SIP Flow Time Interval between Messages of Statistical Analysis

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Abstract—SIP protocol is most often used for voice information transmitting over IP networks via communication session. Communication session process has been managed by SIP proxy server. In order to determine its operating characteristics, such as message service time, and message blocking probability, it is necessary to know the statistical features of the served traffic including the time interval of incoming message flow, the time interval distribution between arriving messages, mean value and their possible deviation. The statistic characteristics of time intervals of individual SIP messages and the total flow entering into SIP Proxy server have been experimentally determined in the paper. It has been found that the inter-arrival time of the sum total of SIP message flow does not correspond to the Poisson distribution thus General distribution should be used in the tests.

Index Terms—Telecommunication services, IP networks, packet switching, internet telephony, signalling.

I. INTRODUCTION

IP-based network resources are increasingly used in voice services. During the provision of voice services, network devices are loaded with signalling and user information. Using packet mode communication it is difficult to guarantee the required quality of service associated with the establishment of the connection session and voice communication. SIP (Session Initiation Protocol) [1]–[3] is the main signalling protocol for the transmission of voice information over IP networks. One of the main characteristics of voice quality related to the servicing of signalling messages at signalling nodes is the time needed to establish the connection session. It depends not only on the intensity of voice services usage, but also on the algorithm implementing the service.

Analytical simulation models are used [4]–[7] in order to perform the time analysis needed to establish connection for services delivered over IP network. While developing any mass servicing system analytic or simulation model, distribution of incoming messages should be determined. For evaluation of statistical characteristics in analytical models of IP telephony networks it is often assumed that incoming messages enter the servicing system according to Poisson distribution [7]. This is correct if characteristics such as the time interval between the calls or the call handling time

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Fig. 1. Typical signalling network used to provide voice services when connection is made in IP network of one VoIP provider.

Statistical features of time intervals between SIP signalling messages arriving to SIP Proxy server (SIP PS) moments obtained during the experiment are presented in this work. The observation of message arriving times was established in SIP PS for one Lithuanian VoIP service

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provider. All observed calls are established using only one SIP PS. IPv4 is used for SIP messages transported for this service provider.

Signalling messages from the basic voice service connection algorithm entering SIP PS were recorded during the experiment (Fig. 2) [1], [8].

Upon initiating a call, INVITE message is created followed by announcements TRYING, RINGING, OK, ACK, BYE, which are related to the creation and termination of the connection session. These messages are interdependent and their sequence is determined by the service algorithm (Fig. 2). Some messages, for example, OK, are transmitted several times during one session.

\[
\begin{align*}
\Lambda_i(t) &= t_{SUM,i} - t_{SUM,i+1} \\
\Lambda_{SUM} &= \sum_{i=1}^{n} \Lambda_i(t)
\end{align*}
\]

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Fig 2. Basic call voice service algorithm.

II. DETERMINATION OF THE DISTRIBUTION OF TIME INTERVALS BETWEEN THE SIGNALLING MESSAGE ARRIVALS TO THE SIP PS

Times of signalling messages coming into the SIP PS servicing the basic voice calls are shown (Fig. 3).

\[
\begin{align*}
\Lambda_{INVITE_i} &= t_{INVITE_i} - t_{INVITE_{i-1}} \\
\Lambda_{RINGING_i} &= t_{RINGING_i} - t_{RINGING_{i-1}} \\
\Lambda_{OK_i} &= t_{OK_i} - t_{OK_{i-1}} \\
\Lambda_{ACK_i} &= t_{ACK_i} - t_{ACK_{i-1}} \\
\Lambda_{BYE_i} &= t_{BYE_i} - t_{BYE_{i-1}} \\
\Lambda_{SUM} &= \sum_{i=1}^{n} \Lambda_{SUM}
\end{align*}
\]

Fig. 3. The model of messages flow coming to SIP proxy.

During observation period 4954 basic voice service calls were serviced. Their arrival times in the SIP PS were captured. Traffic of each type of the signalling messages is characterized by the distributions of time intervals \( \Lambda_{SUM} = t_{SUM,i} - t_{SUM,i+1} \) between two adjacent signalling messages of the same type, and the total flow – interval time between the arrival of two neighbouring

\[
\begin{align*}
\bar{t}_{INVITE} < \bar{t}_{RINGING} < \bar{t}_{OK} < \bar{t}_{ACK} < \bar{t}_{BYE} < \bar{t}_{OKafterBYE}
\end{align*}
\]

Basic voice service connection is initiated when the INVITE message is sent from the user equipment to the SIP server.

The averages of time intervals between the appearance of adjacent messages (separately for each type of messages and total flow) are found

\[
\bar{\Lambda}_i = \frac{\sum_{k=1}^{N} \Lambda_{i,k}}{N_i}.
\]

where \( N_i \) – the number of messages during \( i \)-th type of observation.

Time interval dispersion is evaluated using standard deviation

\[
\sigma(\Lambda_i) = \sqrt{\frac{\sum_{k=1}^{N} (\Lambda_{i,k} - \bar{\Lambda}_i)^2}{N_i - 1}}.
\]

The absolute error of the duration of time intervals between the appearance of adjacent messages of type \( i \) is

\[
\varepsilon_{p,\Lambda_i} = z_p \cdot \frac{\sigma(\Lambda_i)}{\sqrt{N_i}}.
\]

where \( z_p \) – is the standard normal distribution \( p \)-th quintile, selected according to \( p \) value.

The value of relative error of average time interval between adjacent \( i \)-th type signalling messages arrival times with 99% confidence level ( \( p = 0.99 \) ) is

\[
\Delta_{\Lambda_i} = \frac{\varepsilon_{p,\Lambda_i}}{\bar{\Lambda}_i} \cdot 100\%.
\]

The parameters of time intervals between the moments of arrival of adjacent signalling messages are shown in Table I.

<table>
<thead>
<tr>
<th>Message</th>
<th>( \bar{\Lambda}_{i,\text{s}} )</th>
<th>( \sigma(\Lambda_i) )</th>
<th>( \varepsilon_{p,\Lambda_i} )</th>
<th>( \Delta_{\Lambda_i} %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>INVITE</td>
<td>1.079</td>
<td>1.05</td>
<td>0.038</td>
<td>3.57</td>
</tr>
<tr>
<td>RINGING</td>
<td>1.079</td>
<td>0.953</td>
<td>0.035</td>
<td>3.24</td>
</tr>
<tr>
<td>OK</td>
<td>1.084</td>
<td>1.007</td>
<td>0.037</td>
<td>3.41</td>
</tr>
<tr>
<td>ACK</td>
<td>1.084</td>
<td>1</td>
<td>0.037</td>
<td>3.38</td>
</tr>
<tr>
<td>BYE</td>
<td>1.084</td>
<td>1</td>
<td>0.037</td>
<td>3.38</td>
</tr>
<tr>
<td>OK(afterBYE)</td>
<td>1.084</td>
<td>1</td>
<td>0.037</td>
<td>3.38</td>
</tr>
<tr>
<td>Total</td>
<td>0.18</td>
<td>0.881</td>
<td>0.013</td>
<td>7.32</td>
</tr>
</tbody>
</table>
The mean and variance of time intervals between adjacent messages of the same type differ from the observed values by no more than 3.57% and the total signalling messages flow—by no more than 7.32% with 99% confidence level.

Based on the experiment data, histograms of signalling messages servicing times are drawn. Bounds of the histogram grouping intervals are defined as follows

\[ l_{N_{i}_{\text{min}}} = 1.2 \lg N_i, \quad l_{N_{i}_{\text{max}}} = 3.3 \lg N_i. \]  

(6)

In this case the size of the individual signalling messages sample is \( N_i = 4953 \), so \( l_{N_{i},\text{min}} = 4 \) and \( l_{N_{i},\text{max}} = 12 \). The size of total signalling messages sample is \( N_{\text{t}} = 29723 \), so \( l_{N_{\text{t}},\text{min}} = 5 \) and \( l_{N_{\text{t}},\text{max}} = 15 \). For the grouping of time intervals between the arrivals of individual signalling messages \( l_i = 8 \) is used, for the total flow - \( l_i = 10 \).

Sample width is determined for each group of experiment values

\[ IP_{N_{i}} = N_{i,\text{max}} - N_{i,\text{min}}, \]  

(7)

where \( N_{i,\text{min}} \), \( N_{i,\text{max}} \) — the minimum and maximum interval time between the arrival of adjacent \( i \)-th type of signalling messages.

For each type messages histograms are step determined

\[ d_{N_{i}} = \frac{IP_{N_{i}}}{l_{N_{i}}}. \]  

(8)

The probability \( P_{\text{Eksper},i,n}(a_{i,n} \leq \Lambda_{i,k} < b_{i,n}) \) that the \( \Lambda_{i,k} \) falls in the range \([a_{i,n}, b_{i,n})\) is calculated from experimental data using the following equation

\[ P_{\text{Eksper},i,n}(a_{i,n} \leq \Lambda_{i,k} < b_{i,n}) = \frac{z_{i,n}}{N_i}, \]  

(9)

where \( z_{i,n} \) — the number of values of \( \Lambda_{i,k} \) that fall in the range \([a_{i,n}, b_{i,n})\), \( n \) — index of the interval.

The probability of exponential distribution \( P_{\text{Ekspo},i}(a_{i,n} \leq \Lambda_{i,k} < b_{i,n}) \) that the \( \Lambda_{i,k} \) falls in the range \([a_{i,n}, b_{i,n})\) is found by the equation

\[ P_{\text{Ekspo},i}(a_{i,n} \leq \Lambda_{i,k} < b_{i,n}) = \frac{1}{N_i} \int_{a_{i,n}}^{b_{i,n}} e^{- \frac{\Lambda_{i,k}}{N_i}} d\Lambda_{i,k}. \]  

(10)

The calculation results are given in Fig. 4–Fig. 10.

The results indicate that the distributions of the time intervals between the arrival of two adjacent signalling messages provided by experimental data and theoretical calculations (using exponential distribution (10)) are the same (Fig. 4–Fig. 9). The mean and standard deviations of the distributions differ by no more than 3.75% (Table I). Thus the condition of the exponential distributions that the mean and standard deviation are equal is satisfied.

Therefore, we can conclude that the values of time intervals between the arrivals of two adjacent signalling messages of the same type are distributed according to the exponential distribution. Mean while, the total signalling traffic entering into the SIP, PS, while servicing the basic call connection is not exponential (Fig. 10). This is confirmed by the fact that the mean and standard deviation of the distributions differs in value almost five times (Table
As the signalling message sequence of the voice service connection/termination is strictly defined (by the connection establishment algorithm), time interval between the arrival of one type of signalling messages is dependent on the time interval between the arrivals of another type of signalling messages for the same service.

The absence of correlation between the messages of different transactions can be explained by random processes that occur between transactions, independent on the signalling network operation. Call pickup process intervenes between call initiation and connection establishment transactions. Meanwhile, voice message intervenes between connection establishment and call termination. Such processes are dependent on the user behaviour.

III. CONCLUSIONS

1. Distribution of the time intervals between signalling messages of the total flow entering SIP proxy server is not exponential, although it is created by servicing call flow, which time intervals between consecutive messages of the same type are distributed according to the exponential distribution.

2. Time intervals between signalling messages of the same type entering SIP PS are distributed according to exponential distribution.

3. After examining total signalling message flow coming to SIP PS it was determined that this flow is not exponential although it is created by the servicing voice service call flow that is exponential. It was also determined that part of signalling messages inter-arrival times in total messages flow are interdependent. Of your paper observes the textual arrangement on this page.

REFERENCES


