

# DIMENSIONING OF HOME SUBSCRIBER SERVER IN IP MULTIMEDIA SUBSYSTEM

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**Abstract.** *This paper deals with mathematical methods of dimensioning HSS (Home Subscriber Server) in IMS. Today, there are still more and more requirements on QoS (Quality of Service). Optimal QoS has to be reached by optimization of used components in network architecture. Models that are used – Erlang C formula and Markov chains M/M/1/K & M/M/m/K are simulated in MATLAB. Then outputs are displayed in graphs.*

## Keywords

*Dimension of database, Erlang C, HSS, IMS, Markov models.*

## 1. Introduction

The IMS (IP Multimedia Subsystem) is a standardized NGN (Next Generation Network) architecture for the telecommunication operators. It is standardized by 3GPP (Third Generation Project Partnership) and ETSI (European Telecommunications Standards Institute). The IP Multimedia Subsystem is designed for FMC (Fixed Mobile Convergence). The IMS is well integrated with existing voice and data networks while adopting many of their key characteristics. The IMS is also independent of the access technology that supports packet-switched network, for example, UMTS (Universal Mobile Telecommunications System), WiMAX (World Interoperability for Microwave Access) or DSL (Digital Subscriber Line). The older technologies, such as PSTN (Public Switched Telephone Network) and GSM (Global System for Mobile Communications), are supported through the gateways [1], [2] and [12].

The main goal of the IMS is the provision of new services as well as all present and future services that

can provide telecommunication networks. The IMS becomes the core service of VoLTE (Voice over Long Term Evolution) 4G mobile network. The IMS is also popular for attributes that are used for Authorization, Authentication and Accounting (AAA) support, session control and media transmission [1], [2] and [3].

The IMS has a layered architecture. This means that transport services and signalling network are separated. The layers are called transport, core and application. Each layer consists of different entities, and they can be classified into six categories:

- session management and routing (P-CSCF, I-CSCF, S-CSCF),
- databases (HSS, SLF),
- interworking functions (BGCF, MGCF, IMS-MGW, SGW),
- services (application server, MRFC, MRFP),
- support function (SEG),
- charging [4].

## 2. Home Subscriber Server

The HSS is a central repository for subscriber information – database of subscriber profiles. It maintains information that is necessary for establishing sessions between users and for providing services to them. The HSS supports many interfaces – the most important are Cx and Sh. Cx is used to communicate with the I-CSCF (Interrogating - CSCF) and S-CSCF (Serving - CSCF). Sh is connected with application servers. Both interfaces are based on DIAMETER protocol. The HSS includes information about:

- subscriber registration (name, address, services, etc.),
- subscriber preferences,
- subscriber location [5].

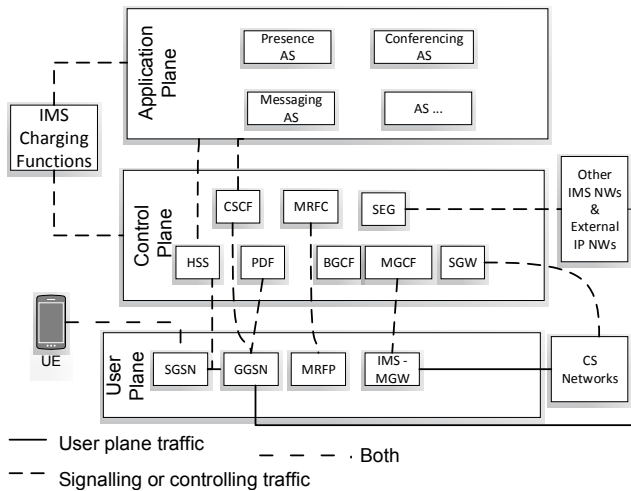


Fig. 1: Layered architecture of IMS [4].

### 2.1. DIAMETER

DIAMETER is a protocol defined by IETF in RFC 3588. It performs AAA in the IMS network and provides following resources:

- management of connection and session,
- user authentication,
- reliable delivery of AVP (attribute-value pair),
- basic charging services [4] and [5].

All DIAMETER implementations must implement and support the list of DIAMETER commands (Tab. 1).

Tab. 1: Defined command codes [7].

Command Name	Abbreviation	Code
User-Authorization-Request	UAR	283
User-Authorization-Answer	UAA	283
Server-Assignment-Request	SAR	284
Server-Assignment-Answer	SAA	284
Location-Info-Request	LIR	285
Location-Info-Answer	LIA	285
Multimedia-Auth-Request	MAR	286
Multimedia-Auth-Answer	MAR	286
Registration-Termination-Request	RTR	287
Registration-Termination-Answer	RTA	287
Push-Profile-Request	PPR	288
Push-Profile-Answer	PPA	288

### 2.2. LIR/LIA and MAR/MAA Commands

This part describes commands that were used for simulation. Here are written some basic items of which commands are composed. The full description of these commands is in RFC 3588.

LIR commands are used by the DIAMETER client in a SIP server to obtain routing information, e.g. the URI of the SIP server. Message format of the LIR is [7]:

```
<LIR> ::= < Diameter Header: 285, REQ,
PXY >
< Session-Id >
{ Auth-Application-Id }
{ Auth-Session-State }
{ Origin-Host }
{ Origin-Realm }
{ Destination-Realm }
{ SIP-AOR }
[ Destination-Host ]
* [ Proxy-Info ]
* [ Route-Record ]
* [ AVP ]
```

This command is used to respond to the previously received LIR message. Message format of LIA follows [7]:

```
<LIA> ::= < Diameter Header: 285, PXY
>
< Session-Id >
{ Auth-Application-Id }
{ Auth-Session-State }
{ Origin-Host }
{ Origin-Realm }
* [ Proxy-Info ]
* [ Route-Record ]
* [ AVP ]
```

MAR command is used to authenticate and authorize user's attempt to use some SIP service. Message format of the MAR is [7]:

```
<MAR> ::= < Diameter Header: 286, REQ,
PXY >
< Session-Id >
{ Auth-Application-Id }
{ Auth-Session-State }
{ Origin-Host }
{ Origin-Realm }
{ Destination-Realm }
* [ Proxy-Info ]
* [ Route-Record ]
* [ AVP ]
```

MAA format [7]:

```
<MAA> ::= < Diameter Header: 286, PXY
>
< Session-Id >
{ Auth-Application-Id }
{ Result-Code }
{ Auth-Session-State }
{ Origin-Host }
{ Origin-Realm }
[ Redirect-Host-Usage ]
[ Redirect-Max-Cache-Time ]
* [ Proxy-Info ]
* [ Route-Record ]
* [ AVP ]
```

### 2.3. Registration

CSCFs (Call Session Control Functions) provide the SIP Proxy and Registrar functionality. P-CSCF (Proxy - CSCF) forwards REGISTER to an I-CSCF in home IMS network. I-CSCF interrogates the HSS to help selecting an appropriate S-CSCF to forward request to. The S-CSCF acts as the Registrar sending an authentication challenge to the user with authentication vectors supplied by the HSS. After successful authentication, the S-CSCF will complete registration and notify the HSS. An HSS may be associated with many S-CSCFs. An IMS network may contain more HSSs. An example of signalling flow is in Fig. 2.

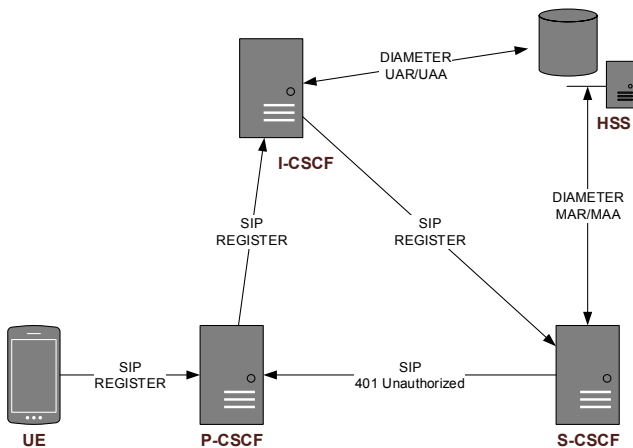


Fig. 2: Signaling session [6].

### 2.4. Database Schema

The organization of the permanent subscriber data is shown in Fig. 3. Each subscription may contain count of users of the subscribed services. Private User Identity identifies users and has NAI form *user@region*. Public User Identity includes all communication with

the user. It has form of a SIP URI or a TEL URL. A user usually has more Public User Identities and with them are associated subscribed services. Subscribed services are located in the *subscriber* table, *users* are in the *user* table, in the *address* table there are Public User Identities, and Service Profiles are in the *profile* table [6].

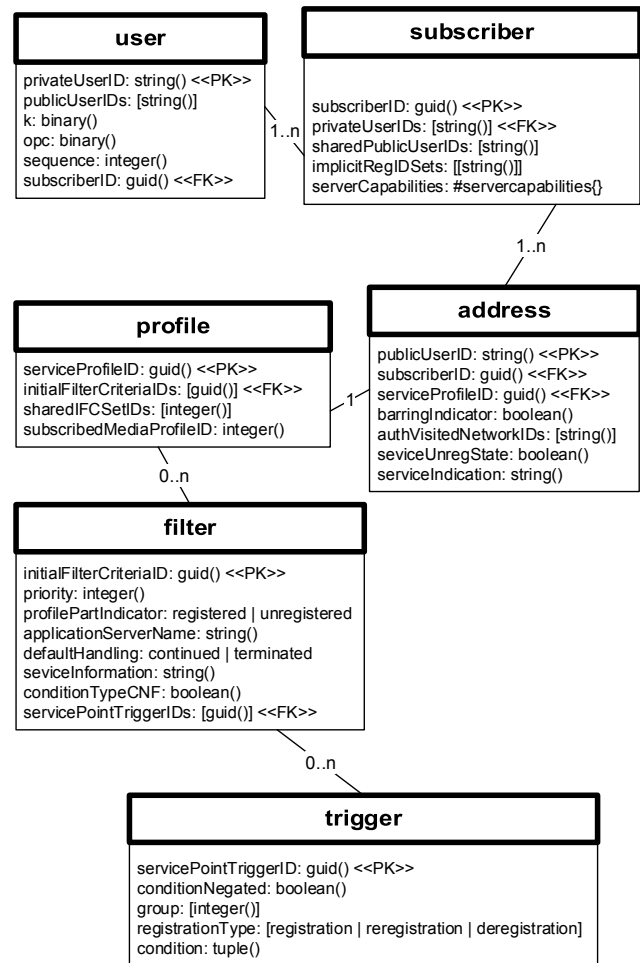


Fig. 3: Organization of permanent subscriber data [6].

Temporary subscriber data are called registrations. They describe the registration status of Public User Identities and contain the name of S-CSCF, where the registration is ongoing. A user profile may be kept without any registrations within S-CSCF, so one entry with unregistered state may remain in table. Public User Identities that are unregistered generally do not have record in the table. While authentication is pending, more entries with not registered state may exist. The organization of temporary subscriber data is in Fig. 4 [6].

location
publicUserID: string() <<PK>> privateUserID: string() state: registered   unregistered   notregistered authenticationPending: boolean() sCSCFName: string() sCSCFDiameter: string()

Fig. 4: Temporary subscriber data in the HSS [6].

### 2.5. Parameters of HSS

The HSS database of the company Alcatel-Lucent was used for a simulation. The HSS contains 362 700 NAI records and real servicing times are in the table. Simulations of two scenarios were done for two types of DIAMETER commands – LIR/LIA and MAR/MAA.

Tab. 2: Servicing times.

Command type	HSS		SLF
	MAR/MAA	LIR/LIA	
Servicing time	120 ms	70 ms	20 ms

## 3. Methods of Dimensioning HSS

### 3.1. Markov Chain M/M/1/K

If the IMS network implements just one database HSS, to calculate the probability of creating a waiting queue, the Markov chain M/M/1/K was used. This queuing model describes the IMS network more realistic. Requests are arriving in the Poisson stream with intensity  $\lambda$  and wait in the queue under the FIFO (first in, first out) order. Poisson arrival distribution means that requests are arriving randomly and independently on the time of the previous requests. There are just K requests in the system and queue has limited length to K-1 [8], [9] and [10].

The parameter  $\mu$  defines the intensity of the stream and it is the inverse value  $\tau$  (time of servicing one request):

$$\mu = \frac{1}{\tau}. \tag{1}$$

Stability (or usage) of the system is defined by following equation:

$$\rho = \frac{\lambda}{\mu}. \tag{2}$$

If  $\rho < 1$ , then conditional stability applies and if not, the system is unstable (waiting queues can be formed).

The probability that the system is empty is determined in the following way:

$$[P_0]_K = \frac{1 - \rho}{1 - \rho^{K+1}}. \tag{3}$$

And if just one requirement is in the system, the probability is

$$[P_1]_K = \rho^1 \cdot [P_0]_K. \tag{4}$$

The overall probability that the request has to wait in the queue is

$$[P_c]_K = 1 - [P_0]_K - [P_1]_K. \tag{5}$$

### 3.2. Markov Chain M/M/m/K

If the IMS architecture implements more than one database HSS, then the Markov chain M/M/m/K is used to calculate the probability of creating the waiting queue [13]

$$\rho = \frac{\lambda}{\mu m}, \tag{6}$$

where  $m$  is number of servers in the system. In case of following simulation,  $m = 7$ .

The probability of empty system is

$$[P_0]_K = \sum_{n=0}^{m-1} \frac{\left(\frac{\lambda}{\mu}\right)^n}{n!} + \frac{\left(\frac{\lambda}{\mu}\right)^m \cdot \left[1 - \left(\frac{\lambda}{\mu m}\right)^{K-m+1}\right]}{m! \cdot \left[1 - \frac{\lambda}{\mu m}\right]}. \tag{7}$$

The probability that servers are busy is

$$[P_7]_K = \frac{1}{7!} \cdot \left(\frac{\lambda}{\mu}\right)^7 \cdot [P_0]_K. \tag{8}$$

Subsequently, the probability of waiting in the queue is given by following equation:

$$[P_c]_K = 1 - [P_0]_K - [P_7]_K. \tag{9}$$

### 3.3. Erlang’s Concept

In 1917, Agner K. Erlang published "Solution of some Problems in the Theory of Probabilities of Significance in Automatic Telephone Exchanges". His work solves problems of waiting time and call loss, and he defined classic formulae [9].

The following equation is used for calculation of the parameter  $A$  that presents traffic load.

$$A = \lambda\tau, \tag{10}$$

where  $\lambda$  is the intensity of arriving requests and  $\tau$  is the servicing time of one request. The probability that the request has to wait in queue is

$$E_2(N, A) = \frac{\frac{A^N}{N!} \cdot \frac{N}{N-A}}{\sum_{k < N} \frac{A^k}{k!} + \frac{A^N}{N!} \cdot \frac{N}{N-A}}. \tag{11}$$

$N$  is the number of servers in the system. In telecommunication industry, this formula is well-known as Erlang C [9].

The next parameter, derived from this equation, is a mean waiting time. This is the time during which the request has to wait to be handled by server [11]:

$$E(W) = \frac{E_2(N, A) \cdot \tau}{N \cdot (1 - A)} \tag{12}$$

### 4. Simulation Results

Simulations were done for two scenarios in the IMS architecture. In the first one, there is one HSS database in the IMS. All requests are routed to the server and they have to be serviced there. Then the probabilities of creating waiting queue and the mean waiting time were calculated.

In the second scenario, the IMS has 7 HSS databases and it includes SLF (Subscriber Location Function) server. For this scenario, the probabilities of creating waiting queue and the mean waiting time were calculated too.

The SLF is a simple database and it is used as a resolution mechanism that enables the I-CSCF, the S-CSCF and the AS to map the address of HSS that holds the subscriber data for a given user identity when multiple and separately addressable HSS servers have been deployed by the network operator. It also implements the DIAMETER protocol [4] and [5].

#### 4.1. First Scenario

In the case, where is just one database HSS, Markov chain M/M/1/K and Erlang C formula were used. The probability of empty system was computed using Eq. (3) and the probability of occupied system by Eq. (4). Then the overall probability of creating a waiting queue Eq. (5) was calculated. Final graph is shown in the Fig. 5. The probability is rising with respect to the given usage of the system. For example, if there are 650 requests per minute in the system, the probability is 57.51 % for LIR/LIA commands and for MAR/MAA commands it is up to 100 %.

The simulation was also performed for Erlang C formula. The probability was calculated by Eq. (11). Graph is shown in the Fig. 6. It is linear and the probabilities are rising slower when compared to the previous simulation. For example, for 650 requests in the system, the probability of creating a waiting queue in the case of LIR/LIA commands is 45.5 % and for MAR/MAA commands it is 78 %.

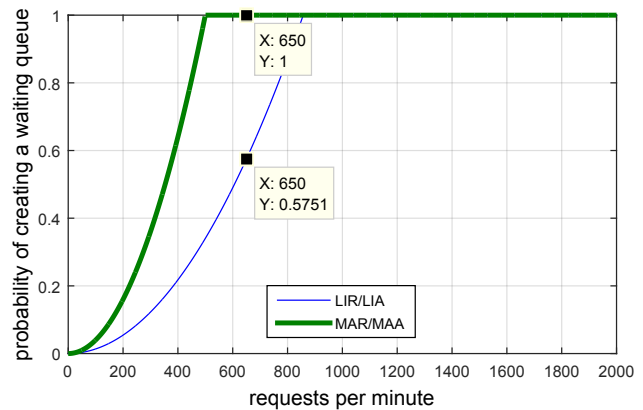


Fig. 5: Probability of creating a waiting queue (1 HSS database).

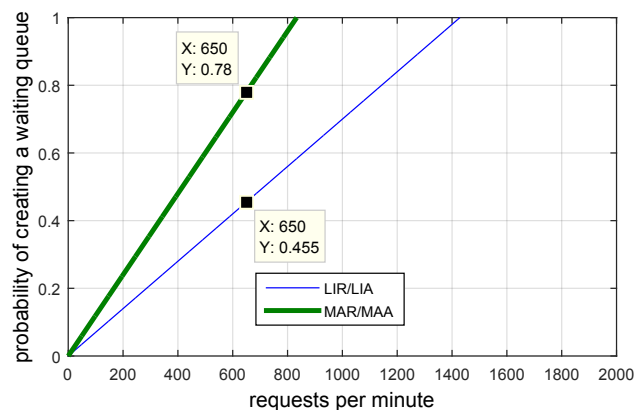


Fig. 6: Probability of creating a waiting queue (7 HSS database).

These simulations are showing that a longer service time has a negative impact on the system – the probability of creating a waiting queue is rising faster.

Next parameter that could be calculated is a mean waiting time. This time expresses a period when a request is waiting to be serviced by a server. The value is calculated by the Eq. (13). A length of the waiting time depends on the traffic load, as it is showed in the graph. For 800 requests per minute, the mean waiting time is 0.03593 seconds for commands LIR/LIA, and for MAR/MAA it is 0.1824 seconds.

#### 4.2. Second Scenario

The next scenario includes 7 HSS databases. Subscribers might be divided into databases alphabetically but there is not guaranteed linear distribution of subscribers. The better solution is if users are linearly partitioned into databases with predefined number of records. This is more efficient and optimal then previous distribution.

This scenario implements the SLF. All requests, which are routed into the system, have to be serviced

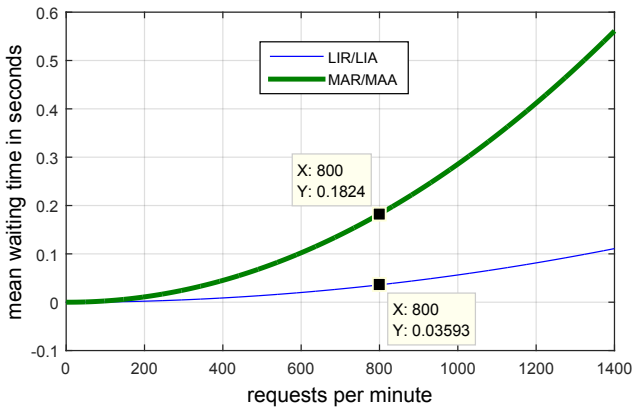


Fig. 7: Mean waiting time (1 HSS database).

by SLF for mapping the correct HSS. And then the requests are serviced by the HSS. For a calculation of final probability, the following formula is used:

$$[P_C] = [P_C]_{SLF} + [(1 - [P_C]_{SLF}) \cdot [P_C]_{HSS}] \cdot (13)$$

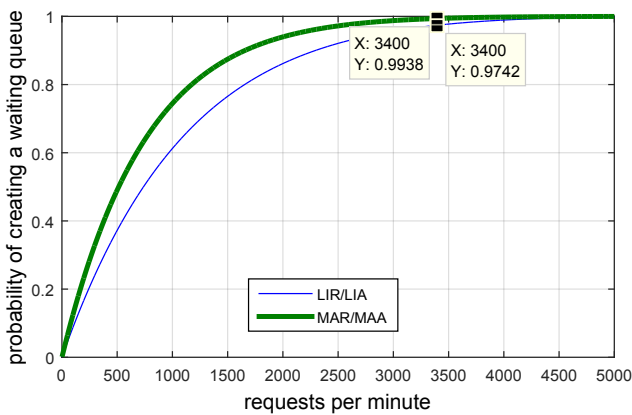


Fig. 8: Probability of creating a waiting queue (7 HSS databases).

For the first simulation, Markov chains M/M/1/K and M/M/m/K were used. Firstly, there is calculated probability for SLF using Eq. (3), Eq. (4) and then Eq. (5), which is the probability of waiting for the SLF. Subsequently, there were used Eq. (7) and Eq. (8) for the calculation of empty or occupied system with 7 HSS databases. The probability of waiting is given by equation Eq. (9). For the final probability of creating a waiting queue, Eq. (13) had to be used. Course of probability is shown in the graph, Fig. 8. If there are 3400 requests in the system per minute, probabilities are: for LIR/LIA commands 97.42 % and for MAR/-MAA commands 99.38 %.

The simulation of Erlang C gave better results than the previous one. First, there was calculated the probability of creating a waiting queue for SLF using Erlang C Eq. (11). Then the same Eq. (11) was used, where parameter  $N$  was equal to 7. Final probability

was calculated by Eq. (13). Results are shown in the graph, Fig. 9. For example, 3400 requests per minute in the system give the probability 75.53 % for commands LIR/LIA and 83.1 % for commands MAR/MAA.

Calculation of mean waiting time is similar to the scenario where there is one HSS. There was used overall probability given by Eq. (13) and it was inserted into Eq. (12). Mean waiting time for the given traffic load is shown in graph (Fig. 10). For 4000 requests per minute, it is 0.04809 seconds for command LIR/LIA and 0.1117 seconds for command MAR/MAA.

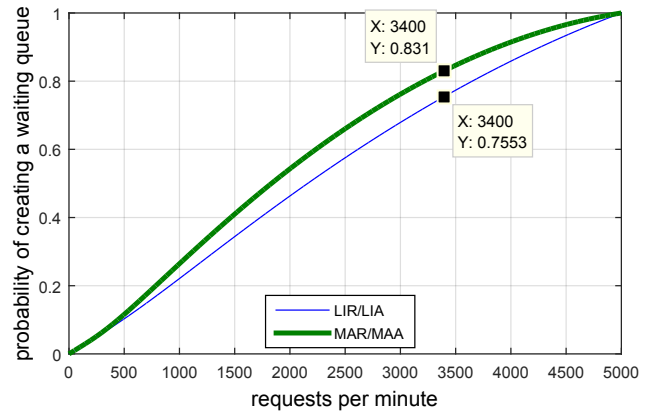


Fig. 9: Probability of creating a waiting queue (7 HSS databases).

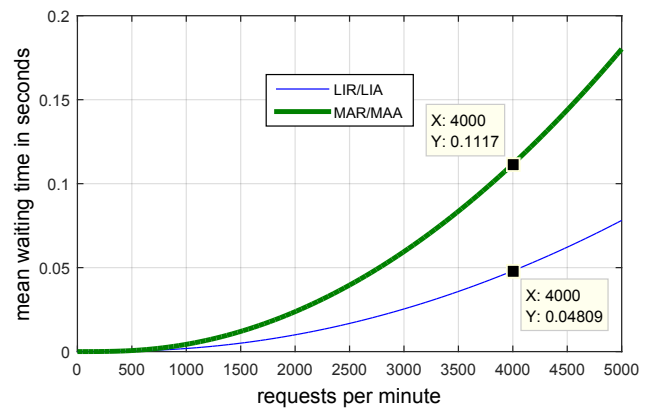


Fig. 10: Mean waiting time (7 HSS databases).

## 5. Conclusion

The aim of this paper was to describe some possibilities of dimensioning of the HSS. Simulations were performed on the database of company Alcatel-Lucent. These simulations show that the serving time is significant element of providing required QoS. Thus, well dimensioned database HSS is important. With reduction of a servicing time the probability of creating a waiting queue and mean waiting time decreases. But for the best optimization of the HSS it is important to mon-



itor overall traffic in the HSS for longer period. The same methods of the dimensioning of database in the 4<sup>th</sup> generation of mobile networks – Long Term Evolution (LTE) are used. In the LTE, the database is also known as the HSS. Methods of dimensioning of the HSS are verified by the university IP Multimedia Subsystem laboratory, which is part of the Centre of Excellence (project IMTS: 26240120005).

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## References

- [1] CHROMY, E., M. KAVACKY and L. DRESTO. Admission Control Methods in IMS Networks. *International Journal of Advances in Telecommunications, Electrotechnics, Signals and Systems*. 2016, vol. 5, no. 3, pp. 142–145. ISSN 1805-5443. DOI: 10.11601/ijates.v5i3.175.
- [2] ALASSANE, B. A., K. KARIM, N. I. CHERVYAKOV, M. A. DERYABIN, M. G. BABENKO and M. N. SHABALINA. Jitter Calculation in Core IMS. In: *NW Russia Young Researchers in Electrical and Electronic Engineering Conference*. St. Petersburg: IEEE, 2016, pp. 112–115. ISBN 978-1-5090-0445-4. DOI: 10.1109/EIConRusNW.2016.7448134.
- [3] TANG, C.-S., Y.-K. CHIANG, Y.-D. TSOU, J.-H. JU and C.-Y. TWU. A converged network architecture for ICT and IoT combined applications. In: *18th Asia-Pacific Network Operations and Management Symposium*. Kanazawa: IEEE, 2016, pp. 1–4. ISBN 978-4-88552-304-5. DOI: 10.1109/APNOMS.2016.7737284.
- [4] POIKSELKA, M. and G. MAYER. *The IMS: IP Multimedia Concepts and Services, 3rd Edition*. Chichester: John Wiley & Sons Ltd, 2009. ISBN 978-0-470-72196-4.
- [5] AL-BEGAIN, K., C. BALAKRISHNA, L. A. GALINDO and D. M. FERNANDEZ. *IMS: A Development and Deployment Perspective*. Chichester: John Wiley & Sons Ltd, 2009. ISBN 978-0-470-74034-7.
- [6] GitHub - sigscale/hss: A 3GPP IP Multimedia Subsystem (IMS) Home Subscriber Server (HSS). In: *GitHub* [online]. 2015. Available at: <https://github.com/sigscale/hss>.
- [7] Nokia. RFC 4740 Diameter Session Initiation Protocol (SIP) Application. In: *IETF Tools* [online]. 2006. Available at: <https://tools.ietf.org/html/rfc4740>.
- [8] STASIAK, M., M. GLABOWSKI, A. WISNIEWSKI and P. ZWIERZYKOWSKI. *Modelling and Dimensioning of Mobile Wireless Networks: From GSM to LTE*. Chichester: John Wiley & Sons Ltd, 2010. ISBN 978-0-470-66586-2.
- [9] FICHE, G. and G. HEBUTERNE. *Communicating Systems and Networks: Traffic and Performance*. Sterling: Kogan Page Ltd., 2004. ISBN 1-903996-35-X.
- [10] VOZNAK, M., A. KOVAC and M. HALAS. Effective Packet Loss Estimation on VoIP Jitter Buffer. In: *International Conference on Research in Networking*. Prague: Springer, 2012, pp. 157–162. ISBN 978-3-642-30038-7. DOI: 10.1007/978-3-642-30039-4\_21.
- [11] GEORGOULAS, S., P. TRIMINTZIOS, G. PAVLOU and K. H. HO. Measurement-based Admission Control for Real-time Traffic in IP Differentiated Services Networks. In: *International Conference on Telecommunications*. Cape Town: IEEE, 2005, pp. 1–5.
- [12] BRESLAU, L., S. JAMIN and S. SHENKER. Comments on the performance of measurement-based admission control algorithms. In: *Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies*. Tel Aviv: IEEE, 2000, pp. 1233–1242. ISBN 0-7803-5880-5. DOI: 10.1109/INFCOM.2000.832506.
- [13] CALLAWAY, R. D., M. DEVETSIKIOTIS and C. KAN. Design and implementation of measurement-based resource allocation schemes within the realtime traffic flow measurement architecture. In: *International Conference on Communications*. Paris: IEEE, 2004, pp. 1118–1122. ISBN 0-7803-8533-0. DOI: 10.1109/ICC.2004.1312674.

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