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MODEL OF A MULTI-SERVICE NETWORK IN THE CLASS OF QUEUING SYSTEM

Siddikov Isomiddin Kxakimovich
Doctor of technical sciences, professor, Tashkent State Technical University named after Islam Karimov Department of Information Processing and Control Systems

Fayzullayeva Barno Bakxadirovna
Assistant, Tashkent University of Information Technologies named after Muhammad al-Khwarizmi department of Mobile Communication Technologies Tashkent, Uzbekistan,
fayzullayeva86@gmail.com

ANNOTATION

The tasks of managing the information flow of telecommunication networks in real time usually require the use of highly efficient servers that have high performance for meeting modern requirements. Real-time on the complexity and requirements for telecommunications networks are considered as multi-channel networks of mass provision.

Key words: information transfer rates, multi-channel networks

The modern development of infocommunication technologies in various fields of activity, the use of transmission media with high information transfer rates and high reliability indicators, a sharp increase in traffic volumes have led to the introduction of the NGN concept (next generation networks), based on multiservice communication networks (MCN), the core of which is the backbone IP-networks [1, 2]. Multiservice networks are characterized by the presence in them of a large number of nodes that use a variety of services that require a high intensity of traffic exchange along with maintaining the required level of quality of service for each of these services [3]. Modern MCNs usually contain as subsystems wireless data transmission networks (WPAN), which are also entrusted with the general task of exchanging information between interacting nodes. To do this, WPANs must provide data transmission with characteristics that allow meeting the requirements of users served by the MCN, in particular, to provide the potential access to the shared resources of the internetwork in a reasonable time.

Methods and analyzes of multichannel systems with priority are developed quite well, although their numerical implementation in the need to obtain Laplace transforms and/or higher moments posed a number of difficult problems that were solved.

The paper presents a method for nodal analysis of a QS(queuing system) that represents k series-connected nodes of type M/M/m/m, based on the definition of the i-th incoming stream ($1\leq i\leq k$). It is also of interest to find the incoming molasses for each branch when the QS is branching. Such a study gives a complete picture of the functioning of each link. This allows you to find the bottlenecks of the QS and optimize its structure.

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However, the complexity of the analysis of priority service disciplines in the transition to multichannel systems. Such problems are usually solved only in the simplest (exponential) case, and the average service duration was assumed to be different literally in single jobs. The paper proposes formulas for calculating the average waiting time to start servicing information flows for the first two moments for QS type $/\vec{M}_k/\vec{G}_k/\vec{1}/\infty$ in a single-channel system with relative priority:

$$\omega_{j,1} = \frac{\sum_{i=1}^{k} \lambda,\mathrm{b}_{\mathrm{i,2}}}{2(1-R_{j-1})(1-R_j)}, \quad (1)$$

$$\omega_{j,1} = \frac{\sum_{i=1}^{k} \lambda,\mathrm{b}_{\mathrm{i,3}}}{3(1-R_{j-1})(1-R_j)} + \frac{\sum_{i=1}^{k} \lambda,\mathrm{b}_{\mathrm{i,2}} \sum_{i=1}^{j} \lambda,\mathrm{b}_{\mathrm{i,2}}}{2(1-R_{j-1})^2 2(1-R_j)^2} + \frac{\sum_{i=1}^{k} \lambda,\mathrm{b}_{\mathrm{i,2}} \sum_{i=1}^{j-1} \lambda,\mathrm{b}_{\mathrm{i,2}}}{2(1-R_{j-1})^3 2(1-R_j)} \quad , (2)$$

Where $R_j = \sum_{i=1}^{k} \lambda, \mathrm{b}_{\mathrm{i,2}}$ load factor of the system with applications up to -th type,
Expressions 1 and 2 determine the first and second moments of the average waiting time for packets in a QS system of type $/\vec{M}_k/\vec{G}_k/\vec{1}/\infty$ with the relative priorities of the communication system.

With a single-channel sieve for different distribution of information flows, the average packet waiting times for the simulation model and calculations were performed for ten types of requests for various service times and delays. An analysis of the results shows that both discussed approaches have the right to be applied. However, the percentage of error between the simulation model and the calculated parts is small, and this means that the results obtained are adequate and closer to accurate. The proposed technique makes it possible to calculate priority systems with arbitrary and different distributions of the service time for information flows.

As it is known that heterogeneous information flows circulate in the TN with MN, in connection with this, in order to service this type of traffic, it becomes necessary to obtain a mathematical model of the priority TN and MN based on the QS model of the type $/\vec{M}_k/\vec{G}_k/\vec{1}/\infty$ with relative priority on the case of "P" priority with an unreliable service device.

On systems with relative priorities, the active thread runs until it exits the processor by itself, going into wait (or an error occurs).

In systems where scheduling is based on relative priorities, the cost of switching the processor from one job to another is minimized. On the other hand, there may be situations where one task takes the processor for a long time. It is clear that a system of time-sharing and real-time is not suitable for such a service discipline: an interactive sentence can wait for its turn for hours until a computational task needs I/O(input-output). But in batch processing systems, relative priorities are widely used.

In this case, when a packet with a high service priority with lower priorities arrives at the network node, the new packet becomes at the head of the queue of pending packets.

To calculate the probabilistic-temporal characteristics of information flows in the model, the Laplace-Stieltjes transform (LST) is used and the model of the QS queuing system of the type

$/\vec{M}_k/\vec{G}_k/\vec{1}/\infty$ (exponential law of receipt of requests, random law in a queuing system with one server and an infinite queue) with relative priorities for servicing information flows.
Let us introduce restrictions on the laws of distribution of random variables characterizing the processes of servicing requirements, i.e. we will consider the laws of distribution of all random variables (receipt of requirements A(t), service B(t), correct operation with the required quality C(t), recovery after impaired functioning D(t) and untimely service or aging Z(t) with the corresponding intensities μ, c, λ, ν and d) are described in the following expressions:

$$\mathrm{A}(t) = 1 - e^{-\lambda\mathrm{t}};\ \mathrm{B(t)=1}\text{-}e^{-\,\mu\mathrm{t}};\quad \mathrm{C(t)=\ 1}\text{-}e^{-\,\mathrm{ct}};\quad \mathrm{D(t)=1}\text{-}e^{-\,\mathrm{dt}};$$

$$\mathrm{Z(t)=\ 1}\text{-}\ e^{-\,\nu\mathrm{t}},\ (3)$$

Then packets with “P” priorities enter the single-line QS and form a Paussian flow with intensity $\lambda_{\kappa}, k = \overline{1, P}$. The total flow is the Pausson intensity $\sigma = \sum_{\kappa=1}^{\mathrm{p}} \lambda_{\kappa}$ . . In an element of a layered network of type $/\vec{M}_k/\vec{G}_k/\vec{1}/\infty$ there are two main processes:
- waiting process characterized by random time $t_{h\kappa}$ from distribution (DF) $W_{\kappa}(t)$.
- service process characterized by random time $t_{w\kappa}$ with DF $H_{\kappa}(t)$.

According to the power of additivity, the random delivery time of a packet with k-m priorities will be determined as

$$t_{g\kappa} = t_{w\kappa} + t_{h\kappa}, \mathrm{k}=\overline{1, P} \quad , \ (4)$$

And the distribution function (DF) of the time the packet stays in the system is determined as

$$V_{\kappa}(t). = W_{\kappa}(t) * H_{\kappa}(t), \ (5)$$

Where * is a Stiltievsian convolution.
From the image (5) we obtain the average residence time of the k-th priority packet in the transmission link

$$T_{\kappa} = \int_0^{\infty} t \times dV_k(t) \ (6)$$

To find the service time $t_{h\kappa}$ of packets of the k-th priority in the transmission link, we use the transformation (LST) with DF$H_{\kappa}(t)$ time packets of the k-th priority are served at time t .

$$Q_{\kappa}(v) = \int_0^{\infty} e^{-vt} \times dV_k(t) = \omega_k(v) \cdot h_k(v) \ (7)$$

Where v −intensity of information aging $v = \frac{1}{T_z}$, and T_z −average aging time;
-$\omega_k(v)$- LST from$W_{\kappa}(t)$ waiting time starts servicing packets of k-th priority at time t.

$-h_k(v)$ LST from DF $H_\kappa(t)$ waiting time starts servicing packets of k-th priority at time t. Formalizing the transfer process in SSN(Special Purpose Network) using a QS $\vec{M}_k\ \vec{M}_k/\vec{G}_k/\vec{1}/\infty$ with relative priorities, we obtain the expression for the time to wait for the start of servicing packets of the k-th priority:

$$\omega_k(v) = \left\{\frac{1-\sum_{i=1}^{p}\rho_i}{\sigma\varphi_1+e(\sigma)[1-\sigma\varphi_1]}\left[e(\sigma)\left(v+\sigma_{k-1}(1-h_{k-1}(v))\right)+\sigma(1-e(\sigma))\left[1-\varphi\left(v+\sigma_{k-1}(1-h_{k-1}(v))\right)\right]\right]+\sum_{i=k+1}^{p}\lambda_i\left[1-B_i\left(v+\sigma_{k-1}(1-h_{k-1}(v))\right)\right]\right\} / \quad v-\lambda_k B_k\left(v+\sigma_{k-1}(1-h_{k-1}(v))\right), \quad (8)$$

where $h_0(v) = \sigma_0 = 0;\quad \sigma = \sum_{i=1}^{p}\lambda_i;\quad \sigma_{k-1} = \sum_{i=1}^{k-1}\lambda_i;$

In particular, if uptime and recovery time are exponentially distributed random variables with parameters c and d, then

$$\mathrm{e}(\sigma) = \int_0^\infty e^{-\sigma t}\, dE(t) = \int_0^\infty e^{-vt}\, d(1-e^{-ct}) = \frac{c}{\sigma + c};$$

$$\varphi(v) = \int_0^\infty e^{-vt} dD(t) = \int_0^\infty e^{-vt}\, d(1-e^{-dt}) = \frac{c}{v+d}$$

$$\varphi(1) = \int_0^\infty t dD(t) = \int_0^\infty te^{-dt}\, dt = \frac{1}{d},$$

- v –package aging rate;
-*d* channel recovery rate;
-*c* –average service device uptime;

$$h_{k-1}(v) = \left\{\frac{1}{\sigma_{k-1}+1}\sum_{i=1}^{k-1}\lambda_i B_i\left(v+\left(\sigma_{k-1}(v)\right)\right)+c\varphi(v)\right\}, \quad (9)$$

$B_i(v)$- LST DF service time for i-th priority

$$B_i(v) = \int_0^\infty e^{-vt} dB_i(t) \quad , (10)$$

$$B_i(t) = \begin{Bmatrix} 0, & t < t_i \\ I, & t < t_i \end{Bmatrix}, \quad (11)$$

where

$$t_i = \frac{L_i + H_i}{C_M} \quad (12)$$

L_i, H_i- the volume of the information and service parts of the packets of the i-th priority, respectively;
$\mathrm{C_м}$ −modulation rate in a digital communication channel. Differentiating and computing at a point v= 0 we get the first initial moment of waiting time for the start of packet service for the k-th priority with a relative priority.

$$\omega_{1,k} = \Big\{\frac{1-\sum_{i=1}^{p} P_i}{\sigma\varphi_1+e(\sigma)[1-\sigma\varphi_1]}\left[e(\sigma)-\sigma\big(1-(\sigma)\big)\varphi_1\right]\cdot\Big(\sigma_{k-1}h_{2,k-1}-\big(1+\sigma_{k-1}h_{2,k-1}\big)\Big)+$$
$$\sigma(1-(\sigma)\cdot\big(1+\sigma_{k-1}h_{2,k-1}\big)^2\varphi_2+\sum_{i=k+1}^{p}\lambda_i\Big\{\Big[B_{2i}(1+\sigma_{k-1}h_{2,k-1})^2+B_{1k}\sigma_{k-1}h_{2,k-1}\cdot$$
$$\Big(1-\lambda_k B_{1k}\cdot\big(1+\sigma_{k-1}h_{2,k-1}\big)\Big)+B_{1i}\big(1+\sigma_{k-1}h_{2,k-1}\big)\lambda_k B_{2k}\big(1+\sigma_{k-1}h_{2,k-1}\big)^2+\lambda_k B_{1k}\cdot$$
$$\sigma_{k-1}h_{2,k-1}\Big]\Big\}\Big\}/2\cdot(\,1-\lambda_k B_{1k}\cdot\big(1+\sigma_{k-1}h_{2,k-1}\big)\,, \quad (13)$$

where $B_{1k,}B_{2k}, B_{1i}, B_{1i}$ is determined by expression (8), i.e.

$$B_i(v) = \int_0^\infty e^{-v}\, dB_i(t) = \mathrm{e}^{-vt}\ ;$$

$$B_i(v) = t_i e^{-vt}, v = 0 \quad B_{1i} = t_i;$$

$$B_i(v) = t_i^2 e^{-vt}, v = 0 \quad B_{2i} = t_i^2\ \ ;$$

$B_{1k,}B_{2k}$ − is also defined similarly.
φ_2 = the second moment from DF ￼which is equal to :$\varphi_2 = \frac{2}{d^2}$￼ .

LST from DF $H_к(t)$ packet service time of k-th priority (with a fixed packet length) for discipline of relative priority corresponds to the expression 10 i.e.

$$h_{k-1}(v) = \frac{1}{\sigma_{k-1}+c}\{\sum_{i=1}^{k-1}\lambda_i B_i(v+(\sigma_{k-1}+c)\cdot(1-h_{k-1}(v)))+c\varphi(v)\}, \ (14)$$

First and second moments from $h_{k-1}(v)$ determined as:

$$h_{k-1} = \frac{\sum_{i=1}^{k-1}\lambda_i B_i+\frac{c}{d}}{\sigma_{k-1}+c)[1-\sum_{i=1}^{p}\lambda_i B_i]}, \quad (15)$$

$$h_{2,k-1} = \frac{\sum_{i=1}^{k-1}\lambda_i B_{2i}(1+(\sigma_{k-1}+c)h_{1,k-1})^2+\frac{2c}{d^2}}{(\sigma_{k-1}+c)[1-\sum_{i=1}^{p}\lambda_i B_i]},(16)$$

The components of formulas 15 and 16 have been previously defined.
Taking into account 14 and 15 poles, the average delay time for a two-pole TN with MN with relative priorities, modeled by QS type $\vec{M}_k/\vec{G}_k/\vec{1}/\infty$ for an arbitrary number of priorities:

$$T_{\text{к}}. = \omega_{1\text{к}} + h_{1,\text{к}}\,,\ \text{k}=\overline{1, P}\ ,\ (17)$$

Failure and recovery processes through availability $К_{Г}$ recovery intensity «d» b work intensity «c». These quantities are interconnected through the expressions $К_{Г} = \frac{d}{d+c}$.

The paper presents the expressions for the probability of timely delivery in the command and control system for special purpose networks (SSN). The ability of a communication system to perform this task is determined by the message transmission time t_{sm} and the probability of timely transmission of messagesP_{sm} as the probability that the message transmission time will not exceed the allowable $\text{P}(t_{sm} \leq \text{T}_{sm.a})$. Given the above, it seems reasonable to have the probability of timely delivery of packets of k-th priority with relative priorities. Given formula 7, the probability of timely delivery of packets of k-th priority, taking into account the intensity of aging of information packets, is determined by:

$$Q_k(v) = w_k(v) \cdot h_k(v)$$

$$Q_k(v) = \left\{ \frac{\left[\frac{1-\sum_{i=1}^{p} \rho_i}{\sigma\varphi_1 + e(\sigma)[1-\sigma\varphi_1]} [e(\sigma)\cdot(G) + \sigma(1-e(\sigma))(1-\varphi_G)] + \sum_{i=1}^{p} \lambda_i [1 - B_i(G)]) \right]}{v - \lambda_k \quad + \lambda_k B_k(G)} \cdot h_{k-1}(v) \right\} \ (18)$$

Where : $\text{G} = v + \sigma_{k-1}(1 - h_{k-1}(v)) \quad if \quad \sum_{i=1}^{p} \rho_i \leq 1$

Thus, the developed mathematical model of priority service in the TN and MN link with a relative in the system $\vec{M}_k/\vec{G}_k/\vec{1}/$ allows you to choose the most appropriate strategy for servicing incoming packets. Determining the optimal service strategy in the link for transmitting packets to the TN and MN is necessary for a complete analysis of the probabilistic-temporal characteristics of networks, as well as for the design and study of TN and MN.

Conclusion

The article proposes an approach to the development of a traffic model that allows taking into account the characteristics of the traffic of wireless data networks in modern multiservice communication networks, while implementing the requirement for the degree of adequacy of real traffic. At the same time, the minimum cost of the network resource of the switching equipment to take into account the handover event for short-term prediction of traffic behavior is achieved by implementing a two-dimensional interpolation model.

Discussion

Further research on the development of mathematical models for priority servicing of heterogeneous information flows should be continued in the following areas:

- for the priority of queuing systems of increased complexity, for example, with a probable pushing mechanism;

- multi-channel queuing systems of increased complexity, for example, with a limited stay of applications;
- non-stationary queuing systems with a finite source of requests and phase-type distributions;
- open and closed non-Markov models of queuing networks.

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