OWAMP Performance and Interoperability Tests

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Abstract. Actual IP networks must support a huge diversity of applications and services and have to cope with many user behaviors and different mechanisms of traffic generation and control. The combined effects of all these factors lead to a highly variable traffic that brings increasing challenges to network management operations. In this context, active traffic monitoring is particularly important as it enables characterizing essential aspects of network operation like, for example, quality of service measured in terms of packet delays and losses. One-Way Active Measurement Protocol (OWAMP) is a recent proposal of the Internet2 group that is currently being standardized by IETF under the scope of the IPPM group. OWAMP is an architecture used to perform active measurements of one-way delays and losses between hosts. Recently, different implementations of OWAMP were developed and their interoperability must be assured. This paper describes a set of performance and interoperability tests that were carried out between two different implementations of the OWAMP protocol (Internet2 OWAMP and J-OWAMP): a first test that intended to illustrate the correct interoperability of both implementations in terms of the expected operating behavior of the different system components; a second test that intended to compare performance measurement results obtained using both implementations and a third test that intended to check for the symmetry/asymmetry of the Internet links connecting the two measurement sites that were used in the experiments. The main results of the tests are presented, as well as the most important conclusions.

keywords: OWAMP, traffic monitoring, active traffic measurement, interoperability, network management.

1 Introduction

This paper describes a set of performance and interoperability tests that were carried out from October 11 to October 12 2005 and from November 21 to November 22 2005 in the context of the OWAMP (One-Way Active Measurement Protocol) interoperability event [1] organized by the MOME project [2]. Since there are different implementations of OWAMP, this event aimed essentially (i) to bring together institutes and researchers that developed OWAMP implementations; (ii) to show the possibilities and limitations of OWAMP; (iii) to improve and debug implementations and (iv) to check the interoperability of implementations.

The tests were carried out between the Aveiro pole of the Institute of Telecommunications (IT) – Aveiro (Portugal) and the Salzburg Research Advanced Networking Center – Salzburg (Austria) using two different implementations of OWAMP. The first one is J-OWAMP, a Java implementation of OWAMP developed at IT, in particular versions 1.0 and 1.1 [3][4] that implement the May 2004 draft proposal of OWAMP [5]. Version 1.0 was used on the tests from October 11 to October 12 2005 and version 1.1 was used on the tests from November 21 to November 22 2005. The second implementation is Internet2 OWAMP, version 1.6f.

The paper is structured in the following way: section 2 presents a brief description of OWAMP, section 3 describes the different measurement scenarios, presents the obtained results and discusses them; section 4 explains how to map the obtained results to the MOME database in order to make them publicly available and, finally, section 4 presents the main conclusions.

2 OWAMP description

The OWAMP is a recent proposal from the Internet2 group, developed under the scope of the End-to-End Performance Initiative project [6], for performing active measurements in a single direction. This proposal is also promoted by the IETF IPPM work group [5].

The OWAMP architecture, shown in Figure 1, is based on two inter-dependent protocols, the OWAMP-Control and the OWAMP-Test, which can guarantee a complete isolation between client entities and server entities. The OWAMP-Control protocol runs over TCP and is used to begin and control measurement sessions and to receive their results. At the beginning of each session, there is a negotiation about the sender and receiver addresses, the port numbers that both terminals will use to send and receive test packets, the instant of session start, the session duration, the packet size and the mean interval between two consecutive packets. The OWAMP-Test runs over UDP and is used to exchange test packets between sender and receiver. These packets include a Timestamp field that contains the time instant of packet emission. Besides, each packet also indicates if the sender is synchronized with some exterior system (using GPS or NTP) and includes a Sequence Number. OWAMP supports some extra facilities like test packets with service differentiation, cipher, authentication, or the use of proprietary protocols in all connections that do not compromise interoperability.

The OWAMP architecture includes the following elements: Session-Sender - the sender of the test packets; Session-Receiver - the receiver of the test packets; Server - the entity that is responsible for the global management of the system, being able to configure the two terminal elements of the testing network and receive the results of a test session; Control-Client - a terminal system that programs demands for test sessions, triggers the beginning of a session set and can also finish one or all ongoing sessions; Fetch-Client - a terminal system that triggers the demands for results of test sessions that have already ended or are still running.
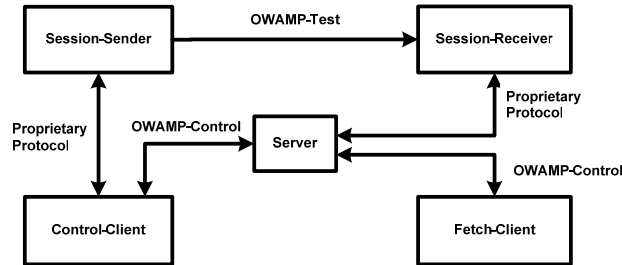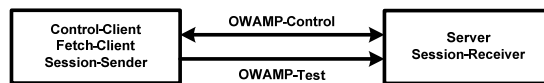
Figure 1 – OWAMP architecture.

Figure 2 – OWAMP simplified architecture.

A network element can carry out several logical functions at the same time. For example, we can have only two network elements (Figure 2): one is carrying out the functions corresponding to a Control-Client, a Fetch-Client and a Session-Sender and the other one is carrying out the functions corresponding to a Server and a Session-Receiver.

3 Measurement Scenarios and Results

The tests were carried out between the Aveiro pole of the Institute of Telecommunications (IT), located at Aveiro (Portugal), and the Salzburg Research Advanced Networking Center (SRANC), located at Salzburg (Austria) (Figure 3). Two different implementations of OWAMP were used during the tests: J-OWAMP [3] and Internet2 OWAMP [6]. Three measurement scenarios were set-up in order to (i) test the interoperability of the OWAMP implementations (Section 0), (ii) compare the results obtained with both implementations (Section 3.2) and (iii) test the symmetry of the Internet in terms of one-way delay (Section 3.3).

Figure 3 – Location of the measurement sites.

3.1 J-OWAMP and Internet2 OWAMP Interoperability Scenario

This measurement scenario was set-up to test the interoperability between the J-OWAMP and the Internet2 OWAMP implementations. Several tests were carried out in order to verify that both implementations can interoperate and perform measurements, on one hand, and to analyze the obtained results, on another hand.

In order to perform the tests between J-OWAMP and Internet2 OWAMP we have installed an OWAMP Sender (*OWAMP_SessionSender*) element and an OWAMP Control-Client (OWAMP_ControlClient) element at the IT site and the OWAMP server and receiver elements (*owampd*) at the SRANC site. The IT OWAMP machine was configured with the 193.136.92.121 IP address and the SRANC OWAMP machine was configured with the cmdaemon.salzburgresearch.at address. We have used the 22368 TCP port to perform the OWAMP control and the 21164 to 21174 UDP port range to perform the OWAMP test measurements. An internal NTP server (gtav.it.pt/193.136.92.1) was used to synchronize the IT OWAMP machine. This NTP server is a Stratum 6 NTP server and its synchronization signal originates at a NTP stratum 2 server (ntp01.fccn.pt/193.136.5.16). This server is synchronized with two NTP stratum 1 servers (tt55.ripe.net/193.136.6.18 and tt72.ripe.net/193.136.2.229), which are synchronized by GPS. The SRANC OWAMP machine is a GPS-equipped Stratum 1 NTP server.
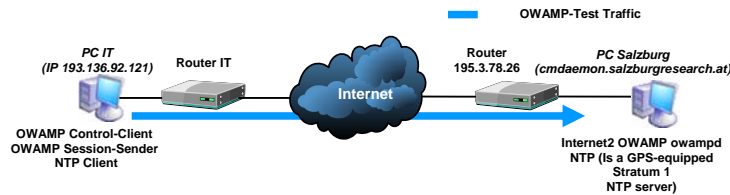

Figure 4 - Interoperability scenario.

To identify the path between both measurement sites we executed a *traceroute* command in both OWAMP machines. The path and the round-trip delays between the IT site and the SRANC site is depicted in Figure 5 and the reverse path and round-trip delays are depicted in Figure 6. The *traceroute* commands show that the path and reverse-path between the IT and SRANC sites pass through the same Internet providers but not through the same routers. Even the number of hops is not the same, 18 from IT to SRANC and 17 from SRANC to IT.

```
Tracing route to cmdaemon.salzburgresearch.at [212.183.10.170] over a maximum of 30 hops:
 1    1 ms    1 ms    1 ms  gtav.it.pt [193.136.93.1]
 2    1 ms    1 ms    1 ms  fw1.core.ua.pt [193.136.86.222]
 3    1 ms    1 ms    1 ms  gt-ext.core.ua.pt [193.137.173.254]
 4    2 ms    1 ms    1 ms  Router2.Porto.fccn.pt [193.136.1.193]
 5    6 ms    5 ms    6 ms  Router3.10GE.Lisboa.fccn.pt [193.136.1.221]
 6    5 ms    5 ms    5 ms  ROUTER1.GE.Lisboa.fccn.pt [193.137.0.11]
 7    6 ms    5 ms    6 ms  fccn.pt1.pt.geant.net [62.40.103.177]
 8   33 ms   32 ms   32 ms  pt.uk1.uk.geant.net [62.40.96.69]
 9   32 ms   32 ms   33 ms  ldn-b2-pos4-0.telia.net [213.248.75.109]
10   33 ms   33 ms   32 ms  ldn-bb1-pos0-1-0.telia.net [213.248.74.1]
11   41 ms   40 ms   40 ms  adm-bb1-pos6-0-0.telia.net [213.248.65.150]
12   46 ms   46 ms   46 ms  hbg-bb1-pos7-1-0.telia.net [213.248.65.154]
13   66 ms   65 ms   65 ms  win-b2-link.telia.net [213.248.64.170]
14   66 ms   66 ms   66 ms  telekom-austria-108216-win-b2.c.telia.net [213.248.76.2]
15   66 ms   66 ms   66 ms  195.3.70.194
16   66 ms   66 ms   66 ms  AUM3-AUX3.highway.telekom.at [195.3.78.53]
17   71 ms   72 ms   71 ms  195.3.78.26
18   77 ms   76 ms   76 ms  cmdaemon.salzburgresearch.at [212.183.10.170]
```

Figure 5 - Result of the 'tracert' command between the IT and SRANC sites.

```
traceroute to 193.136.92.121 (193.136.92.121), 30 hops max, 40 byte packets
 1  212.183.10.161 (212.183.10.161)  3.689 ms  0.975 ms  1.005 ms
 2  195.3.93.129 (195.3.93.129)  4.703 ms  4.933 ms  4.693 ms
 3  195.3.78.25 (195.3.78.25)  167.831 ms  96.260 ms  5.648 ms
 4  IIX1-WARSSW02.highway.telekom.at (195.3.70.195)  10.838 ms  10.115 ms  15.042 ms
 5  win-b2-geth1-1.telia.net (213.248.76.1)  10.834 ms  10.589 ms  10.134 ms
 6  hbg-bb1-link.telia.net (213.248.64.169)  29.623 ms  33.315 ms  29.596 ms
 7  ldn-bb1-link.telia.net (80.91.249.10)  43.425 ms  43.418 ms  43.201 ms
 8  ldn-b2-pos9-0.telia.net (213.248.74.2)  43.189 ms  43.673 ms  43.417 ms
 9  dante-01233-ldn-b2.c.telia.net (213.248.75.110)  42.946 ms  49.614 ms  43.419 ms
10  uk.pt1.pt.geant.net (62.40.96.70)  70.580 ms  70.344 ms  81.231 ms
11  fccn-gw.pt1.pt.geant.net (62.40.103.178)  70.574 ms  71.571 ms  70.351 ms
12  193.137.0.27 (193.137.0.27)  70.576 ms  70.593 ms  70.574 ms
13  Router2.10GE.Porto.fccn.pt (193.136.1.222)  74.278 ms  74.786 ms  73.575 ms
14  UA.Aveiro.fccn.pt (193.136.1.194)  80.940 ms  75.264 ms  75.513 ms
15  fw1-ext.core.ua.pt (193.137.173.253)  76.528 ms  75.028 ms  75.282 ms
16  gt-it.core.ua.pt (193.136.86.202)  77.979 ms !X *  85.876 ms
17..193.136.92.121 (192.136.92.121)
```

Figure 6 - Result of the 'traceroute' command between the SRANC site and the IT site.

To cross check the OWAMP results, we performed a r*ound-trip delay* measurement between the IT and SRANC sites. By executing the *ping* command, we obtained an average round-trip delay of 75 ms.

To perform the OWAMP measurements we carried out several measurement actions between the Aveiro and Salzburg sites in order to evaluate the average one-way delay and packet losses. All tests were performed in a 24 hours period, from 12:00 October 11 to 11:00 October 12 2005. In each hour, sets of 10 tests (including both packet delay and loss) were performed, making a total of 240 tests. In each set, the start time of the individual tests was separated by 2 minutes. All tests lasted for 1 minute and consisted in sending 60 packets of 24 bytes each, at an average rate of 1 packet/second. In order to conveniently characterize the packet average delay and packet loss ratio, we have calculated 90% confidence intervals based on the 10

average values obtained in each set. The average packet one-way delay and packet timeout loss ratio results are presented in Figure 7 and Figure 8, respectively.
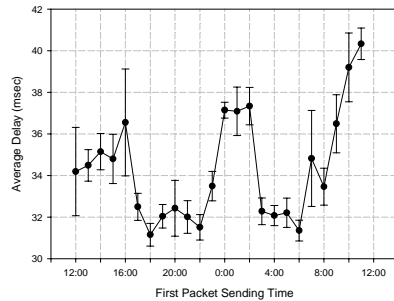
Figure 7 - Average packet delay versus first packet sending time.
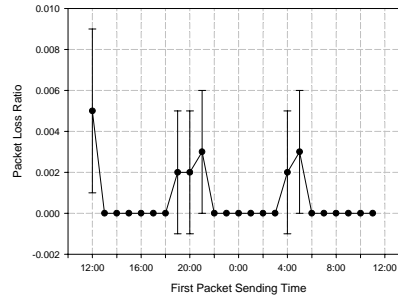
Figure 8 - Packet timeout loss ratio versus first packet sending time.

From the analysis of the average one-way delay values we can see that delays vary between approximately 31 and 41 milliseconds. This result is consistent with the estimates obtained through ping assuming equal delays in each direction. In fact the one way packet delay is almost one half of the round-trip delay (75 ms). Analyzing the packet loss results, the average loss ratio indicates that no packets were actually lost but the average timeout loss ratio reveals that a small fraction of packets were received with excessive delay. The average duplication ratio is null, since no packets were duplicated during the tests. The average throughput values are approximately 24 bytes/second because all tests lasted for 1 minute and consisted in sending 60 packets of 24 bytes each, at an average rate of 1 packet/second.

### 3.2 J-OWAMP and Internet2 OWAMP Comparison Scenario

In this scenario, we intend to compare results obtained using the J-OWAMP and Internet2 OWAMP implementations. We performed one-way delay measurements between the IT and SRANC sites using both implementations simultaneously, but in an independent way. In order to perform the tests with J-OWAMP, we have installed all its elements in the J-OWAMP IT machine (193.136.92.121) and the OWAMP sender (OWAMP_SessionSender) and OWAMP receiver (OWAMP_SessionReceiver) elements in the J-OWAMP SRANC machine (anc-test.salzburgresearch.at). To perform the tests using Internet2 OWAMP, we have installed the OWAMP control-client (owping) element in the IT measurement machine (193.136.92.121) and the OWAMP Server (owampd) element in the SRANC measurement machine (cmdaemon.salzburgresearch.at). The UDP and TCP ports were the same of the previous measurements. The NTP configuration is the same as previous, with the exception of the J-OWAMP SRANC machine (anc-test.salzburgresearch.at) that synchronizes to cmdaemon.salzburgresearch.at. Figure 9 illustrates this measurement scenario.

All tests were performed in a 1 hour period. A set of 10 tests was performed, from 12:05 to 13:05 November 21 2005. The start time of the individual tests was separated by 2 minutes. All tests lasted for 1 minute and consisted in sending 60 packets of 24

bytes each, at an average rate of 1 packet/second. In order to conveniently characterize the packet average delay, we have calculated 90% confidence intervals based on the 10 average values obtained. The obtained results are presented in Table 1, Figure 10 and Figure 11. From the average delay and loss ratio results presented in Table 1, that were obtained using J-OWAMP and Internet2 OWAMP, we can conclude that both implementations produce equivalent results under the same conditions.

Table 1 - J-OWAMP vs. Internet 2 OWAMP test results

| Tool	Start Time	Average Delay and 90% CI (ms)	Average Timeout Loss ratio and 90% CI	Average Not Received Loss ratio and 90% CI
J-OWAMP	12:05:00 21/11/2005	38.11 [37.32 38.9]	0 [0 0]	0 [0 0]
Internet2 OWAMP	12:05:00 21/11/2005	37.554 [37.342 37.765]	0 [0 0]	0 [0 0]
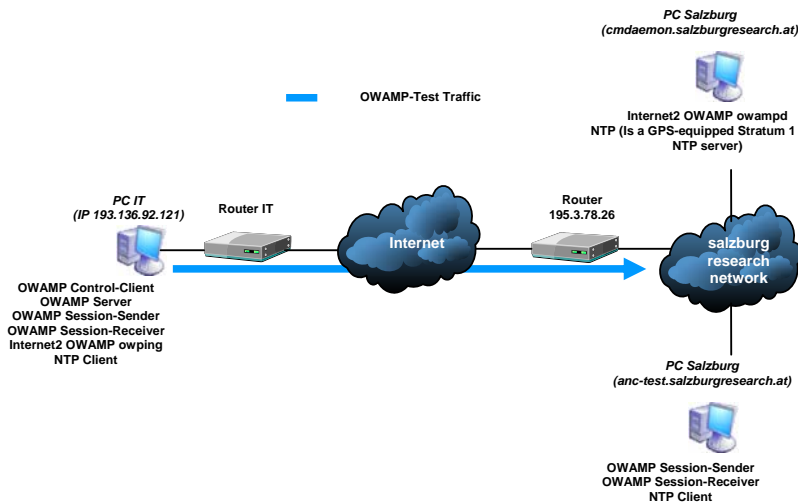
Figure 9 - Results comparison scenario.

3.3 One-Way Delay Measurement in Both Directions using J-OWAMP Scenario

In order to study, using J-OWAMP, the packet delay in both directions between a pair of hosts we performed several tests between the IT and SRANC sites. Maintaining the same configuration, we performed one-way delay measurements in both directions using only J-OWAMP. Tests were carried out between the IT measurement machine (193.136.92.121) and the J-OWAMP SRANC machine (anc-test.salzburgresearch.at).
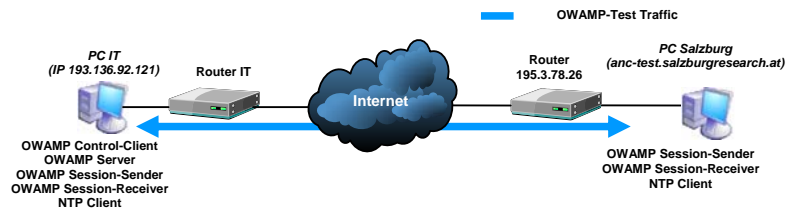
The UDP and TCP ports used were the same of the previous measurements and the NTP configuration was also the same. Figure 12 illustrates the test scenario.
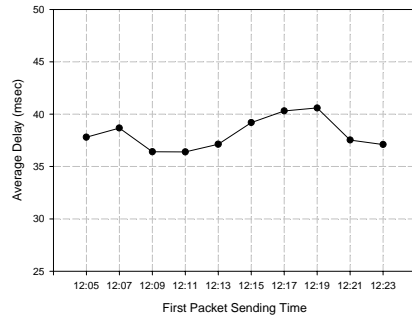
Figure 10 - Average delay between IT and Salzburg using J-OWAMP.
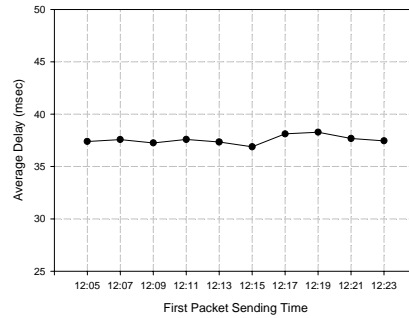
**Figure 11** - Average delay between IT and Salzburg using Internet2 OWAMP.

Figure 12 - One-way delay measurement in both directions scenario.

In this scenario we performed several measurements between IT and Salzburg, in both directions, in order to evaluate the average delay and packet loss. All tests were performed in a 19 hours period, from 12:00 November 21 to 6:00 November 22 2005. In each hour, sets of 10 tests (including both packet delay and loss) were performed, making a total of 190 tests. In each set, the start time of the individual tests was separated by 2 minutes. All tests lasted for 1 minute and consisted in sending 60 packets of 24 bytes each, at an average rate of 1 packet/second. In order to conveniently characterize the packet average delay and packet loss ratio, we have calculated 90% confidence intervals based on the 10 average values obtained in each set. The results are presented in Figure 13 and Figure 14, for the average delay.

The results show that delays are not the same in both directions, but there is no marked difference (they both range from 35 and 50 milliseconds). This can be explained by the fact that although traffic goes through the same Internet providers it does not traverse the same routers. Note that different routers can have different loads depending of the routing tables and the time of the day. We can also observe that the one-way delay from IT to SRANC increases during the night; which can be explained by the fact that the IT Internet access network is shared with the students' residences of University of Aveiro that have much more traffic during the night. The one-way delay results in the other direction have the expected behavior for a research institution, i.e., a lower delay during the night period.
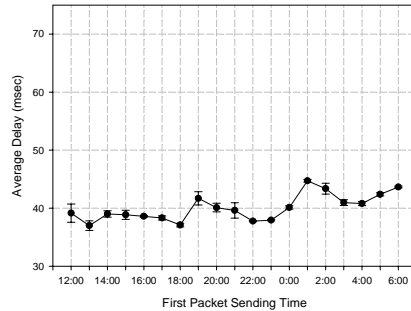
Figure 13 - Average packet delay versus first packet sending time between IT and SRANC.
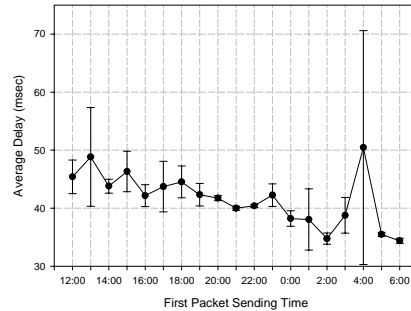
Figure 14 - Average packet delay versus first packet sending time between SRANC and IT.

4 Mapping of J-OWAMP Results to MOME Database

The results of the interoperability tests have been included to the MOME database. The MOME database [8] is a public meta-database for monitoring and measurement results. To extract the meta-data from the J-OWAMP measurements, the following mapping has been applied.

Table 2. Mapping of J-OWAMP results to MOME meta-database structure

MOME meta-database tag	J-OWAMP-extracted value
Dataset name	OWAMP interop test, 21/11/2005 <number of test>
Data type	QoS
File size	<File size of the result table>
File compression	none
Start time	<Send time of first packet>
End time	<Send time of last packet>
Description	A short description on the reason of testing
Dataset location	The URL to the result table
Tool	J-OWAMP, resp. OWAMP
Network Type	WAN, public Internet
Measurement Type	active
Metrics	OWD, loss, throughput, duplications
Sender Location	<location of sender, either Aveiro or Salzburg, incl. IP address>
Receiver Location	like sender location, but vice versa
Sender Platform	Linux PC
Receiver Platform	Linux PC
Timestamp Synch.	NTP, GPS
Number of Values	<the number of single packet data values>
Data Format	HTML

For these initial tests, the results have been entered to the MOME database using the provided web interface. In future, the metadata of the J-OWAMP tests can be extracted automatically after the tests have been executed.

5 Conclusion

Active traffic monitoring plays a particularly important role in actual IP networks since it can bring a new insight into essential aspects of network operation like, for example, quality of service issues. The One-Way Active Measurement Protocol (OWAMP) is a recent proposal of the Internet2 group that is currently being standardized by IETF under the scope of the IPPM group and constitutes an architecture used to perform active measurements of one-way delays and losses between hosts. Since there are different implementations of OWAMP, the evaluation of their accuracy and efficiency and the assurance of their interoperability are critical issues. This paper describes a set of performance and interoperability tests that were carried out between two different implementations of OWAMP (J-OWAMP and Internet2 OWAMP): a test intended to illustrate the correct interoperability of both implementations in terms of the expected operating behavior of the different system components, a test intended to compare performance measurement results obtained using both systems and, finally, a test intended to check for the symmetry/asymmetry conditions of the Internet links connecting the two measurement sites that were used in the experiments. The obtained results show that both implementations of OWAMP could interoperate and achieve consistent results. Moreover, the one-way delay results obtained show that there is an Internet asymmetry between the IT and SRANC sites.

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