MATLAB SIMULATION OF SERVICES OVER IMS USING THE QUEUEING THEORY: THE SESSION-BASED MESSAGING SERVICE

Lubos Nagy

Doctoral Degree Programme (3), FEEC BUT

E-mail: lubos.nagy@phd.feec.vutbr.cz

Supervised by: Vit Novotny

E-mail: novotnyv@feec.vutbr.cz

Abstract: Today's trend in telecommunications leads to convergence of network technologies and integration of large number of various services. One of possible solutions of network convergence is the IMS (IP Multimedia Subsystem) architecture. The objective of this paper is to design a mathematical model of messaging (chat mode) service over IMS using queueing theory. The proposal of model will be based on an open single class network consisting of M/M/1 queue systems. All analytical and simulation results of all important performance parameters (mean waiting and response times, mean queue length) are shown and evaluated. All simulations are tested using Matlab. This paper continues on the previous work published in [1], [2] and [3].

Keywords: IP Multimedia Subsystem, Messaging, Queueing Theory, M/M/1, Jackson's Theorem.

1. INTRODUCTION

One of most popular service in telecommunications is a messaging service. The messaging is used to send the various contents (simple text, pictures, audio or video files, etc.) between users over network. This service can be divided into two different types: an immediate messaging (sometimes called as page mode) or a session-based messaging (called as chat mode). In the case of page-mode, only the SIP MESSAGE is generated by the user equipment. In the chat mode, the SIP and SDP protocols are used to establish session. The typical flow of chat mode consists of SIP INVITE, OK, ACK and BYE messages. The MSRP SEND methods are often used to transmit the messages within created session. The messaging service is often combined with the Presence service [4], [5], [6].

In previous paper [1], the preliminary study about video streaming service over virtualized IMS architecture using the open source projects: OpenIMS (IMS project created by FOKUS organization [7]) with support of UCT project (project created by University Cape of Town [8]) was written. Also, the virtualized network was described. In [2], basic study of IMS based video streaming service performance assessment based on queueing theory with using M/M/1 system was presented. The transport layer, I-CSCF and HSS entities have not been included in the designed mathematical model of VoD service. In [3], the transport layer and next two services (file transfer as data service and voice over IP) were added in the proposed mathematical model. This model was based on an open single class queueing network with feedbacks. Each of included IMS network entity consisted of a FIFO queue, a single server and a control unit. Also, analytical results were presented in this paper. The Jackson's theorem was used to obtain the analytical results. In this paper, the chat mode of messaging service is added into the designed model.

The next structure of article is organized as follow: an implementation of designed model using M/M/1 queueing network is described in the second part of this paper. This section briefly presents the M/M/1 queueing model and own proposal of IMS network with support of messaging service based on M/M/1 nodes. In the third section, all analytical and simulation results are evaluated.

The examination of designed IMS model and future work are discussed in the last part of this paper.

2. DESCRIPTION OF THE MODEL

The various mathematical studies of telecommunication systems are based on the queueing theory. Also, the proposed model (see Figure 1) can be defined as an open single class queueing network with feedbacks consisted of M/M/1 queue systems.

The M/M/1 system is defined by the Kendall's notation as a system with exponentially distributed of arrival (λ [s^{-1}]) and service (sometimes called as throughput, μ [s^{-1}]) rates [9]. The most important performance parameters (the mean response time - $\bar{T}$, the mean waiting time (sometimes called as queueing delay) - $\bar{W}$ and the mean queue length - $\bar{Q}$) of this queueing system are shown in (1), (2) and (3) [9].

$$\bar{T} = \frac{\frac{1}{\mu}}{(1-\rho)} \qquad (1) \quad [9]$$

$$\bar{W} = \frac{\frac{\rho}{\mu}}{(1-\rho)} \qquad (2) \quad [9]$$

$$\bar{Q} = \frac{\rho^2}{(1-\rho)} \qquad (3) \quad [9]$$

where ρ is the server utilization (sometimes called as load rate of single server) defined as λ/μ [9].

One of possible ways of description of queueing networks is using the Jackson's theorem [9]. The Jacksons networks are defined as the open single class networks with the overall unlimited number of jobs; the arrival rate defined by the Poisson distribution; the service rates defined by the exponential distribution; the FCFS service discipline and with interarrival rates defined by the formula:

$$\lambda_i = \lambda_{0i} + \sum_{j=1}^{n} \lambda_j . p_{ji} \qquad i = 1..N \qquad (4) \quad [9]$$

where, p_{ij} are the routing probabilities. The values of these probabilities are defined in the section 3.1.

The simplified scheme of implementation of IMS model is shown in the Figure 1. This scheme is without the elements using to simulation of Data, VoD and VoIP services. These elements and services were in more details described in the previous paper [3]. All simulated users are always situated inside home network and all implemented services are simulated without registrar, re-registrar and de-registrar transactions. Therefore, the IMS core (see Figure 1) consists of the P-CSCF and S-CSCF elements (without I-CSCF, E-CSCF and HSS nodes).

Each nodes of designed model (see P-CSCF node in Figure 1) consisted of the single server, the queue with FCFS service discipline, the control unit and the sink. The control unit is used to generate the responses on received requests and the routing management of these responses. In the case of messaging service, the UEs node consists of two type users (an IM-1 and an IM-2, see Figure 1). The IM-1 node is always used to initialize the session-based connection with the IM-2 node. This node (IM-1) sends the INVITE (to initialize connection) and BYE (to terminate connection) messages.

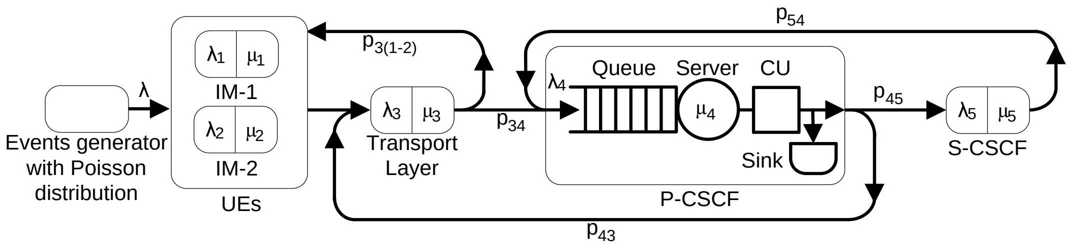

Figure 1. The simplified scheme of designed model without support of VoD, VoIP and Data services.

3. OBTAINED RESULTS

All presented results are obtained only from the simulation of session-based messaging service. In the simulated scenario, the arrival time of events generator with Poisson distribution (see λ in the Figure 1) was set the value to 0.15 s. All service times (see μ_i in the Figure 1) were set the value to 0.05 s. The signaling flow consists of three SIP requests (INVITE, ACK and BYE) and two SIP responses (OK). Also, the MSRP SEND and MSRP OK messages are always used to simulation of the chat mode in the both direction between the IM-1 and IM-2 nodes. The simulation time was set the value to 2500 time units.

3.1. ANALYTICAL RESULTS

The interarrival rates (see λ_i in the Figure 1) can be calculated by the formula (4), the Jackson's algorithm [9] and matrix of linear system shown in (5). These rates are used to determine the performance parameters shown in (1), (2) and (3). All analytical results are shown in Table 1.

$$\begin{pmatrix} 1 & 0 & -p_{31} & 0 & 0 \\ 0 & 1 & -p_{32} & 0 & 0 \\ -p_{13} & -p_{23} & 1 & -p_{43} & 0 \\ 0 & 0 & -p_{34} & 1 & -p_{45} \\ 0 & 0 & 0 & -p_{54} & 1 \end{pmatrix} \begin{pmatrix} -p_{01}\lambda \\ -p_{02}\lambda \\ 0 \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \end{pmatrix} \tag{5}$$

where p_{ij} are the routing probabilities, λ is arrival rate and λ_i is the interarrival rate for each node.

The values of routing probabilities are defined by the number of simulated requests and responses in the simulated scenario. These probabilities are defined as follow: $p_{01} = 0.667$, $p_{02} = 0.333$, $p_{13} = 0.636$, $p_{23} = 0.667$, $p_{43} = 0.5$, $p_{31} = 0.333$, $p_{32} = 0.389$, $p_{34} = 0.278$, $p_{45} = 0.5$, $p_{54} = 1.0$.

The equations of interarrival rates are calculated from (5) as follow:

$$\lambda_1 = \lambda\left(p_{01} + \frac{p_{31}(1-p_{45})(p_{01}p_{13}+p_{02}p_{23})}{(1-p_{45})(1-p_{13}p_{31}-p_{23}p_{32})-p_{34}p_{43}}\right)$$

$$\lambda_2 = \lambda\left(p_{02} + \frac{p_{32}(1-p_{45})(p_{01}p_{13}+p_{02}p_{23})}{(1-p_{45})(1-p_{13}p_{31}-p_{23}p_{32})-p_{34}p_{43}}\right)$$

$$\lambda_3 = \lambda\left(\frac{(1-p_{45})(p_{01}p_{13}+p_{02}p_{23})}{(1-p_{45})(1-p_{13}p_{31}-p_{23}p_{32})-p_{34}p_{43}}\right)$$

$$\lambda_4 = \lambda\left(\frac{p_{34}(p_{01}p_{13}+p_{02}p_{23})}{(1-p_{45})(1-p_{13}p_{31}-p_{23}p_{32})-p_{34}p_{43}}\right)$$

$$\lambda_5 = \lambda\left(\frac{p_{34}p_{45}(p_{01}p_{13} + p_{02}p_{23})}{(1 - p_{45})(1 - p_{13}p_{31} - p_{23}p_{32}) - p_{34}p_{43}}\right)$$

3.2. SIMULATION RESULTS

The measured characteristics of all selected performance parameters are illustrated in Figure 2 and Figure 3. The mean values of these parameters are shown in Table 1. As can be seen in the simulation results of all figures, the TL node reached the highest values. The highest values of TL node are affected by flow of all SIP and MSRP messages are always sent through this node. According to our expectation the values of all obtained (analytical and simulation) performance parameters are very similar (see Table 1).

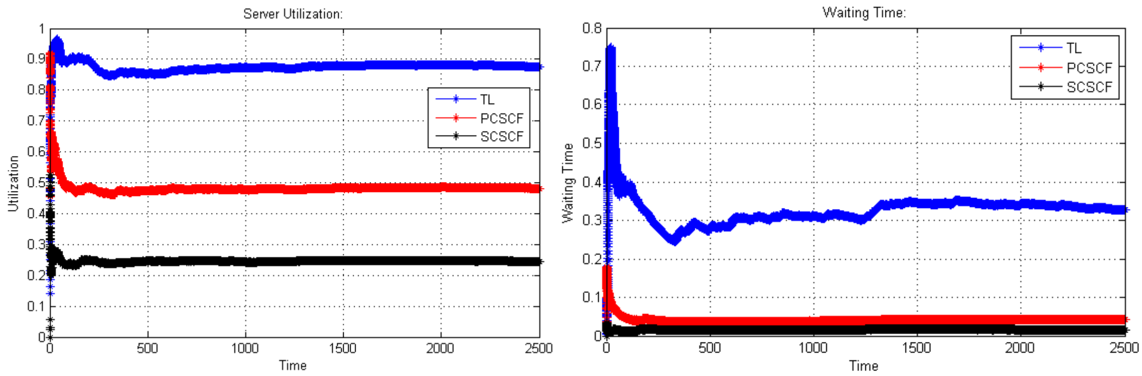

Figure 2. The server utilization (on the left) and the mean waiting time (on the right).

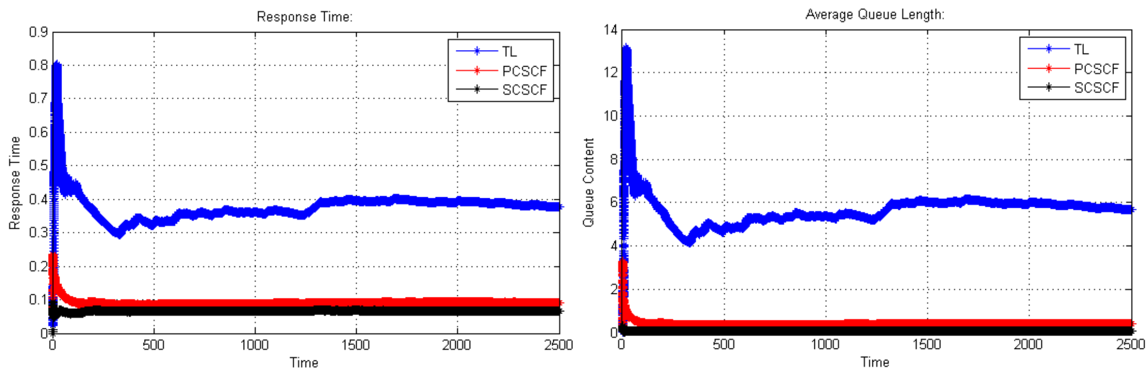

Figure 3. The mean response time (on the left) and the mean queue length (on the right).

Parameters	Node	Analytical results	Mean value of simulation results
The server utilization	Transport Layer	0.8585	0.8752
	P-CSCF	0.4769	0.4831
	S-CSCF	0.2384	0.2462
The mean response time	Transport Layer	0.3534	0.3766
	P-CSCF	0.0956	0.0913
	S-CSCF	0.0657	0.0667
The mean waiting time	Transport Layer	0.3034	0.3262
	P-CSCF	0.0456	0.0415
	S-CSCF	0.0157	0.0159

The mean queue length	Transport Layer	5.2086	5.3721
	P-CSCF	0.4348	0.4049
	S-CSCF	0.0746	0.0770

Table 1. The analytical and simulation results.

4. CONCLUSION

This paper briefly presented the implementation of session-based messaging service (chat mode) over IP Multimedia Subsystem using the queueing theory (M/M/1 system). As can be seen from Table 1, the theoretical and empirical results are very similar.

The future work will be focused to study the M/G/1 queueing system. The service time will be calculated based on the length of the messages. Thanks to M/G/1 system, the service time of INVITE messages will be longer that the service time of ACK messages. The objective of next research studies will be focused mainly to simulation the user equipment from operating system point of view.

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