

Software IMS Core Network under SIP Load Evaluation

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Abstract—The aim of the paper is to present evaluation of software open-source IMS network under the load of SIP messages. The OpenIMS Core platform in virtualized environment were selected for evaluation. Then the performance tests based on the ETSI standard and its metrics are evaluated. The paper also presents some limitations and solutions for this platform which were encountered during our testing.

Keywords— IMS Bench SIPp, Performance, Benchmark Test, Virtualization.

I. INTRODUCTION

THE IP Multimedia Subsystem (IMS) is the first standardized Next Generation Network architecture [1]. It is a standardized access independent control architecture which offer large variety of multimedia services based on IP protocol to end users. The IMS concept was developed by The Third Generation Partnership Project (3GPP) organization and it is based on Internet Engineering Task Force (IETF) standards [2]-[3]. The main task of IMS is to achieve a fixed and a mobile convergence. The performance benchmark has large import in praxis, because the results of a performance tests support to achieve relevant information for testing and design of new products and eventually their further optimization. Therefore, we can achieve not only required Quality of Service, but also satisfaction of end users [5], [6].

Several open-source implementations of the IMS core are available – Open IMS Core, Kamailio and Clearwater [11]-[13]. The Open IMS Core project consists of implementation of basic IMS network components - a subsystem for call/session control (P/I/S-CSCF) and a simple user database (Home Subscriber Server - HSS). These are the basic common components of all IMS architectures defined within 3GPP, 3GPP2 a ETSI TISPAN organizations. All of these IMS components are implemented as a software with open-source code. Open IMS Core project was developed by Franhoufer

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institute in Berlin (FOKUS) and it is designed for a simple testing of IMS networks. It is also suitable for study of an IMS principles and its operation..

II. BENCHMARK STANDARDIZATION

The TISPAN standardization body, working under the guides of the European Telecommunications Standards Institute (ETSI), elaborated in 2007 the ETSI Standard TS 186 008 dealing with IMS / NGN network performance testing [7]-[10]. The last revision of the standard was made in 2015. It should be emphasized that the recommendation is not only relevant for TISPAN IMS but also for IMS from the 3GPP standardization body as it deals with testing the performance of IMS networks from a user perspective for which the two variants are the same. The content of the recommendation itself is quite extensive and is divided into 4 parts.

The first part defines the overall benchmark descriptions, architectures, processes, and information models that are common to all specific benchmarking scenarios. The second part describes specific benchmarking use-cases and scenarios, along with scenario specific metrics and design objectives. It also defines the system under test (SUT) configuration parameters. The third part defines an initial benchmark test through the specification of a traffic set, traffic-time profile and benchmark test procedure. The last part of standard defines Reference Load network quality parameters for the use cases defined in the second part.

The principle of testing itself is that we monitor the behaviour of the system with the growing number of users requiring system service. Therefore, we analysing the work of the queuing system, in our case the IMS system. The performance test consists of a test system and a system whose performance is measured. From the test system we target the simulated load on the tested system (IMS) and based on the measured results we can determine the maximum system capacity.

The basic terms defined by ETSI TS 186 008 standard are:

Use Case - type of interaction between a test system and a system under test.

Design Objective (DO) - probabilistic model of delay and failure requirements for the system under test (SUT) associated with a use-case and specified by threshold values and probabilities for delay and scenario failure.

Design Objective Capacity (DOC) - the largest load that

system under test can sustain within defined DO.

Scenario - operation within IMS network, i.e. sequence of exchanged messages.

Scenario Attempts per Second (SAPS) - average number of scenarios initiated by the test system per second.

Inadequately Handled Scenario Attempts - failed scenario or scenario which exceeds the threshold values.

Design Objective Capacity can be found by *%IHS metric*, which is the ratio of inadequately handled scenarios to the total number of attempted scenario.

III. NETWORK ARCHITECTURE

The architecture of a simple test workstation is illustrated in the Fig. 1. Two virtual machines on one physical machine were created using a virtualization tool, one of which implements the system under test (in our case Open IMS Core), and the second virtual machine implements the test system for which IMS Bench SIPp was selected. VirtualBox or VMware, can be used as a virtualization tool. In our case, we have used VMware Workstation 10 software.

For benchmark testing there are several tools available [11]. The most suitable for our purpose were Seagull multiprotocol traffic generator from Hewlett-Packard and IMS Bench SIPp (IBS) [14]. Our tests were realized with use of IBS tool.

IMS Bench SIPp is a modified version of the SIPp (SIP Traffic Generator) test tool with support of scenarios and several other tools to ensure the full implementation of the test system. At the same time, this test system fully complies with ETSI TS 186 008 standard. IBS allows to generate a total of five possible scenarios:

- Successful connection establishment between users (call),
- Successful exchange of instant messages between users,
- Initial registration of user into IMS network,
- Registration cancellation,
- Repeated registration.

These types of individual scenarios are the most common in real traffic. IMS Bench SIPp also includes a tool for creating a complete report about system under test. This report is based on the acquired information and the measured metrics during the test. The generated report is consistent with the ETSI TS 186 008 standard. We have installed the IMS Bench SIPp on the Ubuntu 14.04 LTS operating system.

As a system under test, we have used LiveCD with preinstalled Debian operating system and Open IMS Core. Creating of users in the Open IMS Core can be done via the HSS graphical interface, but from a practical point of view for testing, when a large number of users need to be created, we have created users using an automated script.

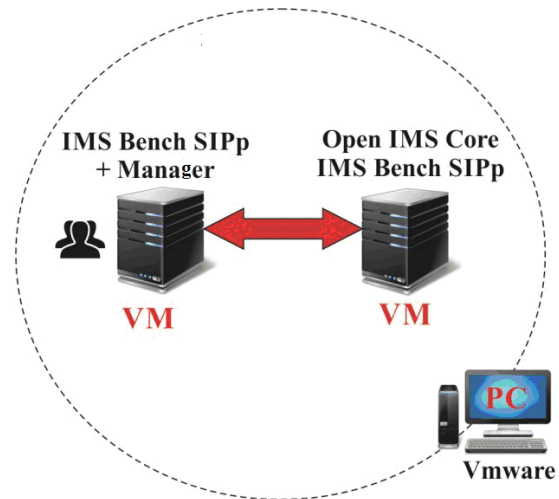


Fig. 1. Test system and system under test

As part of our initial performance tests, we have experienced a limited number of user registrations that were inadequate for planned testing. The effort to register a large number of users was accompanied by a 600 Busy everywhere - Forwarding to S-CSCF failed error message. This error message was generated by the I-CSCF server. This is caused by the incorrect implementation of the activation scripts (pcscsf.sh, icscf.sh and scscf.sh) that trigger the P-CSCF, I-CSCF and S-CSCF components. The individual P/I/S-CSCF components were started only with 32 MB of shared memory. The reported value is insufficient for a large number of registered users. For this reason, it is necessary to modify the activation scripts accordingly. We eliminate this problem by adding the SIP Express Router (SER) parameter '-m 1024' (but the value can be arbitrary) as the CSCF components route SIP traffic based on SER routing scripts. The reported SER parameter will increase the size of the shared memory to the desired value. This problem can be fixed in /usr/sbin folder where the pcscsf.sh, icscf.sh and scscf.sh scripts are located. In the penultimate row of the source code we have to add parameter '-m 1024' just behind '\$ SER' value.

The users in the Open IMS Core system can be added to database by graphical web user interface through FHoSS (Home Subscriber Server). This time consumption way is suitable only for low number of users. For test purposes we need the large number of users (thousands) and the test system IBS could not create the new users by itself. Therefore, we have used simple script to automatically create the test users.

System configuration of test workstation was following:

Physical Machine: CPU: Intel® Core™ i5-4440S 2.80 GHz, RAM: 4 GB DDR3 1600 MHz, HDD: 1 TB SATA 7200 RPM.

Reserved system resources: 1. Virtual Machine - IMS Bench SIPp: RAM: 1 GB, HDD: 20 GB; 2. Virtual Machine - Open IMS Core: RAM: 2 GB, HDD: 20 GB.

IV. METHODOLOGY OF TESTING

ETSI 186 008 standard specifies that performance testing of

the IMS network should consist of all possible scenarios from a set of registration scenarios, connection scenarios, and message exchange scenarios. In our case, this requirement is virtually unrealistic because our test system IMS Bench SIPp does not provide all the possible scenarios mentioned in the standard. Our test system provides only 5 possible scenarios: registration, re-registration, cancellation, successful call, and successful message exchange. However, these scenarios are sufficient in terms of traffic modelling.

At the same time, the standard specifies that all scenarios should run concurrently with other scenarios during operation, depending on their percentages defined in the traffic settings. The ratio of particular scenarios is following – 3% of registration scenarios, 73% of call scenarios and 24% of message exchange scenarios. From practical experience, we found that testing of the Open IMS Core platform with a parallel run of all possible scenarios is practically impossible. We conclude this according to the fact that already at a very low load, i.e. 2 SAPS, all scenarios were cancelled and the metric of the inadequately handled scenarios %IHS reached the threshold 100% and the test was immediately terminated by the IMS Bench SIPp manager. Also, the limit of %IHS according to standard, that sets this limit at 0.1%, was practically impossible to achieve. Despite of the modification of the recommended settings, we have not been able to perform a long-term test to get relevant results, but almost every test, even under a low load (SAPS), ended up exceeding the limit of %IHS.

Furthermore, Open IMS Core platform show signs of instability. Many tests resulted in the fall of individual components and they had to be restarted. Developers of this platform point out that the Open IMS Core platform is not well implemented for stress tests, but serves only for smaller test runs. For these reasons, we decided to modify the traffic setup by testing the performance of the Open IMS Core platform individually for each set of scenarios.

V. RESULTS

The first test was focused on system performance only for registration scenarios (registration, re-registration and cancellation of registration). The second test focused on system performance when making calls, and the last third test was focused on system performance when exchanging messages between users. In all cases, the goal was to test the system for a longer time (30 min - 1 hour). In the next section, the results of these tests, which most reliably reflect the Design Objective Capacity of system under test Open IMS Core, are presented.

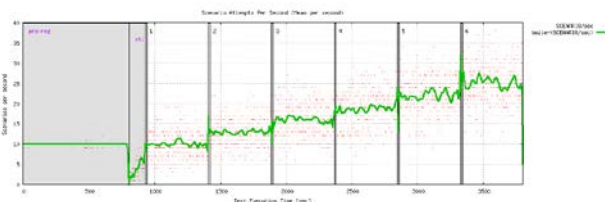


Fig. 3. SAPS load during registration scenario

A. Registration Scenario

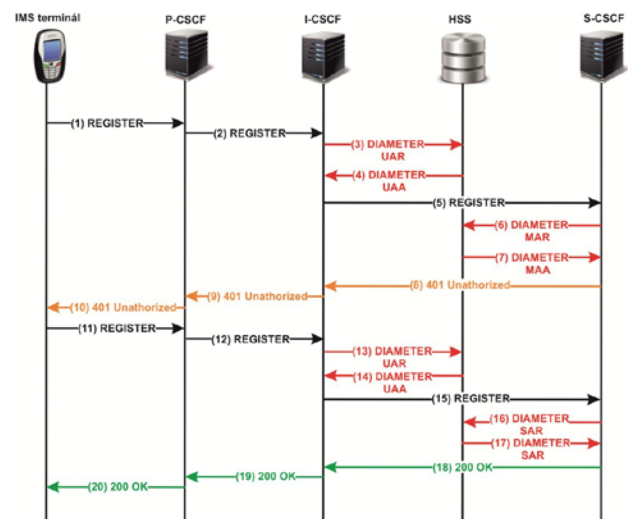


Fig. 2. Exchange of messages during IMS registration

In this test the number of simulated users was set to 10000 according to recommendation of ETSI TS 186 008 standard. Next, we set the maximum number of attempts to register during the pre-registration phase to 10 SAPS (registrations per second). This value appeared to be the most suitable from the long-term testing, with almost no cancellation of scenarios. At the same time, the %IHS metric was set to 1%. The initialization phase has length of 2 min, during which the system under test (Open IMS Core) was gradually loaded in 3 steps to the initialization load value of 10 SAPS. The computation phase was performed in 6 steps, each step lasting 8 minutes. Upon switching to the next step, the load was increased by 3 SAPS. The total duration of the test was 1 hour 3 minutes and 28 seconds.

In the Fig. 2 we can see the graph illustrating the course of increasing effective load per second (10 - 25 SAPS) during the 6 steps of the test (green course). In other words, the graph represents the number of scenarios per second generated by the IMS Bench SIPp. Each step of generating scenarios was based on the Poisson distribution, which is characteristic of telecommunication modelling.

The fig. 4 shows a graph of %IHS course from time on all three scenarios of registrations. We see that in the third and fourth steps, the increase of %IHS was higher, but in the fifth step at even higher load this value stabilized almost to zero (purple course).

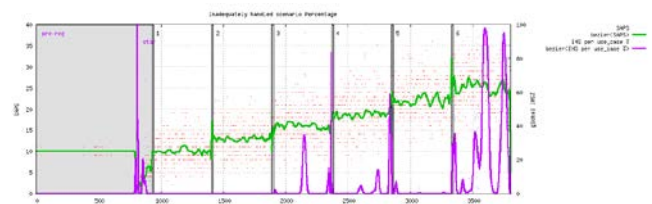


Fig. 4. Inadequately handled scenarios %IHS

This phenomenon is probably caused by the instability of the Open IMS Core platform. By further load increasing, it is already clear that there is a long-term cancellation of scenarios and this condition is unacceptable in the terms of quality of service.

The overall summary of the registration scenario test is shown in Table 1. Columns denoted by the green colour represent the test steps during which the Open IMS Core platform performed the scenario processing almost correctly. On the other hand, red column represents the step of the test, where the scenario attempts were severely cancelled, and the %IHS metric reached the overall value of 28.22%. If we consider the %IHS = 1% threshold, then this value is unacceptable from the traffic quality point of view. The cause of the increased %IHS values in third and fourth steps marked with an orange colour can be attributed to the poor implementation of some Open IMS Core components (instability) and also it may be caused by background applications running during the test. Therefore, we estimate the capacity of the system (DOC) to 22 SAPS resp. 22 registration scenarios per second, because it is the maximum load of Open IMS Core under which we should ensure proper user service in our IMS network.

Table 1. Summary of Registration scenario test

Summary	Pre-reg	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Requested load [SAPS]	10	10	13	16	19	22	25
Effective load [SAPS]	9.94	9.96	12.95	15.96	18.73	22.03	25.10
Ratio of ims_rereg [%]	0.00	50.53	50.93	49.93	50.55	50.54	50.43
Ratio of ims_dereg [%]	0.00	25.31	24.71	25.07	24.69	24.90	24.19
Ratio of ims_reg [%]	100.00	24.16	24.36	24.99	24.77	24.56	25.37
CPU SUT [%]	10.21	9.29	9.26	10.32	11.18	12.50	13.52
RAM SUT [MB]	274.36	402.41	400.38	398.39	396.13	393.84	391.89
Global %IHS [%]	0.18	0.00	0.00	2.81	3.62	0.27	28.22
		✓	✓	✓	✓	✓	✗
							DOC=22 SAPS

B. Call Scenario

For the average time and length of the call the Poisson distribution was chosen, which is characteristic for telecommunication traffic modelling. The ringing time was set to 5 seconds and the length of one connection (call) to 60 seconds. The initialization load was set to 8 SAPS and increased by 2 SAPS in 6 steps (6x8min). In user settings, the total number of users was changed to 3000, because with more users the scenarios were cancelled immediately, which prevented long-term testing. From multiple realized tests, the value of 3000 was the most suitable. The total duration of the test was 35 minutes and 3 seconds.

In the Fig. 3 we can see the graph illustrating the course of increasing effective load per second (8 - 18 SAPS) during the 6 steps of the test (green course). Scenarios were generated with the Poisson distribution.

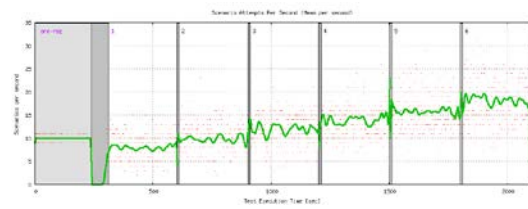


Fig. 5. SAPS load during call scenario

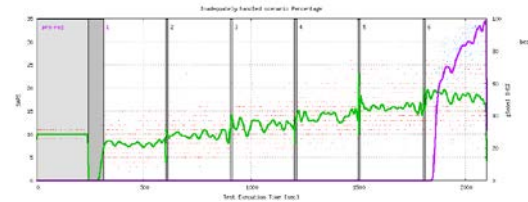


Fig. 6. Inadequately handled scenarios %IHS

In the fig. 6 we can see the course of %IHS dependence on time. We can see that in the 6th step the increasing load has led to significant cancellation of scenarios and this is unacceptable in terms of our proposed goals.

The overall summary of the second test is shown in Table 2. Columns denoted by the green colour represent the test steps during which the Open IMS Core platform performed the scenario processing correctly. On the other hand, red column represents the step of the test, where the scenario attempts were severely cancelled, and the %IHS metric reached the overall value of 66.57%. If we consider the %IHS = 1% threshold, then this value is unacceptable for our proposed goals and from the traffic quality point of view. Therefore, we estimate the capacity of the system (DOC) to 16 SAPS resp. 16 concurrent calls per second, because it is the maximum load under which we should ensure proper user service in our IMS network.

Table 2. Summary of call scenario test

Summary	Pre-reg	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Requested load [SAPS]	10	8	10	12	14	16	18
Effective load [SAPS]	10.00	7.99	9.76	11.96	13.83	15.81	18.00
CPU SUT [%]	7.20	7.19	7.93	8.48	7.97	8.93	8.83
RAM SUT [MB]	302.52	289.11	280.73	275.40	273.02	270.21	267.13
Global %IHS [%]	0.00	0.00	0.00	0.00	0.00	0.00	66.57
		✓	✓	✓	✓	✓	✗
							DOC=16 SAPS

C. Message Scenario

The settings of test system were almost identical to testing with registration scenarios. The initialization load value was set to 100 SAPS and we increased it by 135 SAPS in 6 steps (6x8 min). SAPS values are significantly higher than in the previous case, as only two SIP messages are exchanged for this type of scenario, so it was assumed that the Open IMS Core platform could handle even greater burdens. The larger

number of tests that we have done with this type of scenario has confirmed this premise. The total number of users was set to 10000. The size of the messages was set to 140 B. The total duration of the test was 1 hour and 43 seconds.

In the Fig. 4 we can see the graph illustrating the course of increasing effective load per second (100 - 775 SAPS) during the 6 steps of the test (green course). Also during this test, the generation of scenarios was based on the Poisson distribution.

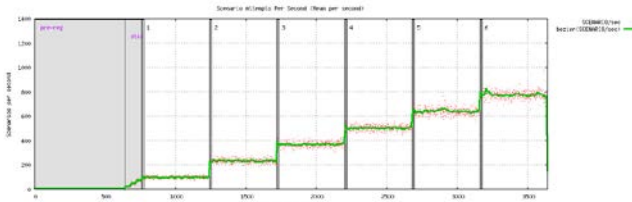


Fig. 7. SAPS load during message scenario

The overall summary of the test is shown in Table 3. Columns denoted by the green colour represent the test steps during which the Open IMS Core platform performed the scenario processing correctly. On the other hand, red columns represent the steps of the test, where the scenario attempts were severely cancelled, and the %IHS metric reached the overall value of 1.24 - 1.81%. If we consider the %IHS = 1% threshold, then these values are unacceptable for our proposed goals. That is why we estimate the capacity of the system (DOC) to 575 SAPS resp. 575 messages per second, in which we should ensure proper user service in our modelled IMS network.

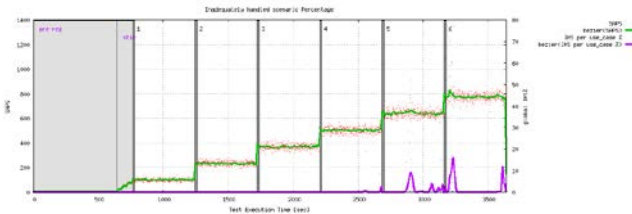


Fig. 8. Inadequately handled scenarios %IHS

In the fig. 8 we can already see the course of %IHS dependence on time. We can see that in the 5th and 6th steps the increasing load has led to raise the percentage of cancelled scenarios.

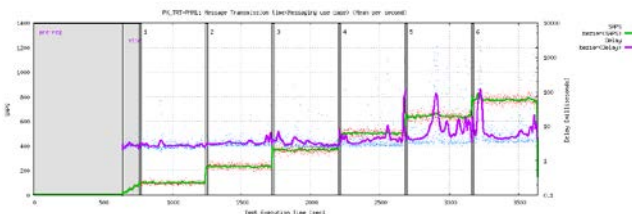


Fig. 9. The mean transmission time of message exchange

The fig. 9 shows the mean transmission time of message exchange. It is the time between the SIP MESSAGE message is sent and 200 OK message is received. The estimation of this

time in our test is about 1 - 4.5 milliseconds.

It is noteworthy that while testing the platform with registration scenarios where 4 SIP messages are exchanged, which is not a big difference compared to 2 SIP messages, the capacity is significantly lower. However, when registering, communication with the HSS database also occurs. In the case of the Open IMS Core platform, this is FHoSS, which implementation is not optimal according to available information. At the same time, with a higher load in the order of hundreds of SAPS, there is already a considerable use of the CPU at the system under test, which in the previous two cases with less SAPS load was not detectable.

Table 3. Summary of message scenario test

Summary	Pre-reg	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Requested load [SAPS]	10	100	235	370	505	640	775
Effective load [SAPS]	10.00	99.86	233.92	369.50	503.60	642.10	774.58
CPU SUT [%]	9.96	16.80	27.61	32.53	35.65	41.71	43.74
RAM SUT [MB]	329.67	324.08	318.38	311.36	302.95	291.59	280.85
Global %IHS [%]	0.00	0.00	0.00	0.00	0.09	1.24	1.81
		✓	✓	✓	✓	✗	✗
Estimated DOC=575 SAPS							

VI. CONCLUSION

Our work was aimed to benchmark testing of software IMS core network. From various available platforms and benchmarking tools we have used the Open IMS Core platform and the IMS Bench SIPp tool. The tests and metrics are based on the series of ETSI TS 186 008 standard. Several limitations on this platform did not allow us to perform tests exactly according to the standard's recommendations.

We have observed that the Open IMS Core platform is suitable only for basic benchmarking and for demonstration of IP Multimedia Subsystem principles. As the developers say the platform was developed only for basic testing and not optimized for performance stress testing. Low stability and support is a negative feature of this platform, but it is typical for such open source systems, and therefore full research is very limited. However, for the demonstration of performance testing for educational purposes the platform is quite sufficient.

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