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ADAPTIVE ROUTING OF STOCHASTIC DATA IN COMMUNICATIONS

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ABSTRACT

Based on a method for calculation of the estimated time for serving of different priority requests in bursty traffic networks, a service time model is proposed for the case of handling of more than one request. The well known methods of handling different priority requests employ the minimal and maximal expected service time, i.e. the pessimistic scenarios for high priority requests and optimistic scenarios for lowest priority requests are applied. The paper proposes calculation of the probability function in dependency of the time of complete handling of one request and respectively the probability for the starting with the proceeding of the next corresponding one. This allows the running different scenarios for ordering request sequences and calculation of their delays on base of the collected experience from earlier requests.

Furthermore, it suggests method of testing scenarios with request time delays greater than expected. The models proposed could be applied also in other fields where service time planning and variant solutions are possible.

Index Terms **–** adaptive routing, time scheduling, probabilistic planning

1. INTRODUCTION

In the communication networks with adaptive routing the possibility for one node to objectively utilize the “collected knowledge” from previous communications with other nodes, might be especially important. Because of the random nature of the traffic, a similar volume of information can be transferred with different delays, other conditions being equal. The transfer time depends on the transferred volume of information and on the lines’ load.

When packages with different sizes and priority are exchanged between two nodes, in order to solve the priority tasks, it is important that at the Service Level Agreement (SLA) - velocities, service quality etc, the delay of the ordered packages is forecasted and agreed.

The aim of the present work is to forecast not only the service duration of the separate requests, and its time distribution [1] – i.e. what is the probability for a present session to terminate towards a definite moment of time. This determines the probability for start the transfer of the next package in the queue. It is possible in this way to optimize and respectively, to plan the order for packages dispatching depending on their priorities at assigned Quality of Services - QoS.

2. PROBABILISTIC MODEL PARAMETERS

It is easy to determine the average duration for assigned volume of information transfer, provided that all packages are of equal size, and the traffic is relatively constant [2, 3, 4]. If the packages are of different sizes or uneven distribution in time (i.e. the flow does not have a Poisson distribution), than the average transfer time for unit information can be determined only from the collected statistical experience (bits, number packages and others).

In [1] is made the assumption that the service time is in directly proportional to the transferred information volume. A proposal for calculating the average serving time of a given volume of information is made on this basis.

On figure 1, an example is shown with the experiment of four sessions between two nodes, at which is transferred a different volume of information (A_1, A_2, A_3 and A_4), but with similar other network work parameters. Because of the current network overload, it is possible that the time for transferring a smaller volume of information be longer than for a bigger volume, and vice versa.

In order to provide the given information volume transfer, it shall be equalized to an information volume, accepted for a unit of measurement. Let’s, for example, use the information volume of the fourth session (A_4) and the volumes of all sessions shall be equalized to it (figure1b).

The service average speed V_{cp} of unit volume, in the present case with size A_4 will be:

$$(1) \quad V_{av} = \frac{A_1}{T_1}.\frac{A_1}{A} + \frac{A_2}{T_2}.\frac{A_2}{A} + \frac{A_3}{T_3}.\frac{A_3}{A} + \frac{A_4}{T_4}.\frac{A_4}{A},$$

Where $A = \sum A_i$, and $\frac{A_i}{A}$ is a coefficient,

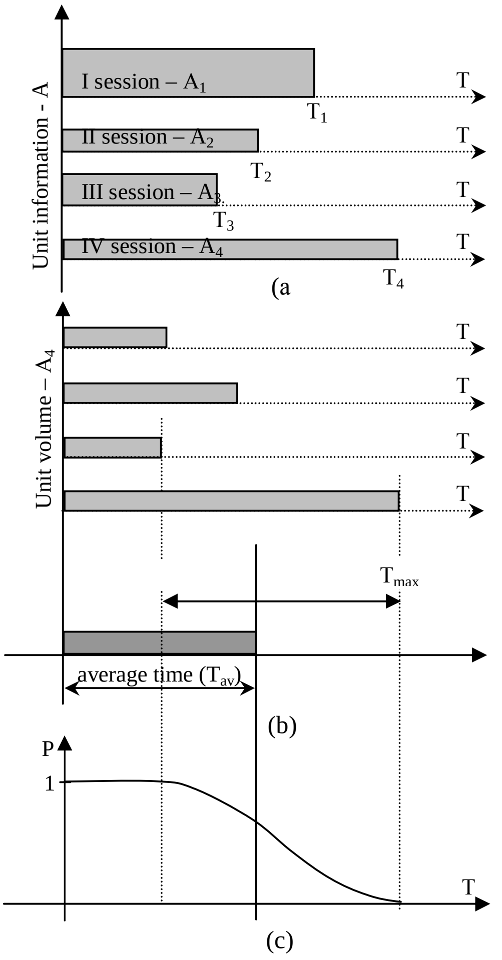


Figure1 Calculation of the average delay for given information volume

signifying the representativeness of the excerpt, i.e. how this experience can influence the entire result.

The calculated average speed V_{av}, changes dynamically in relation to the incoming information for served traffic, and the time for its service.

Then the time for which the information with volume A_4 will be transferred, will be:

$$(2)\quad T_{av} = \frac{A_4}{V_{av}}.$$

Because of the above-accepted allowance for direct proportionality between the transfer time and the transferred information volume, then for a volume of transferred information A', different from A_4 the following is valid:

$$(3)\quad T'_{av} = \frac{T_{av} \times A'}{A_4}.$$

On figure 1b is given the minimum and maximum time (T_{min} and T_{max}) for termination of order with volume A_4. Knowing these times, different scenarios of the route algorithm can be made – optimistic (best case) and pessimistic (worst case). Depending on the order priority, either one of the scenarios can be applied. For example, if the execution of a low-priority application is found critical for the termination of a high-priority application, then for the low priority application, the pessimistic variant is accepted, and an analysis of the times for executing both applications is made.

Probablistic value of non conclusion to *t* moment is given on figure1c. In this case it could be evaluated what is the probability the execution of one application to endanger the correct execution of another, which is with higher priority. If it is acceptable that the probability for delay of the higher priority application is greater than the admissible time i.e. it does not exceed the preliminary determined limit value, the lower-priority can be executed, if its delay is believed to be crucial.

Let's try to solve the following problem: to calculate the probability for non-conclusion of the application servicing with volume $A = A_1 + A_2 + A_3 + A_4$ (the same form from figure 1), where to the moment T_1 are transferred A_1 bits, to the moment T_2 are delivered additional A_2 bits, to moment T_3 are delivered A_3 bits more, and to the moment T_4 - the last A_4 bits, as it is shown at figure 2.

$P(t_0)$, $P(t_1)$, $P(t_2)$, $P(t_3)$ and respective $P(t_4)$ are received under the formula [5]:

$$(4)\quad P(t) = \frac{A(t) - A(t + \Delta t)}{A},$$

Where:

$A(t)$ – the served volume of information to the *t* moment,

$A(t+\Delta t)$ – served information in the interval Δt.

Than, for the probability of not conclusion of the new moments service, is received:

$$(5)\quad P(t_0) = \frac{A}{A} = 1$$

$$(6)\quad P(t_1) = \frac{A - A_1}{A}$$

$$(7)\quad P(t_2) = \frac{A - A_1 - A_2}{A}$$

$$(8)\quad P(t_3) = \frac{A - A_1 - A_2 - A_3}{A}$$

$$(9)\quad P(t_4) = \frac{A - A_1 - A_2 - A_3 - A_4}{A} = 0$$

The graphical representation of the probability function P is given at figure 2. With $\Delta t \to 0$, a curve from the type at figure 1c is achieved.

The average time for termination of the application with volume A is:

$$(10)\quad T_{cpA} = \int_0^\infty t.f(t)dt,$$

Where $f(t)$ is the distribution density.

If the probability for non conclusion of application with volume B, different from A ($B = n.A$) is sleeked, the average service time of B also can be calculated using the reasoning shown in figure 2. The experience

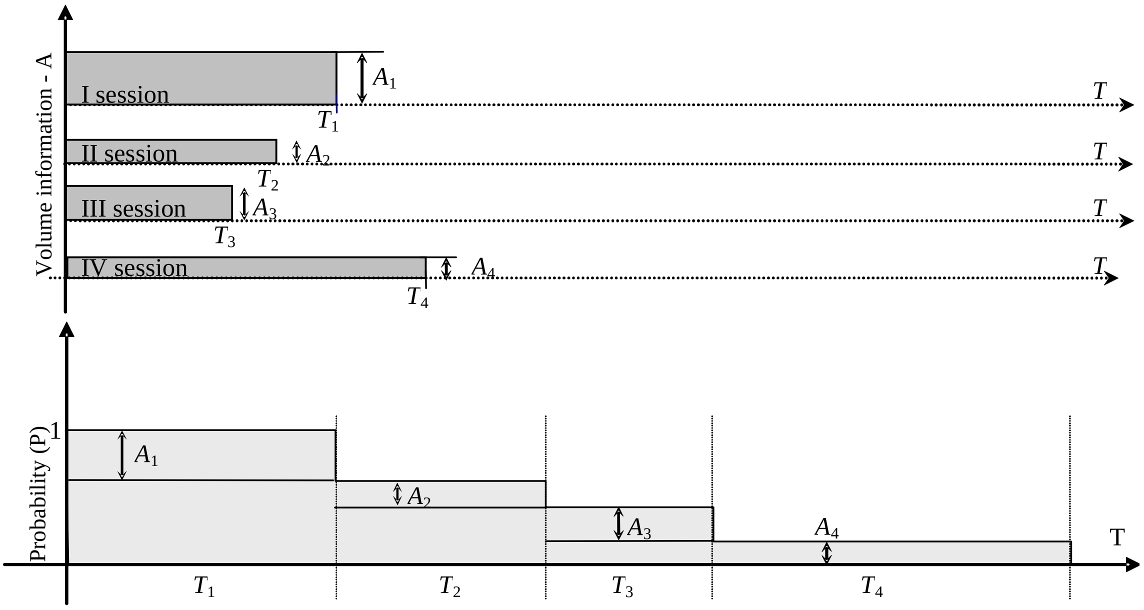
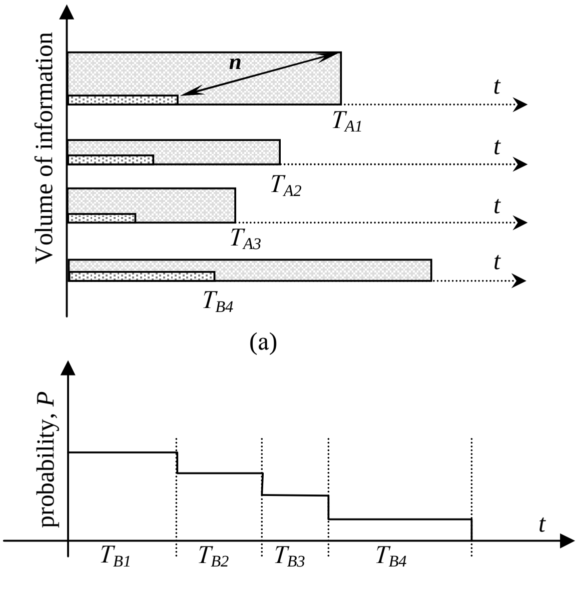


Figure2 Forecast of the probability for non- conclusion of a new application with volume $A = A_1+A_2+A_3+A_4$

collected from previous sessions, for example sessions A_1, A_2, A_3 and A_4 and presented with rectangles, as on figure 1, and figure 2 shall be scaled with coefficient *n*. The separate sessions shall be presented with proportional rectangles at the initial (figure3), i.e.. $\frac{B_1}{T_{1B}} = \frac{A_1}{T_{1A}}$ and $B_1 = n.A_1$, where $n \in (0,\infty)$.



(a)

Figure 3. Providing of the probability for non conclusion of a new application with volume B

The average application service time with volume *B*, is obtained as in (10) or in other words, it is the sum of the rectangle surfaces from figure 3c.

The calculation of the non-conclusion probability, respectively terminating a given application provides a big advantage when optimizing the routing algorithms and at service of applications with different priority. The probability for closing of particular application is simultaneously the probability to begin the next application service.

In this way can be made different scenarios (figure 4) and to be estimated, is the admissible probability for non-conclusion violated for particular application in time. In this way neither a pessimistic, nor an optimistic, but a realistic scenario is used.

3. MODELING PRINCIPLES

If the probability for non-conclusion of the service of an application from time is received, we can split the function of the probability at time intervals T_i (figure 5). These intervals can coincide with the intervals from figure 2 and figure 3, but their meaning here is different. These are intervals for which can be accepted, that the probability for non-conclusion of the application remains constant. This admission does not contradict to (10), because the area under the curved and seesaw line is one and the same, but it allows to pass to embeded Markov chains. If we have the results for the probability to stay in service condition for *n* applications, like at figure 5, we can calculate the probability for service of these *n* serial applications in function of the time. So in each moment of the time it can be found out what is the probability for service of each one of the applications, like in figure 4. The model describing this arrangement is given in figure 6 with embeded Markov chains.

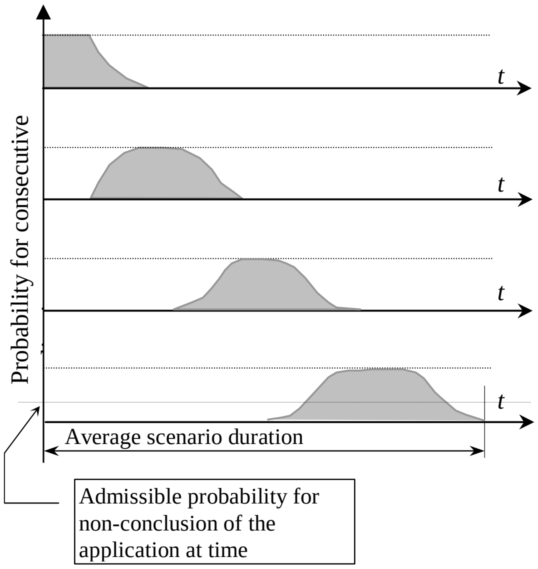


Figure 4. Probability for beginning and termination of the different applications

The first digit from the condition describes the serial position of the application: 1, 2, …, *n*, and the second – the time interval: 1, 2, …, *k*. Here is accepted, that the service intervals for all applications are split at *k* sub-intervals.

Let's ask the follow question: what shall be the probability for the system to service the particular application after passing interval T_1 (figure 5)? Apparently, the service probability to the moment t_1 is P_1, and the probability that the application remain non-served, is $1-P_1$.

If the probability for application 1 in service condition after time t_1 is P_{11}, then the transitional intensities in the model, from condition 11 of figure 6 are respectively P_{11}/T_{11} and $(1-P_{11})/T_{11}$. The first transitional intensity goes towards service condition of the second application, and the second goes to condition, in which the service of the application continues at least for the next interval T_{12}. The average time to remain in condition 11 shall be:

$$\frac{1}{P_{11}/T_{11}+(1-P_{11})/T_{11}}=T_{11},$$

which corresponds to the condition for searching of the probability to remain in service condition, after interval T_1 for the first application, or this is exactly T_1

Following these arguments, can receive all transitional intensities in the model from figure 6. With condition *Z* is marked the service closing of all *n* applications

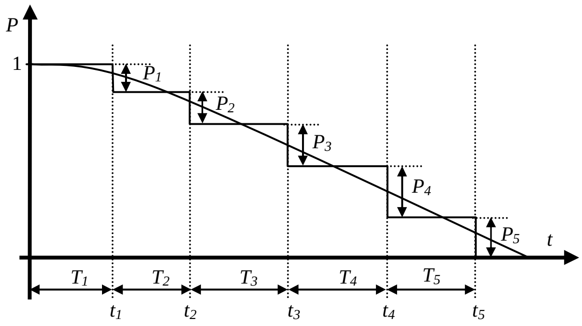


Figure5. Split the probability for stay in condition of intervals service

4. SCENARIOS FOR ADAPTIVE ROUTING

The model from figure 6 allows to calculate the probability for service closing of particular *n* applications arrangement, and to evaluate is it bigger, or not from the admissible.

The model from figure 6 can be transformed under the follow criteria: the application is service in the provided time, or late more than the provided.

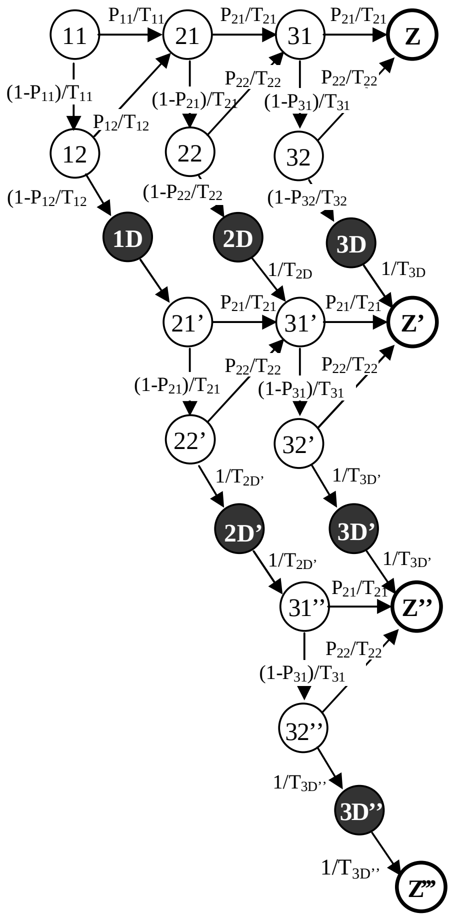


Figure7. Scenarios for the delays

At figure 7 are given scenarios with three applications. The conditions Z, Z', Z'' and Z''' show the closing of the applications sequence without delay, or with one, two or three delays. The condition 11 models the application 1 service. After time T_{11}, with probability P_{11} shall go to the service of the second application – condition 21 or with probability $1-P_{11}$ will begin to serve the same application – condition 12. After time T_{12} with probability P_{12} shall go to service of the second application – condition 21, or with probability $1-P_{12}$ will exceed the provident service time. Than the process will go to condition 1D, corresponded to the first application service delay. From this condition the process can pass only to the scenario for execution of the applications with one delay, as the time for this delay is limited on T_{1D}. In this scenario can be entered and a delay of the second or the third application, respectively trough the 2D and 3D conditions. The scenario with one delay can be executed without more delays, but is possible and the service of applications 2 and 3 to be delayed again – conditions 2D' and 3D' and so on till all probability for delays ended. With the calculation of the probabilities for stay in conditions Z, Z', Z'' and Z''' can be evaluated the most possible time for this consecution of applications closing

5. CONCLUSION

The offered method for use of statistical and probablistic measures at adapting routing has the advantages that it can provide the serving time of the applications separately or in group, and on this basis, to fulfill one or another scenario, depending on the covering of the service quality.

It is possible different scenarios with different delays to be used, which help choose the best sequence for service.

The offered method is applicable in many other spheres, where there are planning and forecasting of the separate activities; operations, applications and others time duration. Similar examples are management of infrastructural projects with different type activities (excavation works, cable placing, installation works etc), producing activities and other. The only difference is in the scale of the time – in the telecommunications it is from the order of ms, the producing operations are from the order of hours, and in the infrastructural projects can be change from days to months

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