

Analysis and simulation of IGP Routing Protocols

Agustin Zaballos, Carles Seguí
University Ramon Llull (URL - La Salle Engineering)
Barcelona (Spain)

E-mail: {zaballos, csegui}@salle.url.edu

Abstract

OSPF [1] and IS-IS [2][3] are two link-state routing protocols based on Dijkstra algorithm to calculate the best path to a destination. The first one is the most used in LANs, but IS-IS is getting importance nowadays.

Some comparisons and test proposals are presented in this article to compare both protocols. Those test proposals are based on RFC4061.

Introduction

The convergence time is a very important aspect in routing protocols. It results quite difficult to determine which protocol converges faster because it depends on several things, as configured timers of the protocol or the design of the network.

Some test proposals are provided in the RFC4061 for measuring OSPF single router plane convergence. Based on this scenarios, we made some variations to test IS-IS as well so we can compare them afterwards.

The main goal of this paper is to compare OSPF and IS-IS protocols with the tests and scenarios proposed in the RFC4061. This test will be implemented and simulated to compare results and to determine the exactitude of OPNET.

This paper is organized as follows. In section II we give some general insights on the RFC4061, in section III we explain some important time parameters that can affect the convergence and in section IV we examine the scenarios we implemented and compare the results with the simulated scenarios.

RFC4061: Benchmarking Basic OSPF Single Router Control Plane Convergence

In this section we give a brief overview of the RFC4061. That document describes a specific set of tests aimed at characterizing the single router control plane convergence performance of OSPF processes. A key objective is to propose methodologies that produce directly comparable convergence-related measurements.

There are some considerations that are outside the scope of the RFC: The interactions of convergence and forwarding and Inter-area route generation, AS-external route generation and simultaneous traffic on the control and data paths within the DUT (Device Under Test).

The RFC proposes two kinds of tests: Basic performance tests and basic intra-area OSPF tests. The first ones measure aspects of the OSPF implementation as a process on the DUT. The second ones measure the performance of an OSPF implementation for basic intra-area tasks.

The measures and tests we made focuses on the second kind of tests.

As well as different kinds of tests, the RFC proposes four different network topologies to implement. Depending on the test, it is necessary to implement one topology or another.

Some clarifications and additional information for this RFC can be found in [4] and [5].

OSPF Time parameters

There are some important time parameters that can affect the convergence in a network. Some of them are included in the standard, but others are defined sometimes by the manufacturer.

The important ones are:

- **Hello Interval:** Is the time between two consecutive Hello messages. The default value is 10 seconds for LANs and 30 seconds for NBMA (Non Broadcast Multi-access Network).
- **Dead Interval:** Is the time that an adjacency is considered available without the reception of a Hello packet. The default value is 4 times the hello interval.
- **SPF delay:** Time from a reception of a LSA and the SPF algorithm is activated to calculate a new topology. By default is 5 seconds.
- **SPF Interval:** Time between two SPF consecutive calculations. By default is 10 seconds.
- **LSA Retransmit Interval:** Time to retransmit an LSA that has not been acknowledged. By default is 5 seconds.
- **LSA transmit interval:** Time to transmit two consecutive LSAs. By default is 1 second.
- **LSA reception interval:** Time to receive two consecutive LSAs. By default is 1 second.

IS-IS Time parameters

For IS-IS the important time parameters are:

- **Hello interval:** Time between two consecutive Hello messages. By default is 10 seconds.
- **Hello multiplier:** Value multiplied with Hello interval to get the time that an adjacency is considered valid without a reception of a Hello message. By default is 3.
- **CSNP interval:** Time between two consecutive CSNPs. By default is 10 seconds.
- **SPF interval:** Time between two SPF calculations and the initial delay for a SPF calculation. By default is 5.5 seconds.
- **LSP transmit interval:** Time between two consecutive LSP. By default is 5 seconds.
- **LSP interval:** Time to retransmit a LSP for an intermediate device. By default is 33 mseconds.

Implemented scenarios and simulations

The following considerations had been done prior to the implementation or simulation of the scenarios:

- All routers are Cisco 2500 or Cisco 2600 with IOS 12.0 or above.
- All point-to-point links were being tested with the following bandwidths: 64 Kbps, 128 Kbps, 256 Kbps, 512 Kbps, and 2,048 Kbps.
- All tests were being repeated enough times to get statistical results.
- For all results the SPF delay must be added to get the final convergence time.

Forming adjacencies on Point-to-Point Link with initialization

This test measures the time required to form an adjacency since a layer two connection is formed between two devices running OSPF or IS-IS.

The topology used for this test is the following:

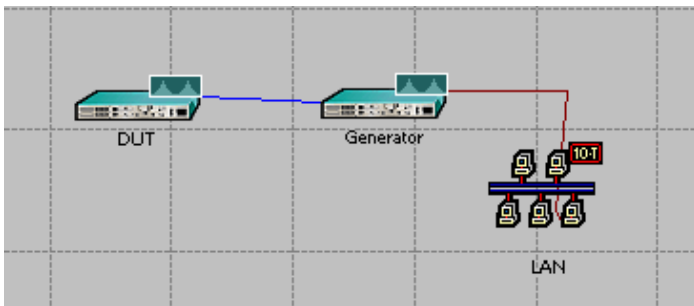


Figure 1: Scenario simulated for “forming adjacencies on point-to-point link with initialization” test

The scenario begins with OSPF configured on both routers and the link between them deactivated on the DUT.

For OSPF (IS-IS) the time is calculated from the link establishment on the Generator to the reception of the last acknowledge, LSack (PSNP), on the Generator for the last LSA (LSP) transmitted to the DUT.

Bandwidth	OSPF test	OSPF simulation
64 Kbps	17.089s	18.193s
128 Kbps	16.793s	18.130s
256 Kbps	17.054s	18.105s
512 Kbps	17.049s	18.095s
2,048 Mbps	17.054s	18.084s
	IS-IS test	IS-IS simulation
64 Kbps	1.724s	1.1011s
128 Kbps	1.364s	1.0051s
256 Kbps	1.188s	1.0025s
512 Kbps	1.133s	1.0013s
2,048 Mbps	1.077s	1.0003s

Table 1: Simulation Results for the “forming adjacencies on point-to-point link with initialization” test

There are no important differences between OSPF tested times and OSPF simulated times and also there are no differences

between IS-IS tested and simulated times. The big difference is between OSPF and IS-IS. OSPF takes about 17 seconds to converge while IS-IS only takes 1 second.

Forming adjacencies with information already in the database

In this test, the DUT is already aware of the entire network topology.

The topology used for this test is the following:

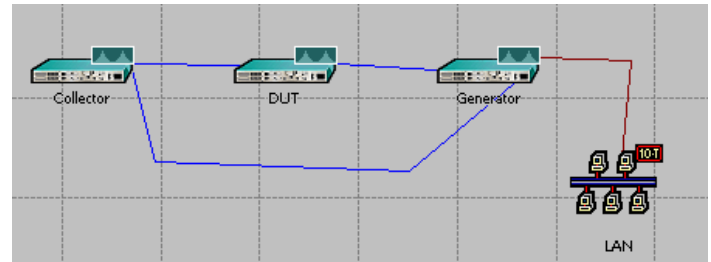


Figure 2: Scenario simulated for the “forming adjacencies with information already in the database” test

The scenario begins with OSPF (IS-IS) configured on all routers and the link between the DUT and the Generator deactivated. DUT knows about the Generator’s LAN through Collector router.

For OSPF (IS-IS) the time is calculated from the link detection in the Generator till the reception of the last acknowledge, LSack (PSNP), on the Generator for the last LSA (LSP) transmitted to the DUT.

Bandwidth	OSPF test	OSPF simulation
64 Kbps	13.156s	13.279s
128 Kbps	13.129s	13.652s
256 Kbps	13.101s	13.921s
512 Kbps	13.057s	13.344s
2,048 Mbps	13.055s	12.955s
	IS-IS test	IS-IS simulation
64 Kbps	1.428s	1.0055s
128 Kbps	1.264s	1.0027s
256 Kbps	1.126s	1.0025s
512 Kbps	1.254s	1.0013s
2,048 Mbps	1.066s	1.0003s

Table 2: Simulation results for the “forming adjacencies with information already in the database” scenario

The results are slightly different compared with the previous test due to that the routers were already known in the router, but there is not important differences between tested times and simulated times

Link down with layer 2 detection

This test measures the time required for a router to notify to its neighbor a link failure with layer 2 detection.

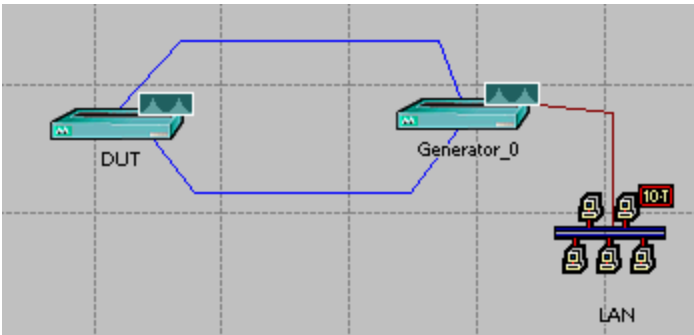


Figure 3: Scenario simulated for the “Link down with layer 2 detection” test

The scenario begins with OSPF (IS-IS) configured on both routers and with full adjacency between them.

For OSPF (IS-IS) the time is calculated from the link failure detection on the Generator till the reception on the generator of a router LSA (LSP) notifying the link failure.

Bandwidth	OSPF test	OSPF simulation
64 Kbps	0.547s	*
128 Kbps	0.538s	*
256 Kbps	0.537s	*
512 Kbps	0.541s	*
2,048 Mbps	0.536s	*
	IS-IS test	IS-IS simulation
64 Kbps	0.086s	*
128 Kbps	0.076s	*
256 Kbps	0.065s	*
512 Kbps	0.056s	*
2,048 Mbps	0.048s	*

Table 3: Simulation results for the “Link down with layer 2 detection” test

Case Study

To test the real behavior of OSPF and IS-IS, a big network of 93 routers was simulated with links of several bandwidths, from 9.6Kbps to 10Mbps.

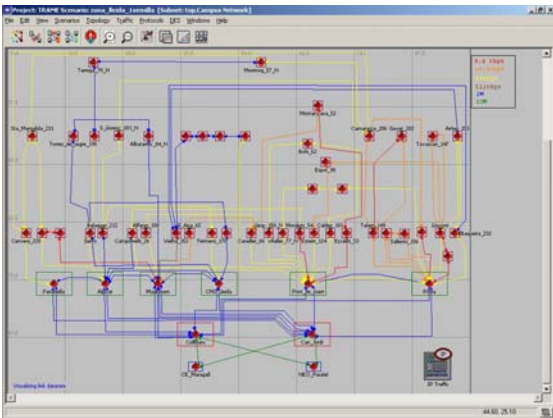


Figure 4: Scenario of the case study simulated.

We tested the initial convergence process and several link and node failures. For each simulation we collected information about the convergence time and link utilization by the routing protocol, OSPF or IS-IS.

Each simulation was done with 10 different seeds to get statistical results and with all the routing protocol timers to their defaults and both protocols run in a single area.

Initial Convergence Process

The convergence time in the initial process is 70 seconds for OSPF and 80 seconds for IS-IS.

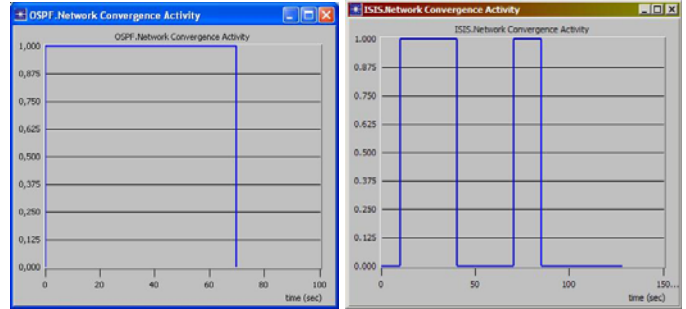


Figure 5: Convergence time of the initial convergence process

IS-IS takes more time to converge due to the slow links of the networks, because they get saturated during the flooding. The next figure shows the queuing delay that the routing protocol introduces in a router. For OSPF, the maximum time is about 12 seconds while for IS-IS is around 70 seconds.

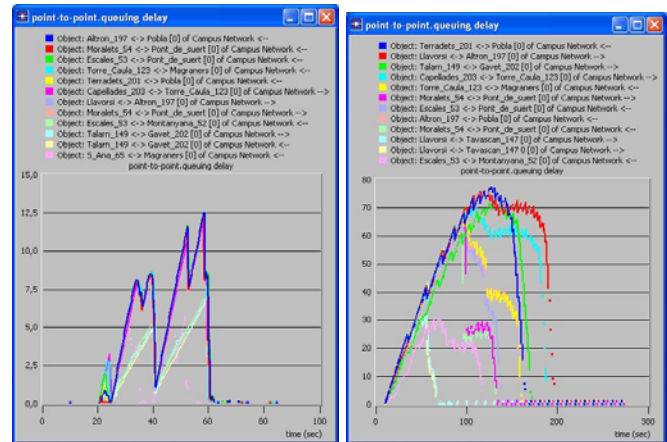


Figure 6: Queuing delay produced by OSPF routing information (left) and IS-IS routing information (right)

The next figure shows the temporal evolutions of the 12 most used links during the convergence for OSPF and IS-IS.

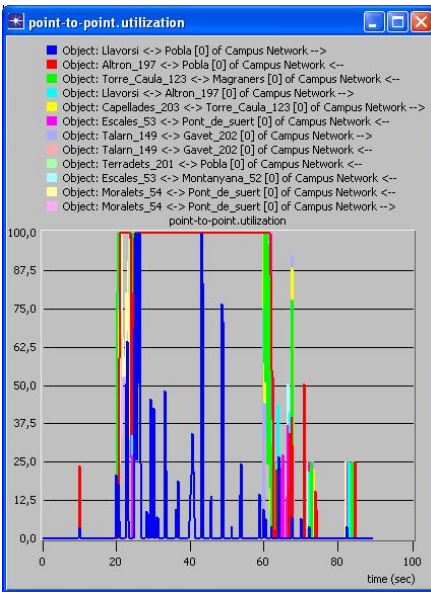


Figure 7: Link utilization with OSPF in the initial convergence process

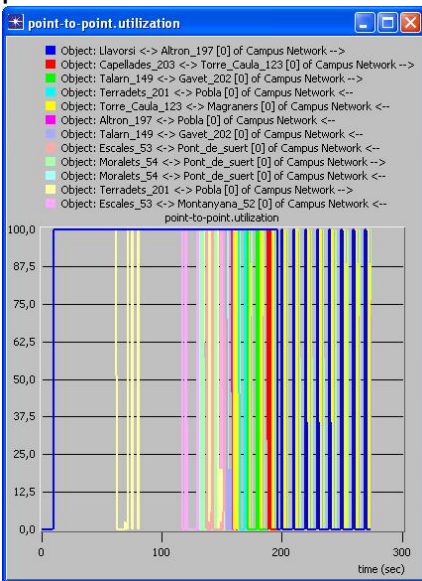


Figure 8: Link utilization with IS-IS protocol in the initial convergence process.

As it can be seen, both protocols have a 100% of utilization in slow links, but IS-IS consumes more bandwidth than OSPF. The short thin lines for OSPF or the long thin lines for IS-IS are the Hello messages that a node sends to all its neighbors every 10 seconds.

The distribution of the maximum link utilization is showed in the next graph. Each color identifies a percentage utilization of a link.

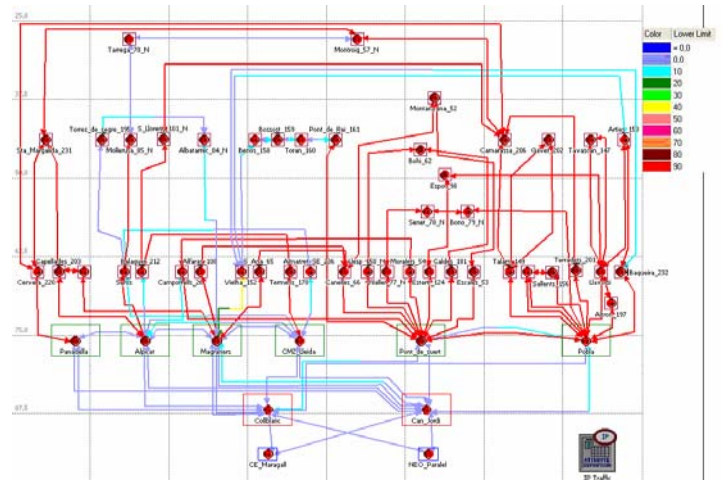


Figure 9: Distribution of the link utilization with OSPF in the network simulated.

In red (>90%) are shown all the links of 9.6 Kbps, 14.4Kbps and 64 Kbps. In blue (<10%) are the links of 2Mbps and 10 Mbps.

With IS-IS the network is slightly different. In red (>90%) are shown the links with a maximum bandwidth of 64Kbps. The major part of 2Mbps links have an utilization of 30-40%, green or yellow color; and the links of 10Mbps presents a blue color (<10%).

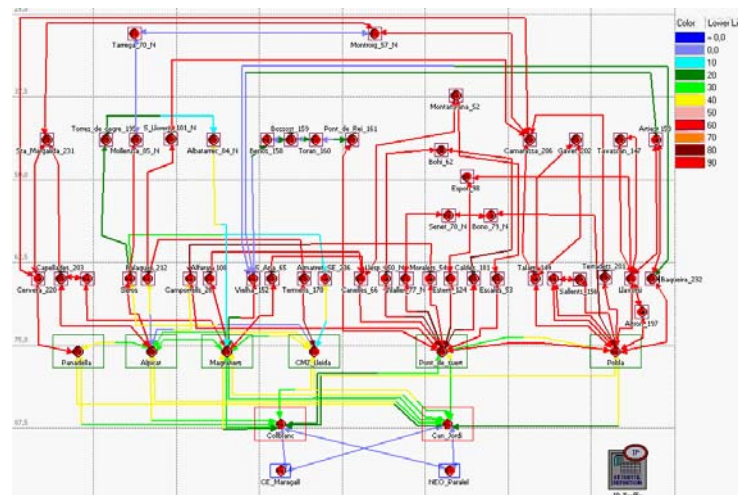


Figure 10: Distribution of the link utilization with IS-IS in the network simulated.

Link Failure

The simulations were done with one, two and three link failures. With OSPF, the protocol takes the same time to converge for each case, 10 seconds to detect the failure and 30 seconds to detect the recover of the link due to timer values.

With IS-IS, the results are quite different. The failure detection and recovery have a duration of between 1 and 6 seconds, depending of which link is the one that fails. These differences between OSPF and IS-IS are due to timer values.

Both protocols have more link utilization during the recovery of the link than the failure of the link. The next graphs show the

evolution of the 12 most used links in the failure and recovery of two links for both OSPF and IS-IS.

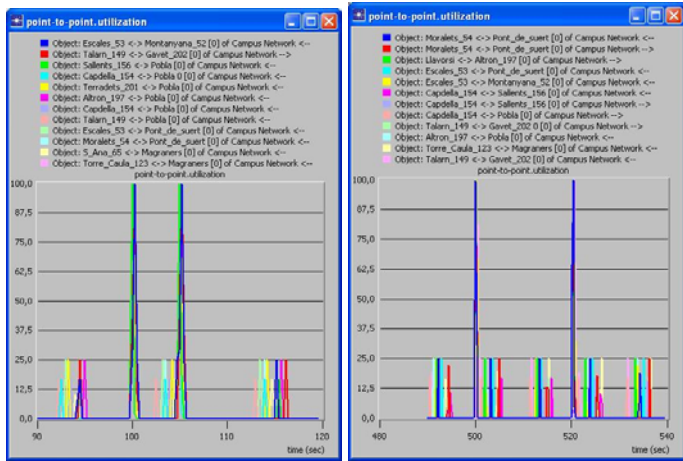


Figure 11: Link utilization with OSPF in the link failure (left) and link recovery (right).

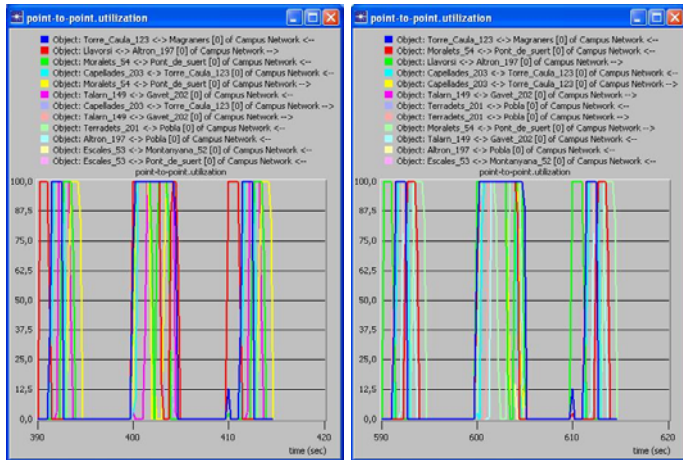


Figure 12: Link utilization with IS-IS in the link failure (left) and link recovery (right)

As it can be seen in the last figures, IS-IS protocol generates more information and links stay in saturation more time.

With OSPF, the links of 9.6Kbps and 14.4Kbps have an utilization from 80-100%. The links of 64 Kbps have an utilization between 10-20% and the rest of the links <10%.

With IS-IS, all links of 64Kbps or less presents an utilization greater than 90% and the rest of links less than 10%.

The results are very similar for the failure and recovery, with slightly greater values in the recovery.

Node Failure

The simulations were done with one and two node failures.

With OSPF, the convergence time for the node failure detection is 40 seconds and the time it takes the network to converge after the node recovery is 50 seconds.

With IS-IS, the failure time and the recovery time is the same, 10 seconds.

The next graphs show the temporal evolution of both OSPF and IS-IS protocols in a node failure and recovery process.

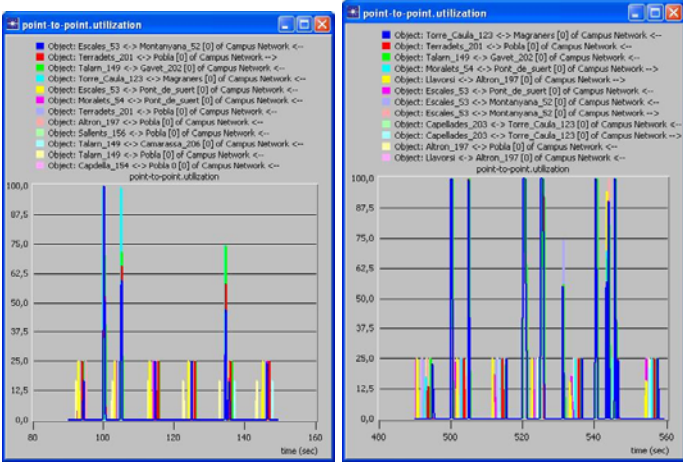


Figure 13: Link utilization with OSPF in the link failure (left) and link recovery (right).

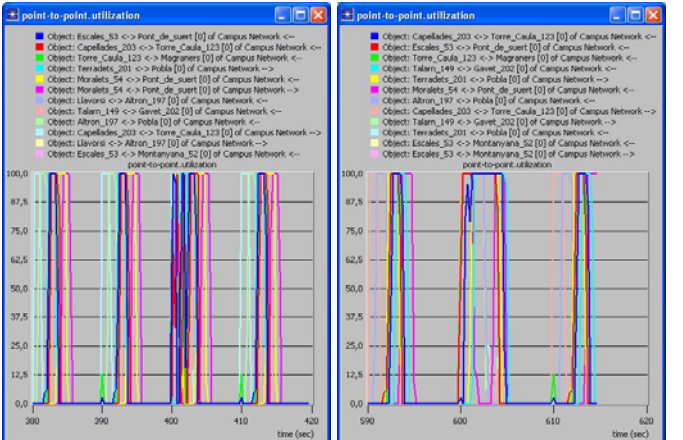


Figure 14: Link utilization with IS-IS in the link failure (left) and link recovery (right)

The link utilization of both protocols is superior in the node recovery than in the node failure.

For OSPF, the links of 9.6Kbps and 14.4Kbps have a saturation greater than 90%, the links of 64Kbps are saturated between 30-50% and the rest less than 10%.

With IS-IS, the saturation of 90 or 100% is present in links of 64Kbps and less, and the rest have a saturation of 10%.

Conclusion

In this paper we have presented some results to compare the convergence time for OSPF and IS-IS based on scenarios and test proposed by an RFC. Afterwards all these tests are being simulated to contrast and validate the results.

With the case study can be concluded that both OSPF or IS-IS protocols are appropriate protocols for large networks, but OSPF is more adequate for networks with heterogeneous bandwidths and IS-IS is more appropriate for networks with high bandwidths, 64 Kbps or more. With slow links, IS-IS has some congestion and it slows the convergence time of the network.

References

- [1] J. Moy, "OSPF version 2", RFC2328, April 1998.
- [2] "Intermediate System to Intermediate System intra-domain routing information exchange protocol for use in conjunction with the protocol for providing the connectionless-mode network service (ISO 8473)", ISO/IEC 10589, November 2002.
- [3] R. W. Callon, "Use of OSI IS-IS for routing in TCP/IP and dual environments" RFC1195, December 1990.
- [4] V. Manral, R. White, "Benchmarking Basic OSPF Single router Control Plane Convergence", RFC4061, April 2005.
- [5] V. Manral, R. White, "OSPF Benchmarking Terminology and Concepts", RFC4062, April 2005.
- [6] V. Manral, R. White, "Considerations when using basic OSPF convergence Benchmarks", RFC4063, April 2005.