ROUTING CONSORTIUM

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

Technical Document

Revision 2.4

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MODIFICATION RECORD

Version 2.4 — March 19, 2009

- Updated Unknown Join Message parts A-C observable results to state the RUT must forward multicast data onto network 0
- Updated Join Message Destination Address part A to send a valid (*,*,RP) Join (was a (*,G) Join) from TR2 on Network 2.
- Updated Transition from Join (*,*,RP) State part A, Transition from (*,G) Join State part A, and Transition from (*,G) Join State part A observable results. The RUT should continue to forward for 105 seconds, not 210 seconds.
- Updated Transition from (*,G) Prune Pending State observable results – the RUT should start forwarding after receiving the Join message, not before.

Version 2.3 — June 7, 2007

- Updated to RFC 4601
- Removed test 1.6d

Version 2.2

- Fixed typos
- Changed topology for test 2.13

Version 2.1 — June 6, 2006

- Fixed typos and network numbering

Version 2.0 — May 14, 2006

- Removed the Assert Section (Section 5)

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INTRODUCTION

Overview

The University of New Hampshire's InterOperability Laboratory (IOL) is an institution designed to improve the interoperability of standards based products by providing an environment where a product can be tested against other implementations of a standard. This suite of tests has been developed to help implementers evaluate the functioning of their 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 **U**nder **T**est
TR: Testing **R**outer
RP: Rendezvous **P**oint
DR: Designated **R**outer
IGMP: Internet **G**roup **M**anagement **P**rotocol
MRIB: **M**ulticast **R**outing **I**nformation **B**ase
RPF: Reverse **P**ath **F**orwarding
TIB: Tree **I**nformation **B**ase
MFIB: Multicast **F**orwarding **I**nformation **B**ase

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 RFC 4601, section 4.11:

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:	Random value between 0 and 2.5
t_periodic:	60 Seconds
t_joinsuppress	Random value between 66 and 84

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 network, 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:

- Request for Comments 4601 – Protocol Independent Multicast - Sparse Mode (PIM-SM): Protocol Specification (Revised)
- Request for Comments 2236 – Internet Group Management Protocol, Version 2

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GROUP 1: Hello Messages and Designated Router Election

Scope:

The following 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 network. 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.

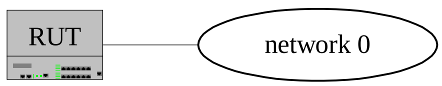
Test PIM-SM.1.1: Sending Hello Messages

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

References: [RFC 4601] – 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 224.0.0.13 (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: Enable PIM-SM on the RUT on network 0.



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 network 0.

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 network 0.

Observable Results:
- In Part A, the RUT should transmit a Hello Message to the ALL-PIM-ROUTERS multicast address 224.0.0.13 on network 0 every 30 seconds (Hello_Period).
- In Part B, the RUT should transmit a Hello Message to the ALL-PIM-ROUTERS multicast address 224.0.0.13 on network 0 every 90 seconds (Hello_Period).

Possible Problems: The RUT may not allow the Hello_Period value to be configured.

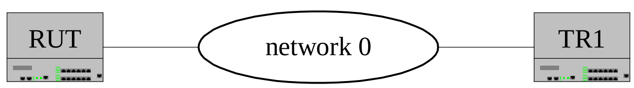
Test PIM-SM.1.2: Triggered Hello Messages

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

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. TR1 should not be running PIM-SM on network 0.



Procedure:

Part A: Message Reception from New Neighbor

1. Begin transmitting Hello messages from TR1 every 30 seconds.
2. Observe packets transmitted by the RUT on network 0.

Part B: New GenID Reception

3. TR1 transmits Hello messages on network 0.
4. TR1 transmits a Hello message with a new GenID on network 0.
5. Observe packets transmitted by the RUT on network 0.

Part C: Default Initial Hello Message Transmission

6. Disable PIM-SM and reset the RUT to factory defaults.
7. Enable PIM-SM on the RUT.
8. Observe the packets transmitted by the RUT on network 0.

Part D: Configured Initial Hello Message Transmission

9. Disable PIM-SM and configure the Hello_Period to a value of 10 seconds on the RUT.
10. Enable PIM-SM on the RUT.
11. Observe the packets transmitted by the RUT on network 0.

Observable Results:

- In all Parts, the RUT should transmit the first Hello Message in less than Triggered_Hello_Delay (5) seconds.
- In Parts C and D, 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.

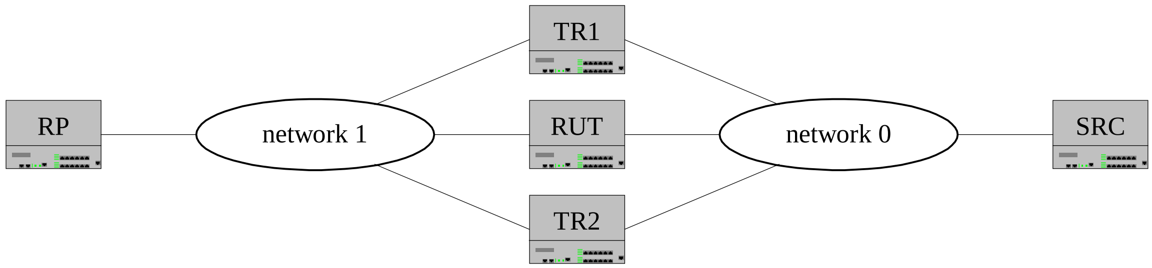
References: [RFC 4601] – Sections 4.3.1 and 4.3.2

Discussion: The DR Priority Option allows the network administrator to allow a particular router to win the DR election process by giving it a numerically larger DR Election Priority. The DR Priority Option SHOULD be included in every Hello message, even if no DR 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 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 Priority Option.

The DR 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:
- PIM-SM should be enabled on the RUT on network 0.
- The RUT should be configured to have a DR Priority of 1.
- TR1 should be configured to have a DR Priority of 2 and an IP address lower than that of TR2 and the RUT.
- TR2 should be configured to have a DR Priority of 1 and an IP address higher than that of TR1 and the RUT.



Procedure:

Part A: RUT has lower DR Priority

1. On network 1, the RP, TR1 and TR2 transmit Hello messages.
2. On network 0, TR1 and TR2 transmit Hello messages.
3. On network 0, the SRC transmits data packets with a multicast destination of 224.0.6.130.
4. Observe packets transmitted by the RUT on network 0.

Part B: RUT has equivalent priority and lower IP Address

5. Configure the RUT to have a DR Priority of 2 and an IP address lower than that of TR1.
6. On network 1, the RP, TR1, and TR2 transmit Hello messages.
7. On network 0, TR1 and TR2 transmit Hello messages.
8. On network 0, the SRC transmits data packets with a multicast destination of 224.0.6.130.
9. Observe packets transmitted by the RUT on network 0.

Part C: RUT has higher DR Priority

10. Configure the RUT to have a DR Priority of 3.
11. On network 1, the RP, TR1, and TR2 transmit Hello messages.
12. On network 0, TR1 and TR2 transmit Hello messages.
13. On network 0, the SRC transmits data packets with a multicast destination of 224.0.6.130.
14. Observe packets transmitted by the RUT on network 0.

Part D: RUT has equivalent priority and higher IP address

15. Configure RUT to have a DR Priority of 2.
16. On network 1, the RP, TR1, and TR2 transmit Hello messages.
17. On network 0, TR1 and TR2 transmit Hello messages.
18. On network 0, the SRC transmits data packets with a multicast destination of 224.0.6.130.
19. Observe the packets transmitted by the RUT on network 0.

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

20. TR2 has an IP address lower than that of the RUT.
21. On network 1, the RP, TR1, and TR2 transmit Hello messages.
22. On network 0, TR1 transmit Hello messages.
23. On network 0, TR2 transmits Hello Messages without the DR Priority Option.
24. On network 0, the SRC on network 0 transmits data packets with a multicast destination of 224.0.6.130.
25. Observe the packets transmitted by the RUT on network 1.

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

26. TR1 has an IP address higher than that of the RUT. TR2 has an IP address lower than that of the RUT.
27. On network 1, the RP, TR1 and TR2 transmit Hello messages.
28. On network 0, TR1 transmits Hello messages.
29. On network 0, TR2 transmits Hello Messages without the DR Priority Option.
30. On network 0, the SRC transmits data packets with a multicast destination of 224.0.6.130.
31. Observe the packets transmitted by the RUT on network 0.

Observable Results:

- In Parts A, B and F, TR1 should be elected DR. The RUT should not forward the multicast data received on network 0.
- In Parts C, D and E, the RUT should be elected DR and encapsulate the multicast data packets on network 0 and forward them to the RP on network 1.

Possible Problems: The RUT may not implement the DR Priority Option.

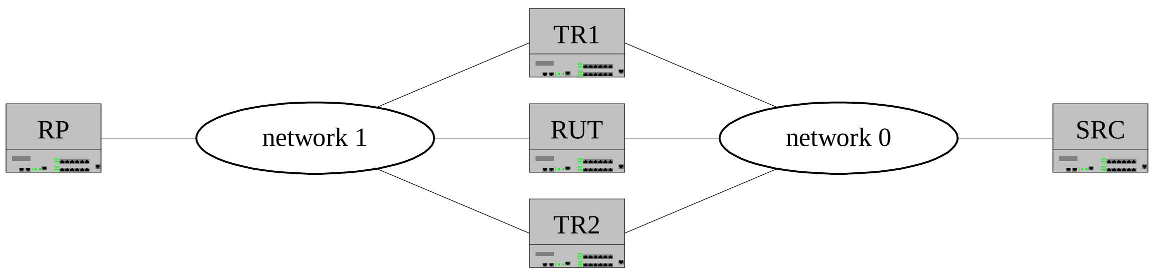
Test PIM-SM.1.4: Change of DR

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

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. 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 network 1, the RP and TR1 transmit Hello messages.
3. On network 0, TR1 transmits a Hello message with a DR Priority of 3.
4. The SRC on network 0 transmits data packets with a multicast destination of 224.0.6.130.
5. Configure the RUT to have a DR Priority of 5.
6. On network 0, the SRC transmits data packets with a multicast destination of 224.0.6.130.
7. Observe the packets transmitted by the RUT on all networks.

Part B: DR Priority decrease transmission

8. Configure the RUT to have a DR Priority of 4.
9. On network 1, the RP and TR1 transmit Hello messages.
10. On network 0, TR1 transmits a Hello message with a DR Priority of 2.
11. On network 0, the SRC transmits data packets with a multicast destination of 224.0.6.130.
12. Configure the RUT to have a DR Priority of 1.
13. On network 0, the SRC host on network 0 transmits data packets with a multicast destination of 224.0.6.130.
14. Observe the packets transmitted by the RUT on all networks.

Part C: DR Priority increase reception

15. Configure the RUT to have a DR Priority of 4.
16. On network 1, the RP and TR1 transmit Hello messages.
17. On network 0, TR1 transmits a Hello message with a DR Priority of 2.
18. On network 0, the SRC transmits data packets with a multicast destination of 224.0.6.130.
19. On network 0, TR1 transmits a Hello message with a DR Priority of 5.
20. On network 0, the SRC transmits data packets with a multicast destination of 224.0.6.130.
21. Observe the packets transmitted by the RUT on all networks.

Part D: DR Priority decrease reception

22. Configure the RUT to have a DR Priority of 3.
23. On network 1, the RP and TR1 transmit Hello messages.
24. On network 0, TR1 transmits a Hello message with a DR Priority of 5.
25. On network 0, the SRC transmits multicast data packets with a multicast destination of 224.0.6.130.
26. On network 0, TR1 transmits a Hello message with a DR Priority of 2.
27. On network 0, the SRC transmits multicast data packets with a multicast destination of 224.0.6.130.
28. Observe the packets transmitted by the RUT on all networks.

Part E: DR Timeout

29. Configure the RUT to have a DR Priority of 4.
30. On network 1, the RP and TR1 transmit Hello messages.
31. On network 0, TR1 transmits a Hello message with a DR Priority of 3.
32. On network 0, TR2 transmits a Hello message with a DR Priority of 9.
33. On network 0, the SRC transmits multicast data packets with a multicast destination of 224.0.6.130.
34. On network 0, TR2 ceases transmission of Hello messages.
35. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Parts A and D, the RUT should elect TR1 the DR. The RUT should not forward any of the multicast data received on network 0. After the priority is reconfigured, the RUT should win the DR election and thus encapsulate and transmit the data received on network 0 onto network 1.
- In Parts B and C, the RUT should be elected the DR and thus encapsulate and transmit the data received on network 0 onto network 1. After the priority is reconfigured, TR1should win the DR election. The RUT should not forward any of the multicast data received on network 0 after the priority is reconfigured.
- In Part E, after TR2 ceases transmission of Hello messages on network 0, the RUT should be elected the DR on network 0. The RUT should start to encapsulate the data and forward it to network 1.

Possible Problems: None.

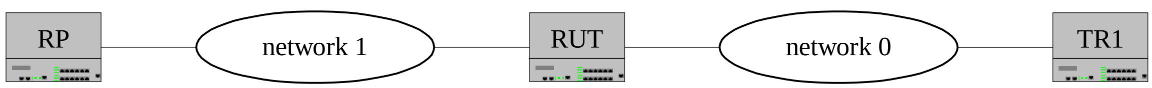
Test PIM-SM.1.5: Generation ID in DR Election

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

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0.



Procedure:
Part A: New GenID for RUT
1. Observe value of GenID transmitted by the RUT on network 0.
2. Restart PIM-SM on the RUT.
3. Observe packets transmitted by the RUT on network 0.
4. Repeat steps 1 to 3 with a large enough sample size to ensure that the GenID is a random number.

Part B: New GenID for The RP
5. On network 0 and 1, the RP and TR1 transmit Hello messages.
6. On network 0, TR1 transmits a (*,G) Join message for group 224.0.6.130
7. On network 1, the RP transmits a Hello message with a new GenID

Observable Results:
- In Part A, the RUT should advertise a new GenID each time it is restarted. The GenID observed should be random.
- In Part B, The RUT should send a join message to the RP for group 224.0.6.130. After the new GenID is received the RUT should send another join message to the RP.

Possible Problems: The RUT may not include the GenID Option in its Hello Messages.

Test PIM-SM.1.6: Holdtime in Hello Messages

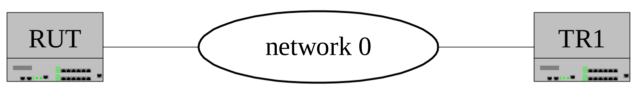
Purpose: To verify that a router properly handles the Hello Holdtime Option.

References: [RFC 4601] – Sections 4.3.1, and 4.3.2.

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: Enable PIM-SM on the RUT on network 0.



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 network 0.

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 network 0.

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 network 0.

Part D: Reception of zero Holdtime Value

10. TR1 transmits several properly formatted Hello messages. TR1 then transmits a Hello message with a Holdtime containing a zero value.
11. TR1 ceases Hello message transmission.
12. Observe packets transmitted by the RUT on network 0.

Part E: Interface on RUT disabled

13. TR1 transmits several properly formatted Hello messages.
14. Disable the RUT's interface to network 0.
15. Observe packets transmitted by the RUT on network 0.

Part F: IP Address of Interface Changed

16. TR1 transmits several properly formatted Hello messages.
17. Change the IP address of the RUT's interface to network 0.
18. Observe packets transmitted by the RUT on network 0.

Observable Results:

- In Part A the RUT should transmit Hello messages with a value of 105 in the Holdtime field.
- In Part B, when TR1 stops transmitting Hello messages, the RUT should wait 140 seconds before removing TR1 from its neighbor list.
- In Part C, when TR1 stops transmitting Hello messages, the RUT should wait 105 seconds before removing TR1 from its neighbor list.
- In Part D, the RUT should immediately remove TR1 from its neighbor list.
- In Parts E and F, 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:

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

Overview:

When a router is connected to a multicast network, 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.

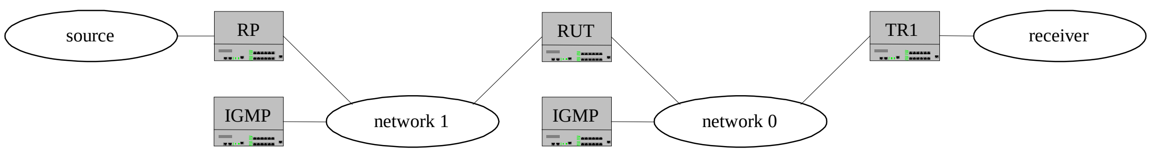
Test PIM-SM.2.1: Forwarding Packets

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

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for group 224.0.6.130. The RUT is the DR for network 0 and network 1.



Procedure:
Part A: Join (,G) Received on downstream network.*
1. On network 0 and 1, the RP and TR1 transmit Hello messages.
2. On network 0, TR1 transmits a (*,G) Join message for the group 224.0.6.130.
3. The RP forwards data packets from the multicast group 224.0.6.130.
4. Observe the packets transmitted by the RUT on all networks.

Part B: IGMP report received on downstream network.
5. On network 1, the RP transmits Hello messages.
6. On network 0, transmit IGMP reports for 224.0.6.130. This should cause the RUT to send a (*,G) Join upstream to the RP.
7. The RP forwards data packets from the multicast group 224.0.6.130.
8. Observe the packets transmitted by the RUT on all networks.

Part C: IGMP reports on upstream and downstream networks.
9. On network 1, the RP transmits Hello messages.
10. On network 0, transmit IGMP reports for 224.0.6.130.
11. On network 1, transmit IGMP reports for 224.0.6.130.
12. The RP forwards data packets from the multicast group 224.0.6.130.
13. On network 0, transmit an IGMP Leave message.
14. Observe the packets transmitted by the RUT on all networks.

Observable Results:
- In Parts A and B, the RUT should forward the data packets onto network 0.
- In Part C, the RUT should forward the data onto network 0 until the Leave message is received.

Possible Problems: None

Test PIM-SM.2.2: Encapsulate Packets

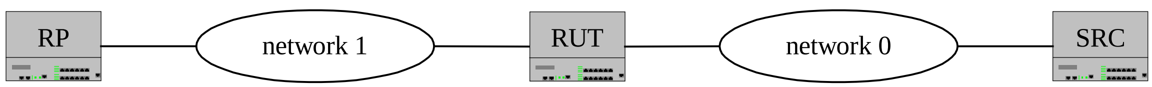
Purpose: To verify that a router properly encapsulates data packets.

References: [RFC 4601] – Section 4.4.1

Last Modification: June 14, 2002

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: Enable PIM-SM on the RUT on network 0. The RUT should be the DR for network 1. The RP should be statically configured for multicast group 224.0.6.130.



Procedure:
Part A: Encapsulate Packets
1. On network 1, the RP transmits Hello messages.
2. On network 0, the SRC transmits data packets with a multicast destination of 224.0.6.130.
3. Observe the packets transmitted by the RUT on all networks.

Observable Results:
- In Part A, the RUT should encapsulate the data packets and forward the packets upstream to network 1 for the RP.

Possible Problems: None.

Test PIM-SM.2.3: Forwarding Encapsulated Data Packets

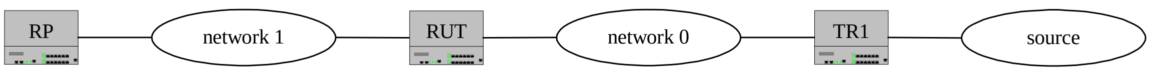
Purpose: To verify that a router properly forwards encapsulated data packets.

References: [RFC 4601] – Section 4.2

Last Modification: June 17, 2002

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: Enable PIM-SM on the RUT on network 0. The RUT should be the DR for network 0 and network 1. TR1 is the DR for the source network. The RP should be statically configured for multicast group 224.0.6.130.



Procedure:
Part A: Forwarding Encapsulated Data Packets
1. On networks 0 and 1, the RP and TR1 transmit Hello messages.
2. On network 0, TR1 transmits encapsulated data packets for multicast group 224.0.6.130 from the source network.
3. Observe the packets transmitted by the RUT on all networks.

Observable Results:
- In Part A, the RUT should forward the encapsulated data packets from network 0 onto network 1 for the RP.

Possible Problems: None.

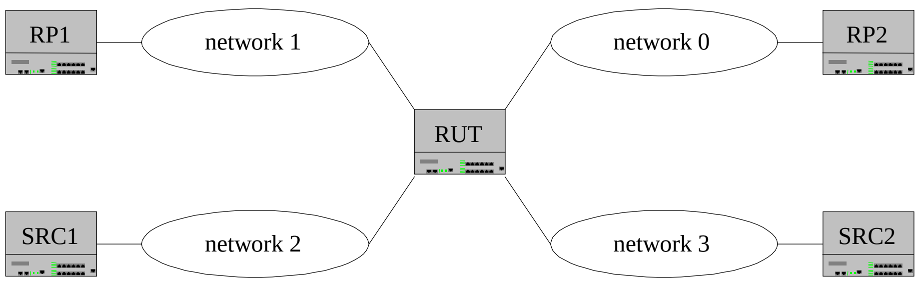
Test PIM-SM.2.4: Encapsulation for Multiple RP's

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

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. The RP1 is statically configured for the multicast group 224.0.6.130 and RP2 is statically configured for the multicast group 224.0.6.131. The RUT is the DR for all networks.



Procedure:
Part A: Encapsulation for Multiple RPs
1. On networks 0 and 1, RP2 and RP1 transmit Hello messages.
2. On network 2, the SRC1 transmits data with a multicast destination address of 224.0.6.130.
3. On network 3, the SRC2 transmits data with a multicast destination address of 224.0.6.131.
4. Observe the packets transmitted by the RUT on all networks.

Observable Results:
- In Part A, the RUT should encapsulate the data packets from network 2 and transmit them onto network 1. The RUT should encapsulate the data packets from network 3 and transmit them onto network 0.

Possible Problems: None.

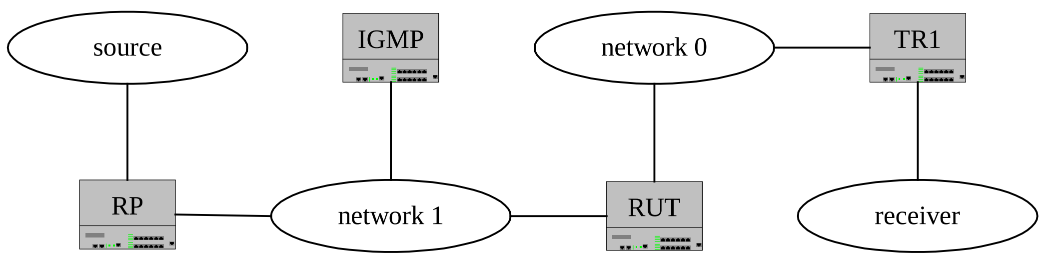
Test PIM-SM.2.5: Source Packets

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

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for group 224.0.6.130. RUT is the DR for network 0 and 1.



Procedure:
Part A: Source Packets
1. On network 0 and 1, TR1 and the RP transmit Hello messages.
2. On network 0, TR1 transmits an (S,G) Join message with a group address 224.0.6.130 and a source address of 10.10.15.81.
3. On network 1, transmit IGMP reports for the group 224.0.6.130.
4. On network 1, the RP transmits data packets from the multicast group 224.0.6.130 with a source address of 10.10.15.80.
5. On network 1, the RP transmits data packets from the multicast group 224.0.6.130 with a source address of 10.10.15.81.
6. Observe the packets transmitted by the RUT on all networks.

Observable Results:
- In Part A, the RUT should forward the data with a source address of 10.10.15.81 onto network 0. The data with a source address of 10.10.15.80 should not be forwarded.

Possible Problems: None.

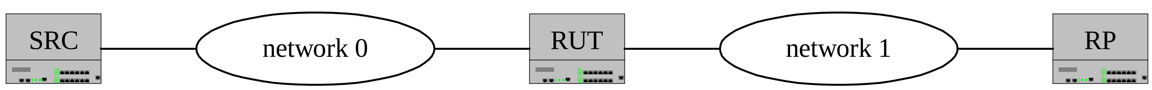
Test PIM-SM.2.6: Forwarding Encapsulated and Decapsulated Data Packets

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

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for group 224.0.6.130. The RUT is the DR for network 0.



Procedure:
Part A: Forwarding Encapsulated and Decapsulated Data Packets

1. On network 1, the RP transmits Hello messages.
2. On network 0, the SRC with an IP address of 10.10.10.80 transmits data packets with a multicast group address of 224.0.6.130. The RUT should encapsulate these packets and forward them to the RP.
3. The RP transmits a Join (S,G) with the source 10.10.10.80 and the group address of 224.0.6.130.
4. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, the RUT should forward both encapsulated and decapsulated data packets onto network 1.

Possible Problems: None.

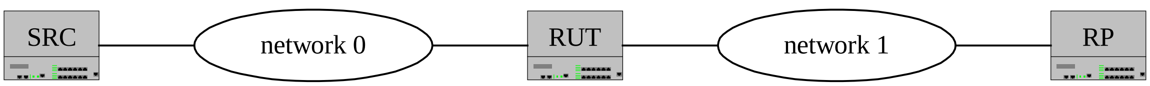
Test PIM-SM.2.7: Register-Stop (S,G)

Purpose: To verify that a router properly accepts a Register-Stop message

References: [RFC 4601] – 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 travels 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 Register-Stop message back to S's DR to prevent the DR unnecessarily encapsulating the packets.

Test Setup: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for group 224.0.6.130. The RUT is the DR for the source. The RUT is the DR for network 0.



Procedure:
Part A: Register-Stop (S,G)

1. On network 1, the RP transmits Hello messages.
2. On network 0, the SRC with an IP address of 10.10.10.80 transmits data packets with a multicast group address of 224.0.6.130. The RUT should encapsulate these packets and forward them to the RP.
3. The RP transmits a Join (S,G) with the source 10.10.10.80 and the group address of 224.0.6.130.
4. After the RP receives both the encapsulated and decapsulated data packets, the RP transmits a Register-Stop to the RUT on network 1.
5. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, upon receiving the Register-Stop, the RUT should stop forwarding the encapsulated data packets. The native data packets should continue to be forwarded onto network 1.

Possible Problems: None.

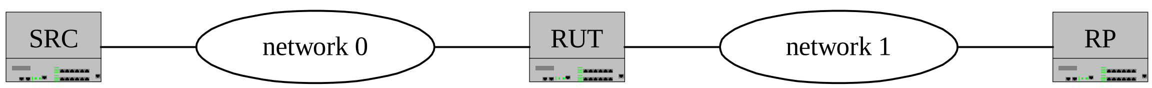
Test PIM-SM.2.8: Register-Stop (*,G)

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

References: [RFC 4601] – Section 4.4.1

Discussion: An RP compliant to RFC 2326 may send a Register-Stop 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 Register-Stop (*,G) is ambiguous or incorrect in some circumstances. In the newly revised PIM-SM specification, an RP should not send Register-Stop (*,G) message, but for compatibility, a DR should be able to accept one if it is received.

Test Setup: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for the multicast group 224.0.6.130. The RUT should be the DR for network 1.



Procedure:
Part A: Register-Stop (,G)*
1. On network 1, the RP transmits Hello messages.
2. On network 0, the SRC transmit data packets with a multicast destination of 224.0.6.130. The RUT should encapsulate these data packets and forward them onto network 1.
3. On network 1, the RP transmits a Join(S,G) for group 224.0.6.130.
4. The RP transmits a Register-Stop (*,G) for the multicast group 224.0.6.130 containing a source address set to a value of all zeros.
5. Observe the packets transmitted by the RUT on all networks.

Observable Results:
- In Part A, upon receiving the Register-Stop, the RUT should accept the Register-Stop and stop encapsulating data.

Possible Problems: None.

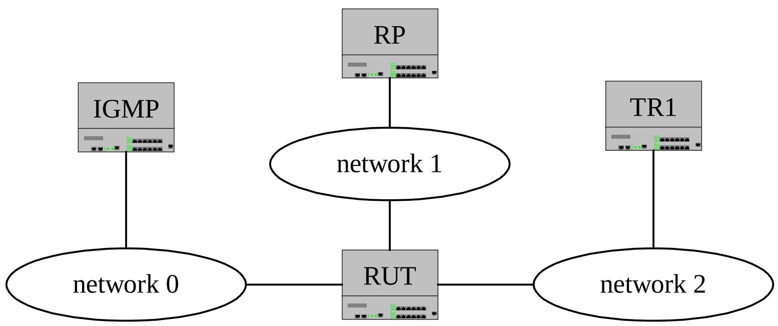
Test PIM-SM.2.9: Data Forwarding to Several Networks

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

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for group 224.0.6.130. The RUT is the DR for network 0 and network 1.



Procedure:
Part A: Received (,G) Join*
1. On network 1 and 2, The RP and TR1 transmit Hello messages.
2. On network 2, TR1 transmits a (*,G) Join message for the group 224.0.6.130.
3. On network 0, transmit IGMP reports for 224.0.6.131.
4. The RP forwards data packets from the multicast group 224.0.6.130.
5. Observe the packets transmitted by the RUT on all networks.

Part B: Received IGMP Report
6. On network 1 and 2, The RP and TR1 transmit Hello messages.
7. On network 2, TR1 transmits a (*,G) Join message for the group 224.0.6.130.
8. On network 0, transmit IGMP reports for 224.0.6.130.
9. The RP forwards data packets from the multicast group 224.0.6.130.
10. Observe the packets transmitted by the RUT on all networks.

Part C: IGMP Leave Message
11. On network 1 and 2, The RP and TR1 transmit Hello messages.
12. On network 2, TR1 transmits a (*,G) Join message for the group 224.0.6.130.
13. On network 0, transmit IGMP reports for 224.0.6.130.
14. The RP forwards data packets from the multicast group 224.0.6.130.
15. On network 0, transmit IGMP leave message for 224.0.6.130.
16. Observe the packets transmitted by the RUT on all networks.

Observable Results:
- In Part A, the RUT should forward the data packets from network 1 to network 2.

- In Part B, the RUT should forward the data packets from network 1 to networks 0 and 2.
- In Part C, the RUT should forward the data packets from network 1 to networks 0 and 2. After the Leave Message is received, data packets should only be forwarded onto network 2.

Possible Problems: None

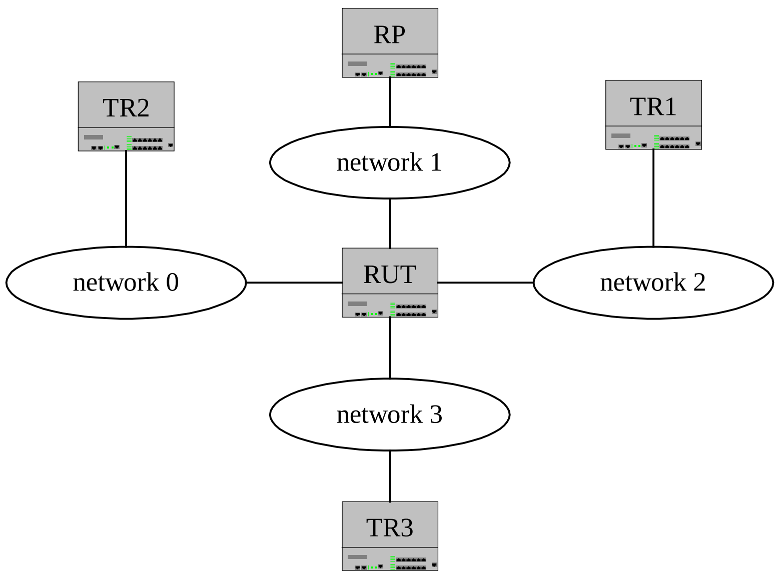
Test PIM-SM.2.10: Multiple Sources

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

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for group 224.0.6.130.



Procedure:

Part A: Multiple Sources

1. On networks 1, 2, 0 and 3, the RP, TR1, TR2 and TR3 transmit Hello messages.
2. On network 2, TR1 transmits an (S,G) Join for the multicast group 224.0.6.130 containing a source of 10.10.15.80.
3. On network 0, TR2 transmits an (S,G) Join for the multicast group 224.0.6.130 containing a source of 10.10.15.84.
4. On network 3, TR3 transmits a (*,G) Join for the multicast group 224.0.6.130.
5. The RP transmits data packets from the multicast group 224.0.6.130 from the source 10.10.15.80.
6. On network 1, The RP transmits data packets from the multicast group 224.0.6.130 from the source 10.10.15.84.
7. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, the RUT should forward the multicast data with a source address of 10.10.15.80 from network 1 to network 2. The RUT should forward the multicast data with a source address of 10.10.15.84 from network 1 to network 0. The RUT should forward both streams of multicast data from network 1 to network 3.

Possible Problems: None.

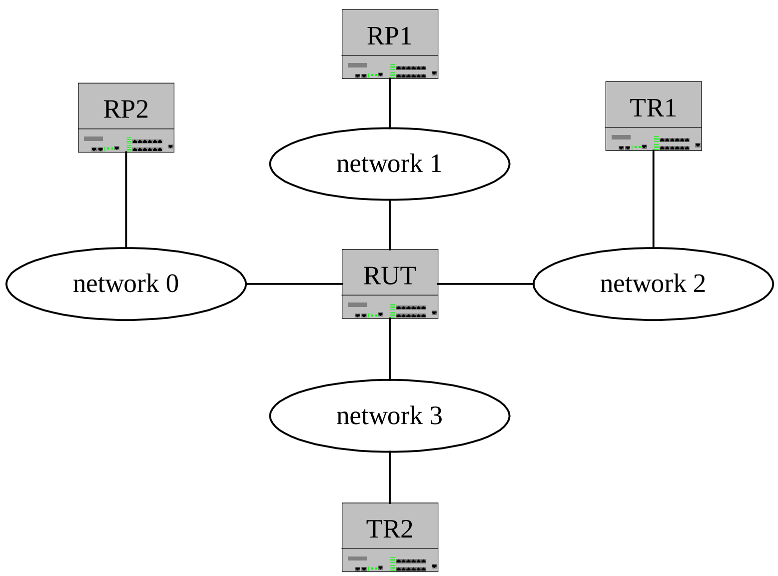
Test PIM-SM.2.11: Forwarding From Multiple RPs

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

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. RP1 is statically configured for the multicast group 224.0.6.130 and RP2 is statically configured for the multicast group 224.0.6.131.



Procedure:
Part A: Forwarding From Multiple RPs
1. On network 0, 1, 2, and 3, RP2, RP1, TR1, and TR2 transmit Hello messages.
2. On network 2, TR1 transmits a (*,G) Join for the multicast group 224.0.6.130.
3. On network 3, TR2 transmits a (*,G) Join for the multicast group 224.0.6.131.
4. On network 1, RP1 transmits data packets from the multicast group 224.0.6.130.
5. On network 0, RP2 transmits data packets from the multicast group 224.0.6.131.
6. Observe the packets transmitted by the RUT on all networks.

Observable Results:
- In Part A, the RUT should forward the data packets with a multicast destination of 224.0.6.130 from network 1 onto network 2. The RUT should forward the data packets with a multicast destination of 224.0.6.131 from network 0 onto network 3.

Possible Problems: None.

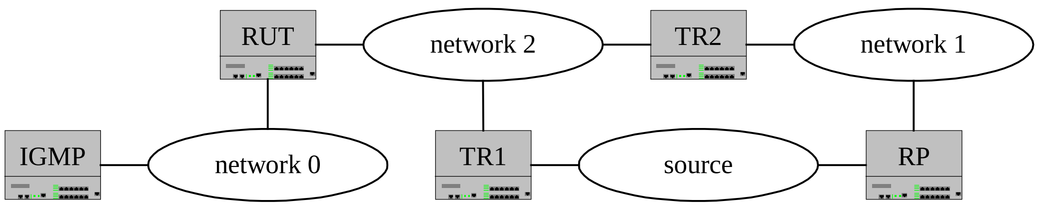
Test PIM-SM.2.12: PIM Tree Receiver

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

References: [RFC 4601] – 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 an (S,G) Join upstream and form the shortest-path tree.

Test Setup: Enable PIM-SM on the RUT on network 0. The RP should be statically configured to be 224.0.6.130. The RUT is the DR for network 0. RUT has a route to the RP through TR2. The RUT has a route to the source network through TR1.



Procedure:
Part A: RP Tree Initialization
1. On networks 2, TR1 and TR2 transmit Hello messages.
2. On network 0, transmit IGMP reports for 224.0.6.130. This should cause the RUT to send a (*,G) Join upstream to the RP.
3. On network 1, the RP will transmit the data packets. The multicast destination address of the data is 224.0.6.130. TR2 will forward the data packets on to network 2.
4. Observe the packets transmitted by the RUT on all networks.

Part B: SPT Switch
5. On network 1, the RUT transmits a Join (S,G) with the source address of 10.10.15.80 and a group address of 224.0.6.130.
6. On network 2, TR1 transmits multicast data packets to TR1.
7. Both TR1 and TR2 are transmitting multicast data packets with a source address of 10.10.15.80 with a group address of 224.0.6.130.
8. Observe the packets transmitted by the RUT on all networks.

Observable Results:
- In Part A, the RUT should forward multicast data packets from network 2 to network 0.
- In Part B, on network 2 the RUT should continue to forward the data packets from network 2.

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

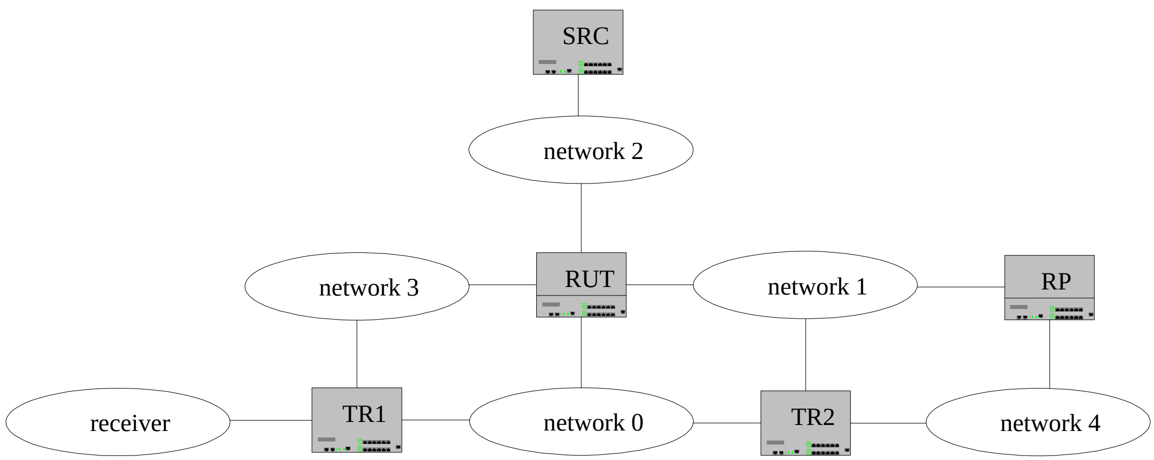
Test PIM-SM.2.13: PIM Tree - Source

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

References: [RFC 4601] – Section 3

Discussion: When connected to the source network 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: Enable PIM-SM on the RUT on network 0. The RP is statically configured for the multicast group 224.0.6.130, the RP address is 10.10.11.69 (network 1). The RUT is the DR for network 2. TR1's route to the RP is through TR2 on network 0. TR1's route to network 2 is through the RUT on network 3. The RUT's route to the RP is through network 1.



Procedure:

Part A: RP Tree

1. On network 1, the RP transmits Hello messages. On network 0, TR1 and TR2 transmits Hello messages.
2. On network 2, SRC transmits multicast data packets for the multicast group 224.0.6.130.
3. On network 0, TR1 transmits a (*,G) Join with a group address of 224.0.6.130.

Part B: Register Stop

4. On network 1, the RP transmits a Join (S,G) with the source address of 10.10.12.80 and a group address of 224.0.6.130.
5. The RP transmits a Register-Stop message on network 2 to the RUT.
6. Observe the packets transmitted by the RUT on all networks.

Part C: shortest-path tree

7. On network 3, the TR1 transmits an (S,G) Join with the source address of 10.10.12.80 and a group address of 224.0.6.130. TR1 receives two copies of the data packets. One from the SPT and one from the RPT.
8. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, the RUT should encapsulate the data packets from SRC and forward them to the RP on network 1.
- In Part B, the RUT should stop encapsulating the data. The RUT should forward data from network 2 onto network 1.
- In Part C, the RUT should forward data packets from network 2 to network 3.

Possible Problems: None.

GROUP 3: Reception of Join and Prune Messages

Scope:

The following 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.

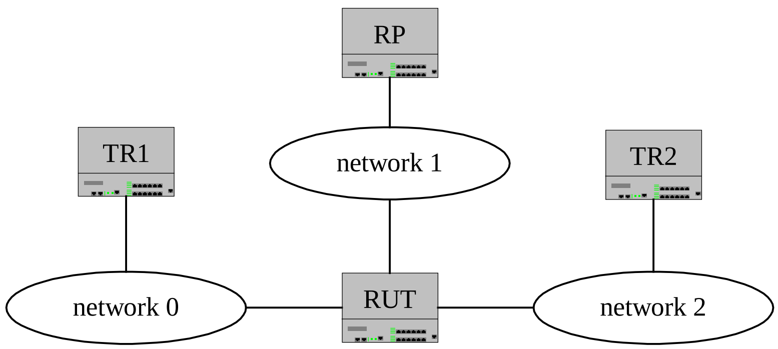
Test PIM-SM.3.1: Unknown Join Messages

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

References: [RFC 4601] – Sections 4.5 and 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for group 224.0.6.130.



Procedure:
Part A: Join (,*,RP) from Unknown Neighbor*
1. On network 0 and 1, TR1 and the RP transmit Hello messages.
2. On network 0 TR1 transmits a Join (*,*,RP) message with a source address of the RP.
3. On network 2, TR2 transmits a Join (*,*,RP) message with a source address of the RP.
4. On network 1, data for multicast group 224.0.6.130 is forwarded by the RP.
5. Observe the packets transmitted by the RUT on all networks.

Part B: Join (,G) from Unknown Neighbor*
6. On networks 0 and 1, TR1 and the RP transmit Hello messages.
7. On network 0, TR1 transmits a Join (*,G) message for the multicast group 224.0.6.130.
8. On network 2, TR2 transmits a Join (*,G) message for the multicast group 224.0.6.130.
9. On network 1, data for multicast group 224.0.6.130 is forwarded by the RP.
10. Observe the packets transmitted by the RUT on all networks.

Part C: Join (S,G) from Unknown Neighbor
11. On network 0 and 1, TR1 and the RP transmit Hello messages.
12. On network 0, TR1 transmits a Join (S,G) message with a source address of 10.10.15.80 for the multicast group 224.0.6.130.
13. On network 2, TR2 transmits a Join (S,G) message with a source address of 10.10.15.80 for the multicast group 224.0.6.130.
14. On network 1, data for multicast group 224.0.6.130 is forwarded by the RP.
15. Observe the packets transmitted by the RUT on all networks.

Part D: Join Message from Neighbor

16. On network 0, 1 and 2, the TR1, RP and TR2 transmit Hello messages.
17. On network 0, TR1 transmits a Join (*,G) message for the multicast group 224.0.6.130.
18. On network 2, TR2 transmits a Join (*,G) message for the multicast group 224.0.6.130.
19. On network 1, data for multicast group 224.0.6.130 is forwarded by the RP.
20. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Parts A, B, and C, the RUT should not forward the multicast data onto network 2. The RUT should forward the multicast data onto network 0.
- In Part D, the RUT should forward the multicast data onto network 0 and 2.

Possible Problems: None.

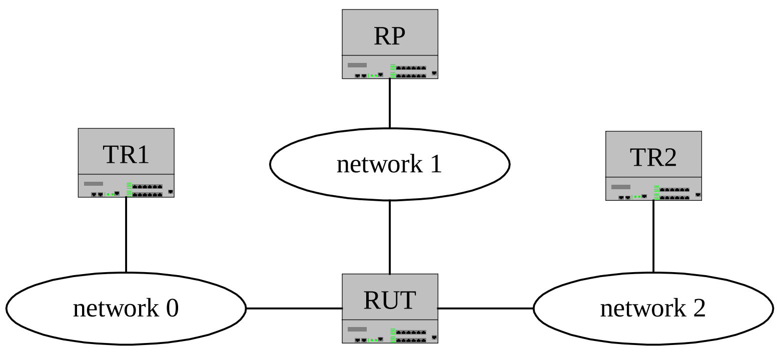
Test PIM-SM.3.2: Join Messages Destination Address

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

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for multicast group 224.0.6.130.



Procedure:
Part A: Unknown Destination in Join (,*,RP)*
1. On networks 0, 1, and 2, TR1, RP and TR2 transmit Hello messages.
2. On network 0, TR1 transmits a Join (*,*,RP) message with a source address of the RP. The upstream neighbor address field should contain the address of TR2.
3. On network 2, TR2 transmits a (*,*,RP) Join message with a source address of the RP. The upstream neighbor address field should contain the address of the RUT.
4. On network 1, data for multicast group 224.0.6.130 is forwarded by the RP.
5. Observe the packets transmitted by the RUT on all networks.

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

6. On network 0, 1, and 2, TR1, RP and TR2 transmit Hello messages.
7. On network 0, TR1 transmit a Join (*,G) message with a group address of 224.0.6.130. The upstream neighbor address field should contain the address of TR2.
8. On network 2, TR2 transmit a Join (*,G) message with a source address of the RP. The upstream neighbor address field should contain the address of the RUT.
9. On network 1, data for multicast group 224.0.6.130 is forwarded by the RP.
10. Observe the packets transmitted by the RUT on all networks.

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

11. On networks 0, 1 and 2, the RP, the TR1 and TR2 transmit Hello messages.
12. On network 0, TR1 transmits a Join (S,G) message with a source address of 10.10.15.80 and a group address of 224.0.6.130. The upstream neighbor address field should contain the address of TR1.

13. On network 2, TR1 transmits a Join (S,G) message with a source address of 10.10.10.80 and a group address of 224.0.6.130. The upstream neighbor address field should contain the address of RUT.
14. On network 1, data with a source address of 10.10.15.80 for multicast group 224.0.6.130 is forwarded by the RP.
15. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, the RUT should forward all the multicast data packets from network 1 to network 2.
- In Part B, the RUT should forward 224.0.6.130 multicast data packets from network 1 to network 2.
- In Part C, the RUT should forward the multicast data packets with a source of 10.10.15.80 and a destination of 224.0.6.130 from network 1 to network 2.

Possible Problems: None.

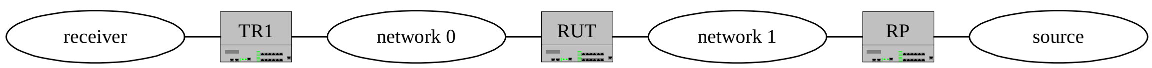
Test PIM-SM.3.3: Transitions from (*,*,RP) NoInfo State

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

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for multicast group 224.0.6.130. The RUT should be in NoInfo State at the beginning of each part.



Procedure:
Part A: Receiving a Join (,*,RP)*
1. On network 0 and 1, TR1 and the RP transmit Hello messages.
2. On network 0, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
3. On network 1, data for multicast group 224.0.6.130 is forwarded by the RP.
4. Observe the packets transmitted by the RUT on all networks.

Part B: Receiving a Prune (,*,RP)*
5. TR1 and the RP transmit Hello messages on network 0 and network 1 respectively.
6. On network 0, TR1 transmits a Prune (*,*,RP) message with a source address of the RP.
7. Multicast data for multicast group 224.0.6.130 is forwarded by the RP on network 1.
8. On network 0, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
9. Observe the packets transmitted by the RUT on all networks.

Observable Results:
- In Part A, the RUT should forward the multicast data packets onto network 0.
- In Part B, the RUT should not forward the multicast data packets onto network 0 until after having received a Join (*,*RP).

Possible Problems: None.

Test PIM-SM.3.4: Transitions from Join (*,*,RP) State

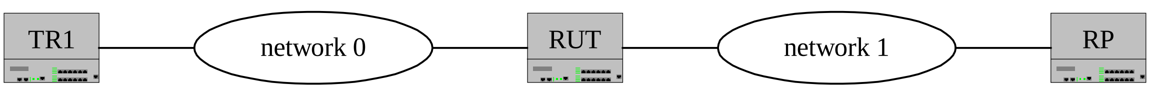
Purpose: To verify that a router properly transitions from the Join State when receiving a (*,*,RP) message.

References: [RFC 4601] – 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 then 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for multicast group 224.0.6.130. The RUT should be in NoInfo State at the beginning of each test.



Procedure:

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

1. On network 0 and 1, TR1 and the RP transmit Hello messages.
2. On network 0, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
3. On network 1, data for multicast group 224.0.6.130 is forwarded by the RP.
4. After 30 seconds, a second Join (*,*,RP) message is transmitted on network 0 with a source address of the RP.
5. Observe the packets transmitted by the RUT on all networks.

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

6. On networks 0 and 1, TR1 and the RP transmit Hello messages.
7. On network 0, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
8. On network 1, data for multicast group 224.0.6.130 is forwarded by the RP.
9. On network 0, TR1 transmits a Prune (*,*,RP) message with a source address of 224.0.6.130.
10. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, the RUT should continue to forward the data 105 seconds after the second Join message was sent. After 105 seconds the RUT should stop sending data onto network 0.
- In Part B, the RUT should stop forwarding data onto network 0 after the Prune is received.

Possible Problems: None.

Test PIM-SM.3.5: Transitions from (*,*,RP) Prune Pending State

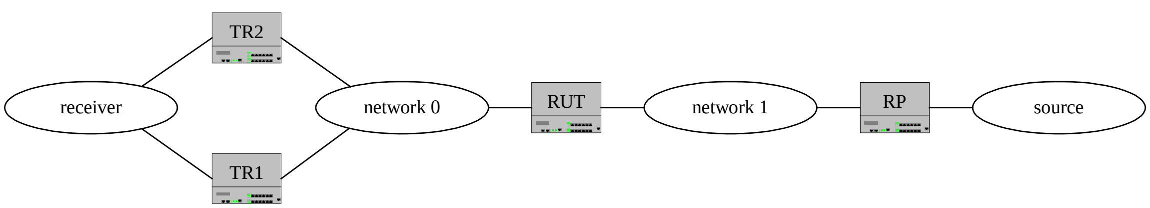
Purpose: To verify that a router properly transitions from the Prune Pending State when receiving a (*,*,RP) message.

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for multicast group 224.0.6.130. The RUT should be in NoInfo State at the beginning of each part.



Procedure:

Part A: Join (,*,RP)*

1. On network 0, TR1 and TR2 transmit Hello messages. On network 1, the RP transmits Hello messages.
2. On network 0, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
3. On network 0, TR2 transmits a Join (*,*,RP) message with a source address of the RP.
4. On network 1, multicast data for multicast group 224.0.6.130 is forwarded by the RP.
5. On network 0, TR2 transmits a Prune (*,*,RP) message with a source address of the RP.
6. On network 0, wait 2.5 seconds, then TR2 transmits a Join (*,*,RP) message with a source address of the RP.
7. Observe the packets transmitted by the RUT on all networks.

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

8. On network 0, TR1 and TR2 transmit Hello messages. On network 1, the RP transmits Hello messages.
9. On network 0, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
10. On network 0, TR2 transmits a Join (*,*,RP) message with a source address of the RP.
11. On network 1, multicast data for multicast group 224.0.6.130 is forwarded by the RP.

12. On network 0, TR1 transmits a Prune (*,*,RP) message with a source address of the RP.
13. Observe the packets transmitted by the RUT on all networks.

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

14. On network 0, TR1 and TR2 transmit Hello messages. On network 1, the RP transmits Hello messages.
15. On network 0, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
16. On network 0, TR2 transmits a Join (*,*,RP) message with a source address of the RP.
17. On network 1, multicast data for multicast group 224.0.6.130 is forwarded by the RP.
18. On network 0, TR1 transmits a Prune (*,*,RP) message with a source address of the RP.
19. On network 0, TR2 transmits a Prune (*,*,RP) message with a source address of the RP.
20. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, the RUT should forward the data onto network 0 during the entire test.
- In Part B, the RUT should forward the data onto network 0 until step 12. After step 12 a Prune Echo should be transmitted onto network 0 and data should not be forwarded.
- In Part C, the RUT should forward the data onto network 0 until step 18. After step 18 a Prune Echo should be transmitted onto network 0 and data should not be forwarded.

Possible Problems: None.

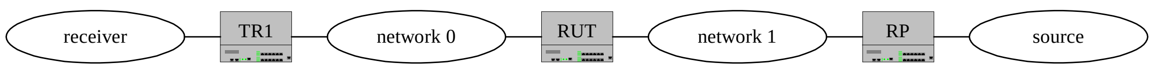
Test PIM-SM.3.6: Transitions from (*,G) NoInfo State

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

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for multicast group 224.0.6.130. The RUT should be in NoInfo State at the beginning of each test.



Procedure:
Part A: Join (,G)*
1. TR1 and the RP transmit Hello messages on network 0 and network 1 respectively.
2. On network 0, TR1 transmits a Join (*,G) message with a group address of 224.0.6.130.
3. Multicast data for multicast group 224.0.6.130 is forwarded by the RP on network 1.
4. Observe the packets transmitted by the RUT on the network 0.

Part B: Prune (,G)*

5. TR1 and the RP transmit Hello message on network 0 and network respectively.
6. On network 0, TR1 transmits a Prune (*,G) message with a group address of 224.0.6.130.
7. Multicast data for multicast group 224.0.6.130 is forwarded by the RP on network 1.
8. On network 0, TR1 transmits a Join (*,G) message with a group address of 224.0.6.130.
9. Observe the packets transmitted by the RUT on all networks.

Observable Results:
- In Part A, the RUT should forward the multicast data packets onto network 0.
- In Part B, the RUT should not forward the multicast data packets onto network 0 until after having received a Join (*,G) message.

Possible Problems: None.

Test PIM-SM.3.7: Transitions from (*,G) Join State

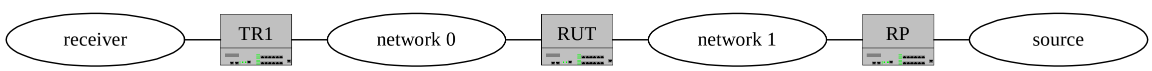
Purpose: To verify that a router properly transitions from the Join State when receiving a (*,G) message.

References: [RFC 4601] – 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 then 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for multicast group 224.0.6.130. The RUT should be in NoInfo State at the beginning of each test.



Procedure:

Part A: Join (,G)*

1. TR1 and the RP transmit Hello messages on network 0 and network 1, respectively.
2. On network 0, TR1 transmits a Join (*,G) message with a group address of 224.0.6.130.
3. Multicast data for multicast group 224.0.6.130 is forwarded by the RP on network 1.
4. After 30 seconds, a second Join (*,G) message is transmitted on network 0 with a source address of the RP.
5. Observe the packets transmitted by the RUT on all networks.

Part B: Prune (,G)*

6. TR1 and the RP transmit Hello messages on network 0 and network 1, respectively.
7. On network 0, TR1 transmits a Join (*,G) message with a group address of 224.0.6.130.
8. Multicast data for multicast group 224.0.6.130 is forwarded by the RP on network 1.
9. On network 0, TR1 transmits a Prune (*,G) message with a group address of 224.0.6.130.
10. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, the RUT should continue to forward the data 105 seconds after the second Join message was sent. After 105 seconds the RUT should stop sending data onto network 0.
- In Part B, the RUT should stop forwarding data onto network 0 after the Prune is received.

Possible Problems: None.

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

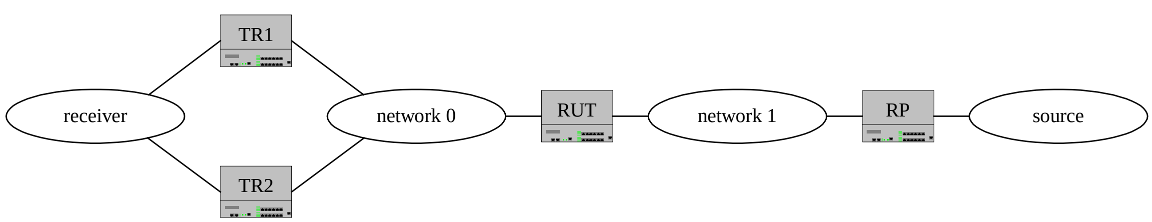
Purpose: To verify that a router properly transitions from the Prune Pending State when receiving a (*,G) message.

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for multicast group 224.0.6.130. The RUT should be in NoInfo State at the beginning of each part.



Procedure:

Part A: Join (,G)*

1. On network 0, TR1 and TR2 transmit Hello messages. On network 1, the RP transmits Hello messages.
2. On network 0, TR1 transmits a Join (*,G) message with a group address of 224.0.6.130.
3. On network 0, TR2 transmits a Join (*,G) message with a group address of 224.0.6.130.
4. On network 1, data for multicast group 224.0.6.130 is forwarded by the RP.
5. On network 0, TR1 transmits a Prune (*,G) message with a group address of 224.0.6.130.
6. After 2.5 seconds on network 0, TR2 transmits a Join message with a group address of 224.0.6.130.
7. Observe the packets transmitted by the RUT on all networks.

Part B: Single Prune (,G)*

8. On network 0, TR1 and TR2 transmit Hello messages. On network 1, the RP transmits Hello messages.
9. On network 0, TR1 transmits a Join (*,G) message with a group address of 224.0.6.130.
10. On network 0, TR2 transmits a Join (*,G) message with a group address of 224.0.6.130.

11. On network 1, data for multicast group 224.0.6.130 is forwarded by the RP.
12. On network 0, TR1 transmits a Prune (*,G) message with a group address of 224.0.6.130.
13. Observe the packets transmitted by the RUT on all networks.

Part C: Multiple Prune (,G)*

14. On network 0, TR1 and TR2 transmit Hello messages. On network 1, the RP transmit Hello messages.
15. On network 0, TR1 transmits a Join (*,G) message with a group address of 224.0.6.130.
16. On network 0, TR2 transmits a Join (*,G) message with a group address of 224.0.6.130.
17. On network 1, data for multicast group 224.0.6.130 is forwarded by the RP.
18. On network 0, TR1 transmits a Prune (*,G) message with a group address of 224.0.6.130.
19. On network 0, TR2 transmits a Prune (*,G) message with a group address of 224.0.6.130.
20. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, the RUT should forward the data onto network 0 during steps 2 through 7.
- In Part B, the RUT should forward the data onto network 0 until step 12. After step 12 a Prune Echo should be transmitted onto network 0 and data should not be forwarded.
- In Part C, the RUT should forward the data onto network 0 until step 19. After step 19 a Prune Echo should be transmitted onto network 0 and data should not be forwarded.

Possible Problems: None.

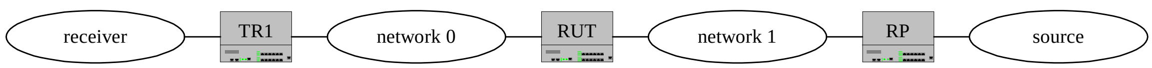
Test PIM-SM.3.9: Transitions from (S,G) NoInfo State

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

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for multicast group 224.0.6.130. The RUT should be in NoInfo State at the beginning of each part.



Procedure:

Part A: Join (S,G) message

1. On network 0 and 1, TR1 and the RP transmit Hello messages.
2. On network 0, TR1 transmits a Join (S,G) message with a source address of 10.10.15.80 and a group address of 224.0.6.130.
3. On network 1, data with a source address of 10.10.15.80 for multicast group 224.0.6.130 is forwarded by the RP.
4. Observe the packets transmitted by the RUT on all networks.

Part B: Prune (S,G) message

5. On network 0 and 1, TR1 and the RP transmit Hello message.
6. On network 0, TR1 transmits a Prune (S,G) message with a source address of 10.10.15.80 and a group address of 224.0.6.130.
7. Data for multicast group 224.0.6.130 with a source address of 10.10.15.80 is forwarded by the RP on network 1.
8. On network 0, TR1 transmits a Join (S,G) message with a source address of 10.10.11.80 and a group address of 224.0.6.130.
9. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, the RUT should forward the multicast data packets onto network 0.
- In Part B, the RUT should not forward the multicast data packets onto network 0 until after having received a Join (S,G) message.

Possible Problems: None.

Test PIM-SM.3.10: Transitions from (S,G) Join State

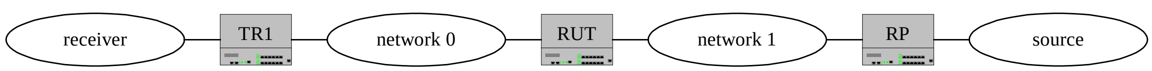
Purpose: To verify that a router properly transitions from the Join State when receiving an (S,G) message.

References: [RFC 4601] – 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) to 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 then 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for multicast group 224.0.6.130. The RUT should be in NoInfo State at the beginning of each part.



Procedure:

Part A: Join (S,G)

1. On network 0 and 1, TR1 and the RP transmit Hello messages.
2. On network 0, TR1 transmits a Join (S,G) message with a source address of 10.10.15.80 and a group address of 224.0.6.130.
3. On network 1, data with a source address of 10.10.15.80 for multicast group 224.0.6.130 is forwarded by the RP.
4. After 30 seconds, transmit a second Join (S,G) message with a source address of 10.10.15.80 and a group address of 224.0.6.130.
5. Observe the packets transmitted by the RUT on all networks.

Part B: Prune (S,G)

6. On network 0 and 1, TR1 and the RP transmit Hello messages.
7. On network 0, TR1 transmits a Join (S,G) message with a source address of 10.10.15.80 and a group address of 224.0.6.130.
8. On network 1, data with a source address of 10.10.15.80 for multicast group 224.0.6.130 is forwarded by the RP.
9. On network 0, TR1 transmits a Prune (S,G) message with a source address of 10.10.15.80 and a group address of 224.0.6.130.
10. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, the RUT should continue to forward the data 105 seconds after the second Join message was sent.

- In Part B, the RUT should stop forwarding data onto network 1 after the Prune is received.

Possible Problems: None.

Test PIM-SM.3.11: Transitions from (S,G) Prune Pending State

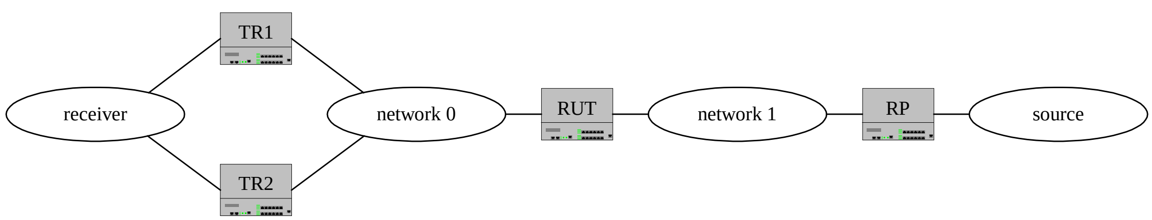
Purpose: To verify that a router properly transitions from the Prune Pending State when receiving an (S,G) message.

References: [RFC 4601] – 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for multicast group 224.0.6.130. The RUT should be in NoInfo State at the beginning of each part.



Procedure:

Part A: Join (S,G) message

1. On network 0, TR1 and TR2 transmit Hello messages. On network 1, the RP transmits Hello messages.
2. On network 0, TR1 transmits a Join (S,G) message with a source address of 10.10.11.80 and a group address of 224.0.6.130.
3. On network 0, TR2 transmits a Join (S,G) message with a source address of 10.10.11.80 and a group address of 224.0.6.130.
4. On network 1, data with a source address of 10.10.11.80 for multicast group 224.0.6.130 is forwarded by the RP.
5. On network 0, TR1 transmits a Prune (S,G) message with a source address of 10.10.11.80 and a group address of 224.0.6.130.
6. After 2.5 seconds, on network 0, TR2 transmits a Join message with a source address of 10.10.11.80 and a group address of 224.0.6.130.
7. Observe the packets transmitted by the RUT on all networks.

Part B: Single Prune (S,G)

8. On network 0 TR1 and TR2 transmit Hello messages. On network 1, the RP transmits Hello messages.
9. On network 0, TR1 transmits a Join (S,G) message with a source address of 10.10.11.80 and a group address of 224.0.6.130.
10. On network 0, TR2 transmits a Join (S,G) message with a source address of 10.10.11.80 and a group address of 224.0.6.130.
11. On network 1, data with a source address of 10.10.10.80 for multicast group 224.0.6.130 is forwarded by the RP.
12. On network 0, TR1 transmits a Prune (S,G) message with a source address of 10.10.11.80 and a group address of 224.0.6.130.
13. Observe the packets transmitted by the RUT on all networks.

Part C: Multiple Prunes (S,G)

14. On network 0, TR1 and TR2 transmit Hello messages. On network 1, the RP transmits Hello messages.
15. On network 0, TR1 transmits a Join (S,G) message with a source address of 10.10.11.80 and a group address of 224.0.6.130.
16. On network 0, TR2 transmits a Join (S,G) message with a source address of 10.10.11.80 and a group address of 224.0.6.130.
17. On network 1, data with a source address of 10.10.10.80 for multicast group 224.0.6.130 is forwarded by the RP.
18. On network 0, TR1 transmits a Prune (S,G) message with a source address of 10.10.11.80 and a group address of 224.0.6.130.
19. On network 0, TR2 transmits a Prune (S,G) message with a source address of 10.10.11.80 and a group address of 224.0.6.130.
20. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, the RUT should forward the data onto network 0.
- In Part B, the RUT should forward the data onto network 0 until step 12. After step 12 a Prune Echo should be transmitted onto network 0 and data should not be forwarded.
- In Part C, the RUT should forward the data onto network 0 until step 19. After step 18 a Prune Echo should be transmitted onto network 0 and data should not be forwarded.

Possible Problems: None.

GROUP 4: Transmission of Join and Prune Messages

Scope:

The following 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.

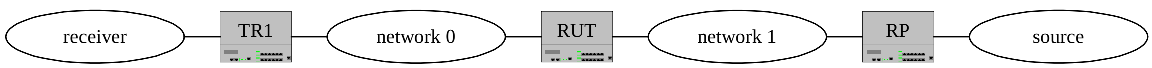
Test PIM-SM.4.1: Transitions from (*,*,RP) NotJoined State

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

References: [RFC 4601] – 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 should 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for group 224.0.6.130.



Procedure:
Part A: Transitions from (,*,RP) NotJoined State*
1. On networks 0 and 1, TR1 and the RP transmit Hello messages.
2. On network 0, TR1 transmits a Join (*,*,RP) message with a source address of the RP.
3. Observe the packets transmitted by the RUT on network 1.

Observable Results:
- In Part A, 60 seconds after step 2 the RUT should transmit a Join (*,*,RP) message to the RP. The RUT should also set the Join Timer for TR1. After 60 seconds the RUT should transmit another Join (*,*,RP) to the RP.

Possible Problems: None.

Test PIM-SM.4.2: Transitions from (*,*,RP) Joined State, Setup 1

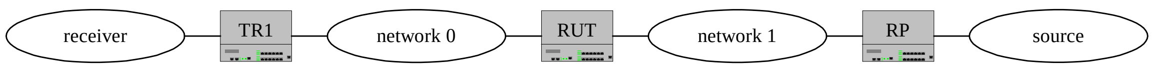
Purpose: To verify a router properly transitions its state while in (*,*,RP) Joined state.

References: [RFC 4601] – 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 should send a Join(*,*,RP) to the appropriate upstream neighbor and restart the Join timer seconds.

Test Setup: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for group 224.0.6.130. TR1 should be elected DR on network 0.



Procedure:

Part A: Transitions from (,*,RP) Joined State, Setup 1*

1. TR1 and the RP transmit Hello messages.
2. On network 0, 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 networks.

Observable Results:

- In Part A, After step 2 the RUT should transmit a Join (*,*,RP) to the RP and reset the Join Timer to 60 seconds. After 60 seconds, the RUT should transmit another Join (*,*,RP) message to the RP.

Possible Problems: None.

Test PIM-SM.4.3: Suppression and Override in (*,*,RP) Joined State

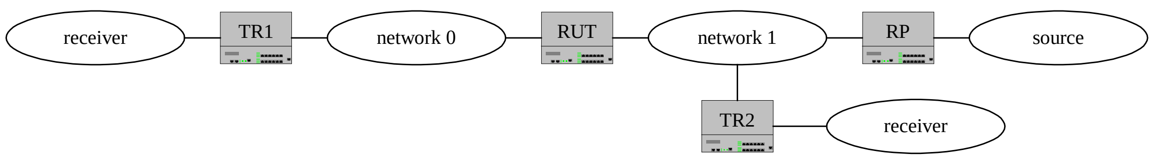
Purpose: To verify a router properly transitions its state while in Joined State.

References: [RFC 4601] – 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_joinsuppress seconds, reset it so that it expires after t_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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for group 224.0.6.130. TR1 and TR2 should be elected DR on network 0 and network 1, respectively.



Procedure:
Part A: Join Suppression
1. On network 0, TR1 transmits Hello Messages. On network 1, the RP and TR2 transmit Hello messages.
2. On network 0, TR1 transmits a Join (*,*,RP) messages with a source address of the RP.
3. On network 1, TR2 transmits a Join (*,*,RP) messages with a source address of the RP.
4. Observe the packets transmitted by the RUT on all networks.

Part B: Prune Override

5. On network 0, TR1 transmits Hello messages. On network 1, the RP and TR2 transmit Hello Messages.
6. On network 0, TR1 transmits a Join (*,*, RP) messages with a source address of the RP.
7. On network 1, TR2 transmits a Join (*,*,RP) messages with a source address of the RP.
8. On network 1, TR2 transmits a Prune (*,*,RP) messages with a source address of the RP.
9. Observe the packets transmitted by the RUT on all networks.

Observable Results:
- In Part A, the RUT should transmit a Join (*,*,RP) message and wait t_joinsuppress seconds before transmitting another Join (*,*,RP) message on network 1.
- In Part B, the RUT should transmit a Join (*,*,RP) message within t_override seconds of seeing the Prune (*,*,RP) message sent on network 1.

Possible Problems: None.

Observable Results:

- In Part A, after step 3 the RUT should transmit a Join (*,*,RP) message to TR3. The RUT should then send a Prune (*,*,RP) message to TR2 and set the Join Timer to expire after 60 seconds. After 60 seconds the RUT should transmit another Join (*,*,RP) message to TR2.
- In Part B, after step 7 the RUT should set the Join Timer to t_override seconds. After 60 seconds the RUT should transmit a second Join (*,*,RP) message to TR2.

Possible Problems: None.

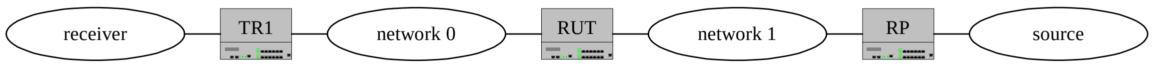
Test PIM-SM.4.5: Transitions from (*,G) NotJoined State

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

References: [RFC 4601] – 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 should 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for multicast group 224.0.6.130.



Procedure:
Part A: Transitions from (,G) NotJoined State*

1. On network 0 and 1, TR1 and the RP transmit Hello messages.
2. On network 0, TR1 transmits a Join (*,G) message with source address of the RP for multicast group 224.0.6.130.
3. Observe the packets transmitted by the RUT on network 1.

Observable Results:

- In Part A, immediately after step 2 the RUT should transmit a Join (*,G) message to the RP for multicast group 224.0.6.130. The RUT should also set the Join Timer for TR1. Wait 60 seconds, the RUT should transmit another Join (*,G) to the RP for multicast group 224.0.6.130.

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.

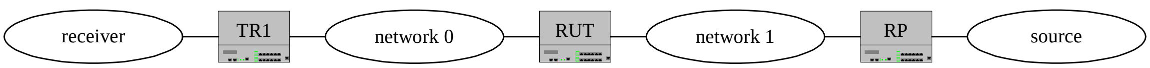
References: [RFC 4601] – Section 4.5.6

Last Modification: June 12, 2002

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

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

Test Setup: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for multicast group 224.0.6.130. TR1 should be the DR on network 0.



Procedure:

Part A: Join Time Expires

1. On network 0 and 1, TR1 and the RP transmit Hello messages. The RP should be the upstream next hop for the RUT.
2. On network 0, TR1 transmits a Join (*,G) message for the multicast group 224.0.6.130.
3. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, immediately after step 2 the RUT should transmit a Join (*,G) message for multicast group 224.0.6.130 to the RP and reset the Join Timer to 60 seconds. After 60 seconds the RUT should transmit another Join (*,G) message for multicast group 224.0.6.130 to the RP.

Possible Problems: None.

Test PIM-SM.4.7: Suppression and Override in (*,G) Joined State

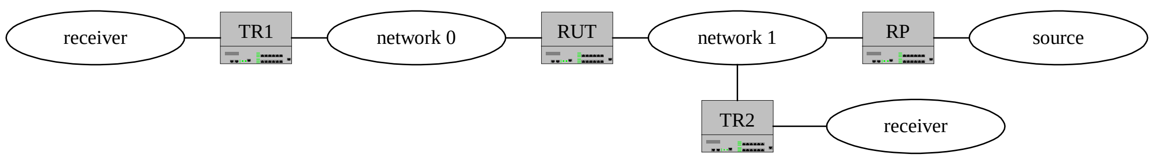
Purpose: To verify a router properly transitions state when in (*,G) Joined state.

References: [RFC 4601] – 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_joinsuppress seconds, reset it so that it expires after t_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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for group 224.0.6.130. TR1 and TR2 should be elected DR on network 0 and network 1, respectively.



Procedure:
Part A: Join Suppression
1. On network 0, TR1 transmits Hello messages. On network 1, the RP and TR2 transmit Hello messages.
2. On network 0, TR1 transmits a Join (*,G) message for the multicast group 224.0.6.130.
3. On network 1, TR2 transmits a Join (*,G) message for the multicast group 224.0.6.130.
4. Observe the packets transmitted by the RUT on all networks.

Part B: Prune Override
5. On network 0, TR1 transmits Hello messages. On network 1, the RP and TR2 transmit Hello Messages.
6. On network 0, TR1 transmits a Join (*,G) for the multicast group 224.0.6.130.
7. On network 1, TR2 transmits a Join (*,G) for the multicast group 224.0.6.130.
8. On network 1, TR2 transmits a Prune (*,G) for the multicast group 224.0.6.130.
9. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, the RUT should transmit a Join (*,G) message for multicast group 224.0.6.130 and wait t_joinsuppress seconds before transmitting another Join (*,G) message for 224.0.6.130 on network 1.
- In Part B, the RUT should transmit a Join (*,G) message for multicast group 224.0.6.130 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

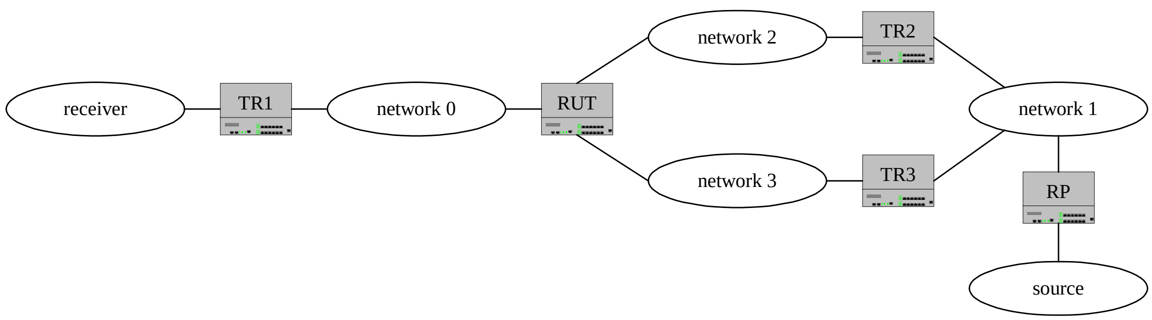
Purpose: To verify a router properly transitions state when in (*,G) Joined state.

References: [RFC 4601] – 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 should 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 should set the Join Timer to expire in t_override seconds.

Test Setup: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for multicast group 224.0.6.130. TR2 should be the upstream next hop for the RUT.



Procedure:

Part A: Next Hop Changes in MRIB

1. On network 0, TR1 transmits Hello messages. On networks 1 and 2, TR2 transmits Hello messages. On network 1 and 3, TR3 transmits Hello messages. TR2 and TR3 should be elected DR on network 2 and network 3, respectively.
2. On network 0, TR1 transmits a Join (*,G) message for multicast group 224.0.6.130.
3. The RUT's next hop for the RP changes from TR2 to TR3.
4. Observe the packets transmitted by the RUT on network 1 and network 2.

Part B: New GenID from Next Hop

5. On network 0, TR1 transmits Hello messages. On network 1 and 2, TR2 transmits Hello messages. On networks 1 and 3, TR3 transmits Hello messages. TR2 and TR3 should be elected DR on network 1 and network 2, respectively.
6. On network 0, TR1 transmits a Join (*,G) message for multicast group 224.0.6.130.
7. On network 2, TR2 transmits a Hello message with a new GenID.
8. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, the RUT should transmit Join (*,G) message for multicast group 224.0.6.130 on network 2 and then Prune (*,G) message for multicast group 224.0.6.130 on network 2.

- In Part B, after t_override seconds the RUT should transmit Join (*,G) message for multicast group 224.0.6.130 on network 2.

Possible Problems: None.

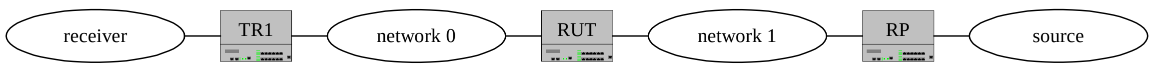
Test PIM-SM.4.9: Transitions from (S,G) NotJoined State

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

References: [RFC 4601] – Section 4.5.7

Discussion: When the upstream (S,G) state-machine is in NotJoined state, reception of an (S,G) Join on a downstream interface causes a state transition. The router should 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for group 224.0.6.130.



Procedure:

Part A: Transitions (S,G) NotJoined State

1. On network 0 and 1, TR1 and the RP transmit Hello messages.
2. On network 0, TR1 transmits a Join (S,G) message with a source address of 10.10.15.80 for the multicast group 224.0.6.130.
3. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, immediately after step 2 the RUT should transmit a Join (S,G) message to the RP. The RUT should also set the Join Timer for TR1. After 60 seconds, the RUT should transmit another Join (S,G) message to TR2.

Possible Problems: None.

Test PIM-SM.4.10: Transitions from (S,G) Joined State, Setup 1

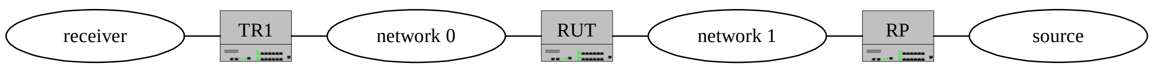
Purpose: To verify a router properly transitions state while in (S,G) Joined State.

References: [RFC 4601] – 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 should send a Join (S,G) to the appropriate upstream neighbor and restart the Join timer seconds.

Test Setup: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for group 224.0.6.130.



Procedure:
Part A: Join Timer Expires

1. On network 0 and 1, TR1 and the RP transmit Hello messages. The RP should be the upstream next hop for the RUT.
2. On network 0, TR1 transmits a Join (S,G) message for source 10.10.15.80 and multicast group 224.0.6.130.
3. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, immediately after step 2 the RUT should transmit a Join (S,G) message to the RP and reset the Join Timer to 60 seconds. After 60 seconds the RUT should 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

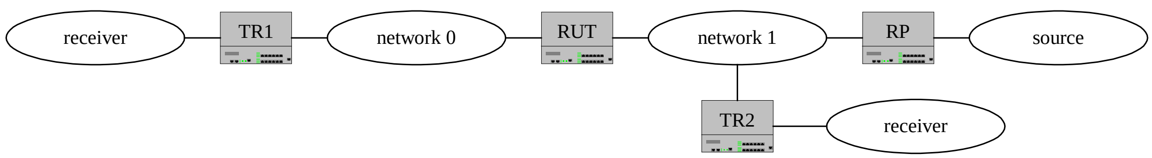
Purpose: To verify a router properly transitions state while in (S,G) Joined State.

References: [RFC 4601] – 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 should set its Join Timer to expire in t_joinsuppress seconds, or leave the timer alone if it is already greater than t_joinsuppress.
- The router sees another router on the upstream interface send a Prune (S,G). A router should 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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for group 224.0.6.130. TR1 and TR2 should be elected DR on network 0 and network 1, respectively.



Procedure:
Part A: Join Suppression

1. On network 0, TR1 transmits Hello messages. On network 1, the RP and TR2 transmit Hello messages.
2. On network 0, TR1 transmits a Join (S,G) message with source address of 10.10.15.80 for the multicast group 224.0.6.130.
3. On network 1, TR2 transmits a Join (S,G) message with a source address of 10.10.15.80 for the multicast group 224.0.6.130.
4. Observe the packets transmitted by the RUT on network 1.

Part B: Prune Override

5. On network 0, TR1 transmits Hello messages. On network 1, the RP and TR2 transmit Hello messages.
6. On network 0, TR1 transmits a Join (S,G) message with source address of 10.10.15.80 for the multicast group 224.0.6.130.
7. On network 1, TR2 transmits a Join (S,G) message with the source address of 10.10.15.80 for the multicast group 224.0.6.130.
8. On network 1, TR2 transmits a Prune (S,G) message with the source address of 10.10.15.80 for the multicast group 224.0.6.130.
9. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, the RUT should transmit a Join (S,G) message for multicast group 224.0.6.130 and wait t_joinsuppress seconds before transmitting another Join (S,G) message for multicast group 224.0.6.130 on network 1.
- In Part B, the RUT should transmit a Join (S,G) message for multicast group 224.0.6.130 within t_override seconds of seeing the Prune (S,G) message.

Possible Problems: None.

Test PIM-SM.4.12: Transitions from (S,G) Joined State, Setup 2

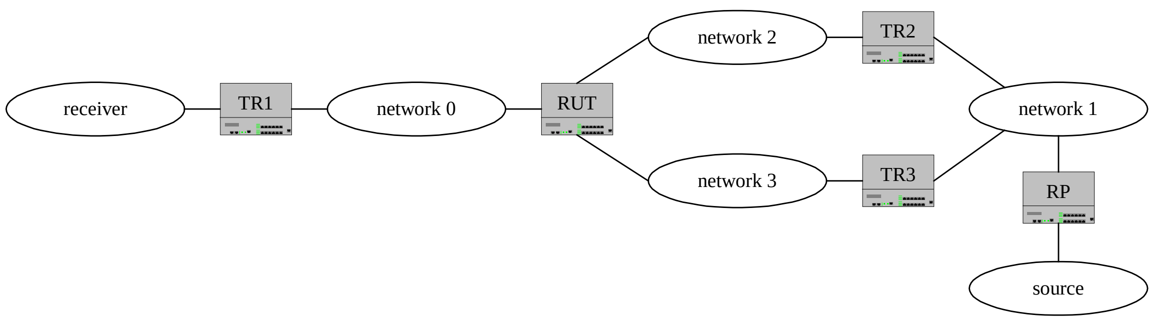
Purpose: To verify a router properly transitions state while in (S,G) Joined State.

References: [RFC 4601] – 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 should 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 should set the Join Timer to expire in t_override seconds.

Test Setup: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for multicast group 224.0.6.130. 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 network 0, network 2 and network 3. On network 0, TR1 transmits Hello messages. On network 1 and 2, TR2 transmits Hello messages. On network 1 and 3, TR3 transmits Hello messages. On network 1, the RP transmits Hello messages. TR2 and TR3 should be elected DR on network 1 and network 2, respectively.
2. On network 0, TR1 transmits a Join (S,G) message with a source address of the RP for multicast group 224.0.6.130. This should cause the RUT to transition to (S,G) Joined state.
3. On network 1, the RUT’s next hop changes to TR3.
4. Observe the packets transmitted by the RUT on network 2 and network 3.

Part B: New GenID from Next Hop

5. Configure the RUT to transmit Hello messages on network 0, network 2 and network 3. On network 0, TR1 transmits Hello messages. On network 1 and 2, TR2 transmits Hello messages. On network 1 and 3, TR3 transmits Hello messages. On network 1, the RP transmits Hello messages. TR2 and TR3 should be elected DR on network 1 and network 2, respectively
6. On network 0, TR1 transmits a Join (S,G) message with a source address of the RP for multicast group 224.0.6.130. This should cause the RUT to transition to (S,G) Joined state.

7. On network 2, TR2 transmits a Hello message with a new GenID.
8. Observe the packets transmitted by the RUT on network 2.

Observable Results:

- In Part A, after Step 3 the RUT should transmit Join (S,G) message for multicast group 224.0.6.130 on network 3 and then Prune (S,G) message for multicast group 224.0.6.130 on network 2.
- In Part B, after t_override seconds the RUT should transmit Join (S,G) message for multicast group 224.0.6.130 on network 2.

Possible Problems: None.

Test PIM-SM.4.13: Transitions from (S,G,rpt) NotPruned State

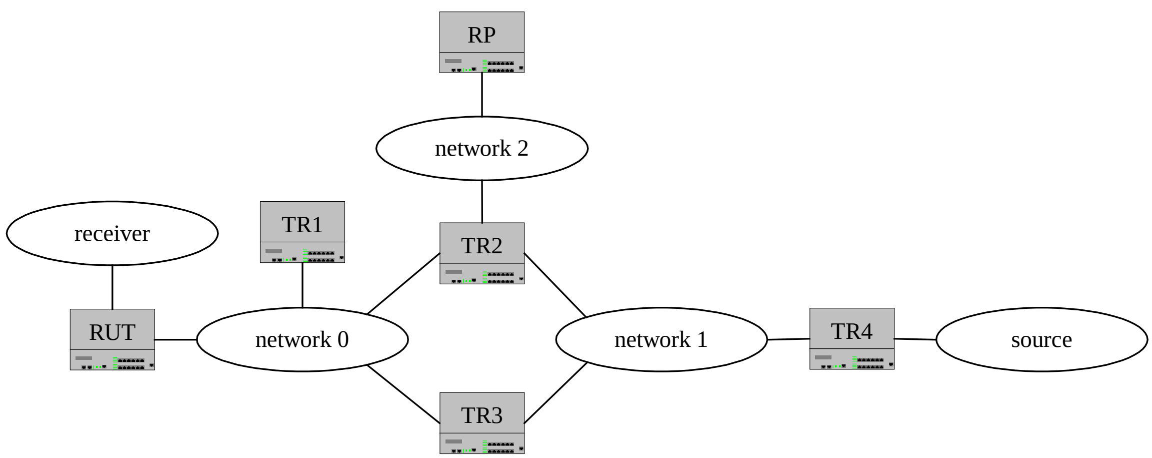
Purpose: To verify a router properly transitions state while in (S,G,rpt) NotPruned State

References: [RFC 4601] – Section 4.5.9

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: Enable PIM-SM on the RUT on network 0. The RP should be statically configured for multicast group 224.0.6.130.



Procedure:

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

1. On network 0, TR1, TR2 and TR3 transmit Hello messages. On network 1, TR2 and TR4 transmit Hello messages. On network 2, the RP and TR2 transmit Hello messages.
2. On network 0, TR1 transmits a Join (*,G) message for multicast group 224.0.6.130 with upstream neighbor address set to the address of TR2.
3. On network 1, TR4 forwards data from source 10.10.15.80 for multicast group 224.0.6.130.
4. An IGMP report for multicast group 224.0.6.130 is transmitted by the receiver. The RUT should transmit a Join (*,G) message upstream.
5. On network 0, TR1 transmits a Join (S,G) message for source 10.10.15.80 and multicast group 224.0.6.130 with upstream neighbor address set to the address of TR3.
6. On network 0, TR1 transmits a Prune(S,G,rpt) message for multicast group 224.0.6.130 with upstream neighbor address set to the address of TR2.
7. Observe the packets transmitted by the RUT on all networks.

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

8. On network 0, TR1, TR2 and TR3 transmit Hello messages. On network 1, TR2 and TR4 transmit Hello messages. On network 2, the RP and TR2 transmit Hello messages.
9. On network 0, TR1 transmits a Join (*,G) message for multicast group 224.0.6.130 with upstream neighbor address set to the address of TR2.
10. On network 1, TR4 forwards data from source 10.10.15.80 for multicast group 224.0.6.130.
11. An IGMP report for multicast group 224.0.6.130 is transmitted to the RUT. The RUT should send a Join (*,G) message upstream.
12. On network 0, TR1 transmits a Join (S,G) message for source 10.10.15.80 and multicast group 224.0.6.130 with upstream neighbor address set to the address of TR3.
13. On network 0, TR1 transmits a Prune(S,G,rpt) message for multicast group 224.0.6.130 with upstream neighbor address set to the address of TR2.
14. On network 0, TR1 transmits a Join(S,G,rpt) message for multicast group 224.0.6.130 with upstream neighbor address set to the address of TR2.
15. Observe the packets transmitted by the RUT on all networks.

Observable Results:

- In Part A, the RUT should set the Override Timer to t_override seconds. After t_override seconds, the RUT should transmit a Join(S,G,rpt) message for source 10.10.15.80 and multicast group 224.0.6.130 with upstream neighbor address set to the address of TR2.
- In Part B, the RUT should cancel the Override Timer and should not transmit a Join(S,G,rpt) message.

Possible Problems: None.