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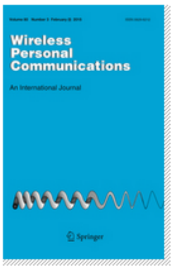

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The Optimal Sizing of HSS Database in IMS

Authors Authors and affiliations

Milan Kellovsky, Ivan Baronak, Matej Kavacky, Erik Chromy

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Abstract

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Keywords

IMS HSS Erlang C formula Markov chain

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The Optimal Sizing of HSS Database in IMS

Milan Kellovsky[1] · Ivan Baronak[1] · Matej Kavacky[1] · Erik Chromy[1]

Abstract Our paper deals with the architecture and standards of IP the multimedia subsystem from next generation networks point of view. It describes the structure of the home subscriber server database and then derives equations for sizing of its load in the proposed scenarios. We have used two methods for the database sizing—Erlang C formula and Markov chains. Finally, the achieved results and used methods are evaluated and discussed.

Keywords IMS · HSS · Erlang C formula · Markov chain

1 Introduction

The evolution of the telecommunication system gradually tends to full internet protocol (IP) environment and next generation network (NGN) architecture standard from 3GPP is one building block of this evolution. This architecture becomes a basis for the IP multimedia subsystem (IMS) [1] which consists of four main layers according to the 3GPP standard. The undermost access layer is responsible for convergence and allows access of various endpoint terminals into the IMS system [2, 3]. The second layer—transport layer

✉ Milan Kellovsky
kellovsky.milan@gmail.com

Ivan Baronak
baronak@ut.fei.stuba.sk

Matej Kavacky
kavacky@ut.fei.stuba.sk

Erik Chromy
chromy@ut.fei.stuba.sk

1 Faculty of Electrical Engineering and Informational Technology, Institute of Telecommunications, Slovak University of Technology in Bratislava, Illkovicova 3, 812 19 Bratislava, Slovak Republic

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is responsible for the transport of the media flow. The transport layer consists of an optical backbone network. The control of this transport is done by the third—control—layer. Control layer processes the signaling flow and allows endpoint terminals to access the prepaid services [4, 5]. These prepaid services run in the Application layer, which is the highest layer of the NGN model. Application layer consists of servers and server farms. A block diagram of the NGN architecture is depicted in Fig. 1. Details can be found in [6–8].

The rest of this paper is organized as follows: Sect. 2 is devoted to the HSS database. In Sect. 3 there are information about sizing of HSS database and information about HSS modelling (markov chains and Erlang C formula). In Sects. 3.6 and 3.7 are simulations of two scenarios. The first scenario describes the IMS system with one HSS database and the second scenario describes a system with five HSS databases and a location database SLF. Section 4 summarizes the results.

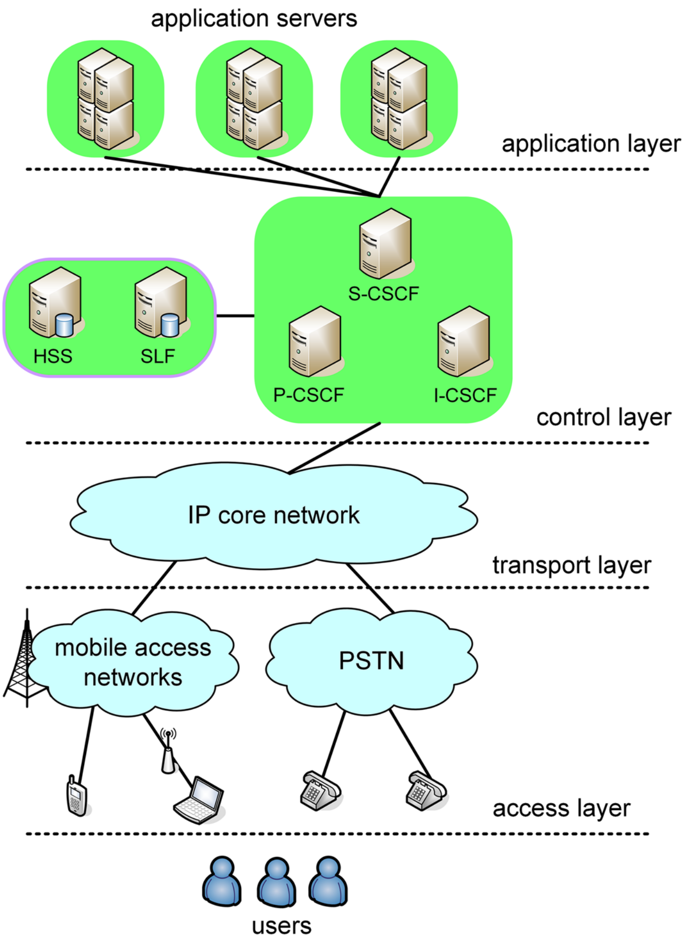

Fig. 1 IMS architecture

2 HSS Database

Home subscriber server (HSS) is the main database in IMS system. HSS is a relational database with two main tasks. It stores user information and generates security information [9, 10].

User information:

- subscription, identification, numbering,
- registration,
- user profiles.

Security information:

- mutual authentication,
- communication integrity control,
- encryption.

2.1 Block Diagram of Database

Block diagram of such relational database is depicted in Fig. 2. We can see the structure of the permanent user data. The internal structure consists of six mutually linked tables. Data related to the IMS services subscribers are stored in such structured HSS database. Each subscription can cover a wide range of users of subscribed services. Users are identified within the IMS through network access identifier (NAI) in the form “user@area”. The

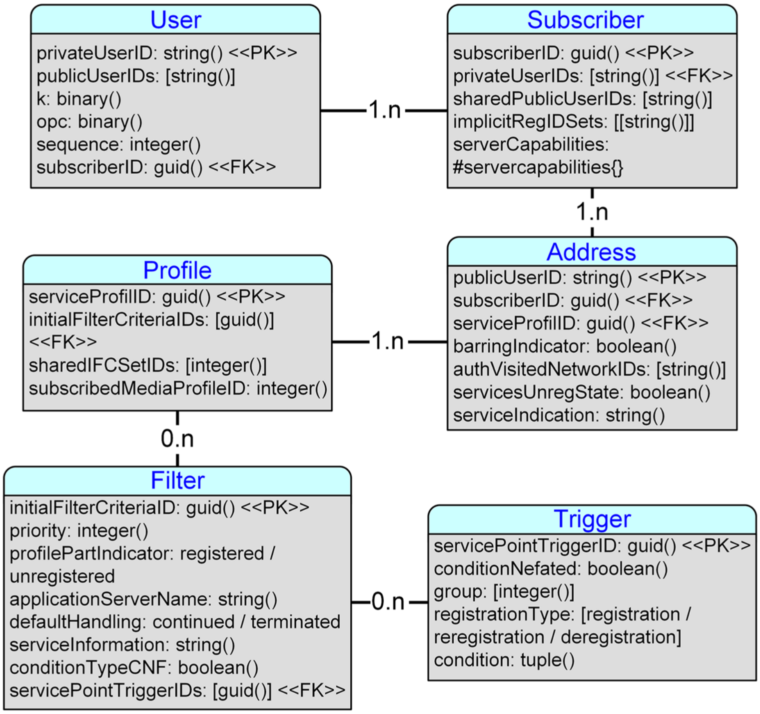

Fig. 2 Block diagram of HSS

whole communication with users is through public user identity, such as SIP URI or TEL URI. Users are usually linked to several public user identities, which can be shared among users of common subscription. User services are interconnected with public user identities. Subscriptions are stored in user table records, public user identities are recorded in address table and user profiles are stored in table of profiles [9, 10].

The registrations are temporary user data and are used for description of the registration state of public user identities, including a name of S-CSCF where the registration is located. Public user identities can be concurrently registered by multiple users, hence the more records can appear in the table with the same identity. S-CSCF can maintain the user profile stored without registration, therefore the one access with non-registered state can remain in the table in some cases. The non-registered public user identities are generally not recorded in the table. One or more records can exist without the registration while their verifying is in progress. The structure of temporary user data is depicted in Fig. 3. [9, 10].

3 Sizing of Database

The HSS database is the main user database in the IMS system. It stores all the user information, subscribed services and some information for the application servers. Such a large scale of information together with a high number of connected users generates a high volume of requests to this database. It slows down searching of information in the database and increases the service time, so the quality of service is degraded. An optimal number of users connected to HSS database can preserve the required QoS, because the database searching is the slowest operation in the communication chain between the end terminals. We can calculate the probability of the waiting queue through the Markov chains and Erlang C formula and also the total delay [11, 12] of the request in the database can be calculated by Markov chains. For the purpose of simulation of various systems we proposed the second scenario based on five HSS databases where the use of another SLF database is needed [13].

3.1 HSS Database of Alcatel-Lucent

The Alcatel-Lucent provided us with information about their database for the purpose of HSS sizing. This separate database from production environment with load we will sized through Markov chains and Erlang C equation. The sizing will be based on the measured request service times. Two types of requests arrive to database—location-info-request/answer (LIR/LIA) and multimedia-auth-request/answer (MAR/MAA). The LIR/LIA messages are used to

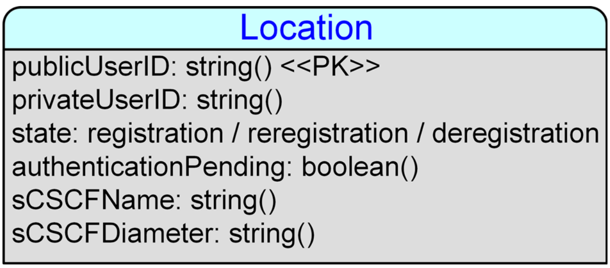

Fig. 3 Structure of temporary data

Table 1 Hardware configuration of HSS database

CPU	Frequency (MHz)	Size (MB)
0	1593	1
1	1593	1
2	1593	1
3	1593	1

Table 2 Measured service times of requests

Messages	1 HSS MAR/MAA	1 HSS LIR/LIA	5 HSS MAR/MAA	5 HSS LIR/LIA	SLF LIR/LIA and MAR/MAA
Real values (ms)	145	88	145	88	25

obtain the name and address of serving-call session control function (S-CSCF) server, which serves the user. The MAR/MAA messages are used for the authentication between the user and home IMS network. The Alcatel-Lucent database contains 362,700 records (NAI), what means 36,270 requests in the busy hour, i.e. 604 requests per minute. Hardware equipment of the designed database is summarized in Table 1 (system configuration: SunMicrosystems sun4u Netra 440, System clock frequency: 177 MHZ, memory size: 16 GB). Measured values are presented in Table 2. [6, 14].

3.2 Markov Chain M/M/1/K

Contrary to M/M/1/∞ system, the M/M/1/K chain has limited the waiting queue and therefore it is closer to conditions in the real IMS system. M/M/1/K system has Poisson distribution of arrivals, exponential distribution of service time, one serving server and waiting queue length K. Every queuing system is described by various parameters. The Poisson Arrival process is the most widely applied model of the arrival process and is the most tractable mathematically [15]. The number of requests μ is served by the system per defined time unit, where τ is service time of one request. The parameter μ can be calculated as follows [13]:

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

The requests arrive to the system with rate intensity λ, what means that time between arrivals is $1/\lambda$. The stability of system can be evaluated by calculation of the parameter ρ. If the system is stable, the value of ρ is below 1 [13].

$$\rho = \frac{\lambda}{\mu}; \quad \rho < 1 \tag{2}$$

P_0 represents the probability of an empty system, and P_1 is the probability of exactly one request in the system. These parameters can be calculated by Eqs. (3) and (4) [13].

$$P_0 = \frac{1 - \frac{\lambda}{\mu}}{1 - \left(\frac{\lambda}{\mu}\right)^{k+1}} \tag{3}$$

$$P_1 = P_0 \left(\frac{\lambda}{\mu}\right)^k; \quad k = 1 \tag{4}$$

The probability of a waiting queue formation in the system with one HSS and the probability of a waiting queue in the SLF database with five HSS databases have been calculated in simulations through this Markov chain.

3.3 Markov Chain M/M/m/K

This Markov chain was used for calculation of waiting queue formation probability in the scenario with 5 HSS databases. The parameters are the same as in the previous chain, but for the system stability the following equation was used [13]:

$$\rho = \frac{\lambda}{\mu \cdot m} \tag{5}$$

The probability of an empty system can be obtained from Eq. (6) and the probability of exactly one request in the system can be calculated according to Eq. (7) [13]:

$$P_0 = \left[\sum_{n=0}^{m-1} \frac{\left(\frac{\lambda}{\mu}\right)^k}{n!} + \frac{\left(\frac{\lambda}{\mu}\right)^m \left[1 - \left(\frac{\lambda}{\mu \cdot m}\right)^{K-m+1}\right]}{m!\left[1 - \frac{\lambda}{\mu \cdot m}\right]}\right]^{-1} \tag{6}$$

$$P_1 = P_0 \left(\frac{\lambda}{\mu}\right)^k \frac{1}{k!}; \quad k = 1 \tag{7}$$

3.4 Erlang C Formula

Through the Erlang C equation we can calculate the probability of a waiting queue formation in the systems with waiting queues. This equation is in the following form [2, 8, 14]:

$$P_c = \frac{\frac{A^m m}{m!(m-A)}}{\sum_{i=0}^{m-1} \frac{A^i}{i!} + \frac{A^m m}{m!(m-A)}} \tag{8}$$

where A is traffic load and m is number of servers (databases in our case). For comparison of results the equation must be modified. Traffic load A in Eq. (8) can be substituted by Eq. (9).

$$A = \frac{\lambda}{\mu} \tag{9}$$

where,

$$\mu = \frac{1}{\tau} \tag{10}$$

and τ is service time of one request. Then we obtain:

$$P_c = \frac{\frac{\left(\frac{\lambda}{\mu}\right)^m m}{m!\left(m-\frac{\lambda}{\mu}\right)}}{\sum_{i=0}^{m-1}\frac{\left(\frac{\lambda}{\mu}\right)^i}{i!}+\frac{\left(\frac{\lambda}{\mu}\right)^m m}{m!\left(m-\frac{\lambda}{\mu}\right)}} \tag{11}$$

Then, the final equation for calculation of a waiting queue formation is as follows:

$$P_c = \frac{\frac{(m\rho)^m}{m!(1-\rho)}}{\sum_{i=0}^{m-1}\frac{(m\rho)^i}{i!}+\frac{(m\rho)^m}{m!(1-\rho)}} \tag{12}$$

3.5 Delay

When the waiting queue occurs, the delay of the request in the system will be increased. This delay can be estimated through Markov chains. The average number of requests in database N for the first scenario is necessary to calculate according to the Eq. (13). The delay of the request in the system can be calculated through the Eq. (14) [13].

$$N = \frac{\frac{\lambda}{\mu}\left(1-\left(\frac{\lambda}{\mu}\right)^k\right)\left(k+1-k\left(\frac{\lambda}{\mu}\right)\right)}{\left(1-\left(\frac{\lambda}{\mu}\right)^{k+1}\right)\left(1-\frac{\lambda}{\mu}\right)} \tag{13}$$

$$T = \frac{N}{\lambda} \tag{14}$$

The calculations for the second scenarios are more complex. The estimation of the delay in the SLF database is the same as in the first scenario. The delay in HSS databases is calculated in the first step through the Eq. (15), which represents an average number of requests in the waiting queue Q. Then, the Eq. (16) for the average waiting time of the request in the queue is used and a delay of the request in the HSS databases is calculated through the Eq. (17). The total delay of the request in the system is the sum of SLF delay and HSS delay according to Eq. (18).

$$Q = \frac{P_0\left(\frac{\lambda}{\mu}\right)^{m+1}}{(m-1)!\left(m-\left(\frac{\lambda}{\mu}\right)^2\right)\left(1-\left(\frac{\lambda}{m\mu}\right)^{k-m-1}\right)} - (k-m-1)\left(\frac{\lambda}{m\mu}\right)^{k-m}\left(1-\frac{\lambda}{m\mu}\right) \tag{15}$$

$$W = \frac{Q}{\lambda} \tag{16}$$

$$T_1 = W + \tau \tag{17}$$

$$T_c = T + T_1 \tag{18}$$

3.6 The First Scenario

This scenario is based on the IMS system with one HSS database and the following parameters:

- number of records—362700 NAI,
- service time of LIR/LIA request 88 ms,
- service time of MAR/MAA request 145 ms.

The probability of a waiting queue formation P_c in such database is calculated by Markov chains through Eqs. (3) and (4) and obtained values are used in the Eq. (19). In the case of Erlang C formula the above probability can be calculated through the Eq. (12). The obtained probabilities of a waiting queue formation are depicted in Fig. 4.

$$P_c = 1 - P_0 - P_1 \quad (19)$$

In Fig. 4 we can see probabilities calculated through the Erlang C formula (in blue) and probabilities calculated through Markov chains (in red). The level of 605 requests per minute is also shown, which represents Alcatel-Lucent database load in the busy hour.

The probability of queue formation obtained through Erlang C formula has linear character and probability of queue formation calculated through Markov chains has character of S-curve. From the accuracy of HSS database sizing point of view, method with Erlang C formula is more precise. This equation was developed for monotone traffic with one type of signal. Contrary, the Markov chains assume multimedia traffic. Requests for HSS database always are of the same size, hence the Erlang C formula is preferable. In such assumption, the values of probability for particular requests are as follows:

- MAR/MAA—0.8758,
- LIR/LIA 0.5315.

Based on this result we can say that the HSS database of Alcatel-Lucent is correctly sized, because LIR/LIA requests are the majority of total number of HSS database requests. Probability of queue formation for MAR/MAA is higher, but requests of this type are relatively not frequent. The average number of particular types of requests in HSS database requires traffic analysis of a longer period, e.g. 1 year. In such case the simulation will be more accurate.

When the waiting queue will occur, the request service time will increase and quality of service will degrade. Average delay of request in HSS database can be calculated through Markov chains from Sect. 3.4. Graph of delay is depicted in Fig. 5.

The behavior of the delay is linear in the first section, then there is a sharp growth and finally there is a slow decrease. This decrease is caused by the drop of requests from the

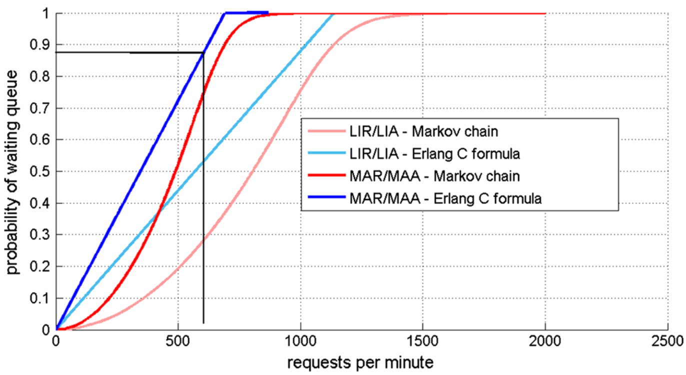

Fig. 4 Probabilities of queue formation for scenario 1. (Color figure online)

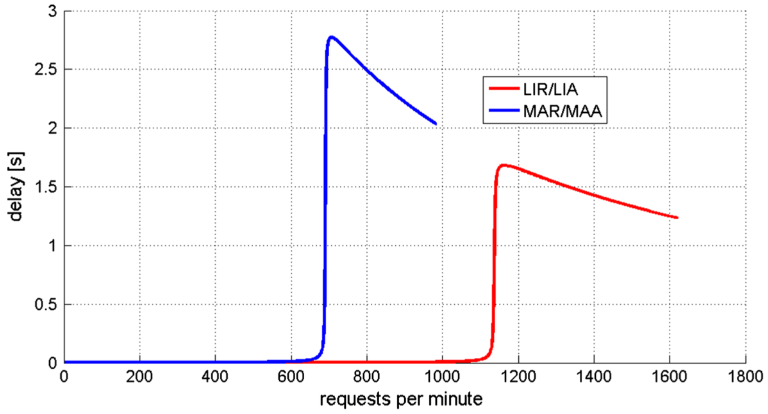

Fig. 5 Delay of request in HSS database for scenario 1. (Color figure online)

Table 3 Delay of request for scenario 1

Messages	MAR/MAA Theoretical estimation	MAR/MAA Measured estimation	LIR/LIA Theoretical estimation	LIR/LIA Measured estimation
Delay (ms)	11.67	145	11.67	88
Number of requests	605	684	1052	1126

queue. Four points are emphasized on the delay curves for each message type. The point on curve for MAR/MAA for a theoretical number of requests in the busy hour—605 per minute shows delay of 11,67 ms. The second point on this curve shows the measured value of delay—145 ms in the case of 684 requests per minute. The curve for LIR/LIA messages figure out the same points. Values are summarized in Table 3.

As we can see, the theoretical estimation is close to the measured values.

3.7 The Second Scenario

The second scenario describes a system with five HSS databases and a location database SLF. This location database is used when multiple HSS databases are implemented in the IMS system. Multiple HSS databases are useful for systems with a large number of users where the users can be classified by name, location, type of the subscribed service and so on. Another advantage of the multiple HSS is an increased number of requests that can be served without waiting for the queue formation. When sizing the HSS through Markov chains, the probability of the queue formation in SLF will be calculated by the use of Eqs. (3) and (4) and then the total probability P_{cSLF} is as follows:

$$P_{cSLF} = 1 - P_0 - P_1 \tag{20}$$

The probability of the queue formation on particular HSS databases can be calculated through Eqs. (6) and (7) and total probability P_{cHSS} is as follows:

$$P_{cHSS} = 1 - P_0 - P_1 \tag{21}$$

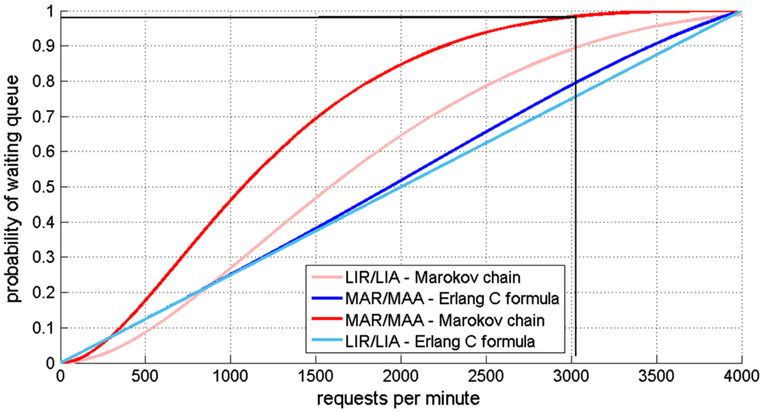

Fig. 6 Probabilities of queue formation for scenario 2. (Color figure online)

The total probability of the queue formation of the whole system is then calculated through the Eq. (22):

$$P_c = P_{cSLF} + (1 - P_{cSLF})P_{cHSS} \tag{22}$$

When sizing the HSS through Erlang C formula, the probability of the queue formation in SLF can be calculated through the Eq. (12)—(P_{cSLF}) and also in HSS databases—(P_{cHSS}). The final probability can be obtained from the Eq. (16).

In Fig. 6 we can see probabilities calculated through Erlang C formula (in blue) and probabilities calculated through Markov chains (in red). The level of 3025 requests per minute is also shown, which represents Alcatel-Lucent database load in the busy hour.

The probability of the queue formation obtained through Erlang C formula has a linear character and the probability of the queue formation calculated through Markov chains has a character of S-curve. Also in this scenario, from the accuracy of the HSS database sizing point of view, the method with Erlang C formula is more precise. In such assumption, the values of probability for the particular requests are as follows:

- MAR/MAA—0.7947,
- LIR/LIA 0.7555.

Based on this result we can say that the HSS databases of Alcatel-Lucent in the second scenario are not correctly sized, because the probability of the queue formation is up to 80%. This probability is almost the same in both types of requests and is caused by the request service time of the location database SLF. The lower values of the queue formation probability can be reached by more powerful hardware of SLF and HSS databases, lower number of users or by adding of another HSS database.

The total delay of request in the HSS database for the second scenario can be estimated through Markov chains from Sect. 3.4. Graphical representation of this delay is depicted in Fig. 7.

The behavior of the delay is very similar to curves from the first scenario. Four points are emphasized on the delay curves for each message type. The point on curve for MAR/MAA for theoretical number of requests in the busy hour—3025 per minute shows delay of 11.66 ms. The second point on this curve shows the measured value of delay—145 ms in the case of 3362 requests per minute. The curve for LIR/LIA messages figure out the same points. Values are summarized in Table 4.

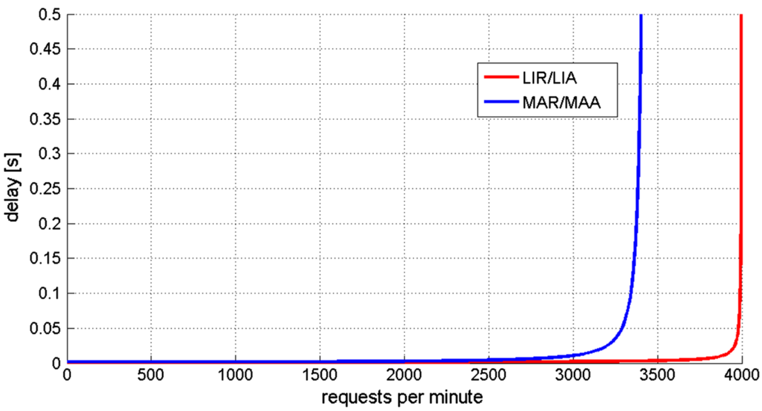

Fig. 7 Delay of request in HSS database for scenario 2. (Color figure online)

Table 4 Delay of request in second scenario

Messages	MAR/MAA Theoretical estimation	MAR/MAA Measured values	LIR/LIA Theoretical estimation	LIR/LIA Measured values
Delay (ms)	11.67	145	11.66	88
Number of requests	3025	3362	3899	3989

As we can see, the theoretical estimation is also in this case close to the measured values.

4 Conclusion

HSS is a relational database which stores user profiles. High volume of requests for information searching can overload the database and leads to the waiting queue formation. It is an undesirable behavior which degrades the QoS. Therefore we have described the HSS database sizing in our paper.

The sizing process is described on production IMS system from Alcatel-Lucent, which provides real data, settings and hardware configuration of the HSS database in a loaded network. We have used two methods for the HSS sizing—Erlang C formula and Markov chains. The sizing process has two steps. The first step is to estimate the probability of the queue formation and the second is to calculate the delay of the request in the database. In this paper we have created two scenarios which are used.

The first scenario represents the IMS system with one HSS database. It is a real system of Alcatel-Lucent in which the average service time of one LIA/LIR request is 88 ms and for MAR/MAA request it is 145 ms. This database contains 362700 records (NAI), what represents 36270 requests in the busy hour, i.e. 604 requests per minute. Such system is correctly sized. The optimal size is confirmed by graphs of the queue formation probability in which this probability for LIR/LIA is around 0.5 and for MAR/MAA is around 0.8. The higher probability in the case of MAR/MAA requests is caused by higher demands of such requests, but the requests of this type are not as frequent as LIR/LIA requests. For calculation of delays we used Markov chains. The delay in a theoretical busy hour for MAR/MAA (605 requests per minute) was 11.67 ms, while the anticipated and measured delay of 145 ms was in the case of 684 requests. For LIR/LIA requests the same delay 11.67 ms was in the case of 1052 requests per minute and the measured delay was 88 ms in the case of 1126 requests. Such sized system has an optimal ratio of the hardware capacity to the number of connected users.

The second scenario consists of five HSS databases and one SLF location database. The HSS databases are identical to Alcatel-Lucent database and SLF is designed as very fast database with service times for LIR/LIA and MAR/MAA of 25 ms. All the databases together contain 1813500 records (NAI), what represents 181350 requests in the busy hour, i.e. 3025 requests per minute. We have used the Markov chains and Erlang C formula for sizing of such system. The probability of the queue formation is around 0.8 for both types of messages, what is a relatively high probability. The delay in the theoretical busy hour for MAR/MAA (3025 requests per minute) was 11.66 ms, while the anticipated and measured delay was 145 ms in the case of 3362 requests. For LIR/LIA requests the same delay 11.66 ms was in the case of 3899 requests per minute and the measured delay was 88 ms in the case of 3989 requests. Such sized system is not optimal and can cause degradation of QoS. The lower probability of the queue formation can be reached by more powerful hardware of SLF and HSS databases, a lower number of users or by adding another HSS database.

More precise simulations can be reached by the analysis of the long-term traffic, e.g. from one year, because then the accurate ratio between LIA/LIAA and MAR/MAA messages can be stated. From this ratio the average service time can be estimated irrespective of the request type and then the simulations can be more exact.

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Milan Kellovsky was born in Liptovsky Mikulas, Slovakia, in 1990. He received the Master degree from the Slovak University of Technology in Bratislava in 2015.

Ivan Baronak was born in Zilina, Slovakia, on July 1955. He received the electronic engineering degree from Slovak Technical University Bratislava in 1980. Since 1981 he has been a lecturer at Department of Telecommunications STU Bratislava. Nowadays he works as a professor at Institute of Telecommunications of FEI STU Bratislava. Scientifically, professionally and pedagogically he focuses on problems of digital switching systems, ATM, Telecommunication management (TMN), NGN, IMS, VoIP, QoS, problem of optimal modeling of private telecommunication networks and services.

Matej Kavacky was born in Nitra, Slovakia, in 1979. He received the M.Sc. degree in telecommunications in 2004 from FEEIT STU in Bratislava. In 2006 he submitted Ph.D. work quality of service in Broadband Networks". Nowadays he works as assistant professor at the Institute of Telecommunications of FEI STU Bratislava.

Erik Chromy was born in Velky Krtis, Slovakia, in 1981. He received the Master degree in telecommunications in 2005 from Faculty of Electrical Engineering and Information Technology of Slovak University of Technology (FEI STU) Bratislava. In 2007 he submitted PhD work. Nowadays he works as assistant professor at the Institute of Telecommunications of FEI STU Bratislava.