a source address of the RP.
16. Observe the packets transmitted by the RUT on all links.

Part C: Multiple Prunes (,*,RP)*

17. On link A, TR1 and TR2 transmit Hello messages.
18. On link B, the RP transmit Hello messages.
19. On link A, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
20. On link A, TR2 transmits a Join (*,*,RP) message with a source address of the RP.
21. On link B, multicast data for multicast group ff1e::1:2 is forwarded by the RP.
22. Observe the packets transmitted by the RUT on all links.
23. On link A, TR1 transmits a Prune (*,*,RP) message with a source address of the RP.
24. On link B, TR2 transmits a Prune (*,*,RP) message with a source address of the RP.
25. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 8: The RUT must forward the multicast data packets onto link A during the entire test.
- *In Part B,*
Step 14: The RUT must forward the multicast data packets onto link A.
Step 16: The RUT should transmit a Prune Echo onto link A and multicast data packets must not be forwarded.
- *In Part C,*
Step 23: The RUT should forward the multicast data packets onto link A.
Step 25: The RUT should transmit a Prune Echo onto link A and multicast data packets must not be forwarded.

Possible Problems:

- None.

Test PIM_SM.3.6: Transitions from (*,G) NoInfo State

Purpose: To verify that a router properly transitions from the NoInfo State when receiving (*,G) message.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.2

Discussion: When in NoInfo State a Join (*,G) will cause a transition in the downstream state machine to the Join State. The Expiry Timers (ET) should be set to the Hold Timer, included in the Join message, and started.

Test Setup: RP should be statically configured for multicast group ff1e::1:2. The RUT should be in NoInfo State at the beginning of each test.



Procedure:

Part A: Join (,G)*

1. On link A and B, TR1 and RP transmit Hello messages.
2. On link A, TR1 transmits a Join (*,G) message with a group address of ff1e::1:2.
3. Multicast data for multicast group ff1e::1:2 is forwarded by the RP on link B.
4. Observe the packets transmitted by the RUT on all links.

Part B: Prune (,G)*

5. On link A and B, TR1 and RP transmit Hello messages.
6. On link A, TR1 transmits a Prune (*,G) message with a group address of ff1e::1:2.
7. Multicast data for multicast group ff1e::1:2 is forwarded by the RP on link B.
8. Observe the packets transmitted by the RUT on all links.
9. On link A, TR1 transmits a Join (*,G) message with a group address of ff1e::1:2.
10. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 4: The RUT must forward the multicast data packets onto link A.
- *In Part B,*
Step 9: The RUT must not forward the multicast data packets onto link A.
Step 10: The RUT must forward the multicast data packets onto link A.

Possible Problems:

- None.

Test PIM_SM.3.7: Transitions from (*,G) Join State

Purpose: To verify that a router properly transitions from the Join State when receiving a (*,G) message.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.2

Discussion: When in Join State (*,G), the following events may trigger a transition:

- Receiving a Join (*,G) will cause the Expiry Timer (ET) is reset. The ET timer's value should be set to the Hold Time included within the Join message. When the ET expires the downstream state machine should transition to the NoInfo State.
- Expiry Timer for the (*,G) downstream state machine expires. The downstream interface should transition to the NoInfo State.
- Receiving a Prune (*,G) should cause the downstream state machine to transition to the Prune Pending state from the Join State. If there are more than one neighbors the Prune Pending Timer should be set, when it expires a Prune Echo should be transmitted. If there is only one PIM neighbor a Prune Echo need not be sent on an interface containing only one PIM neighbor.

Test Setup: RP should be statically configured for multicast group ff1e::1:2. The RUT should be in NoInfo State at the beginning of each test.



Procedure:

Part A: Join (,G)*

1. On link A and B, TR1 and RP transmit Hello messages.
2. On link A, TR1 transmits a Join (*,G) message with a group address of ff1e::1:2.
3. Multicast data for multicast group ff1e::1:2 is forwarded by the RP on link B.
4. After 30 seconds, a second Join (*,G) message is transmitted on link A with a source address of the RP.
5. Observe the packets transmitted by the RUT on all links.

Part B: Prune (,G)*

6. On link A and B, TR1 and RP transmit Hello messages.
7. On link A, TR1 transmits a Join (*,G) message with a group address of ff1e::1:2.
8. Multicast data for multicast group ff1e::1:2 is forwarded by the RP on link B.
9. On link A, TR1 transmits a Prune (*,G) message with a group address of ff1e::1:2.
10. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 5: The RUT must continue to forward the data 105 seconds after the second Join message was sent. After 105 seconds the RUT should stop sending data onto link A.

*University of New Hampshire
InterOperability Laboratory*

- *In Part B,*
Step 10: The RUT must stop forwarding data onto link A after the Prune is received.

Possible Problems:

- None.

Test PIM_SM.3.8: Transitions from (*,G) Prune-Pending State

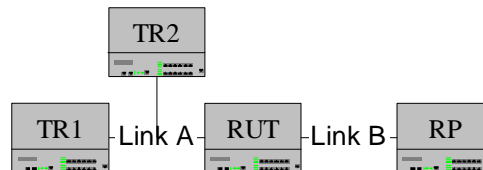
Purpose: To verify that a router properly transitions for the Prune Pending State when receiving a (*,G) message.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.2

Discussion: When in Prune Pending State the following events may trigger a transition:

- Receiving a Join (*,G) will cause the downstream state machine to transition to the Join State. The Expiry Timer (ET) should be reset to the Hold Time included in the Join message.
- Expiry Timer for the (*,G) downstream state machine expires. The downstream interface should transition to the NoInfo State.
- Receiving a Prune (*,G) will cause the downstream state machine to stay in Prune Pending State. The Prune Pending Timer is not reset.
- The Prune Pending Timer (PPT) for the (*,G) downstream state machine expires. The downstream interface should transition to the NoInfo State. When the PPT has expired a Prune Echo should be transmitted unless that interface only contains one PIM neighbor.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. The RUT should be in NoInfo State at the beginning of each part.



Procedure:

Part A: Join (,G)*

1. On link A, TR1 and TR2 transmit Hello messages.
2. On link B, the RP transmit Hello messages.
3. On link A, TR1 transmits a Join (*,G) message with a group address of ff1e::1:2.
4. On link A, TR2 transmits a Join (*,G) message with a group address of ff1e::1:2.
5. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
6. Observe the packets transmitted by the RUT on all links.
7. On link A, TR1 transmits a Prune (*,G) message with a group address of ff1e::1:2.
8. After 2.5 seconds on link A, TR2 transmits a Join message with a group address of ff1e::1:2.
9. Observe the packets transmitted by the RUT on all links.

Part B: Single Prune (,G)*

10. On link A, TR1 and TR2 transmit Hello messages.
11. On link B, the RP transmit Hello messages.
12. On link A, TR1 transmits a Join (*,G) message with a group address of ff1e::1:2.
13. On link A, TR2 transmits a Join (*,G) message with a group address of ff1e::1:2.

*University of New Hampshire
InterOperability Laboratory*

14. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
15. Observe the packets transmitted by the RUT on all links.
16. On link A, TR1 transmits a Prune (*,G) message with a group address of ff1e::1:2.
17. Observe the packets transmitted by the RUT on all links.

Part C: Multiple Prune (,G)*

18. On link A, TR1 and TR2 transmit Hello messages.
19. On link B, RP transmit Hello messages.
20. On link A, TR1 transmits a Join (*,G) message with a group address of ff1e::1:2.
21. On link A, TR2 transmits a Join (*,G) message with a group address of ff1e::1:2.
22. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
23. Observe the packets transmitted by the RUT on all links.
24. On link A, TR1 transmits a Prune (*,G) message with a group address of ff1e::1:2.
25. On link A, TR2 transmits a Prune (*,G) message with a group address of ff1e::1:2.
26. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
 - Step 6:** The RUT must forward the data onto link A.
 - Step 9:** The RUT must forward the data onto link A.
- *In Part B,*
 - Step 15:** The RUT must forward the data onto link A.
 - Step 17:** The RUT should transmit a Prune Echo onto link A and data must not be forwarded.
- *In Part C,*
 - Step 23:** The RUT must forward the data onto link A.
 - Step 26:** The RUT should transmit a Prune Echo onto link A and data must not be forwarded.

Possible Problems:

- None.

Test PIM_SM.3.9: Transitions from (S,G) NoInfo State

Purpose: To verify that a router properly transitions from the NoInfo state when receiving a (S,G) message.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.3

Discussion: When in NoInfo State a Join (S,G) will cause a transition in the downstream state machine to the Join State. The Expiry Timers (ET) should be set to the Hold Timer, included in the Join message, and started.

Test Setup: RP should be statically configured for multicast group ff1e::1:2. The RUT should be in NoInfo State at the beginning of each part. 3005:: must not be the prefix of any link.



Procedure:

Part A: Join (S,G) message

1. On link A and B, TR1 and the RP transmit Hello messages.
2. On link A, TR1 transmits a Join (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
3. On link B, data with a source address of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
4. Observe the packets transmitted by the RUT on all links.

Part B: Prune (S,G) message

5. On link A and B, TR1 and the RP transmit Hello message.
6. On link A, TR1 transmits a Prune (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
7. On link A, TR1 transmits a Join (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
8. On link B, data with a source address of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
9. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 4: The RUT must forward the multicast data packets onto link A.
- *In Part B,*
Step 9: The RUT must forward the multicast data packets onto link A.

Possible Problems:

- None.

Test PIM_SM.3.10: Transitions from (S,G) Join State

Purpose: To verify that a router properly transitions from the Join State when receiving a (S,G) message.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.3

Discussion: When in Join State (S,G), the following events may trigger a transition:

- Receiving a Join (S,G) will cause the Expiry Timer (ET) is reset. The ET timer's value should be set to the Hold Time included within the Join message. When the ET expires the downstream state machine should transition to the NoInfo State.
- Expiry Timer for the (S,G) downstream state machine expires. The downstream interface should transition to the NoInfo State.
- Receiving a Prune (S,G) should cause the downstream state machine to transition to the Prune Pending state from the Join State. If there are more than one neighbors the Prune Pending Timer should be set, when it expires a Prune Echo should be transmitted. If there is only one PIM neighbor a Prune Echo need not be sent on an interface containing only one PIM neighbor.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. The RUT should be in NoInfo State at the beginning of each part.



Procedure:

Part A: Join (S,G)

1. On link A and B, TR1 and RP transmit Hello messages.
2. On link A, TR1 transmits a Join (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
3. On link B, data with a source address of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
4. After 30 seconds, transmit a second Join (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
5. Observe the packets transmitted by the RUT on all links.

Part B: Prune (S,G)

6. On link A and B, TR1 and the RP transmit Hello messages.
7. On link A, TR1 transmits a Join (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
8. On link B, data with a source address of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
9. Observe the packets transmitted by the RUT on all links.
10. On link A, TR1 transmits a Prune (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
11. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 5: The RUT must continue to forward the data 105 seconds after the second Join message was sent.
- *In Part B,*
Step 9: The RUT must forward the multicast data packets onto link A.
Step 11: The RUT must not forward the multicast data packets onto link A.

Possible Problems:

- None.

Test PIM_SM.3.11: Transitions from (S,G) Prune Pending State

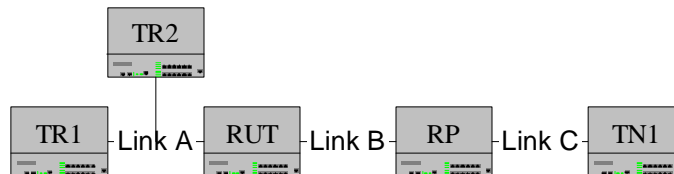
Purpose: To verify that a router properly transitions for the Prune Pending State when receiving a (S,G) message.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.3

Discussion: When in Prune Pending State the following events may trigger a transition:

- Receiving a Join (S,G) will cause the downstream state machine to transition to the Join State. The Expiry Timer (ET) should be reset to the Hold Time included in the Join message.
- Expiry Timer for the (S,G) downstream state machine expires. The downstream interface should transition to the NoInfo State.
- Receiving a Prune (S,G) will cause the downstream state machine to stay in Prune Pending State. The Prune Pending Timer is not reset.
- The Prune Pending Timer (PPT) for the (S,G) downstream state machine expires. The downstream interface should transition to the NoInfo State. When the PPT has expired a Prune Echo should be transmitted unless that interface only contains one PIM neighbor.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. The RUT should be in NoInfo State at the beginning of each part.



Procedure:

Part A: Join (S,G) message

1. On link A, TR1 and TR2 transmit Hello messages.
2. On link B, the RP transmit Hello messages.
3. On link A, TR1 transmits a Join (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
4. On link A, TR2 transmits a Join (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
5. On link B, data with a source address of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
6. On link A, TR1 transmits a Prune (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
7. After 2.5 seconds, on link A, TR2 transmits a Join message with a source address of TN1 and a group address of ff1e::1:2.
8. Observe the packets transmitted by the RUT on all links.

Part B: Single Prune (S,G)

9. On link A, TR1 and TR2 transmit Hello messages.

*University of New Hampshire
InterOperability Laboratory*

10. On link B, the RP transmit Hello messages.
11. On link A, TR1 transmits a Join (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
12. On link A, TR2 transmits a Join (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
13. On link B, data with a source address of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
14. Observe the packets transmitted by the RUT on all links.
15. On link A, TR1 transmits a Prune (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
16. Observe the packets transmitted by the RUT on all links.

Part C: Multiple Prunes (S,G)

17. On link A, TR1 and TR2 transmit Hello messages.
18. On link B, RP transmit Hello messages.
19. On link A, TR1 transmits a Join (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
20. On link A, TR2 transmits a Join (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
21. On link B, data with a source address of 3005::1 for multicast group ff1e::1:2 is forwarded by the RP.
22. On link A, TR1 transmits a Prune (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
23. On link A, TR2 transmits a Prune (S,G) message with a source address of TN1 and a group address of ff1e::1:2.
24. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 8: The RUT must forward the multicast data packets onto link A.
- *In Part B,*
Step 14: The RUT must forward the data onto link A.
Step 16: The RUT should transmit a Prune Echo onto link A and multicast data packets must not be forwarded.
- *In Part C,*
Step 22: The RUT must forward the data onto link A.
Step 25: The RUT should transmit a Prune Echo should be transmitted onto link A and multicast data packets must not be forwarded.

Possible Problems:

- None.

GROUP 4: Transmission of Join and Prune Messages

Scope:

These tests are designed to verify conformance with transmission of Join and Prune messages in PIM-SM.

Overview:

Transmission of Join and Prune messages is dependent upon a per-interface state machine kept by a router. A state machine is kept for (*,*,RP), (*,G), (S,G) and (S,G,rpt) states on each interface

Test Implementation:

In each test in this section, a test tool is used to transmit and receive PIM-SM packets. This simulates all test routers involved in the test procedure.

Test PIM_SM.4.1: Transitions from (*,*,RP) NotJoined State

Purpose: To verify a router properly transitions to (*,*,RP) Joined state.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.5

Discussion: When the upstream (*,*, RP) state-machine is in NotJoined state, reception of a (*,*,RP) Join on a downstream interface causes a state transition. The router must transition to Joined state, send Join(*,*,RP) to the appropriate upstream neighbor and set the Join Timer to expire after t_periodic seconds.

Test Setup: The RP should be statically configured for group ff1e::1:2.



Procedure:

1. On links A and B, TR1 and the RP transmit Hello messages.
2. On link A, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
3. Observe the packets transmitted by the RUT on link A.

Observable Results:

Step 3: The RUT must transmit a Join (*,*,RP) to RP for multicast group ff1e::1:2.

Possible Problems:

- None.

Test PIM_SM.4.2: Transitions from (*,*,RP) Joined State, Setup 1

Purpose: To verify a router properly transitions its state while in (*,*,RP) Joined state.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.5

Discussion: When the upstream (*,*,RP) state-machine is in Joined state, the following events may trigger state transitions:

- The Join Timer expires. A router must send a Join(*,*,RP) to the appropriate upstream neighbor and restart the Join timer seconds.

Test Setup: The RP should be statically configured for group ff1e::1:2. TR1 should be elected DR on link A.



Procedure:

1. On link A and B, TR1 and the RP transmit Hello messages.
2. On link A, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
3. After 10 seconds, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
4. Observe the packets transmitted by the RUT on all links.

Observable Results:

Step 4: 60 seconds after step 3 the RUT must transmit a Join (*,*,RP) to RP and reset the Join Timer to 60 seconds. After 60 seconds, the RUT must transmit another Join (*,*,RP) message to the RP.

Possible Problems:

- None.

Test PIM_SM.4.3: Suppression and Override in (*,*,RP) Joined State

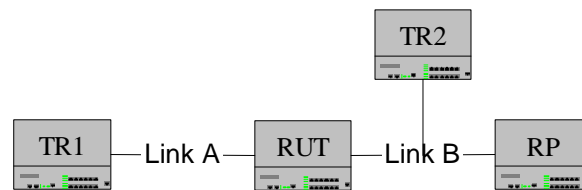
Purpose: To verify a router properly transitions its state while in Joined State.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.5

Discussion: When the upstream (*,*,RP) state-machine is in Joined state, the following events may trigger state transitions:

- A router sees another router send a Join (*,*,RP) to the upstream next hop. If the Join Timer is set to expire in less than $t_{\text{joinsuppress}}$ seconds, reset it so that it expires after $t_{\text{joinsuppress}}$.
- A router sees another router send a Prune (*,*,RP) to the upstream next hop. If the Join Timer is set to expire in less than t_{override} seconds, reset it so that it expires after t_{override} seconds.

Test Setup: The RP should be statically configured for group ff1e::1:2. TR1 and TR2 should be elected DR on link A and link B, respectively.



Procedure:

Part A: Join Suppression

1. On link A, TR1 transmits Hello Messages.
2. On link B, RP and TR2 transmit Hello messages.
3. On link B, TR2 transmits a Join (*,*,RP) messages with a source address of the RP.
4. On link A, TR1 transmits a Join (*,*,RP) messages with a source address of the RP.
5. Observe the packets transmitted by the RUT on all links.

Part B: Prune Override

6. On link A, TR1 transmits Hello messages.
7. On link B, the RP and TR2 transmit Hello Messages.
8. On link A, TR1 transmits a Join (*,*, RP) messages with a source address of the RP.
9. On link B, TR2 transmits a Join (*,*,RP) messages with a source address of the RP.
10. On link B, TR2 transmits a Prune (*,*,RP) messages with a source address of the RP.
11. Observe the packets transmitted by the RUT on all links.

Observable Results:

- In Part A,
 - Step 5:** The RUT must wait $t_{\text{joinsuppress}}$ seconds before transmitting a Join (*,*,RP) messages on link A.
- In Part B,

*University of New Hampshire
InterOperability Laboratory*

Step 11: The RUT must transmit a Join (*,*,RP) message within 60 seconds of seeing the Prune (*,*,RP) message sent on link A.

Possible Problems:

- None.

Test PIM_SM.4.4: Transitions from (*,*,RP) Joined State, Setup 2

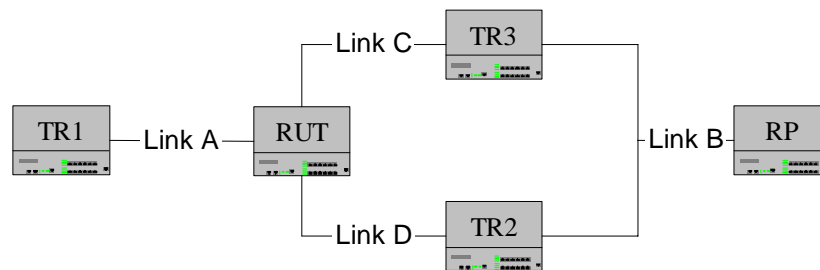
Purpose: To verify a router properly transitions its state while in Joined State.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.5

Discussion: When the upstream (*,*,RP) state-machine is in Joined state, the following events may trigger state transitions:

- A change in the MRIB causes the upstream next hop to change. A router must send a Prune (*,*,RP) to the old upstream neighbor, a Join(*,*,RP) to the new upstream router and set the Join Timer to expire after 60 seconds.
- The GenID of the upstream next hop changes. A router must reset the Join Timer to t_override seconds if it is set to expire in more than t_override seconds.

Test Setup: RP should be statically configured for group ff1e::1:2. TR1, TR2 and TR3 should be elected DR on link A, link B and link C, respectively.



Procedure:

Part A: Next Hop Changes

1. On link A, TR1 transmits Hello messages.
2. On link B and D, TR2 transmits Hello messages.
3. On link B and C, TR3 transmits Hello messages.
4. On link B, RP transmits Hello messages. TR2 should be the upstream next hop for the RUT.
5. On link A, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
6. The RUT next hop to the RP changes from TR2 to TR3.
7. Observe the packets transmitted by the RUT on all links.

Part B: GenID Changes

8. On link A, TR1 transmits Hello messages.
9. On link B and D, TR2 transmits Hello messages.
10. On link B and C, TR3 transmits Hello messages.
11. On link B, RP transmits Hello messages. TR2 should be the upstream next hop for the RUT.
12. On link A, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
13. On link D, TR2 transmits a Hello Message with a new GenID.
14. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 7: 60 seconds after step 5 the RUT must transmit a Prune (*,*,RP) message to TR2. The RUT must then send a Join (*,*,RP) message to TR3 and set the Join Timer to expire after 60 seconds. After 60 seconds the RUT must transmit another Join (*,*,RP) message to TR2.
- *In Part B,*
Step 14: 60 seconds after step 12 the RUT must set the Join Timer to t_override seconds. Wait 60 seconds the RUT must transmit a Join (*,*,RP) message to TR2.

Possible Problems:

- None.

Test PIM_SM.4.5: Transitions from (*,G) NotJoined State

Purpose: To verify a router properly transitions state when in (*,G) NotJoined state.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.6

Discussion: When the upstream (*,G) state-machine is in NotJoined state, reception of a (*,G) Join on a downstream interface causes a state transition. The router must transition to Joined state, send Join (*,G) to the appropriate upstream neighbor and set the Join Timer to expire after t_periodic seconds.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2.



Procedure:

1. On link A and B, TR1 and the RP transmit Hello messages.
2. On link A, TR1 transmits a Join (*,G) message with source address of the RP for multicast group ff1e::1:2.
3. Observe the packets transmitted by the RUT on link B.

Observable Results:

Step 3: The RUT must transmit a Join (*,G) to RP for multicast group ff1e::1:2.

Possible Problems:

- None.

Test PIM_SM.4.6: Transitions from (*,G) Joined State, Setup 1

Purpose: To verify a router properly transitions state when in (*,G) Joined state.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.6

Discussion: When the upstream (*,G) state-machine is in Joined state, the following events may trigger state transitions:

- The Join Timer expires. A router must send a Join (*,G) to the appropriate upstream router and reset the Join Timer to expire after 60 seconds.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. TR1 should be the DR on link A.



Procedure:

Part A: Join Time Expires

1. On link A and B, TR1 and the RP transmit Hello messages. The RP should be the upstream next hop for the RUT.
2. On link A, TR1 transmits a Join (*,G) message for the multicast group ff1e::1:2.
3. Observe the packets transmitted by the RUT on all links.

Observable Results:

Step 3: 60 seconds after step 2 the RUT must transmit a Join (*,G) message for multicast group ff1e::1:2 to the RP and reset the Join Timer to 60 seconds. After 60 seconds the RUT must transmit another Join (*,G) message for multicast group ff1e::1:2 to the RP.

Possible Problems:

- None.

Test PIM_SM.4.7: Suppression and Override in (*,G) Joined State

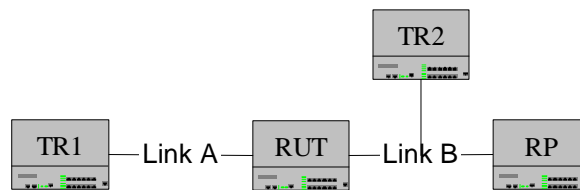
Purpose: To verify a router properly transitions state when in (*,G) Joined state.

References: [draft-ietf-pim-sm-v2-new-05] Section 4.5.6

Discussion: When the upstream (*,G) state-machine is in Joined state, the following events may trigger state transitions:

- A router sees another router send a Join (*,G) to the upstream next hop. If the Join Timer is set to expire in less than $t_{\text{joinsuppress}}$ seconds, reset it so that it expires after $t_{\text{joinsuppress}}$.
- A router sees another router send a Prune (*,G) to the upstream next hop. If the Join Timer is set to expire in less than t_{override} seconds, reset it so that it expires after t_{override} seconds.

Test Setup: The RP should be statically configured for group `ff1e::1:2`. TR1 and TR2 should be elected DR on link A and link B, respectively.



Procedure:

Part A: Join Suppression

1. On link A, TR1 transmits Hello messages. On link B, the RP and TR2 transmit Hello messages.
2. On link B, TR2 transmits a Join (*,G) message for the multicast group `ff1e::1:2`.
3. On link A, TR1 transmits a Join (*,G) message for the multicast group `ff1e::1:2`.
4. Observe the packets transmitted by the RUT on all links.

Part B: Prune Override

5. On link A, TR1 transmits Hello messages.
6. On link B, the RP and TR2 transmit Hello Messages.
7. On link A, TR1 transmits a Join (*,G) for the multicast group `ff1e::1:2`.
8. On link B, TR2 transmits a Join (*,G) for the multicast group `ff1e::1:2`.
9. On link B, TR2 transmits a Prune (*,G) for the multicast group `ff1e::1:2`.
10. Observe the packets transmitted by the RUT on all links.

Observable Results:

- In Part A,
 - Step 4:** The RUT must wait $t_{\text{joinsuppress}}$ seconds before transmitting a Join (*,G) message for multicast group `ff1e::1:2` on link A.
- In Part B,

*University of New Hampshire
InterOperability Laboratory*

Step 10: The RUT must transmit a Join (*,G) message for multicast group ff1e::1:2 within t_override seconds of seeing the Prune (*,G) message.

Possible Problems:

- None.

Test PIM_SM.4.8: Transitions from (*,G) Joined State, Setup 2

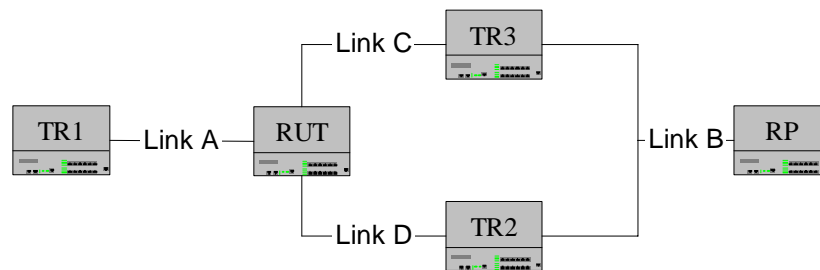
Purpose: To verify a router properly transitions state when in (*,G) Joined state.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.6

Discussion: When the upstream (*,G) state-machine is in Joined state, the following events may trigger state transitions:

- The next hop upstream for a router changes as a result of a change in the MRIB. A router must send Prune (*,G) to the old next hop, Join (*,G) to the new next hop and set the Join Timer to expire after t_{periodic} seconds.
- The next hop upstream for a router transmits a new GenID. A router must set the Join Timer to expire in t_{override} seconds.

Test Setup: The RP should be statically configured for multicast group `ff1e::1:2`. TR2 should be the upstream next hop for the RUT.



Procedure:

Part A: Next Hop Changes in MRIB

1. On link A, TR1 transmits Hello messages.
2. On link B and D, TR2 transmits Hello messages. TR2 must be elected DR on link C.
3. On link B and C, TR3 transmits Hello messages. TR3 must be elected DR on link D.
4. On link A, TR1 transmits a Join (*,G) message for multicast group `ff1e::1:2`.
5. The RUT's next hop for the RP changes from TR2 to TR3.
6. Observe the packets transmitted by the RUT on all links.

Part B: New GenID from Next Hop

7. On link A, TR1 transmits Hello messages.
8. On link B and C, TR2 transmits Hello messages. TR2 must be elected DR on link C.
9. On link B and D, TR3 transmits Hello messages. TR3 must be elected DR on link D.
10. On link A, TR1 transmits a Join (*,G) message for multicast group `ff1e::1:2`.
11. On link D, TR2 transmits a Hello message with a new GenID.
12. Observe the packets transmitted by the RUT on all links.

Observable Results:

- In Part A,

*University of New Hampshire
InterOperability Laboratory*

Step 6: The RUT must transmit Prune (*,G) message for multicast group ff1e::1:2 on link D and then Join (*,G) message for multicast group ff1e::1:2 on link C.

- *In Part B,*

Step 12: The RUT must transmit Join (*,G) message for multicast group ff1e::1:2 on link C.

Possible Problems:

- None.

Test PIM_SM.4.9: Transitions (S,G) NotJoined State

Purpose: To verify a router properly transitions state while in (S,G) NotJoined state.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.7

Discussion: When the upstream (S,G) state-machine is in NotJoined state, reception of a (S,G) Join on a downstream interface causes a state transition. The router must transition to Joined state, send Join (S,G) to the appropriate upstream neighbor and set the Join Timer to expire after `t_periodic` seconds.

Test Setup: The RP should be statically configured for group `ff1e::1:2`.



Procedure:

1. On link A and B, TR1 and RP transmit Hello messages.
2. On link A, TR1 transmits a Join (S,G) message with a source address of TN1 for the multicast group `ff1e::1:2`.
3. Observe the packets transmitted by the RUT on all links.

Observable Results:

Step 3: The RUT must transmit a Join (S,G) to RP for multicast group `ff1e::1:2`.

Possible Problems:

- None.

Test PIM_SM.4.10: Transitions from (S,G) Joined State, Setup 1

Purpose: To verify a router properly transitions state while in (S,G) Joined State.

References: [draft-ietf-pim-sm-v2-new-05] Section 4.5.7

Discussion: When the upstream (S,G) state-machine is in Joined state, the following events may trigger state transitions:

- The Join Timer expires. A router must send a Join (S,G) to the appropriate upstream neighbor and restart the Join timer seconds.

Test Setup: The RP should be statically configured for group ff1e::1:2.



Procedure:

1. On link A and B, TR1 and the RP transmit Hello messages. RP must be the upstream next hop for the RUT.
2. On link A, TR1 transmits a Join (S,G) message for source of TN1 for the multicast group ff1e::1:2.
3. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 3: After step 2 the RUT must transmit a Join (S,G) message to RP and reset the Join Timer to 60 seconds. After 60 seconds the RUT must transmit another Join (S,G) message to the RP.

Possible Problems:

- None.

Test PIM_SM.4.11: Suppression and Override in (S,G) Joined State

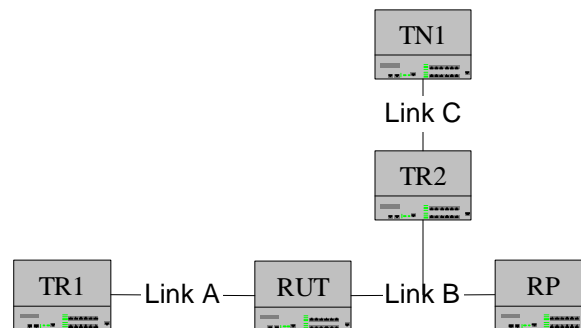
Purpose: To verify a router properly transitions state while in (S,G) Joined State.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.7

Discussion: When the upstream (S,G) state-machine is in Joined state, the following events may trigger state transitions:

- The router sees another router on the upstream interface send a Join (S,G). A router must set its Join Timer to expire in $t_{\text{joinsuppress}}$ seconds, or leave the timer alone if it is already greater than $t_{\text{joinsuppress}}$.
- The router sees another router on the upstream interface send a Prune (S,G). A router must set the Join Timer to expire in t_{override} seconds, or leave the timer alone if it is already less than t_{override} seconds.

Test Setup: The RP should be statically configured for group `ff1e::1:2`. TR1 and TR2 should be elected DR on link A and link B, respectively.



Procedure:

Part A: Join Suppression

1. On link A TR1 transmits Hello messages.
2. On link B the RP and TR2 transmit Hello messages.
3. On link B, TR2 transmits a Join (S,G) message with a source address of TN1 for the multicast group `ff1e::1:2`.
4. On link A, TR1 transmits a Join (S,G) message with source address of TN1 for the multicast group `ff1e::1:2`.
5. Observe the packets transmitted by the RUT on link B.

Part B: Prune Override

6. On link A, TR1 transmits Hello messages.
7. On link B, the RP and TR2 transmit Hello messages.
8. On link A, TR1 transmits a Join (S,G) message with source address of TN1 for the multicast group `ff1e::1:2`.
9. On link B, TR2 transmits a Join (S,G) message with the source address of TN1 for the multicast group `ff1e::1:2`.

*University of New Hampshire
InterOperability Laboratory*

10. On link B, TR2 transmits a Prune (S,G) message with the source address of TN1 for the multicast group ff1e::1:2.
11. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 5: The RUT must wait $t_{\text{joinsuppress}}$ seconds before transmitting a Join (S,G) message for multicast group ff1e::1:2 on link B.
- *In Part B,*
Step 11: The RUT must transmit a Join (S,G) message for multicast group ff1e::1:2 within t_{override} seconds of seeing the Prune (*,G) message.

Possible Problems:

- None.

Test PIM_SM.4.12: Transitions from (S,G) Joined State, Setup 2

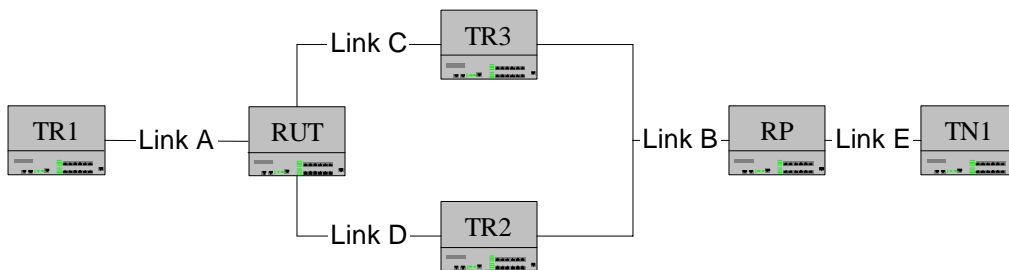
Purpose: To verify a router properly transitions state while in (S,G) Joined State.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.7

Discussion: When the upstream (S,G) state-machine is in Joined state, the following events may trigger state transitions:

- The next hop upstream for a router changes as a result of a change in the MRIB. A router must send Prune (S,G) to the old next hop, Join (S,G) to the new next hop and set the Join Timer to expire after t_{periodic} seconds.
- The next hop upstream for a router transmits a new GenID. A router must set the Join Timer to expire in t_{override} seconds.

Test Setup: The RP should be statically configured for multicast group `ff1e::1:2`. TR2 should be the upstream next hop for the RUT.



Procedure:

Part A: Next Hop Changes in MRIB

1. Configure the RUT to transmit Hello messages on link A, link C and link D.
2. On link A, TR1 transmits Hello messages.
3. On link B and D, TR2 transmits Hello messages. TR2 must be elected DR on link D.
4. On link C and D, TR3 transmits Hello messages. TR3 must be elected DR on link C.
5. On link B, the RP transmits Hello messages.
6. On link A, TR1 transmits a Join (S,G) message with a source address of the TN1 for multicast group `ff1e::1:2`. This should cause the RUT to transition to (S,G) Joined state.
7. On link C, the RUT's next hop changes to TR3.
8. Observe the packets transmitted by the RUT on all links.

Part B: New GenID from Next Hop

9. Configure the RUT to transmit Hello messages on link A, link C and link D.
10. On link A, TR1 transmits Hello messages.
11. On link B and D, TR2 transmits Hello messages. TR2 must be elected DR on link D.
12. On link B and C, TR3 transmits Hello messages. TR3 must be elected DR on link C.
13. On link B, the RP transmits Hello messages.
14. On link A, TR1 transmits a Join (S,G) message with a source address of the TN1 for multicast group `ff1e::1:2`. This should cause the RUT to transition to (S,G) Joined state.
15. On link D, TR2 transmits a Hello message with a new GenID.

16. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 8: After 60 seconds the RUT must transmit Prune (S,G) message for multicast group ff1e::1:2 on link D and then Join (S,G) message for multicast group ff1e::1:2 on link C.
- *In Part B,*
Step 16: After t_override seconds the RUT must transmit Join (S,G) message for multicast group ff1e::1:2 on link D.

Possible Problems:

- None.

Test PIM_SM.4.13: Transitions from (S,G,rpt) NotPruned State

Purpose: To verify a router properly transitions state while in (S,G,rpt) NotPruned State

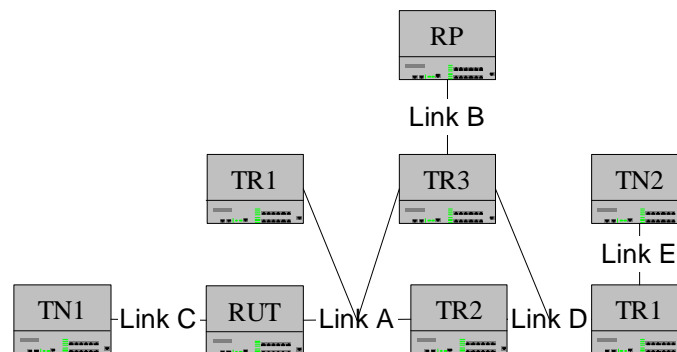
References: [draft-ietf-pim-sm-v2-new-10] Section 4.5.9

Last Modification: June 20, 2002

Discussion: When in (S,G,rpt) NotPruned State, the following events trigger state transitions:

- The router sees a Prune(S,G,rpt) on its upstream interface. A router should set the Override Timer to t_{override} and send a Join(S,G,rpt) once the timer expires.
- The router sees a Join(S,G,rpt) on its upstream interface and its Override Timer is running. A router should cancel the Override Timer.
- The Override Timer expires. A router should send a Join(S,G,rpt) to the next hop.
- The next hop for the router changes as a result of an (S,G) Assert. A router should set the Override Timer to a randomized prune-override interval t_{override} . If this timer expires the router should send a Join(S,G,rpt).

Test Setup: The RP should be statically configured for multicast group ff1e::1:2.



Procedure:

Part A: See Prune(S,G,rpt) Upstream

1. On link A, TR1, TR2 and TR3 transmit Hello messages.
2. On link B, RP and TR3 transmit Hello messages.
3. On link D, TR1, TR2 and TR4 transmit Hello messages.
4. On link A, TR1 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR2.
5. On link B, TR4 forwards data from source TN1 for multicast group ff1e::1:2.
6. On link C, TN1 transmits an MLD report for multicast group ff1e::1:2.
7. Observe the packets transmitted by the RUT on all links.
8. On link A, TR1 transmits a Join (S,G) message for source of TN2 and multicast group ff1e::1:2 with upstream neighbor address set to the address of TR3.
9. On link A, TR1 transmits a Prune(S,G,rpt) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR2.
10. Observe the packets transmitted by the RUT on all links.

*University of New Hampshire
InterOperability Laboratory*

Part B: See Join(S,G,rpt) Upstream

11. On link A, TR1, TR2 and TR3 transmit Hello messages.
12. On link D, TR2, TR3 and TR4 transmit Hello messages.
13. On link B, RP and TR2 transmit Hello messages.
14. On link A, TR1 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR2.
15. On link D, TR4 forwards data from source TN1 for multicast group ff1e::1:2.
16. On link C, TN1 transmits an MLD Report for multicast group ff1e::1:2 is transmitted to the RUT.
17. Observe the packets transmitted by the RUT on all links.
18. On link A, TR1 transmits a Join (S,G) message for source of TN2 and multicast group ff1e::1:2 with upstream neighbor address set to the address of TR3.
19. On link A, TR1 transmits a Prune(S,G,rpt) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR2.
20. On link A, TR1 transmits a Join(S,G,rpt) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR2.
21. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
 - Step 7:** The RUT must transmit a Join (*,G) message upstream.
 - Step 10:** The RUT must set the Override Timer to t_override seconds. After t_override seconds, the RUT must transmit a Join(S,G,rpt) message for source of TN1 and multicast group ff1e::1:2 with upstream neighbor address set to the address of TR2.
- *In Part B,*
 - Step 17:** The RUT must send a Join (*,G) message upstream.
 - Step 20:** The RUT must cancel the Override Timer and should not transmit a Join(S,G,rpt) message.

Possible Problems:

- None.

GROUP 5: Assert Messages

Scope:

These tests are designed to verify conformance with the Assert process in PIM-SM.

Overview:

If more than one upstream router has valid forwarding state for a packet there can be duplication on a link. When this occurs the Assert process begins and a single forwarder is elected for the duplicated packets.

Test Implementation:

In each test in this section, a test tool is used to transmit and receive PIM-SM packets. This simulates all test routers involved in the test procedure.

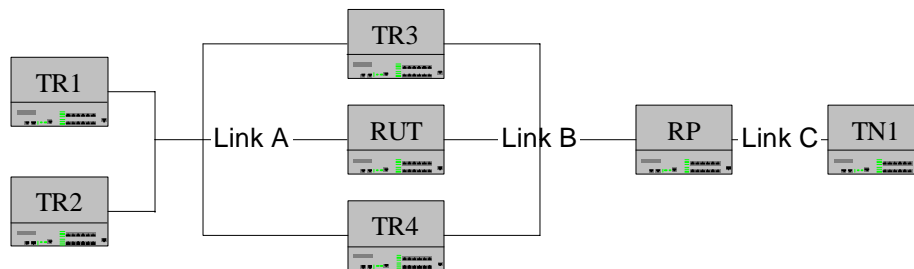
Test PIM_SM.5.1: Unknown Assert

Purpose: To verify that a router properly ignores Asserts from unknown neighbors.

References: [draft-ietf-pim-sm-v2-new-10] Sections 4.3.1 and 4.6

Discussion: A PIM Assert message should only be accepted for processing if it comes from a known PIM neighbor. A PIM router hears about PIM neighbors through PIM Hello messages. If a router receives an Assert message from a particular IP address and it has not seen a PIM Hello message from that source address, then the Assert message should be discarded without further processing.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. The RUT is the upstream next hop to the RP from TR1. TR3 is the upstream next hop to the RP from TR2.



Procedure:

1. On link A, TR1 and TR2 transmit Hello messages.
2. On link A and B, TR3 transmits Hello messages.
3. On link B, the RP transmits Hello messages.
4. On link A, TR1 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
5. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of TR3.
6. On link B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
7. On link A, data from source of TN1 for multicast group ff1e::1:2 is forwarded by TR3.
8. On link A, TR3 transmits an Assert (S,G) message for source of TN1 and multicast group ff1e::1:2 with a metric worse than RUT metric.
9. On link A, TR4 transmits an Assert (S,G) message for source of TN1 and multicast group ff1e::1:2 with a metric better than RUT metric.
10. Observe packets transmitted by the RUT on all links.

Observable Results:

Step 10: The RUT should ignore the Assert message from TR4. The RUT should transmit an Assert (S,G) message and set its assert timer to 177 seconds (Assert_Time – Assert_Override_Interval). After 177 seconds the RUT should transmit another Assert (S,G) message. The RUT must forward all the multicast data onto link A after the Assert message.

Possible Problems:

- None.

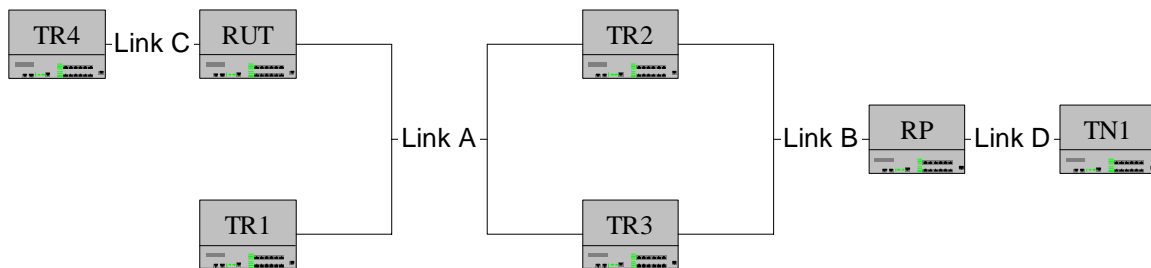
Test PIM_SM.5.2: Upstream Assert

Purpose: To verify that a router properly transmits PIM-SM messages after an upstream Assert.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.6

Discussion: Where multiple PIM routers peer over a shared LAN it is possible for more than one upstream router to have valid forwarding state for a packet, which can lead to packet duplication. PIM detects when this has happened and elects a single forwarder amongst upstream routers to prevent further duplication. Assert messages are also received by downstream routers on the LAN. These messages cause subsequent Join/Prune messages to be sent to the upstream router that won the Assert.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. The RUT should list TR2 as its upstream next hop towards the RP. TR3 is the upstream next hop to the RP from TR1. The MRIB in the RUT should contain a better metric for TR2.



Procedure:

Part A: Upstream Join (*,G)

1. On link A TR1 transmits Hello messages.
2. On link A and B TR2 and TR3 transmit Hello messages. TR2 must be elected DR on link A.
3. On link B, the RP transmits Hello messages.
4. On link C, TR4 transmits a Join (*,G) message for the multicast group ff1e::1:2.
5. On link A, TR1 transmits a Join (*,G) message for multicast group ff1e::1:2 and upstream neighbor address set to the address of TR3.
6. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
7. Observe the packets transmitted by the RUT on all links.
8. TR3 has a better unicast metric to the RP than TR2.
9. TR2 and TR3 begin the Assert process. TR3 now has a better metric and is elected forwarder on link A.
10. Observe the packets transmitted by the RUT on all links.

Part B: Upstream Join (S,G)

11. On link A, TR1 transmits Hello messages.
12. On link A and B, TR2 and TR3 transmit Hello messages. TR2 must be elected DR on link A.

*University of New Hampshire
InterOperability Laboratory*

13. On link B, the RP transmits Hello messages.
14. On link C, TR4 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2.
15. On link A, TR1 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of TR3.
16. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
17. Observe the packets transmitted by the RUT on all links.
18. TR3 has a better unicast metric to the RP than TR2.
19. TR2 and TR3 begin the Assert process. TR3 now has a better metric and is elected forwarder on link A.
20. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
 - Step 7:** The RUT must transmit a Join message to TR2.
 - Step 10:** The RUT must transmit a Join message to TR3. All multicast data must be forwarded downstream onto link C.
- *In Part B,*
 - Step 17:** The RUT must transmit a Join message to TR2.
 - Step 20:** The RUT must transmit a Join message to TR3.

Possible Problems:

- None.

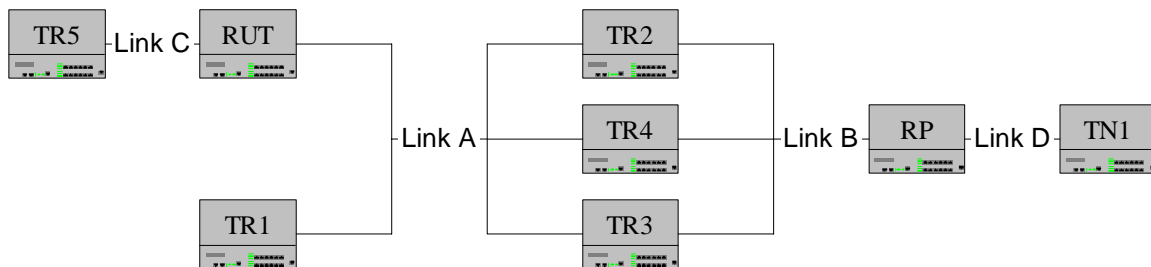
Test PIM_SM.5.3: Unknown Upstream Assert

Purpose: To verify that a router properly transmits PIM-SM messages after an upstream Assert.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.6

Discussion: Where multiple PIM routers peer over a shared LAN it is possible for more than one upstream router to have valid forwarding state for a packet, which can lead to packet duplication. PIM detects when this has happened and elects a single forwarder amongst upstream routers to prevent further duplication. Assert messages are also received by downstream routers on the LAN. These messages cause subsequent Join/Prune messages to be sent to the upstream router that won the Assert.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. The RUT should list TR2 as its upstream next hop towards the RP. TR3 is the upstream next hop to the RP from TR1. The Assert messages transmitted in this test are Assert (S,G) for source of TN1 and multicast group ff1e::1:2.



Procedure:

1. On link A, TR1 transmits Hello messages.
2. On link A and B, TR2 and TR3 transmit Hello messages. TR2 must be elected DR on link A.
3. On link B, the RP transmits Hello messages.
4. On link C, TR5 transmits a Join(*,G) message for the multicast group ff1e::1:2.
5. On link A, TR1 transmits a Join (*,G) message for multicast group ff1e::1:2 and upstream neighbor address set to the address of TR3.
6. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
7. Observe the packets transmitted by the RUT on all links.
8. TR3 has a better unicast metric to the RP than TR2. TR4 has a better unicast metric to the RP than TR3.
9. On link A, TR2, TR3 and TR4 transmit Assert messages.
10. Observe the packets transmitted by the RUT on all links.

Observable Results:

Step 7: The RUT must transmit a Join (*,G) message to TR2.

*University of New Hampshire
InterOperability Laboratory*

Step 10: The RUT must transmit a Join (*,G) message to TR3. The RUT must ignore the Assert received from TR4. The multicast data must be forwarded onto link C

Possible Problems:

- None.

Test PIM_SM.5.4: Transitions from (S,G) NoInfo State

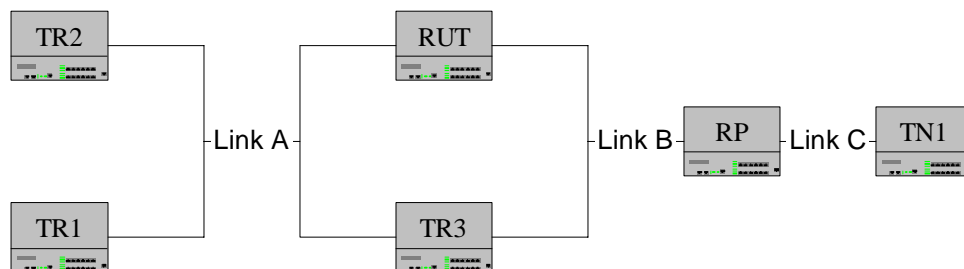
Purpose: To verify a router properly transitions its state while in (S,G) NoInfo state.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.6.1
[draft-ietf-pim-sm-v2-new-10] Figure 10: Per-interface (S,G) Assert State-machine

Discussion: When in NoInfo state, the following events may trigger a transition:

- An (S,G) assert is received with the RPT bit cleared and an inferior assert metric. The router transitions to “I am Assert Winner” state. The router then transmits an Assert (S,G) message and sets the assert timer to (Assert_Time – Assert_Override_Interval).
- An (S,G) assert is received with the RPT bit set. The router transitions to “I am Assert Winner” state. The router then transmits an Assert (S,G) message and sets the assert timer to (Assert_Time – Assert_Override_Interval).
- An (S,G) data packet arrives on a downstream interface that is in the (S,G) outgoing interface list of the receiving router. The router transitions to “I am Assert Winner” state. The router then transmits an Assert (S,G) message and sets assert timer to (Assert_Time – Assert_Override_Interval).
- An (S,G) assert is received with the RPT bit cleared and a superior assert metric. A router should transition to “I am Assert Loser” state and set assert timer to Assert_Time.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. TR1 should list the RUT as its upstream next hop towards the RP. TR2 should list TR3 as its upstream next hop towards the RP.



Procedure:

Part A: Receive Inferior Assert with RPT bit set

1. On link A, TR1 and TR2 transmit Hello messages.
2. On link A and B, TR3 transmits Hello messages.
3. On link B, the RP transmits Hello messages.
4. On link A, TR1 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
5. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of TR3.
6. On link B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
7. On link A, TR3 transmits an Assert (S,G) message for source address of TN1 and multicast group ff1e::1:2 with a metric of worse than that of the RUT.

*University of New Hampshire
InterOperability Laboratory*

8. Observe the packets transmitted by the RUT on all links.

Part B: Receive (,G)Assert*

9. On link A, TR1 and TR2 transmit Hello messages.
10. On link A and B, TR3 transmits Hello messages.
11. On link B, the RP transmits Hello messages.
12. On link A, TR1 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
13. On link A, TR2 transmits a Join (*,G) message with source address of TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of TR3.
14. On link B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
15. On link A, TR3 transmits an Assert (*,G) message with the RPT bit cleared for source address of TN1 and multicast group ff1e::1:2 with a metric of worse than RUT metric.
16. Observe the packets transmitted by the RUT on all links.

Part C: Receive AssertCancel

17. On link A, TR1 and TR2 transmit Hello messages.
18. On link A and B, TR3 transmits Hello messages.
19. On link B, the RP transmits Hello messages.
20. On link A, TR1 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
21. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of TR3.
22. On link B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
23. On link A, TR3 transmits an AssertCancel (S,G) message for source address of TN1 and multicast group ff1e::1:2 with a metric of infinity.
24. Observe the packets transmitted by the RUT on all links.

Part D: Receive Data Packet

25. On link A, TR1 and TR2 transmit Hello messages.
26. On link A and B, TR3 transmits Hello messages.
27. On link B, the RP transmits Hello messages.
28. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of TR3.
29. On link A, TR1 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
30. On link A and B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP and TR3.
31. On link A, the RUT should send an Assert (S,G) message for source address TN1 for multicast group ff1e::1:2 with a metric better then TR3 on link A. As a result TR3 should not transmit an Assert (S,G) message.
32. Observe the packets transmitted by the RUT on all links.

Part E: Receive Superior Assert with RPT bit cleared

33. On link A, TR1 and TR2 transmit Hello messages.
34. On link A and B, TR3 transmits Hello messages.
35. On link B, the RP transmits Hello messages.
36. On link A, TR1 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
37. On link A, TR2 transmits a Join (S,G) message with source address TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of TR3.
38. On link B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP.

*University of New Hampshire
InterOperability Laboratory*

39. On link A, TR3 transmits an Assert (S,G) message for source address of TN1 and multicast group ff1e::1:2 with a metric of better than RUT metric.
40. On link B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
41. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 8: the RUT must transition to “I am Assert Winner” state. The RUT must then transmit an Assert (S,G) message and set its assert timer to 177 seconds (Assert_Time – Assert_Override_Interval). The RUT must forward multicast data onto link A.
- *In Part B,*
Step 16: The RUT must transition to “I am Assert Winner” state. The RUT must then transmit an Assert (S,G) message and set its assert timer to 177 seconds (Assert_Time – Assert_Override_Interval). The RUT must forward multicast data onto link A.
- *In Part C,*
Step 24: the RUT must transition to “I am Assert Winner” state. The RUT must then transmit an Assert (S,G) message and set its assert timer to 177 seconds (Assert_Time – Assert_Override_Interval). The RUT must forward multicast data onto link A.
- *In Part D,*
Step 32: The RUT must transition to “I am Assert Winner” state. The RUT should then transmit an Assert (S,G) message and set its assert timer to 177 seconds (Assert_Time – Assert_Override_Interval). The RUT must forward multicast data onto link A.
- *In Part E,*
Step 40: The RUT should transition to the “I am Assert Loser” state. The RUT should set assert timer to 180 seconds (Assert_Time) and stop forwarding multicast data onto link A.

Possible Problems:

- None.

Test PIM_SM.5.5: Transitions from (S,G) “I am Assert Winner” State

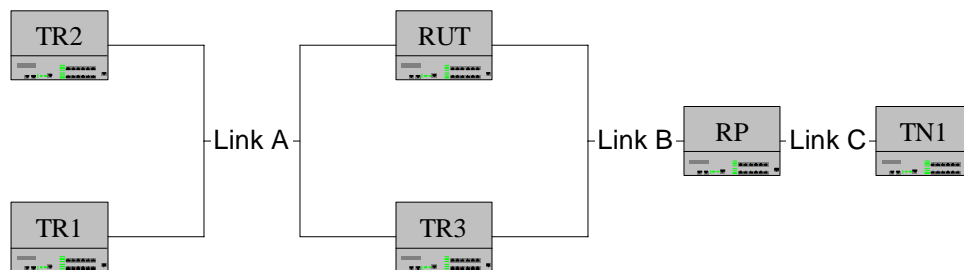
Purpose: To verify that a router properly transitions its state while in (S,G)“I am Assert Winner” state.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.6.1
[draft-ietf-pim-sm-v2-new-10] Figure 10: Per-interface (S,G) Assert State-machine

Discussion: When in (S,G) “I am Assert Winner” state the following events may trigger a transition:

- The (S,G) assert timer expires. A router should resend the (S,G) Assert and reset the assert timer to (Assert_Time – Assert_Override_Interval).
- An (S,G) assert or a (*,G) assert mentioning S with a worse metric is received. A router should resend an (S,G) Assert and reset the assert timer to (Assert_Time – Assert_Override_Interval).
- An (S,G) assert with a better metric is received. A router should transition to “I am Loser State”, store the new assert winner and set assert timer to Assert_Time.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. TR1 should list the RUT as its upstream next hop towards the RP. TR2 should list TR3 as its upstream next hop towards the RP.



Procedure:

Part A: Timer Expires

1. On link A, TR1 and TR2 transmit Hello messages.
2. On link A and B, TR3 transmits Hello messages.
3. On link B, The RP transmits Hello messages.
4. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.
5. On link A, TR1 transmits a Join (S,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
6. On link A and B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP and TR3.
7. On link A, the RUT should send an Assert (S,G) message for source address of TN1 for multicast group ff1e::1:2 with a metric better than TR3 on link A. As a result TR3 should not transmit an Assert (S,G).

*University of New Hampshire
InterOperability Laboratory*

8. Observe the packets transmitted by the RUT on all links.

Part B: Receive Inferior Assert (S,G)

9. On link A, TR1 and TR2 transmit Hello messages.
10. On link A and B, TR3 transmits Hello messages.
11. On link B, the RP transmits Hello messages.
12. On link A, TR2 transmits a Join (S,G) message with source address TN1 for multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.
13. On link A, TR1 transmits a Join (S,G) message with source address TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
14. On link A and B, data from source TN1 for multicast group ff1e::1:2 is forwarded by the RP and TR3.
15. On link A, TR3 transmits an Assert (S,G) for source address of TN1 and multicast group ff1e::1:2 with a metric worse than that of the RUT metric.
16. Observe the packets transmitted by the RUT on all links.

Part C: Receive Inferior Assert (,G)*

17. On link A, TR1 and TR2 transmit Hello messages.
18. On link A and B, TR3 transmits Hello messages.
19. On link B, The RP transmits Hello messages.
20. On link A, TR2 transmits a Join (*,G) messages with source address of TN1 for multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.
21. On link A, TR1 transmits a Join (S,G) messages with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
22. On link A and B, data from source TN1 for multicast group ff1e::1:2 is forwarded by the RP and TR3.
23. On link A, TR3 transmits an Assert (*,G) message for source address of TN1 and multicast group ff1e::1:2 with a metric worse than that of the RUT metric.
24. Observe the packets transmitted by the RUT on all links.

Part D: Receive AssertCancel

25. On link A, TR1 and TR2 transmit Hello messages.
26. On link A and B, TR3 transmits Hello messages.
27. On link B, The RP transmits Hello messages.
28. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.
29. On link A, TR1 transmits a Join (S,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
30. On link A and B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP and TR3.
31. On link A, TR3 transmits an AssertCancel (S,G) message for source address of TN1 and multicast group ff1e::1:2 with a metric of infinity.
32. Observe the packets transmitted by the RUT on all links.

Part E: Receive Preferred Assert

33. On link A, TR1 and TR2 transmit Hello messages.
34. On link A and B, TR3 transmits Hello messages.
35. On link B, The RP transmits Hello messages.
36. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.

*University of New Hampshire
InterOperability Laboratory*

37. On link A, TR1 transmits a Join (S,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
38. On link A and B, data from source address of TN1 for multicast group ff1e::1:2 is forwarded by the RP and TR3.
39. On link A, TR3 transmits an Assert (S,G) for source address of TN1 and multicast group ff1e::1:2 with a metric better than that of the RUT metric.
40. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Parts A,*
Step 8: The RUT must transition and remain in the “I am Assert Winner” state. The RUT should transmit an Assert (S,G) message for source address of TN1 and multicast group ff1e::1:2 and set the assert timer to 177 seconds (Assert_Time – Assert_Override_Interval). Multicast data must be forwarded after the Assert messages onto link A. Each time the assert timer expires, the RUT should transmit an Assert (S, G) message.
- *In Part B,*
Step 16: The RUT must transition and remain in the “I am Assert Winner” state. The RUT should transmit an Assert (S,G) message for source address of TN1 and multicast group ff1e::1:2 and set the assert timer to 177 seconds (Assert_Time – Assert_Override_Interval). Multicast data must be forwarded after the Assert messages onto link A. Each time the assert timer expires, the RUT must transmit an Assert (S, G) message.
- *In Part C,*
Step 24: The RUT must transition and remain in the “I am Assert Winner” state. The RUT should transmit an Assert (S,G) message for source address of TN1 and multicast group ff1e::1:2 and set the assert timer to 177 seconds (Assert_Time – Assert_Override_Interval). Multicast data must be forwarded after the Assert messages onto link A. Each time the assert timer expires, the RUT must transmit an Assert (S, G) message.
- *In Part D,*
Step 32: The RUT must transition and remain in the “I am Assert Winner” state. The RUT should transmit an Assert (S,G) message for source address of TN1 and multicast group ff1e::1:2 and set the assert timer to 177 seconds (Assert_Time – Assert_Override_Interval). Multicast data must be forwarded after the Assert messages onto link A. Each time the assert timer expires, the RUT must transmit an Assert (S, G) message.
- *In Part E,*
Step 40: Upon the reception of the preferred assert the RUT must transition to the “I am Assert Loser” state. The RUT must then set the assert timer to 180 seconds (Assert_Time) and stop forwarding multicast data onto link A.

Possible Problems:

- None.

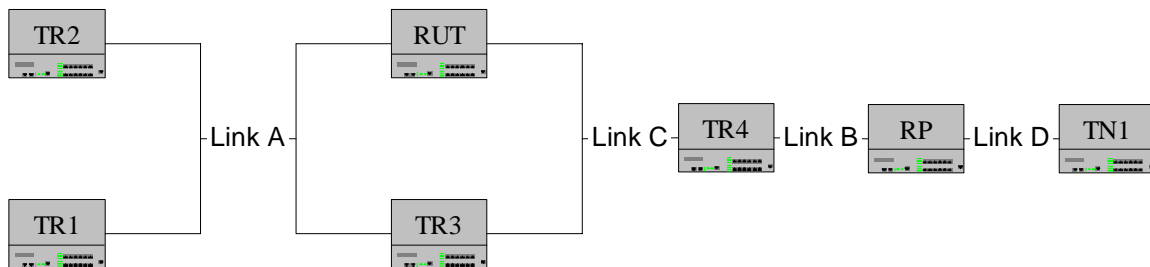
Test PIM_SM.5.6: AssertCancel Message Transmission

Purpose: To verify that a router properly transmits an AssertCancel message.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.6.1
[draft-ietf-pim-sm-v2-new-10] Figure 10: Per-interface (S,G) Assert State-machine

Discussion: When in (S,G) “I am Assert Winner” state, a change in (S,G) forwarding state or RPF interface causes a router to be unable to perform the operations of the assert winner. A router should transition to NoInfo state and send an AssertCancel(S,G).

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. TR1 should list the RUT as its upstream next hop towards the RP. TR2 should list TR3 as its upstream next hop towards the RP.



Procedure:

Part A: PIM Disabled

1. On link A, TR1 and TR2 transmit Hello messages.
2. On link A and C, TR3 transmits Hello messages.
3. On link C, TR4 transmits Hello messages.
4. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.
5. On link A, TR1 transmits a Join (S,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
6. On link A and C, data from source address of TN1 for multicast group ff1e::1:2 is forwarded by the RP and TR3.
7. On link A, TR3 sends an Assert (S,G) message for source address of TN1 for multicast group ff1e::1:2 with a metric worse than the RUT.
8. On link A, the RUT should send an Assert (S,G) message for source address of TN1 for multicast group ff1e::1:2 with a metric better than TR3 on link A. As a result TR3 should not transmit an Assert (S,G) message.
9. Once the RUT transitions to the “I am Assert Winner” state, disable PIM on the RUT on link C.
10. Observe the packets transmitted by the RUT on all links.

Part B: PIM Disabled on upstream router

11. On link A, TR1 and TR2 transmit Hello messages.

*University of New Hampshire
InterOperability Laboratory*

12. On link A and C, TR3 transmits Hello messages.
13. On link C, TR4 transmits Hello messages.
14. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.
15. On link A, TR1 transmits a Join (S,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
16. On link A and B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP and TR3.
17. On link A, the RUT should send an Assert (S,G) message for source of TN1 for multicast group ff1e::1:2 with a metric better than TR3 on link A. As a result TR3 should not transmit an Assert (S,G) message.
18. TR4 ceases Hello message transmission.
19. Observe the packets transmitted by the RUT on all links.

Part C: Prune Messages received

20. On link A, TR1 and TR2 transmit Hello messages. On link A and 2, TR3 transmits Hello messages. On link C, TR4 transmits Hello messages.
21. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.
22. On link A, TR1 transmits a Join (S,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
23. On link A and B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP and TR3.
24. On link A, the RUT should send an Assert (S,G) message for source of TN1 for multicast group ff1e::1:2 with a metric better than TR3 on link A. As a result TR3 should not transmit an Assert (S,G) message.
25. TR1 and TR2 transmit Prune (S,G) message with source address of TN1 for multicast group ff1e::1:2 and the upstream neighbor address of the RUT.
26. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 10: The RUT must transition to the NoInfo state and send an AssertCancel (S,G) message for source of TN1 and multicast group ff1e::1:2. The RUT must not forward multicast data onto link A after the AssertCancel is transmitted.
- *In Part B,*
Step 19: The RUT must transition to the NoInfo state and send an AssertCancel (S,G) message for source of TN1 and multicast group ff1e::1:2. The RUT must not forward multicast data onto link A after the AssertCancel is transmitted.
- *In Part C,*
Step 26: The RUT must transition to the NoInfo state and send an AssertCancel (S,G) message for source of TN1 and multicast group ff1e::1:2. The RUT must not forward multicast data onto link A after the AssertCancel is transmitted.

Possible Problems:

- None.

Test PIM_SM.5.7: (S,G) “I am Assert Loser” State Transition, Message Reception

Purpose: To verify a router properly transitions when in “I am Assert Loser” state upon reception of messages.

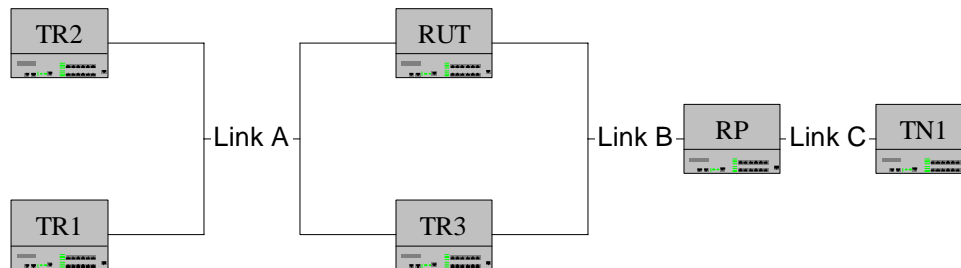
References: [draft-ietf-pim-sm-v2-new-10] Section 4.6.1

Discussion: When in “I am Assert Loser” state, reception of the following messages causes a transition in state:

- An assert is received containing a metric better than that of the current assert winner. A router should store the new assert winner and set its assert timer to Assert_Time.
- An assert is received from the current winner, containing a metric better than the router’s own, but possibly worse than the winner’s previous. A router should set its assert timer to Assert_Time.
- An assert is received from the current winner, containing a metric worse than the router’s own. A router should transition to NoInfo state and allow the normal Join/Prune mechanisms to operate.
- A Join (S,G) with the Upstream Neighbor Address field set to one of the router’s IP addresses. A router should transition to NoInfo state and allow the normal Join/Prune mechanisms to operate.
- A Hello Message containing a new GenID is received from the current assert winner. A router should transition to NoInfo state and delete this (S,G) assert information.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2.

- TR1 should list the RUT as its upstream next hop towards the RP.
- TR2 should list TR4 as its upstream next hop towards the RP.
- TR3 should list TR5 as its upstream next hop towards the RP.
- It is assumed that the Assert messages transmitted in this test are (S,G) with the RPT bit clear, unless noted otherwise



Procedure:

Part A: Receive Preferred Assert

1. On link A, TR1 and TR2 transmit Hello messages.
2. On link A and B, TR3 transmits Hello messages.
3. On link B, the RP transmits Hello Messages.

*University of New Hampshire
InterOperability Laboratory*

4. On link A TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.
5. On link B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
6. On link A, TR1 transmits a Join (S,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
7. On link A, TR3 transmits an Assert (S,G) message for source of TN1 and multicast group ff1e::1:2 with a better assert metric than the RUT, making TR3 the assert winner.
8. On link A, TR3 transmits a new Assert (S,G) message for source of TN1 and multicast group ff1e::1:2 with a better assert metric than TR5.
9. Observe the packets transmitted by the RUT on all links.

Part B: Receive Acceptable Assert from Current Winner

10. On link A, TR1 and TR2 transmit Hello messages.
11. On link A and B, TR4 transmits Hello messages.
12. On link B, the RP transmits Hello messages.
13. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 upstream neighbor address set to the address of TR4.
14. On link B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
15. On link A, TR1 transmits a Join (S,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
16. On link A, TR4 transmits an Assert (S,G) message for source of TN1 and multicast group ff1e::1:2 with a better assert metric than the RUT, making TR3 the assert winner.
17. On link A, TR4 transmits another Assert (S,G) message for source of TN1 and multicast group ff1e::1:2 with a new assert metric worse than it's previously transmitted, but still better than the RUT's metric.
18. Observe the packets transmitted by the RUT on all links.

Part C: Receive Inferior Assert from Current Winner

19. On link A, TR1 and TR2 transmit Hello messages.
20. On link A and B, TR4 transmits Hello messages.
21. On link B, the RP transmits Hello messages.
22. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.
23. On link B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
24. On link A, TR1 transmits a Join (S,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
25. On link A, TR4 transmits an Assert (S,G) message for source of TN1 and multicast group ff1e::1:2 with a better assert metric than the RUT, making TR3 the assert winner.
26. TR4 transmits another Assert (S,G) for source of TN1 and multicast group ff1e::1:2 with a new assert metric worse than the RUT's assert metric on link A.
27. Observe the packets transmitted by the RUT on all links.

Part D: Receive Join (S,G)

28. On link A, TR1 and TR2 transmit Hello messages.
29. On link A and B, TR4 transmits Hello messages.
30. On link B, the RP transmits Hello messages.
31. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.
32. On link B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP.

*University of New Hampshire
InterOperability Laboratory*

33. On link A, TR1 transmits a Join (S,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
34. On link A, TR4 transmits an Assert (S,G) message for source of TN1 and multicast group ff1e::1:2 with a better assert metric than the RUT, making TR3 the assert winner.
35. On link A, TR1 transmits a Join (S,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
36. Observe the packets transmitted by the RUT on all links.

Part E: Current Winner's GenID changes

37. On link A, TR1 and TR2 transmit Hello messages.
38. On link A and B, TR4 transmits Hello messages.
39. On link B, the RP transmits Hello messages.
40. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR3.
41. On link B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
42. On link A, TR1 transmits a Join (S,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
43. On link A, TR4 transmits an Assert (S,G) message for source of TN1 and multicast group ff1e::1:2 with a better assert metric than the RUT, making TR3 the assert winner.
44. On link A, TR4 transmits a Hello message with a new GenID.
45. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 9: The RUT must remain in the “I am Loser State” and not forward multicast data for multicast group ff1e::1:2 onto link A.
- *In Part B,*
Step 18: The RUT must remain in the “I am Loser State” and not forward multicast data for multicast group ff1e::1:2 onto link A.
- *In Parts C,*
Step 27: The RUT must transition to the NoInfo state. The RUT must delete the assert info and not forward the multicast data.
- *In Part D,*
Step 36: The RUT must transition to the NoInfo state. The RUT must then transition to “I am a Winner State” after receiving the data packets, and should forward the data packets onto link A.
- *In Part E,*
Step 45: The RUT must transition to the NoInfo state. The RUT must delete the assert info and not forward the multicast data.

Possible Problems:

- None.

Test PIM_SM.5.8: (S,G) “I am Assert Loser” State Transition, Internal Event

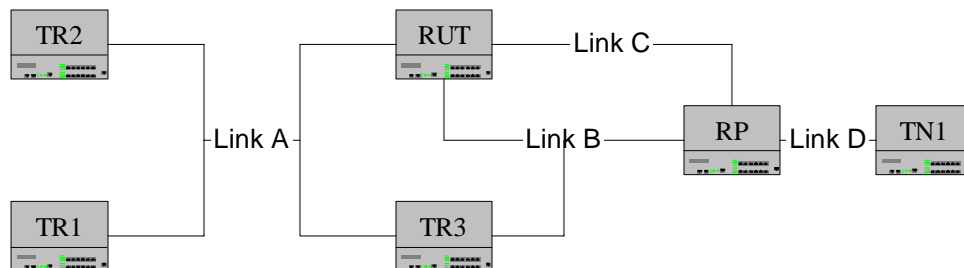
Purpose: To verify a router properly transitions while in (S,G) “I am Assert Loser” state and internal events occur.

References: [draft-ietf-pim-sm-v2-new-10], Section 4.6.1
[draft-ietf-pim-sm-v2-new-10] Figure 10: Per-interface (S,G) Assert State-machine

Discussion: When in “I am Assert Loser” state, the following events cause a transition in state:

- The (S,G) assert timer expires. A router should transition to NoInfo state and delete the (S,G) assert information.
- The router’s forwarding state changes so that (S,G) Asserts on a given interface are no longer of interest. A router should transition to NoInfo state and delete the (S,G) assert information.
- The router’s assert metric becomes better than the current assert winner’s. A router should transition to NoInfo state, delete this (S,G) state and allow normal PIM Join/Prune mechanisms to operate.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. TR1 should list the RUT as its upstream next hop towards the RP. TR2 should list TR3 as its upstream next hop towards the RP.



Procedure:

Part A: Timer Expires

1. On link A, TR1 and TR2 transmit Hello messages.
2. On link A and B, TR3 transmits Hello messages.
3. On link B and C, the RP transmits Hello messages.
4. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of TR3.
5. On link A, TR1 transmits a Join (S,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
6. On link A, TR3 transmits an Assert (S,G) message for source address of TN1 and multicast group ff1e::1:2 with a better assert metric than that of the RUT.
7. On link B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
8. Observe the packets transmitted by the RUT on all links.

Part B: Lose interest in Assert

9. On link A, TR1 and TR2 transmit Hello messages.

*University of New Hampshire
InterOperability Laboratory*

10. On link A and B, TR3 transmits Hello messages.
11. On link B and C, the RP transmits Hello messages.
12. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of TR3.
13. On link A, TR1 transmits a Join (S,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
14. On link A, TR3 transmits an Assert (S,G) message for source of TN1 and multicast group ff1e::1:2 with a better assert metric than that of the RUT.
15. On link A, TR1 transmits a Prune (S,G) message for source of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
16. On link A, TR3 transmits an Assert (S,G) message for source of TN1 and multicast group ff1e::1:2 with a new metric worse than the RUT's previously advertised metric.
17. On link B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
18. Observe the packets transmitted by the RUT on link A.

Part C: RUT's metric becomes better than Assert Winner's

19. On link A, TR1 and TR2 transmit Hello messages.
20. On link A and B, TR3 transmits Hello messages.
21. On link B and C, the RP transmits Hello messages.
22. On link A, TR2 transmits a Join (S,G) with source address of TN1 for multicast group ff1e::1:2 and upstream neighbor address set to the address of TR3.
23. On link A, TR1 transmits a Join (S,G) with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
24. On link A, TR3 transmits an Assert (S,G) for source of TN1 and multicast group ff1e::1:2 with a better assert metric than that of the RUT.
25. TR3 has a worse unicast metric to the RP than the RUT.
26. Allow the link to re-converge.
27. On link B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the RP.
28. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 8: The RUT must transition to the NoInfo state after the Assert Timer expires. The RUT must delete the assert info and not forward the Multicast Data.
- *In Part B,*
Step 18: After the Prune is transmitted, the RUT must transition to the NoInfo state. The RUT must delete the assert info and not forward the Multicast Data.
- *In Part C,*
Step 28: After the link converges, the RUT must transition to the NoInfo state. The RUT must delete the assert info and not forward the Multicast Data.

Possible Problems:

- None.

Test PIM_SM.5.9: (*,G) NoInfo State Transition

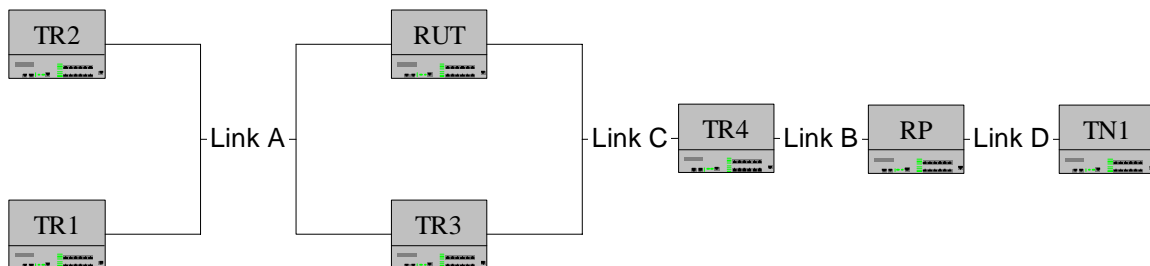
Purpose: To verify that a router properly transitions state while in (*,G) NoInfo state.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.6.2
[draft-ietf-pim-sm-v2-new-10] Figure 11: (*,G) Assert State-machine

Discussion: When in (*,G) NoInfo state, the following events trigger transitions, but only if the (S,G) assert state machine is in NoInfo state:

- A (*,G) assert is received with an inferior assert metric. A router should transition to “I am Assert Winner” state, send an Assert (*,G) and set assert timer to (Assert_Time – Assert_Override_Interval).
- A (*,G) data packet arrives on a downstream interface that is in the (*,G) outgoing interface list. A router should transition to “I am Assert Winner” state, send an Assert (*,G) and set assert timer to (Assert_Time – Assert_Override_Interval).
- A (*,G) assert is received with a superior assert metric. A router should transition to “I am Assert Loser” state and set assert timer to Assert_Time.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. TR1 should list the RUT as its upstream next hop towards the RP. TR2 should list TR3 as its upstream next hop towards the RP.



Procedure:

Part A: Receive Inferior Assert

1. On link A, TR1 and TR2 transmit Hello messages.
2. On link A and C, TR3 transmits Hello messages.
3. On link C and B, TR4 transmits Hello messages. On link B, the RP transmits Hello messages.
4. On link A, TR1 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of the RUT.
5. On link A, TR2 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR3.
6. On link A, TR3 transmits a Assert (*,G) message for multicast group ff1e::1:2 containing an assert metric worse than that of the RUT.
7. On link B, data for multicast group ff1e::1:2 is forwarded by RP.
8. On link C, data for multicast group ff1e::1:2 is forwarded by TR4.

*University of New Hampshire
InterOperability Laboratory*

9. On link A, data for multicast group ff1e::1:2 is forwarded by the TR3.
10. Observe the packets transmitted by the RUT on all links.

Part B: Receive Data Packet

11. On link A, TR1 and TR2 transmit Hello messages.
12. On link A and C, TR3 transmits Hello messages.
13. On link C and B, TR4 transmits Hello messages.
14. On link B, the RP transmits Hello messages.
15. On link A, TR2 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR3.
16. On link A, TR1 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of the RUT.
17. On link B, data for multicast group ff1e::1:2 is forwarded by RP.
18. On link C, data for multicast group ff1e::1:2 is forwarded by TR4.
19. On link A, data for multicast group ff1e::1:2 is forwarded by the TR3.
20. Observe the packets transmitted by the RUT on all links.

Part C: Receive Superior Assert

21. On link A, TR1 and TR2 transmit Hello messages.
22. On link A and C, TR3 transmits Hello messages.
23. On link C and B, TR4 transmits Hello messages.
24. On link B, the RP transmits Hello messages.
25. On link A, TR1 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of the RUT.
26. On link A, TR2 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR3.
27. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
28. On link C, data for multicast group ff1e::1:2 is forwarded by TR4.
29. On link A, data for multicast group ff1e::1:2 is forwarded by the TR3.
30. On link A, TR3 transmits a Assert (*,G) message for multicast group ff1e::1:2 containing an assert metric better than that of the RUT.
31. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Parts A,*
Step 10: The RUT must transition to the “I am Assert Winner” state. The RUT must then transmit an Assert (*,G) message for multicast group ff1e::1:2 and set its assert timer to 177 seconds (Assert_Time – Assert_Override_Interval). The RUT must forward multicast data onto link A.
- *In Part B,*
Step 20: The RUT must transition to the “I am Assert Winner” state. The RUT must then transmit an Assert (*,G) message for multicast group ff1e::1:2 and set its assert timer to 177 seconds (Assert_Time – Assert_Override_Interval). The RUT must forward multicast data onto link A.
- *In Part C,*
Step 31: The RUT must transition to “I am Assert Loser” state. The RUT must then set assert timer to 188 seconds (Assert_Time) and stop forwarding multicast data onto link A.

Possible Problems:

- None.

Test PIM_SM.5.10: (*,G) “I am Assert Winner” State Transition, Message Reception

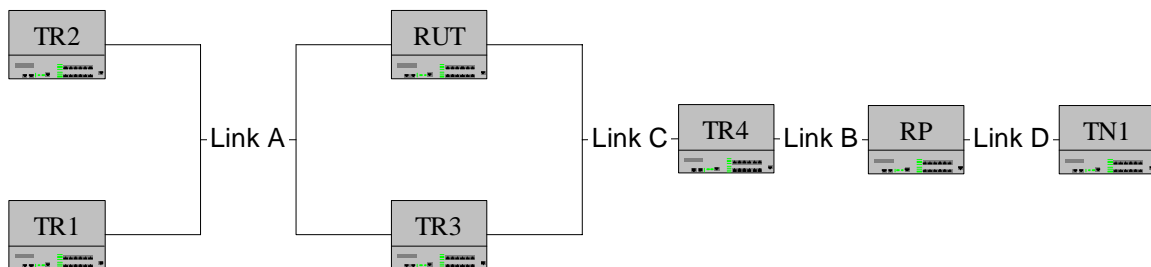
Purpose: To verify a router properly transitions while in (*,G) “I am Assert Winner” state when a message is received.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.6.2
[draft-ietf-pim-sm-v2-new-10] Figure 11: (*,G) Assert State-machine

Discussion: When in (*,G) “I am Assert Winner” state, the following events trigger transitions, but only if the (S,G) assert state machine is in NoInfo state:

- An inferior (*,G) assert is received. A router should resend a (*,G) Assert and reset the assert timer to (Assert_Time – Assert_Override_Interval).
- A (*,G) assert is received with a superior assert metric. A router should transition to “I am Assert Loser” state and set assert timer to Assert_Time.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. TR1 should list the RUT as its upstream next hop towards the RP. TR2 should list TR3 as its upstream next hop towards the RP.



Procedure:

Part A: Receive Inferior Assert

1. On link A, TR1 and TR2 transmit Hello messages.
2. On link A and C, TR3 transmits Hello messages.
3. On link C and B, TR4 transmits Hello messages.
4. On link B, the RP transmits Hello messages.
5. On link A, TR2 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR3.
6. On link A, TR1 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of the RUT.
7. On link A and C, data for multicast group ff1e::1:2 is forwarded by TR3 and the TR4.
8. On link A, TR3 transmits an Assert (*,G) message for multicast group ff1e::1:2 with an assert metric worse than that of the RUT.
9. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
10. On link C, data for multicast group ff1e::1:2 is forwarded by the TR4.
11. On link A, TR3 transmits another Assert (*,G) message for multicast group ff1e::1:2 with an assert metric worse than that of the RUT.

*University of New Hampshire
InterOperability Laboratory*

12. Observe the packets transmitted by the RUT on all links.

Part B: Receive Superior Assert

13. On link A, TR1 and TR2 transmit Hello messages.
14. On link A and C, TR3 transmits Hello messages.
15. On link C and B, TR4 transmits Hello messages.
16. On link B, the RP transmits Hello messages.
17. On link A, TR2 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR3.
18. On link A, TR1 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of the RUT.
19. On link A and 2, data for multicast group ff1e::1:2 is forwarded by TR3 and the TR4.
20. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
21. On link C, data for multicast group ff1e::1:2 is forwarded by the TR4.
22. On link A, TR3 transmits an Assert (*,G) for multicast group ff1e::1:2 with an assert metric worse than the RUT.
23. After RUT becomes Assert Winner, on link A, TR3 transmits an Assert (*,G) for multicast group ff1e::1:2 with an assert metric better than the RUT.
24. Observe the packets transmitted by the RUT on all links.

Part C: (S,G) Assert Received, RUT in "I am Winner State"

25. On link A, TR1 and TR2 transmit Hello messages.
26. On link A and C, TR3 transmits Hello messages.
27. On link C and B, TR4 transmits Hello messages. On link B, the RP transmits Hello messages.
28. On link A, TR2 transmits a Join (S,G) message with source address of TN1 for multicast group ff1e::1:2 to TR3.
29. On link A, TR1 transmits a Join (S,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
30. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
31. On link A and C, data for multicast group ff1e::1:2 is forwarded by TR3 and the TR4.
32. On link A, TR3 transmits an Assert (S,G) message for source of TN1 and multicast group ff1e::1:2 with an assert metric worse than that of the RUT.
33. On link A, TR3 transmits an Assert (*,G) message for multicast group ff1e::1:2 with an assert metric better than that of the RUT.
34. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 12: The RUT must remain in the "I am Assert Winner" state. The RUT must transmit an Assert (*,G) message for multicast group ff1e::1:2 and set its assert timer to 177 seconds (Assert_Time – Assert_Override_Interval). The RUT must forward multicast data onto link A.
- *In Part B,*
Step 24: The RUT must transition to the "I am Assert Loser" state. The RUT must then set assert timer to 188 seconds (Assert_Time) and stop forwarding multicast data onto link A.
- *In Part C,*

*University of New Hampshire
InterOperability Laboratory*

Step 34: The RUT must ignore the Assert (*,G) message transmitted by TR3 and continue forwarding multicast data for multicast group ff1e::1:2.

Possible Problems:

- None.

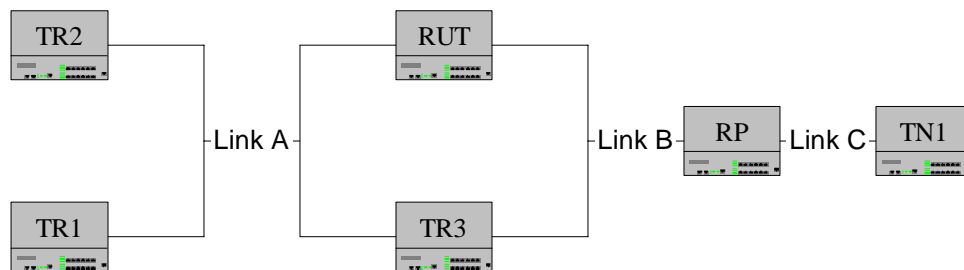
Test PIM_SM.5.11: (*,G) “I am Assert Winner” State Transition, Internal Event

Purpose: To verify a router properly transitions state while in (*,G) “I am Assert Winner” state and internal events occur.

References: [draft-ietf-pim-sm-v2-new-05] Section 4.6.2
[draft-ietf-pim-sm-v2-new-05] Figure 11: (*,G) Assert State-machine

Discussion: When in (*,G) “I am Assert Winner” state, the following events trigger transitions: The assert timer expires. A router should send a (*,G) Assert and reset the assert timer to (Assert_Time – Assert_Override_Interval). A change in (*,G) forwarding state or RPF interface causes a router to be unable to perform the operations of the assert winner. A router should transition to NoInfo state and send an AssertCancel (*,G).

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. TR1 should list the RUT as its upstream next hop towards the RP. TR2 should list TR3 as its upstream next hop towards the RP.



Procedure:

Part A: Timer Expires

1. On link A, TR1 and TR2 transmit Hello messages.
2. On link A and B, TR3 transmits Hello messages.
3. On link B, the RP transmits Hello messages.
4. On link A, TR2 transmits a Join (*,G) message for ff1e::1:2 with upstream neighbor address set to the address of TR3.
5. On link A, TR1 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of the RUT.
6. On link A and B, data for multicast group ff1e::1:2 is forwarded by TR3 and the RP.
7. On link A, TR3 transmits a (*,G)Assert message with a metric worse than the RUT’s.
8. Observe the packets transmitted by the RUT on all links.

Part B: PIM Disabled

9. On link A, TR1 and TR2 transmit Hello messages.
10. On link A and B, TR3 transmits Hello messages.
11. On link A, the RP transmits Hello messages.
12. On link A, TR2 transmits a Join (*,G) message with source address of TN1 for multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.
13. On link A, TR1 transmits a Join (*,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.

*University of New Hampshire
InterOperability Laboratory*

14. On link A and B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by TR3 and the RP.
15. Once the RUT transitions to the “I am Assert Winner” state, disable PIM on the RUT on link B.
16. Observe the packets transmitted by the RUT on all links.

Part C: PIM Disabled on upstream router

17. On link A, TR1 and TR2 transmit Hello messages.
18. On link A and B, TR3 transmits Hello messages.
19. On link A, the RP transmits Hello messages.
20. On link A, TR2 transmits a Join (*,G) message with source address of TN1 for multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.
21. On link A, TR1 transmits a Join (*,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
22. On link A and B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by TR3 and the RP.
23. RP ceases Hello message transmission on link B.
24. Observe the packets transmitted by the RUT on all links.

Part D: Prune Messages received

25. On link A, TR1 and TR2 transmit Hello messages.
26. On link A and B, TR3 transmits Hello messages.
27. On link A, the RP transmits Hello messages..
28. On link A, TR2 transmits a Join (*,G) message with source address of TN1 for multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.
29. On link A, TR1 transmits a Join (*,G) message with source address of TN1 and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
30. On link A and B, data from source of TN1 for multicast group ff1e::1:2 is forwarded by TR3 and the RP.
31. On link A, TR1 and TR2 transmit Prune (*,G) message with source address of TN1 for multicast group ff1e::1:2 and the upstream neighbor address of the RUT.
32. Observe the packets transmitted by the RUT on all links.

Observable Results:

- In Part A,
Step 8: The RUT must remain in the “I am Assert Winner” state and transmit an Assert message after 177 seconds (Assert_Time – Assert_Override_Interval). The assert timer must be reset to 177 seconds after each Assert transmission.
- In Parts B,
Step 16: The RUT must transition to the NoInfo state and send an AssertCancel (S,G) message for source of TN1 and multicast group ff1e::1:2. The RUT must not forward multicast data onto link A after the AssertCancel is transmitted.
- In Part C,
Step 24: The RUT must transition to the NoInfo state and send an AssertCancel (S,G) message for source of TN1 and multicast group ff1e::1:2. The RUT must not forward multicast data onto link A after the AssertCancel is transmitted.
- In Part D,

*University of New Hampshire
InterOperability Laboratory*

Step 32: The RUT must transition to the NoInfo state and send an AssertCancel (S,G) message for source of TN1 and multicast group ff1e::1:2. The RUT must not forward multicast data onto link A after the AssertCancel is transmitted.

Possible Problems:

- None.

Test PIM_SM.5.12: Transitions from (*,G) “I am Assert Loser” State, (S,G) NoInfo

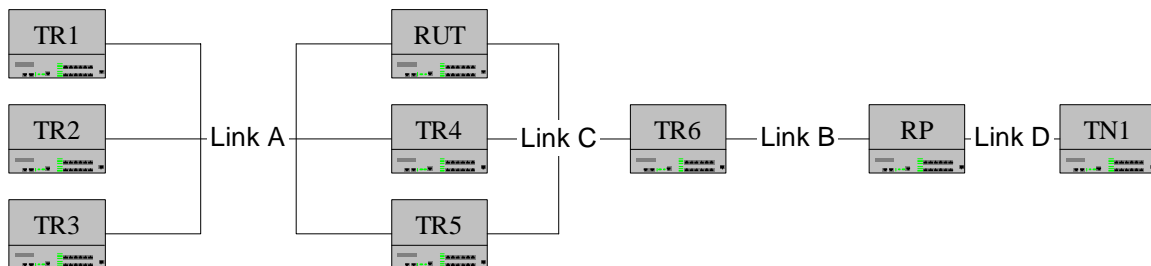
Purpose: To verify a router properly transitions state while in (*,G) “I am Assert Loser” State and (S,G) NoInfo state.

References: [draft-ietf-pim-sm-v2-new-10] Section 4.6.2
[draft-ietf-pim-sm-v2-new-10] Figure 11: (*,G) Assert State-machine

Discussion: When in “I am Assert Loser” state, the following events trigger transitions, but only if the (S,G) state machine is in the NoInfo state:

- An assert is received containing a metric better than that of the current assert winner. A router should store the new assert winner and set its assert timer to Assert_Time.
- An assert is received from the current winner, containing a metric better than the router’s own, but possibly worse than the winner’s previous. A router should set its assert timer to Assert_Time.
- An assert is received from the current winner, containing a metric worse than the router’s own. A router should transition to NoInfo state and allow the normal Join/Prune mechanisms to operate.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. TR1 should list the RUT as its upstream next hop towards the RP. TR2 should list TR4 as its upstream next hop towards the RP. TR3 should list TR5 as its upstream next hop towards the RP.



Procedure:

Part A: Receive Superior Assert

1. On link A, TR1, TR2 and TR3 transmit Hello messages.
2. On link A and C, TR4, TR5 and TR6 transmit Hello messages.
3. On link B, the RP transmits Hello messages.
4. On link A, TR2 transmits a Join (*,G) messages for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR3.
5. On link A, TR1 transmits a Join (*,G) messages with a multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
6. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
7. On link C, data from source of TN1 for multicast group ff1e::1:2 is forwarded by the TR6.
8. On link A, TR5 transmits an Assert (*,G) message for multicast group ff1e::1:2 with a better assert metric than the RUT and TR4, making TR5 the assert winner.

*University of New Hampshire
InterOperability Laboratory*

9. On link A, TR4 transmits a new Assert (*,G) messages for multicast group ff1e::1:2 with a better assert metric than TR5.
10. Observe the packets transmitted by the RUT on all links.

Part B: Receive Acceptable Assert from Current Winner

11. On link A, TR1, TR2 and TR3 transmit Hello messages.
12. On link A and C, TR4, TR5 and TR6 transmit Hello messages. On link B, the RP transmits Hello messages.
13. On link A, TR2 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR3.
14. On link A, TR1 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of the RUT.
15. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
16. On link C, data for multicast group ff1e::1:2 is forwarded by the TR6.
17. On link A, TR4 transmits an Assert (*,G) message for multicast group ff1e::1:2 with a better assert metric than the RUT, making TR3 the assert winner.
18. On link A, TR4 transmits another Assert (*,G) message for multicast group ff1e::1:2 with a new assert metric worse than its previously transmitted, but still better than the RUT's assert metric.
19. Observe the packets transmitted by the RUT on all links.

Part C: Receive Inferior Assert from Current Winner

20. On link A, TR1, TR2 and TR3 transmit Hello messages.
21. On link A and C, TR4, TR5 and TR6 transmit Hello messages.
22. On link B, the RP transmits Hello messages.
23. On link A, TR2 transmits a Join (*,G) message with a multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.
24. On link A, TR1 transmits a Join (*,G) message with multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
25. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
26. On link C, data for multicast group ff1e::1:2 is forwarded by the TR6.
27. On link A, TR3 transmits an Assert (*,G) message for source of TN1 and multicast group ff1e::1:2 with a better assert metric than the RUT, making TR3 the assert winner.
28. On link A, TR3 transmits another Assert (S,G) message for source of TN1 and multicast group ff1e::1:2 with a new assert metric worse than the RUT metric.
29. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Parts A,*
Step 10: The RUT must remain in the “I am Assert Loser” state and not forward data for multicast group ff1e::1:2 onto link A.
- *In Part B,*
Step 19: The RUT must remain in the “I am Assert Loser” state and not forward data for multicast group ff1e::1:2 onto link A.
- *In Part C,*
Step 28: The RUT must transition to the NoInfo state.

Possible Problems:

- None.

Test PIM_SM.5.13: Transitions from (*,G) “I am Assert Loser” State

Purpose: To verify a router properly transitions states while in (*,G) “I am Assert Loser” state.

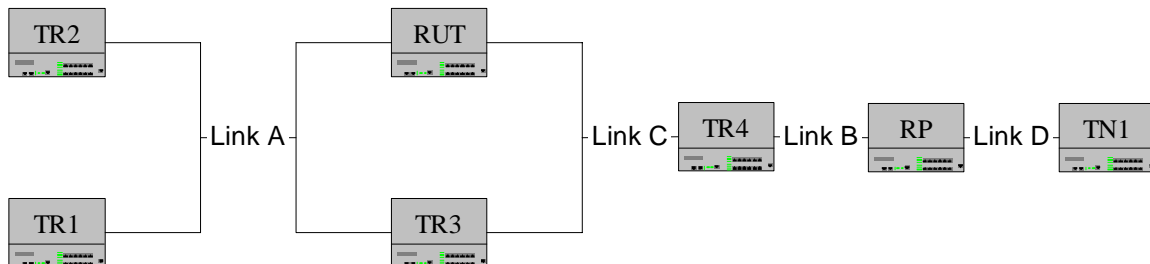
References: [draft-ietf-pim-sm-v2-new-05] Section 4.6.2

Last Modification: June 19, 2002

Discussion: When in “I am Assert Loser” state, the following events trigger transitions:

- The (*,G) assert timer expires. A router should transition to NoInfo state and delete the (*,G) assert information.
- A Hello Message containing a new GenID is received from the current assert winner. A router should transition to NoInfo state and delete this (*,G) assert information.
- The router’s forwarding state changes so that (*,G) Asserts on a given interface are no longer of interest. A router should transition to NoInfo state and delete the (*,G) assert information.
- The router’s assert metric becomes better than the current assert winner’s. A router should transition to NoInfo state, delete this (*,G) state and allow normal PIM Join/Prune mechanisms to operate.
- The RPF interface for S has changed. A router should transition to NoInfo state and delete this (*,G) assert state.
- A Join (*,G) or Join(*,*,RP) with the Upstream Neighbor Address field set to one of the router’s IP addresses. A router should transition to NoInfo state and allow the normal Join/Prune mechanisms to operate.

Test Setup: The RP should be statically configured for multicast group ff1e::1:2. TR1 should list the RUT as its upstream next hop towards the RP. TR2 should list TR3 as its upstream next hop towards the RP.



Procedure:

Part A: Timer Expires

1. On link A, TR1 and TR2 transmit Hello messages.
2. On link A and C, TR3 transmits Hello messages.
3. On link C and B, TR4 transmits Hello messages.
4. On link B, the RP transmits Hello messages.
5. On link A, TR2 transmits a Join (*,G) message for multicast group ff1e::1:2 upstream neighbor address set to the address of TR3.

*University of New Hampshire
InterOperability Laboratory*

6. On link A, TR1 transmits a Join (*,G) message for and multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
7. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
8. On link C, data for multicast group ff1e::1:2 is forwarded by the TR4.
9. On link A, TR3 transmits an Assert (*,G) message for multicast group ff1e::1:2 with a better assert metric than the RUT, making TR3 the assert winner.
10. Observe the packets transmitted by the RUT on all links.

Part B: Current Winner's GenID changes

11. On link A, TR1 and TR2 transmit Hello messages.
12. On link A and C, TR3 transmit Hello messages.
13. On link C and B, TR4 transmit Hello messages.
14. On link B, the RP transmits Hello messages.
15. On link A, TR2 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR3.
16. On link A, TR1 transmits a Join (*,G) message for multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
17. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
18. On link C, data for multicast group ff1e::1:2 is forwarded by the TR4.
19. On link A, TR3 transmits an Assert (*,G) for multicast group ff1e::1:2 with a better assert metric than the RUT, making TR3 the assert winner.
20. On link A, TR3 transmits a Hello message with a new GenID.
21. Observe the packets transmitted by the RUT on all links.

Part C: Lose Interest in Assert

22. On link A, TR1 and TR2 transmit Hello messages.
23. On link A and C, TR3 transmit Hello messages.
24. On link C and B, TR4 transmit Hello messages.
25. On link B, the RP transmits Hello messages.
26. On link A, TR2 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR3.
27. On link A, TR1 transmits a Join (*,G) message for multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
28. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
29. On link C, data for multicast group ff1e::1:2 is forwarded by the TR4.
30. On link A, TR3 transmits an Assert (*,G) message for multicast group ff1e::1:2 with a better assert metric than the RUT, making TR3 the assert winner.
31. On link A, TR1 transmits a Prune (*,G) message for multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
32. On link A, TR3 transmits an Assert (*,G) message for multicast group ff1e::1:2 with a new metric worse than the RUT's previously advertised metric.
33. Observe the packets transmitted by the RUT on all links.

Part D: RUT's metric becomes better than Assert Winner's

34. On link A, TR1 and TR2 transmit Hello messages.
35. On link A and C, TR3 transmit Hello messages.
36. On link C and B, TR4 transmit Hello messages.
37. On link B, the RP transmits Hello messages.
38. On link A, TR2 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR3.

*University of New Hampshire
InterOperability Laboratory*

39. On link A, TR1 transmits a Join (*,G) message for multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
40. On link A, TR3 transmits an Assert (*,G) message for multicast group ff1e::1:2 with a better assert metric than the RUT, making TR3 the assert winner.
41. TR3 has a worse unicast metric to the RP than the RUT.
42. Allow the link to re-converge.
43. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
44. On link C, data for multicast group ff1e::1:2 is forwarded by the TR4.
45. Observe the packets transmitted by the RUT on all links.

Part E: Receive Join (,G)*

46. On link A, TR1 and TR2 transmit Hello messages.
47. On link A and 1, TR3 transmit Hello messages.
48. On link C and B, TR4 transmit Hello messages
49. On link B, the RP transmits Hello messages.
50. On link A, TR2 transmits a Join (*,G) message for multicast group ff1e::1:2 with upstream neighbor address set to the address of TR3.
51. On link A, TR1 transmits a Join (*,G) message for multicast group ff1e::1:2 and upstream neighbor address set to the address of the RUT.
52. On link B, data for multicast group ff1e::1:2 is forwarded by the RP.
53. On link C, data for multicast group ff1e::1:2 is forwarded by the TR4.
54. On link A, TR3 transmits an Assert (*,G) for multicast group ff1e::1:2 with a better assert metric than the RUT, making TR3 the assert winner.
55. Observe the packets transmitted by the RUT on all links.

Observable Results:

- *In Part A,*
Step 10: The RUT must transition to the NoInfo state. The RUT must delete the assert info and must not forward the multicast data.
- *In Part B,*
Step 21: The RUT must transition to the NoInfo state. The RUT must delete the assert info and must not forward the multicast data.
- *In Part C,*
Step 33: The RUT must transition to the NoInfo state. The RUT must delete the assert info and must not forward the multicast data.
- *In Part D,*
Step 44: The RUT must transition to the NoInfo state. The RUT must delete the assert info and must not forward the multicast data.
- *In Part E,*
Step 55: The RUT must transition to the NoInfo state. The RUT must delete the assert info and must not forward the multicast data.

Possible Problems:

- None.