Network Working Group
Request for Comments: 4063
Category: Informational

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April 2005

Considerations When Using Basic OSPF Convergence Benchmarks

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Abstract

This document discusses the applicability of various tests for measuring single router control plane convergence, specifically in regard to the Open Shortest First (OSPF) protocol. There are two general sections in this document, the first discusses advantages and limitations of specific OSPF convergence tests, and the second discusses more general pitfalls to be considered when routing protocol convergence is tested.

1. Introduction

There is a growing interest in testing single router control plane convergence for routing protocols, and many people are looking at testing methodologies that can provide information on how long it takes for a network to converge after various network events occur. It is important to consider the framework within which any given convergence test is executed when one attempts to apply the results of the testing, since the framework can have a major impact on the results. For instance, determining when a network is converged, what parts of the router’s operation are considered within the testing, and other such things will have a major impact on the apparent performance that routing protocols provide.

This document describes in detail various benefits and pitfalls of tests described in [BENCHMARK]. It also explains how such measurements can be useful for providers and the research community.

NOTE: In this document, the word "convergence" refers to single router control plane convergence [TERM].

2. Advantages of Such Measurement

- To be able to compare the iterations of a protocol implementation. It is often useful to be able to compare the performance of two iterations of a given implementation of a protocol in order to determine where improvements have been made and where further improvements can be made.

- To understand, given a set of parameters (network conditions), how a particular implementation on a particular device will perform. For instance, if you were trying to decide the processing power (size of device) required in a certain location within a network, you could emulate the conditions that will exist at that point in the network and use the test described to measure the performance of several different routers. The results of these tests can provide one possible data point for an intelligent decision.

  If the device being tested is to be deployed in a running network, using routes taken from the network where the equipment is to be deployed rather than some generated topology in these tests will yield results that are closer to the real performance of the device. Care should be taken to emulate or take routes from the actual location in the network where the device will be (or would be) deployed. For instance, one set of routes may be taken from an ABR, one set from an area 0 only router, various sets from stub area, another set from various normal areas, etc.

- To measure the performance of an OSPF implementation in a wide variety of scenarios.

- To be used as parameters in OSPF simulations by researchers. It may sometimes be required for certain kinds of research to measure the individual delays of each parameter within an OSPF implementation. These delays can be measured using the methods defined in [BENCHMARK].

- To help optimize certain configurable parameters. It may sometimes be helpful for operators to know the delay required for individual tasks in order to optimize the resource usage in the network. For example, if the processing time on a router is

found to be x seconds, determining the rate at which to flood LSAs to that router would be helpful so as not to overload the network.

3. Assumptions Made and Limitations of Such Measurements

- The interactions of convergence and forwarding; testing is restricted to events occurring within the control plane. Forwarding performance is the primary focus in [INTERCONNECT], and it is expected to be dealt with in work that ensues from [FIB-TERM].

- Duplicate LSAs are Acknowledged Immediately. A few tests rely on the property that duplicate LSA Acknowledgements are not delayed but are done immediately. However, if an implementation does not acknowledge duplicate LSAs immediately on receipt, the testing methods presented in [BENCHMARK] could give inaccurate measurements.

- It is assumed that SPF is non-preemptive. If SPF is implemented so that it can (and will be) preempted, the SPF measurements taken in [BENCHMARK] would include the times that the SPF process is not running, thus giving inaccurate measurements. ([BENCHMARK] measures the total time taken for SPF to run, not the amount of time that SPF actually spends on the device's processor.)

- Some implementations may be multithreaded or use a multiprocess/multirouter model of OSPF. If because of this any of the assumptions made during measurement are violated in such a model, measurements could be inaccurate.

- The measurements resulting from the tests in [BENCHMARK] may not provide the information required to deploy a device in a large-scale network. The tests described focus on individual components of an OSPF implementation's performance, and it may be difficult to combine the measurements in a way that accurately depicts a device's performance in a large-scale network. Further research is required in this area.

- The measurements described in [BENCHMARK] should be used with great care when comparing two different implementations of OSPF from two different vendors. For instance, there are many other factors than convergence speed that need to be taken into consideration when comparing different vendors' products. One difficulty is aligning the resources available on one device to the resources available on another.

4. Observations on the Tests Described in [BENCHMARK]

Some observations recorded while implementing the tests described in [BENCHMARK] are noted in this section.

4.1. Measuring the SPF Processing Time Externally

The most difficult test to perform is the external measurement of the time required to perform an SPF calculation because the amount of time between the first LSA that indicates a topology change and the duplicate LSA is critical. If the duplicate LSA is sent too quickly, it may be received before the device being tested actually begins running SPF on the network change information. If the delay between the two LSAs is too long, the device may finish SPF processing before receiving the duplicate LSA. It is important to closely investigate any delays between the receipt of an LSA and the beginning of an SPF calculation in the tested device; multiple tests with various delays might be required to determine what delay needs to be used to measure the SPF calculation time accurately.

Some implementations may force two intervals, the SPF hold time and the SPF delay, between successive SPF calculations. If an SPF hold time exists, it should be subtracted from the total SPF execution time. If an SPF delay exists, it should be noted in the test results.

4.2. Noise in the Measurement Device

The device on which measurements are taken (not the device being tested) also adds noise to the test results, primarily in the form of delay in packet processing and measurement output. The largest source of noise is generally the delay between the receipt of packets by the measuring device and the receipt of information about the packet by the device's output, where the event can be measured. The following steps may be taken to reduce this sampling noise:

- Increasing the number of samples taken will generally improve the tester's ability to determine what is noise, and to remove it from the results. This applies to the DUT as well.

- Try to take time-stamp for a packet as early as possible. Depending on the operating system being used on the box, one can instrument the kernel to take the time-stamp when the interrupt is processed. This does not eliminate the noise completely, but at least reduces it.

- Keep the measurement box as lightly loaded as possible. This applies to the DUT as well.

- Having an estimate of noise can also be useful.

The DUT also adds noise to the measurement.

4.3. Gaining an Understanding of the Implementation Improves Measurements

Although the tester will (generally) not have access to internal information about the OSPF implementation being tested using [BENCHMARK], the more thorough the tester's knowledge of the implementation is, the more accurate the results of the tests will be. For instance, in some implementations, the installation of routes in local routing tables may occur while the SPF is being calculated, dramatically impacting the time required to calculate the SPF.

4.4. Gaining an Understanding of the Tests Improves Measurements

One method that can be used to become familiar with the tests described in [BENCHMARK] is to perform the tests on an OSPF implementation for which all the internal details are available. Although there is no assurance that any two implementations will be similar, this will provide a better understanding of the tests themselves.

5. LSA and Destination Mix

In many OSPF benchmark tests, a generator injecting a number of LSAs is called for. There are several areas in which injected LSAs can be varied in testing:

- The number of destinations represented by the injected LSAs

  Each destination represents a single reachable IP network; these will be leaf nodes on the shortest path tree. The primary impact to performance should be the time required to insert destinations in the local routing table and handling the memory required to store the data.

- The types of LSAs injected

  There are several types of LSAs that would be acceptable under different situations; within an area, for instance, types 1, 2, 3, 4, and 5 are likely to be received by a router. Within a not-so-stubby area, however, type-7 LSAs would replace the type-5 LSAs received. These sorts of characterizations are important to note in any test results.

- The number of LSAs injected

  Within any injected set of information, the number of each type of LSA injected is also important. This will impact the shortest path algorithm's ability to handle large numbers of nodes, large shortest path first trees, etc.

- The order of LSA injection

  The order in which LSAs are injected should not favor any given data structure used for storing the LSA database on the device being tested. For instance, AS-External LSAs have AS wide flooding scope; any type-5 LSA originated is immediately flooded to all neighbors. However, the type-4 LSA, which announces the ASBR as a border router, is originated in an area at SPF time (by ABRs on the edge of the area in which the ASBR is). If SPF isn't scheduled immediately on the ABRs originating the type-4 LSA, the type-4 LSA is sent after the type-5 LSA's reach a router in the adjacent area. Therefore, routes to the external destinations aren't immediately added to the routers in the other areas. When the routers that already have the type 5s receive the type-4 LSA, all the external routes are added to the tree at the same time. This timing could produce different results than a router receiving a type 4 indicating the presence of a border router, followed by the type 5s originated by that border router.

  The ordering can be changed in various tests to provide insight into the efficiency of storage within the DUT. Any such changes in ordering should be noted in test results.

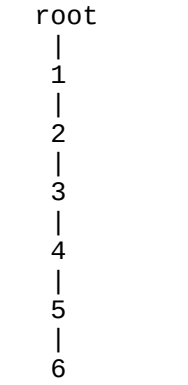
6. Tree Shape and the SPF Algorithm

The complexity of Dijkstra's algorithm depends on the data structure used for storing vertices with their current minimum distances from the source; the simplest structure is a list of vertices currently reachable from the source. In a simple list of vertices, finding the minimum cost vertex would then take O(size of the list). There will be O(n) such operations if we assume that all the vertices are ultimately reachable from the source. Moreover, after the vertex with minimum cost is found, the algorithm iterates through all the edges of the vertex and updates the cost of other vertices. With an adjacency list representation, this step, when iterated over all the vertices, would take O(E) time, with E being the number of edges in the graph. Thus, the overall running time is:

O(sum(i:1, n)(size(list at level i) + E).

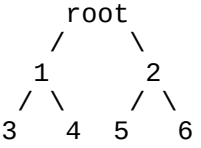
So everything boils down to the size(list at level i).

If the graph is linear,



and source is a vertex on the end, then size(list at level i) = 1 for all i. Moreover, E = n - 1. Therefore, running time is O(n).

If the graph is a balanced binary tree,



size(list at level i) is a little complicated. First, it increases by 1 at each level up to a certain number, and then it goes down by 1. If we assume that the tree is a complete tree (as shown above) with k levels (1 to k), then size(list) goes on like this: 1, 2, 3,

Then the number of edges E is still n - 1. It then turns out that the run-time is O(n^2) for such a tree.

If the graph is a complete graph (fully-connected mesh), then size(list at level i) = n - i. Number of edges E = O(n^2). Therefore, run-time is O(n^2).

Therefore, the performance of the shortest path first algorithm used to compute the best paths through the network is dependent on the construction of the tree. The best practice would be to try to make any emulated network look as much like a real network as possible, especially in the area of the tree depth, the meshiness of the

network, the number of stub links versus transit links, and the number of connections and nodes to process at each level within the original tree.

7. Topology Generation

As the size of networks grows, it becomes more and more difficult to actually create a large-scale network on which to test the properties of routing protocols and their implementations. In general, network emulators are used to provide emulated topologies that can be advertised to a device with varying conditions. Route generators tend to be either a specialized device, a piece of software which runs on a router, or a process that runs on another operating system, such as Linux or another variant of Unix.

Some of the characteristics of this device should be as follows:

- The ability to connect to several devices using both point-to-point and broadcast high-speed media. Point-to-point links can be emulated with high-speed Ethernet as long as there is no hub or other device between the DUT and the route generator, and the link is configured as a point-to-point link within OSPF [BROADCAST-P2P].

- The ability to create a set of LSAs that appear to be a logical, realistic topology. For instance, the generator should be able to mix the number of point-to-point and broadcast links within the emulated topology and to inject varying numbers of externally reachable destinations.

- The ability to withdraw and add routing information into and from the emulated topology to emulate flapping links.

- The ability to randomly order the LSAs representing the emulated topology as they are advertised.

- The ability to log or otherwise measure the time between packets transmitted and received.

- The ability to change the rate at which OSPF LSAs are transmitted.

- The generator and the collector should be fast enough that they are not bottlenecks. The devices should also have a degree of granularity of measurement at least as small as is desired from the test results.

8. Security Considerations

This document does not modify the underlying security considerations in [OSPF].

9. Acknowledgements

Thanks to Howard Berkowitz (hcb@clark.net) and the rest of the BGP benchmarking team for their support and to Kevin Dubray (kdubray@juniper.net), who realized the need for this document.

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Acknowledgement

Funding for the RFC Editor function is currently provided by the Internet Society.