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IP MULTIMEDIA SUBSYSTEM — DIMENSIONING OF THE HOME SUBSCRIBER SERVER DATABASE

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The article describes the architecture and standardization of the IP Multimedia Subsystem (IMS) from the perspective of the new generations of networks (NGN). Further, it discusses the database structure and derives the Home Subscriber Server (HSS) equation to be used for designing the load of this database in two proposed scripts. At the end the article compares the plot of each method and evaluates which method is preferable.

K e y w o r d s: IP Multimedia Subsystem, new generations of networks

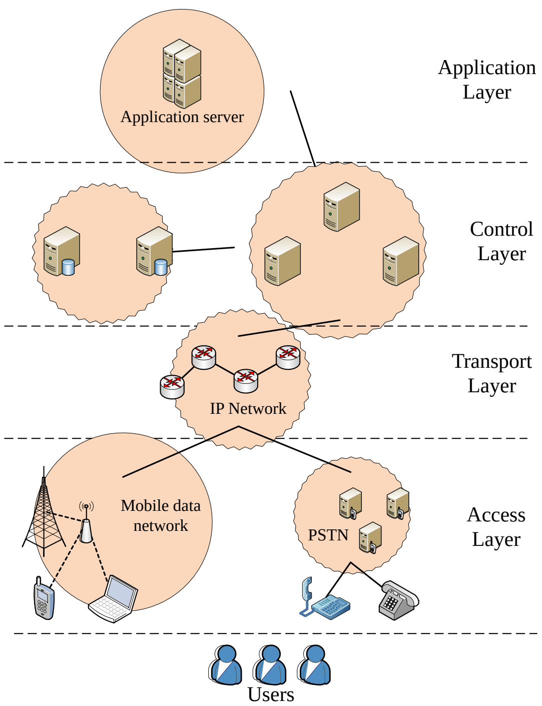

Fig. 1. Architecture of IMS (3GPP standard)

1 INTRODUCTION

NGN networks include the IMS. IMS is a system (architecture) providing the Internet protocol for multimedia services [1]. Originally it was designed for wireless standards 3GPP (3rd Generation Partnership Project), and for the development of the GSM (Global System for Mobile Communications). It helps to ensure "web services" over GPRS (General Packet Radio Service). However, this idea was updated (3GPP2), which makes this technology support GPRS, wireless LAN (Local area network), CDMA2000 (Code Division Multiple Access) and landlines. The architecture of the system is shown in Fig. 1 [1].

2 DATABASE HSS

The HSS Database is a network element within the IMS. HSS is the main database for a given user. HSS is a subject that contains information about the subscriptions related to the support of network entities for responding the requests of the users [2–4].

HSS stores the following type of information:

- subscription, identification, numbering,
- registration,
- authentication and encryption,
- profile services.

HSS generates the security information:

- mutual authentication,
- checking the integrity of communications,
- encryption.

2.1 Database scheme

The diagram in Fig. 2 shows the organization of the permanent subscriber data. HSS maintains the data related to the subscribers of IMS services. Each subscription can include a variety of users subscribed services. Within the IMS, the users are identified using the identity of a private person in the Network Access Identifier (NAI) in the form of "user@area". The whole communication with the users concerns the public user identity in the form of either SIP URI (*Session Initiation Protocol* — Uniform Resource Identifier) or TEL URL (Uniform Resource Locators for Telephone Calls). The users can be and usually are associated with one public user identity which can be shared between the users of a common subscription. User services are linked to the public user identity. Subscriptions are stored in the subscriber *table*, the records of the users are in the user table. The public user identity and the address table service profiles are in the profile table [5].

Registrations are temporary subscriber data describing the status of public user identities, including the name of the S-CSCF (Serving Call Session Control Function), where the registration is located. The public user identity

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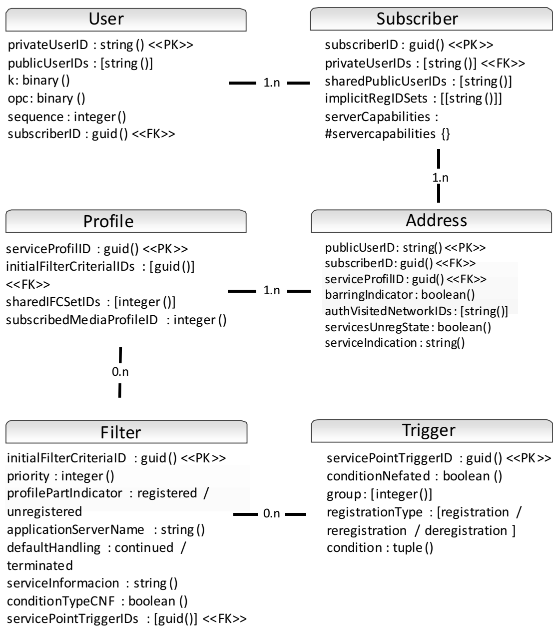

Fig. 2. Internal structure of the HSS database [5]

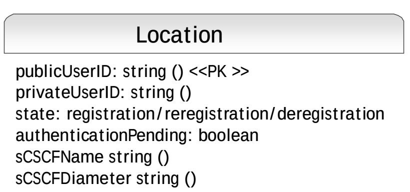

Fig. 3. Organization of temporary subscriber data [5]

may be registered by several users at once, so more items in the ground state may occur in the table with the same identity. S-CSCF can contain a user profile saved without registering, thus in some cases only one access to unregistered states can remain in the table. Unregistered public user identities generally have no record in the table. There may be one or more records without registering, while the process of their verification is in progress. The diagram in Fig. 3 shows the organization of temporary subscriber data.

3 DIMENSIONING OF THE DATABASE

Immediately after connecting each user to the IMS network pre-registration and registration occur. Such data as information about subscription, access parameters etc. are found in HSS database. HSS database is accessed also by application servers which store here their data for various applications. When the connection is established, I-CSCF (Interrogating Call Session Control Function) searches information about the user and on its basis performs the connection.

This search employs the database for some time and in the case of a large number of requirements coming from the users or application servers the so-called waiting queues may arise.

The waiting queue is undesirable because the user must wait for servicing the requirements, in such a case it is an access to the database, and this waiting causes reduction of the service quality and user dissatisfaction with the system. Therefore, it is necessary to dimension the HSS database for the number of users. In the present paper, two methods are used for dimensioning: Markov models (M/M/1/K and M/M/m/K), and the Erlang C formula [6–9].

3.1 Markov model M/M/1/K

This system is preferred to the M/M/1/? because it has a limited length of the waiting queue. Hence, this model is significantly closer to the real situation in the IMS. The M/M/1/K model has a Poisson arrival process, exponential distribution of the service time, one utility server and a waiting queue with length K. Each queuing system is described by several parameters [10].

The first parameter is μ, the number of requirements to be served by the system at a given time unit. It can be calculated as a reciprocal value of τ, which is the time of servicing one requirement

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

The requirements enter the system with speed λ, which means that the time between two successive arrivals is $1/\lambda$. The stability of the system can be expressed by parameter ρ [10]

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

P_0 expresses the probability that the system is empty. This parameter is calculated from Eq. (3), and P_1 is the probability that the system contains exactly one requirement. This probability is expressed by (4) [10]

$$P_0 = \frac{1 - (\lambda/\mu)}{1 - (\lambda/\mu)^{K+1}} , \tag{3}$$

$$P_k = P_0 \Big(\frac{\lambda}{\mu}|Bigr)^k , \quad k \le K . \tag{4}$$

Here, k is the number of requirements in the system, in our case $k = 1$. In this way one can calculate the probability of the queue in a system with 1 HSS and the probability of the queue at the subscriber location function (SLF) database in a system with 5 HSS databases.

3.2 Markov model M/M/m/K

The Markov model is used to calculate the queue in the scenario of 5 HSS databases. The parameters are the same as in the previous chain but the stability analysis of the system is changed according to

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

Table 1. Times of servicing one requirement

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

	1 HSS		5 HSS		SLF
Messages	MAR/ MAA	LIR/ LIA	MAR/ MAA	LIR/ LIA	LIR/LIA & MAR/MAA
Simulation	100 ms	50 ms	100 ms	50 ms	30 ms
Real values	145 ms	88 ms	145 ms	88 ms	25 ms

where m is the number of servers (thus of HSS databases). The probability that the system is empty is obtained from Eq. (6), and for a system containing only one requirement one obtains Eq. (7).

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

$$P_k = P_0 \left(\frac{\lambda}{\mu}\right)^k \frac{1}{k!}, \quad k \le K. \tag{7}$$

3.3 Erlang C formula

For systems with queues the Erlang C formula, (8) is used to calculate the probability of developing the queue

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

In this equation, A means the working load and m is the number of servers (in our case databases).

So as to allow comparing the results of dimensioning with each other, this equation must be modified in such a way as to use the same operators. The working load A in Eq. (8) can be replaced by

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

$$\text{where } \mu = \frac{1}{\tau}. \tag{10}$$

Here, τ is the time of servicing one requirement. Hence, after substituting we get

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

After some manipulation the final equation for calculating the probability of the waiting queue takes the form

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

4 TESTING AND REAL SERVICE TIMES FROM ALCATEL–LUCENT

Two scenarios have been proposed for dimensioning the database in which the databases were dimensioned by the Markov model and the Erlang C formula. In both scripts the systems were set at the same service times LIR/LIA (Location-Info-Request/Answer) and MAR/MAA (Multimedia-Auth-Request/Answer). The LIR/LIA requests are used to get the name and address of the S-CSCF serving the user. MAR/MAA are commands which are used to exchange information in support of authentication between the end user and the home IMS network. The times of servicing these messages by the HSS database are listed in Table 1.

The first simulation is based on the testing values and the second graph is based on the real HSS database. These values were provided by Alcatel-Lucent. Measurement was carried out at reports LIR/LIA and MAR/MAA on the Cx interface to the real productive network with a load and a separate HSS database (HSS as a separate server) [11–13].

System configuration of the server on which the database was running HSS is:
System Configuration: Sun Microsystems sun4u Netra 440,
System clock frequency: 177 MHZ,
Memory size: 16 GB

5 THE FIRST SCRIPT

The first script describes a system with a single HSS database whose dimensioning is shown in Figs. 4a and 4b. These graphs, calculated from Eqs. (3) and (4), show the probability of waiting queue formation.

The overall probability is calculated from

$$P_c = 1 - P_0 - P_1. \tag{13}$$

When dimensioning using the Erlang C formula, (12) was used from which directly the probability of the waiting queue formation is obtained.

Figures 4a and 4b show the dependences of the probability of a waiting queue on the number of requests that come to the database per minute. Figure 4a shows the simulation from the test values of the response of HSS database to LIR/LIA and MAR/MAA requests. Figure 4b shows the simulation from the real values provided by Alcatel-Lucent.

Dimensioning using the Markov model is more accurate for networks with multimedia content. Nevertheless, in this case it is better to use the Erlang C formula, as the database requirements do not change their size, so essentially it is a monotone service. The next advantage of dimensioning using the Erlang C formula is the simplicity of calculation, in which one obtains directly the probability of the waiting queue formation, and the linearity of the plot of the probability of the waiting queue and of the

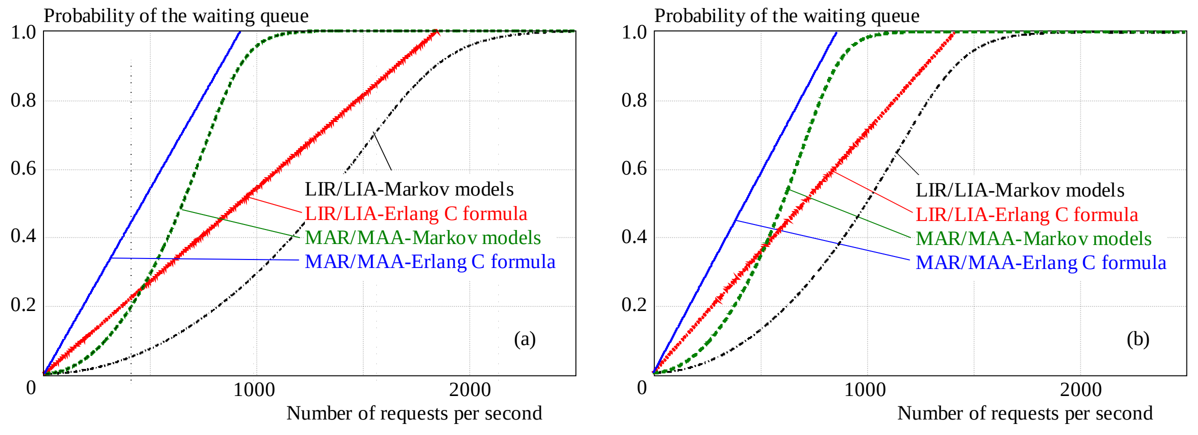

Fig. 4. Probability of the waiting queue with 1 HSS: (a) – test values, (b) – real values

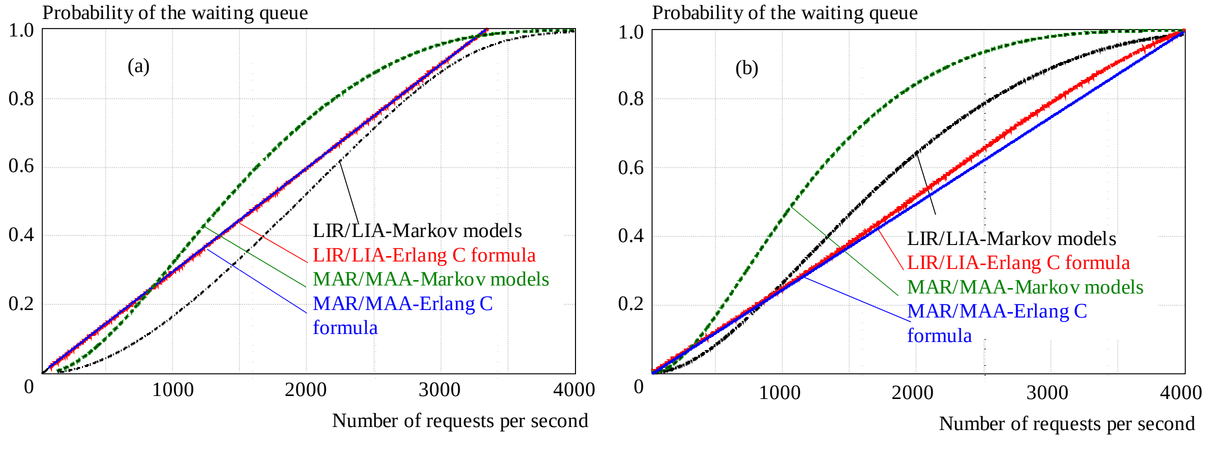

Fig. 5. Probability of the waiting queue with 5 HSS: (a) – test values, (b) – real values

number of requests that come to the database per minute. Linearity allows simple and unambiguous interpretation of this dependence.

6 THE SECOND SCRIPT

The second script describes a system with 5 HSS databases and with the subscriber location function database.

This database is used when more HSS databases are implemented is in the IMS. Using multiple HSS databases is particularly useful when sorting the user profiles based on the alphabet, location, type of prepaid services, etc. Another advantage is a manifold increase of the number of requests per minute that can be served by these databases without incurring a waiting queue.

When dimensioning via the Markov model, the probability of the waiting queue at the SLF database is calculated from Eqs. (3) and (4) as

$$P_{cSLF} = 1 - P_0 - P_1 \,. \tag{14}$$

The probabilities of waiting queue on individual HSS databases are calculated from (6) and (7) and the overall probability of the waiting queue on the HSS database is expressed again as

$$P_{cHSS} = 1 - P_0 - P_1 \,. \tag{15}$$

The overall probability of the waiting queue of the entire system is calculated from

$$P_c = P_{\rm cSLF} + \big[\big(1 - P_{\rm cSLF}\big) P_{cHSS}\big] \,. \tag{16}$$

For dimensioning by the Erlang C formula, Eq. (12) is used to calculate the probability of the waiting queue on the to SLF database, $P_{\rm cSLF}$, and also on the to HSS databases, P_{cHSS}. The resulting probability is obtained also from Eq. (16).

Figure 5a shows the simulation from the test values of the responses of SLF and HSS databases to LIR/LIA and MAR/MAA requests, and Fig. 5b shows the simulation from real values provided by Alcatel-Lucent. Similarly like in the system with a 5 HSS databases it is better to use the Erlang C formula, from which one obtains almost linear characteristics.

7 CONCLUSION

The article compares two options for dimensioning the HSS database. Utilization of the Markov model is recommended for multimedia service (such as IMS) as it accurately approximates the response of the system to the requirements of different transmission band width. On the other hand, dimensioning by the Erlang formulas is recommended for systems with one type of signal, for example voice. So as to allow comparing the characteristics, the Erlang C formula was modified to such a form which makes possible to use the same variables in the Markov model and in the Erlang formula.

Two scripts were proposed and simulations were conducted for different service times of LIR/LIA and MAR/MAA requests. The first setting used the test values and the second setting is from the real network. These real times service requirements were provided by Alcatel-Lucent.

The first script describes a system with one HSS database on which LIR/LIA and MAR/MAA requirements arrive with various service times by the database. The graphs show the dependence of the waiting queue on the number of requests that come to the HSS database. These dependences were plotted using Erlang C formula and Markov model. It is optimal to dimension the HSS database by the use Erlang C formula as the LIR/LIA and MAR/MAA messages have a constant size, so this is basically a mono-service with one type of signal. Such a use has more advantages, for example, calculation of the probability of the waiting queue is simpler than in the Markov model.

The second script describes a system with 5 HSS databases and an SLF database. Using multiple HSS databases in the system has a variety of reasons, such as sorting the profiles (in alphabetical order, location, type of subscription service ....), increasing the speed of servicing the requirements, etc. This solution requires to use another database which designates one of the HSS databases to service the operating requirement. This is the very fast SLF database which has in its records only information about the contents of individual HSS databases. As in the previous case, also here the databases were dimensioned using the Markov model and the Erlang C formula. The use of the Erlang C formula proved to be more convenient.

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References

[1] CAMARILLO, G—GARCÍA-MARTÍN, M. A.: The 3G IP Multimedia Subsystem (IMS): Merging the Internet and the Cellular Worlds, John Wiley & Sons, New Jersey, 2008.

[2] POIKSELKA, M.—MAYER, G.: The IMS: IP Multimedia Concepts and Services in the Mobile Domain, John Wiley & Sons, New Jersey, 2009.

[3] AL-BEGAIN, K.—BALAKRISHNA, C.—GALINDO, L. A.—MORO, D.: IMS: A Development and Deployment Perspective, John Wiley & Sons, New Jersey, 2009.

[4] VOZNAK, M.—REZAC, F.: Web-based IP Telephony Penetration System Evaluating Level of Protection from Attacks, WSEAS Transactions on Communications **10** No. 02 (2011), 66–76.

[5] The 3Gdb Home Subscriber Server (HSS): https://code.google.com/p/hss/ 2013.

[6] http://www.3gpp.org/ftp/Specs/html-info/23228.htm 3GPP, 2011.

[7] YEGANEH, H.—SHAKIBA, M.—DARVISHAN, A. H.: NGN functional architecture for Resource allocation and Admission control, International Journal of hybrid information technology **2** No. 03 (2009), 11–34.

[8] CAO, Z.—CHI, C.—HAO, R.—XIAO, Y.: User Behavior Modeling and Traffic Analysis of IMS Presence Servers IEEE Global, 2008, Telecommunications conference.

[9] CHROMY, E.—DIEZKA, J.—KOVACIK, M.—KAVACKY, M.: Traffic Analysis in Contact Centers, Proceedings of the 11th International Conference KTTO (2011), 19–24.

[10] POLEC, J.—KARLUBÍKOVÁ, T.—VARGIC, R.: Pravdepodobnostné modely v telekomunikáciách, Nakladateľstvo STU BA, Bratislava, 2007.

[11] CHROMY, E.—JADRON, M.—BEHUL, T.: Admission control methods in IP networks, Advances in Multimedia **13** No. 7 (2013), 7–?.

[12] BARONAK, I.—VOZNAK, M.: CaC in ATM the Diffuse Method, Acta Polytechnica **64** No. 03 (2006), 57–63.

[13] LIAO, J.—WANG, J.—LI, T.—WANG, J.—ZHU, X.: A Token-bucket Based Notification Traffic Control Mechanism for IMS, Computer Communications **34** No. 10 (July 2011), 1243–1257.

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