Simulation of Protocol for Initiation of Communication Sessions using dynPLA Model

H. Pranevicius, A. Paulauskaite–Taraseviciene

Department of Business Informatics, Kaunas University of Technology, Lithuania
Studentu 56-301, LT-51424 Kaunas, phone: (837)300376, e-mail: henrikas.pranevicius@ktu.lt, agne@ifko.ktu.lt

A. Jarutis

Department of Telecommunications, Kaunas University of Technology, Lithuania
Studentu 50-440, LT-51424 Kaunas, phone: (837300513, e-mail: ajarutis@ktu.lt

Introduction

In providing voice services, user created and signaling information is transferred over telecommunication networks. While service quality is important as the voice information is transmitted, but not less important characteristic is to identify the establishment time of communication sessions or its components [4]. It is also an important characteristic of packets loss.

There exist a number of protocols created for the establishment of communication sessions over IP networks. One of the first standardized protocols is H.323, which has recently being replaced by the Session Initiation Protocol (SIP) protocol [5, 9]. Furthermore, SIP protocol is used as a basis to manage the communication sessions in modern telecommunications networks, based on IP Multimedia Subsystem (IMS) architecture [4]. In SIP protocol, there can be used three types of servers: Proxy.

The establishment time of communication sessions is judged by a number of factors, such as how the algorithm is realized, how the characteristics of networks, servers, and devices influence the delay, as well as the packets loss. The signaling characteristics are studied in analytical [1], simulation [9, 2], or experimental way. In addition to the establishment time of sessions, an important characteristic is the packets loss while transferring the signaling information [4]. One of the drawbacks in scientific publications, the algorithm for the specific provision of the service is not taken into account in many instances.

The establishment of communication sessions can be implemented in various ways. In a separate case, it is possible to establish the session without the use of a server, and its functions devolving to the smart terminal device. In each case, the different algorithm is applied to establish the communication session. In any way, there are always two types of agents taking part into the establishment of communication session [5] that are implemented in terminal devices and servers, in addition participating in the process of messages exchange. This can best be assessed through simulation.

In this paper, the simulation model is created based on formal method – dynPLA, which allows to describe the systems that change their structure in time. The considered problem is viewed as the system with changing structure in which both occurrence and removal of the communication sessions causes changes in the system's structure.

SIP Conceptual model

In the SIP, two types of messages are used: requests sent from client to server and server responses. One of the basic algorithms is call processing algorithm with SIP as intermediary – a Proxy server. A Proxy server is an intermediary between the client and server. Server processes all incoming requests by FIFO (*first in, first out*) method. The resulting queries are either served in or forwarded to other servers.
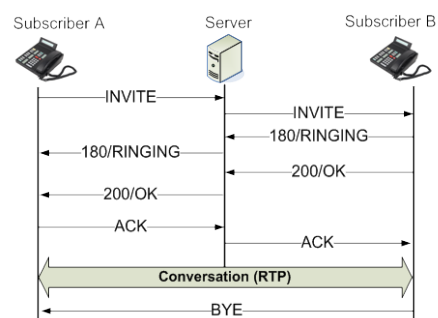

Fig. 1. Algorithm of SIP for successful calls

In the network, at certain time moments the calls are initiated between subscribers, who can communicate in accordance with different algorithms. In Fig. 1 the processing algorithm of successful call (when subscriber answers the call) using Proxy server is presented. However, only 60% of calls ends with creation of communication

session [2]. The rest part of calls due to various factors (e.g., line is busy, wrong number and so on) are unsuccessful. According to situation the different algorithms are realized. Algorithms when the called subscriber is busy (Fig. 2, a) and doesn't answer (Fig. 2, b) are presented bellow.
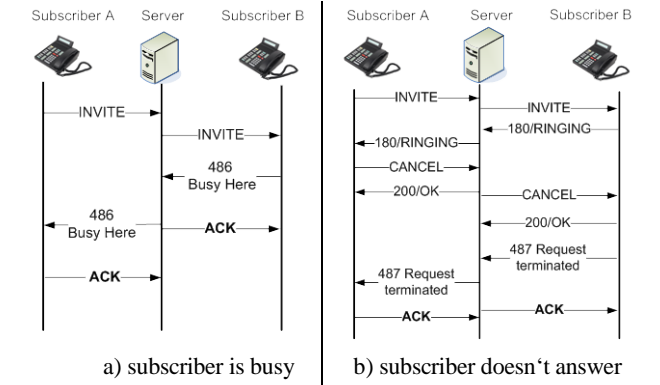

| a) subscriber is busy | b) subscriber doesn't answer |

Fig. 2. Algorithms of SIP for unsuccessful calls

Voice services using SIP can be provided in various network architectures. Depending on the type of service and users location different devices and software are used. If users communicate in a local area network (LAN) all requests and responds are transmitted through the Proxy server. Therefore, for each initiated call the new communication session between two subscribers and Proxy server is created.

SIP dynPLA model

dynPLA is the extension of piece linear aggregate (PLA) [8] method including dynamic features which allow to specify structural changes of the systems. In dynPLA both aggregate and system of aggregates have a possibility to change their structure in time [6, 7].

Definition. dynPLA is a structure:

$$A_{dyn} = \langle A_{\Sigma}(t), R_{\Sigma}(t) \rangle \qquad (1)$$

with the following constraints:
$\{A_1(t),...,A_n(t)\} \in A_{\Sigma}(t)$ – the set of system aggregates;
$R_{\Sigma}(t) = (A_n(t) \times Y_n(t)) \rightarrow (A_m(t) \times X_m(t))$ –the links set;

$\forall A_i(t) \in A_{\Sigma}(t)$ – an aggregate with structure;

$A_i(t) = \langle X(t), Y(t), E(t), Z(t), H(t), G(t), A(t), R(t) \rangle$, where

$X(t)$ – the set of input signals;

$Y(t)$ –the set of output signals;

$E(t) = E'(t) \cup E''(t)$ – the set of aggregate's events,

$E'(t)$ – the set of external events;

$E''(t) = E_1''(t) \cup E_2''(t)$ – the set of internal events,

$E_1''(t)$ – the set of state-events;

$E_2''(t)$ – the set of structural-events;

$Z(t) = \langle v(t), z_v(t), A_i(t) \rangle$ - the state of aggregate A_i;

$z_v(t)$ – continuous component;

$v(t)$ – discrete component;

$H(t)$ – the set of transition operators;

$G(t)$ – the set of output operators;

$A(t)$ – the set of internal aggregates;

$R(t)$ – the set of links among internal aggregates.

For description of possible structural changes in dynPLA abstract data types were included with following operations: addition of a new link (*AddR*) or aggregate (*AddAg*); removal of a link (*RemoveR),* or existing aggregate (*RemoveAg*) [7]. Using dynPLA notation the model of SIP in local area network can be defined as a aggregate system „Network", which consists of such aggregates: "Proxy", "Ak$_i$", "Bk$_i$", where $k = \overline{1,3}$, $i = \overline{1,n}$ (Fig. 3). Aggregate "Proxy" describes the server, aggregates "A1$_i$" and "B1$_i$" the subscriber pairs which communicate using the successful call algorithm (Fig. 1), aggregates "A2$_i$", "B2$_i$" and "A3$_i$", "B3$_i$" describes the subscriber pairs which communicate using the unsuccessful call algorithms depicted in Fig. 2, a and Fig. 2, b accordingly. The structure of aggregate system "Network" is changing, because at the certain time moments new communication sessions have been created or ended, meaning that the particular aggregates have to be added and removed.
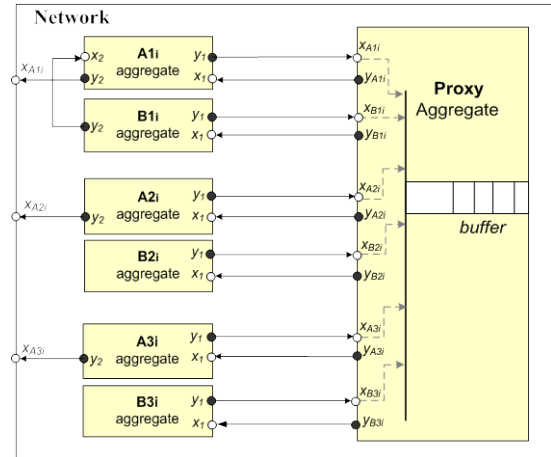

Fig. 3. Aggregate schema of SIP in local area network

Creation of new session is described as "Network" internal event during which new subscribers' aggregates connected with each other and/or aggregate "Proxy" by *r* links are added to the system. An operation *AddAgR* [6], which adds new connected aggregates to the system, has been used to describe the creation of new sessions (2)

$$Network(t_{m+1}) = AddAgR(Network(t_m), Ak_n, Bk_n, r). \quad (2)$$

Behavior of created aggregates is defined according to the SIP algorithm depicted above (Fig. 1-2): Whenever "Network" gets the input signal x_{Aki}, $k = \overline{1,3}$, which denotes that "Ak$_i$" and "Bk$_i$" have finished their communication session, it removes these aggregates using operation *RemoveAg* [6], which allows to delete the connected aggregates (3)

$$\begin{cases} Network(t_{m+1}) = RemoveAg(Network(t_m), Ak_i); \\ Network(t_{m+1}) = RemoveAg(Network(t_m), Bk_i). \end{cases} \quad (3)$$

An aggregate "Proxy" is defined as intermediary which transfers the requests among subscribers' aggregates. All requests are described as input signals of "Ak$_i$" and "Bk$_i$". These signals are processed in "Proxy" aggregate and forwarded to the addressee. Incoming requests are placed in the end of FIFO queue.

Experiments

The developed model was used to evaluate the time duration of session creation. The initial data used in the modeling are given in Table 1. The simulation is used to study the algorithms applied for establishment of communication sessions and their influence on signaling parameters, such as the duration of connection, the message loss, the number of requests waiting in a queue, and more.

**Table 1.** Simulation parameters and their values

Parameters	Value, Comments
t_{pro} – duration of request processing in server.	uniform dist. $2 \div 20 \cdot 10^{-3}$ s.
t_{ats} – message processing time in subscriber's device.	$10 \cdot 10^{-6}$ s.
p_1 –probability of successful answer of requested subscribers, p_2 – probability of unsuccessful answer (busy) of requested subscribers, p_3 – probability of unsuccessful answer (no answer) of requested subscribers.	
$P1 = (p1,p2,p3)$	(50%, 50%, 0%)
$P2 = (p1,p2,p3)$	(60%, 30%, 10%)
$P3 = (p1,p2,p3)$	(70%, 10%, 20%)
D – size of server buffer.	(8, 9, 10, 11, 12)
λ – rate of communication sessions	Input stream is Poisson

It was investigated how subscriber's stream influences the connection characteristics of communication sessions (Fig. 4, Fig. 5). Table 2 shows the estimates of analyzed characteristics and their confidence intervals.

Table 2. Mean connection duration of successful session establishment and its confidence interval

		Call distribution probabilities		
	Call stream	p1<=0,5; 0,5<p2<=1; p3=0	p1<=0,6; 0,6<p2<=0,9; 0,9<p3<=1	p1<=0,7; 0,7<p2<=0,8; 0,8<p3<=1
Mean connection duration	2 call/s	0,0469	0,0473	0,0477
	5 call/s	0,0521	0,535	0,0548
	8 call/s	0,0589	0,061	0,065
	11 call/s	0,0684	0,074	0,081
	14 call/s	0,082	0,0948	0,11
	17 call/s	0,105	0,134	0,182
Confidence interval	2 call/s	±4,20E-05	±4,03E-05	±3,60E-05
	5 call/s	±9,03E-05	±7,30E-05	±5,68E-05
	8 call/s	±1,06E-04	±1,59E-04	±1,28E-04
	11 call/s	±2,30E-04	±2,16E-04	±3,82E-04
	14 call/s	±3,78E-04	±5,22E-04	±7,14E-04
	17 call/s	±6,37E-04	±1,32E-03	±1,90E-03

It was investigated how subscriber's stream influences the connection characteristics of communication sessions (Fig. 4, Fig. 5). Table 2 shows the estimates of analyzed characteristics and their confidence intervals.
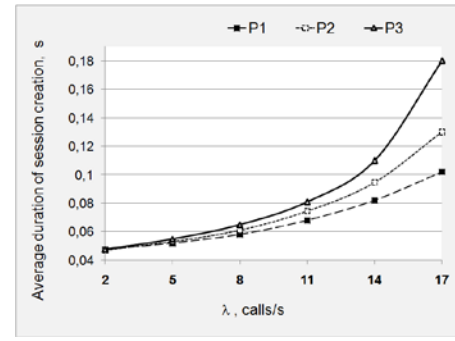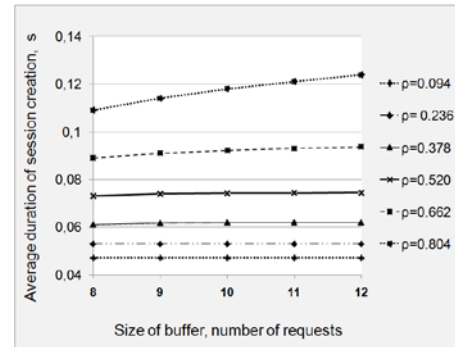

Fig. 4. Communication session creation's duration dependence on incoming call stream
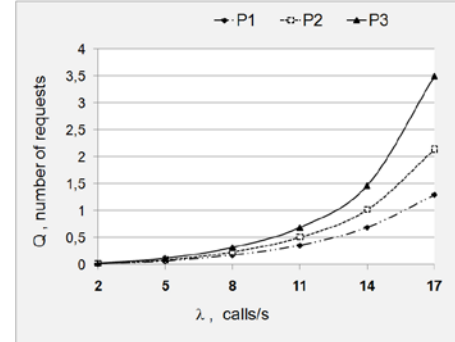
Fig. 5. Server's request queue dependence on incoming call stream

In the following, two dependencies under different buffer sizes are depicted: mean connection session establishment's time dependence (Fig. 6) and the number of lost requests dependence (Fig. 7). These dependences are analyzed then subscriber's stream is indicated by the distribution *P3*.

Fig. 6. Mean communication session creation duration dependence on server's buffer size

Server load factor ρ is introduced, which is calculated by the following formula:

$$\rho = \lambda' \cdot m[t_{pro}], \qquad (4)$$

where $\lambda' = \lambda \cdot (p1 \cdot k_1 + p2 \cdot k_2 + p3 \cdot k_3)$ – stream rate of incoming requests to the server; k_i, $i = \overline{1,3}$ – number of requests maintained by the server during the connection session; $m[t_{pro}] = 11 \cdot 10^{-3}$ s – mean processing time of one request in the server.

The stream rate of incoming requests to the server is calculated as $\lambda' = \lambda \cdot (0,7 \cdot 4 + 0,1 \cdot 3 + 0,2 \cdot 6)$ if subscriber's stream is determined by distribution *P3*.
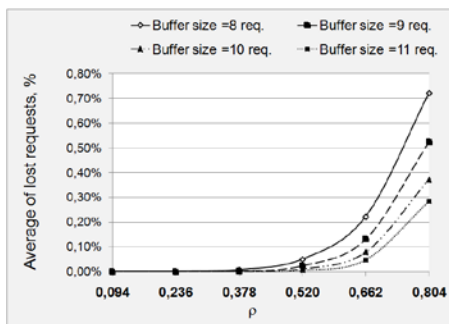

Fig. 7. Lost requests dependence on server's buffer size

Conclusions

The usage of dynPLA model allowed to formally describe the connection session establishment processes taking place in the local network. The emergence of new communication sessions and their termination were described using abstract data types operations applying them for structural changes in SIP network model.

The obtained simulation results allow the requirements on server's technical characteristics be based upon given connection session intensity. The presented methodology can be extended considering more complex cases when users are on different networks.

References

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H. Pranevicius, A. Paulauskaite–Taraseviciene, A. Jarutis. Simulation of Protocol for Initiation of Communication Sessions using dynPLA Model // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 5(101). – P. 35–38.

In the paper, Session Initiation Protocol (SIP) formal model was created using dynamic PLA (dynPLA). The considered problem was presented as the system with changing structure in which both occurrence and removal of the communication sessions causes changes in the system's structure. The simulation was used to study the algorithms applied for establishment of communication sessions and their influence on signaling parameters, such as the duration of connection, the message loss, and more. The obtained simulation results allow the requirements on server's technical characteristics be based upon given connection session intensity. The presented methodology can be extended considering more complex cases when users are on different networks. Ill. 7, bibl. 9, tabl. 2 (in English; abstracts in English, Russian and Lithuanian).

Г. Пранявичюс, А. Паулаускайте–Тарасевичиене, А. Ярутис. Моделирование протокола инициализации сессий соединения используя dynPLA модель // Электроника и электротехника. – Каунас: Технология, 2010. – № 5(101). – С. 35–38.

В данной работе, используя динамический PLA метод (dynPLA) создана формальная модель и протокола инициализации сессии (ПИС). Метод dynPLA предназначен для моделирования систем с изменяющейся структурой. В случае решаемой задачи, моделируемая система оценивалась как система с изменяющейся структурой, в которой возникновение сеансов связей и их удаление вызывали изменения структуры самой системы. Выполненное имитационное моделирование, во время которого исследовалось влияние алгоритмов создания сеансов связи на параметры сигнализации, таких как время соединения, потеря пакетов и др. Полученные результаты имитационного моделирования позволили обосновать требования для технических характеристик сервера при заданных интенсивностях сеанса связи. Изложенную методику можно расширить, оценивая более сложные случаи, при которых пользователи присутствуют в нескольких сетях. Ил. 7, библ. 9, табл. 2 (на английском языке; рефераты на английском, русском и литовском яз.).

H. Pranevičius, A. Paulauskaitė–Tarasevičienė, A. Jarutis. Komunikavimo sesijų inicijavimo protokolo imitavimas panaudojant dynPLA modelį // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 5(101). – P. 35–38.

Darbe, taikant dinaminį PLA (dynPLA) metodą, sukurtas formalus sesijos inicijavimo protokolo (SIP) modelis. dynPLA metodas skirtas kintamų struktūrų sistemoms modeliuoti. Nagrinėjamu atveju modeliuojamoji sistema buvo vertinama kaip kintamos struktūros sistema, kurioje ryšio seansų atsiradimas ir jų pašalinimas keičia sistemos struktūrą. Atliktas imitacinis modeliavimas, kurio metu buvo tiriama ryšio seansų sudarymo algoritmų įtaką signalizacijos parametrams, tokiems kaip sujungimo laikas, pranešimų praradimas ir kt. Gauti imitacinio modeliavimo rezultatai leido pagrįsti reikalavimus serverio techninėms charakteristikoms, kai yra žinomas ryšio seanso intensyvumas. Pateiktą metodiką galima praplėsti, įvertinant sudėtingesnius atvejus, kai vartotojai yra skirtinguose tinkluose. Il. 7, bibl. 9, lent. 2 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).