Journal of Siberian Federal University. Mathematics & Physics 2018, 11(5), 581–587

УДК 517.9

The Problems and Peculiarities of Modelling Integrated Systems of Heterogeneous Traffic Services

Oleg Ja. Kravets*
Sustainable Developments in Civil Engineering Research Group
Faculty of Civil Engineering
Ton Duc Thang University
19 Nguyen Huu Tho, District 7, 700 000, Ho Chi Minh City
Vietnam

Oleg N. Choporov†
Chair of Information Security Systems
Voronezh State Technical University
14, Moskovskiy Prospekt, Voronezh, 394026
Russia

Received 08.12.2017, received in revised form 10.12.2017, accepted 20.06.2018

The article considers some problems and peculiarities of the modelling and rational design of heterogeneous traffic servicing integrated systems. The aim of the article is to undertake a comparative analysis of existing technologies in modelling distributed systems with a heterogeneous medium as part of a subsystem of managing the modelling and upgrading of the systems in question. The research subject is a system consisting of air and cable multiple-access systems.

The authors have used the methodology of conceptual and mathematical modelling within the queuing systems theory. The article presents a model of heterogeneous subsystem representation, assigns the optimal task for choosing the multicriteria of a system building variants, and proposes integrated protocols for the functioning of the system as well as a mathematical model based on z-transferring of delivery time and the service interval distribution series.

The obtained results can be used for the reconfiguration of both static and dynamic heterogeneous (according to the transmission medium) information systems.

Keywords: heterogeneous medium, communication system, mathematical model, optimal design.
DOI: 10.17516/1997-1397-2018-11-5-581-587.

Introduction

At the current stage of social development, there is a move towards an information society implying new forms of social and economic activities based on the converging use of information and telecommunication technologies. The technological base of this emerging society is a common infrastructure providing possibilities of access to information resources and their management.

Prospects for the development of integrated information systems require their transformation into a common information and telecommunication system on the basis of distributed corporate information management systems, thus providing a wide range of inclusive services. The integral heterogeneous corporation subsystems use different technologies of traffic maintenance and consequently, it is necessary to solve the problem of their compatibility [1, 2].

*olegkravets@tdt.edu.vn
†choporov oleg@mail.ru

It is evident that the integrated system aimed at implementing the cooperation of different technologies should be based on open standards [3]. Despite the virtual non-existence of mathematical models for integrated systems, the related international standards are being developed within a seven-tier Open System Interconnection (OSI) Reference Model, proposed by the International Standard Organization (ISO). This study examines the architecture of the systems built in accordance with the OSI concept.

Integrated information management systems largely represent the further development of aggregated information and digital telecommunication systems. Nevertheless, the challenge of their creation is of particular relevance as can be seen by the recent popularity of such systems as a research object in terms of mathematical modelling. It is important to note the lack of formal modelling and development technique based on implementing existing theoretical and practical outcomes [4]. Thus, hardware and service integration will provide users with several advantages of the integrated information-and-management system, such as service integration, transmission media, and, eventually, consolidation with some other technologies.

The reader is offered an initial integrated article, part of a planned series on the subject, which will contain a synthesis of the obtained results.

1. Elements of the comparative analysis of existing technologies

The development of these distributed integrated corporate information management systems is a challenge not only in terms of their continuous improvement and modernization, but also in terms of such an important and necessary trend as moving from actual systems to solving common issues relating to their research. The latter relates to methods of mathematical and simulation modelling enabling the processes of exchange and processing of various types of information to be coordinated between the equipment of integrated systems.

In implementing the concept of information management systems with service integration, one can emphasize the tasks of developing a structure and algorithms for studying such system characteristics. This determines, to a large extent, the degree to which the system fits its purpose.

To effectively solve the tasks, it is necessary to develop theoretical bases for formalizing the processes in heterogeneous information management systems, create machine-oriented mathematical models for their identification, conduct analysis and synthesis of information processing and management systems, and implement the architecture of such systems.

The urgency of building corporate information management systems combining transmission media, as well as protocols and traffic types, and including information and communication components, are substantiated.

The research object is a system consisting of air and cable multiple-access subsystems connected through an interface [5]. The coverage of the air subsystem is determined by the area of a circle of radius R. The cable subsystem link length is determined by the value L (Fig. 1).

2. Modelling a corporate information management system

The system structure is represented in a general way by the vector $\overline{W} = [\overline{Y}, \overline{X}, \overline{E}, \overline{A}]$, where the subvector $\overline{Y}$ shows the topological structure type, $\overline{X}$ displays the Control Protocol type, $\overline{E}$ represents the terminal device type, and $\overline{A}$ shows the type of administrative control system. The

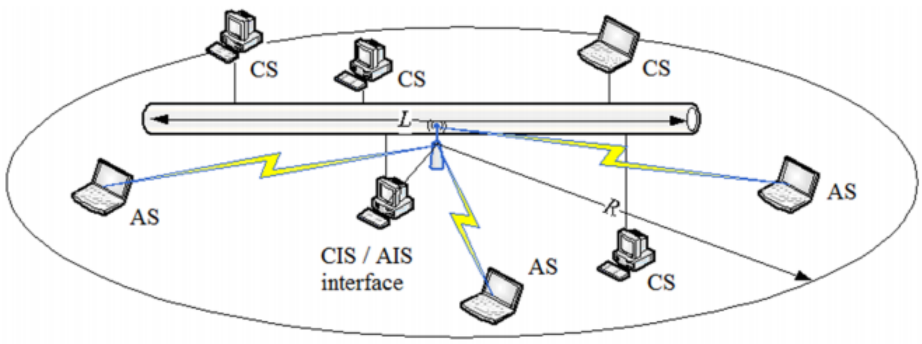

Fig. 1. Integrated information management system: CS — Cable Station; AS — Air Station; CIS — Cable Interface System; AIS — Air Interface System

modified structure $\overline{W}^*$, considered under work, is represented by a set of structures of integral subsystems $\overline{W}^* = [\overline{W}_1, \overline{W}_2, \ldots, \overline{W}_j, \ldots, \overline{W}_J]$, $j = \overline{1, J}$ [6] (Fig. 2).

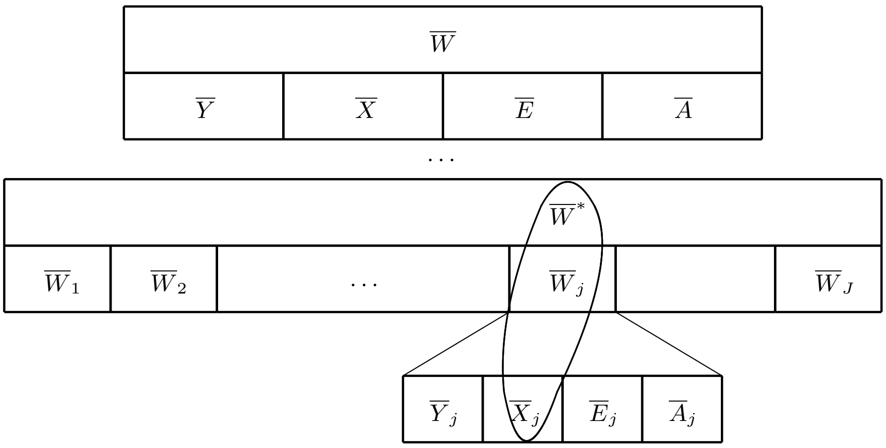

Fig. 2. Model representing the structure of heterogeneous systems

Improvements in the modelling and modernization process management of the systems are dictated by the need to narrow the set of admissible solutions in order to increase the effectiveness of the outlined processes and to reduce economic costs [7]. Therefore, it is necessary to solve a decision-making optimization problem. The statement of the optimization multicriteria choice problem has the form

$$C(\overline{W}^*) = \arg\min \bar{t}_{q_j}(w), \quad w \in \overline{W}^*, \tag{1}$$

$$C(\overline{W}^*) = \arg\max \overline{\Pi}_{q_j}(w), \; w \in \overline{W}^*, \tag{2}$$

$$C(\overline{W}^*) = \arg\min \overline{K}(w), \quad w \in \overline{W}^* \tag{3}$$

under the constraints

$$\bar{t}_{q_j} \leqslant \bar{t}_{q_j adm}, \; j = \overline{1, J}, \quad \overline{\Pi}_{q_j} \geqslant \overline{\Pi}_{q_j adm}, \; j = \overline{1, J}, \tag{4}$$

where $\bar{t}_{q_j}$ is the average time to deliver j-type messages, $\bar{t}_{q_j adm}$ is an acceptable value for the average time to deliver j-type messages, $\overline{\Pi}_{q_j}$ is the probability of j-type messages being delivered on time, $\overline{\Pi}_{q_j adm}$ is an acceptable value for the probability of j-type messages being delivered on time, and K is the initial cost criterion. The choice function $(\overline{W}^*)$ represents the preferred elements of the set $\overline{W}^*$.

The effectiveness of the discrete message processing is assessed in terms of the average time for messages to be delivered or by the probability of them being delivered on time.

$$\overline{\Pi}_{q_j} = F(\rho, \bar{t}_{q_j adm}, \mu, k_g, T_p), \quad (5)$$

$$\bar{t}_{q_j} = \varphi(\rho, \mu, k_g, T_p), \quad (6)$$

where ρ is the intensity of incoming loads

$$\rho = x + y, \quad (7)$$

y is the intensity of the services load, x is the intensity of the lost load; μ is the intensity of message processing; k_g and T_p are the parameters characterizing the system reliability: the channel availability coefficient and system recovery time, respectively.

The terms of on-time message delivery are: $\bar{t}_{q_j} \leqslant \bar{t}_{q_j adm}$. In the simulated integral system, time constraints have the following ranges: for interactive real-time data $0,1\ m/s \leqslant \bar{t}_{q \cdot adm} \leqslant$ $\leqslant 10\ m/s$ for voice isochronous traffic according to ITU-T G.114 $\bar{t}_{q \cdot adm \cdot voice} \leqslant 50\ m/s$.

The relevant integral protocols for the functioning of the system are cyclograms re-flecting changes in states at discrete instants of time. Fig. 3 shows cyclograms of the state changes of the simulated integrated traffic servicing subsystem. The agreed notation is as follows: ordinal numbers and indices 'a' and 'b' indicate the state transition sequence; the indices 'p' and 'd' denote the traffic type. For the air transmission system: 1d, 1p – right for transmission; $2_a d$, $2_a p$ – information packet transmission; $2_b p$, $2_b d$, 3p, 4d – disengage confirm; 3d – response. For the cable subsystem: $1_a d$, $1_a d$ – information packet transmission; $1_b d$, $1_b p$, 2p, 3d – right for transmission; 2d – response.

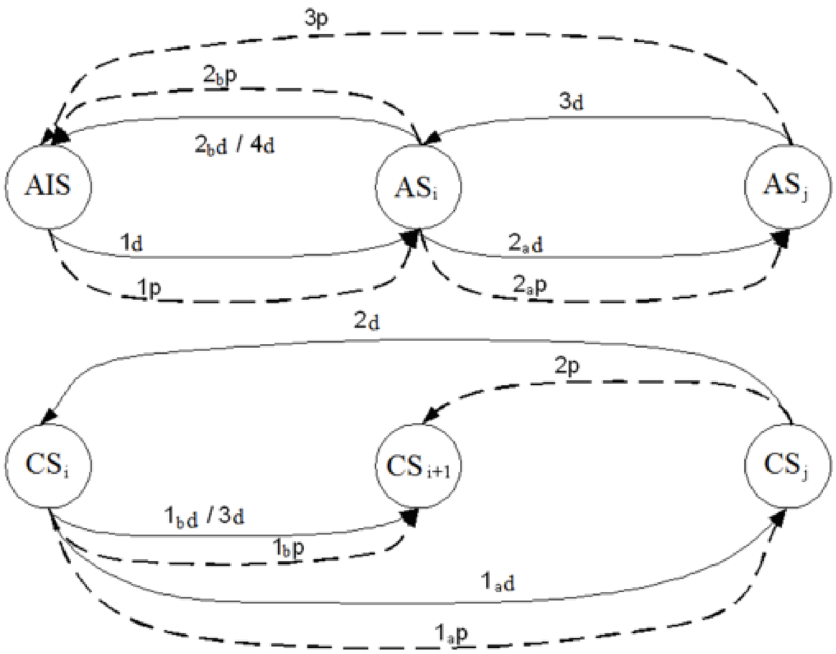

Fig. 3. Generalized cyclograms of the simulated system states

Information and telecommunication subscriber systems are structured according to the ISO Model architecture and are simulated by means of multiphase stochastic systems. The protocol functions of each level are displayed by means of a single-phase stochastic system within discrete time [8]. The article uses the approach considering the CAT operation as a probabilistic process directly linked with an input flow that gives an opportunity to examine some significant transient modes.

The mathematical model is given by *z*-transformations of the delivery time distribution series $f_q(z)$ and the servicing interval $g(z)$. The distribution series of a delivery time interval $f_q(n_q)$ is determined by means of the inversion formula based on the inverse *Z*-transformation.

$$f_q(n_q) = \frac{1}{2\pi j} \oint_{|z|=1} f_q(z) z^{n_q - 1} dz, \tag{8}$$

or, from the expression:

$$\overline{n}_q = \left(d/dz^{-1}\right) f_q(z)\big|_{z=1}, \tag{9}$$

where $\overline{n}_q$ is the discrete interval of the message processing, and $f_q(z)$ is determined by the expressions (10) and (11). According to CAT Kendall's classification [9] the subsystems are designated as $M^d/G^d/1$, i.e. the subsystem model is represented as a general view stochastic service system within discrete time.

z-transformation of a discrete interval $\overline{n}_q$ for a non-priority service procedure FIFO has the form

$$f_q(z) = \frac{(1-\Theta)(1-z)g(z)}{1 - p_r z - q_r z g(z)}, \tag{10}$$

where Θ is the busy state buffer probability

$$\Theta = q_r \overline{n}_s;\ \Theta < 1;\ \overline{n}_s = \left(d/dz^{-1} g(z)\right|_{z=1}, \tag{11}$$

$g(z)$ is *z*-transformation of a servicing interval distribution series, $p_r = 1 - q_r$, q_r is the probability of an on-time step request.

The system determined by the expression (10) has a *z*-transformation of a servicing interval distribution range

$$g(z) = g_a\left(g_s^{-1}(z)\right), \tag{12}$$

where the $g_a(z)$ and $g_s(z)$ parameters set the error control protocol and access protocol, respectively.

Discrete delivery time is made up of the average delivery time and the average latency

$$f'_q(1) = g'_q(1) + \frac{q_r g''(1)}{2(1-\Theta)}, \tag{13}$$

where $g''(1) = \left(d^2/dz^{-2}\right) g(z)\big|_{z=1}$

The average delivery time in continuous time is determined as

$$\overline{t}_q = V_c^{-1} \cdot \overline{n}_q, \tag{14}$$

where V_c is channel transmission rate, and $\overline{n}_q$ is solved from the expression (9).

Analytical expressions for a specific configuration of the system with the cyclogram in Fig. 3 are not available due to significant nonlinearities. As a result, algorithms for determining the average delivery time are developed. The obtained expressions will provide a transition to determining $\overline{t}_q$ in subsystems taking into account heterogeneity and the given integral services. Fig. 4 shows the algorithm for determining $\overline{t}_q$ taking into account the peculiarities of the system being researched.

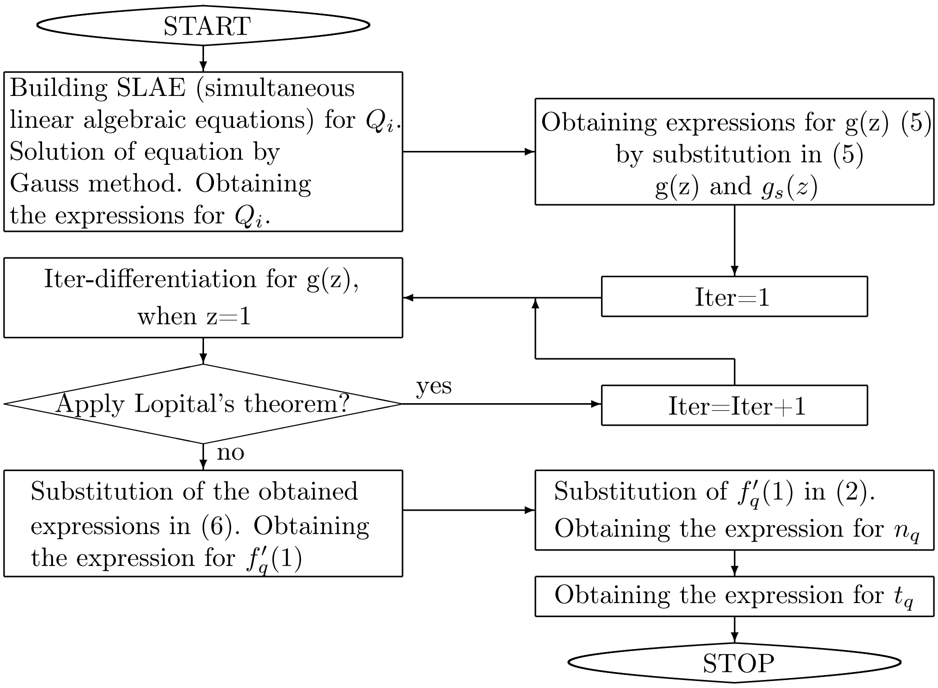

Fig. 4. Algorithm for determining the average delivery time

Conclusions

The authors have used the methodology of conceptual and mathematical modelling within the queuing systems theory. The article presents a model of heterogeneous subsystem representation, assigns the optimal task for choosing the multicriteria of a system building variants, and proposes integrated protocols for the functioning of the system as well as a mathematical model based on z-transferring of delivery time and service interval distribution series.

Functions of each level protocols are represented as a single-phase stochastic system within discrete time. Definition algorithms expressing the average times for messages to be delivered are developed.

The obtained results can be used both for static and dynamic heterogeneous (according to the transmission medium) information system reconfiguration.

References

[1] Z.Qian, J.Li, X.Li, M.Zhang, H.Wang, Modeling heterogeneous traffic flow: A pragmatic approach, *Transportation Research Part B: Methodological*, **99**(2017), 183–204.

[2] Ch.Mallikarjuna, K.Ramachandra Rao, Heterogeneous traffic flow modelling: a complete methodology, *Transportmetrica*, **7**(2011), no. 5, 321–345.

[3] The OSI Model's Seven Layers Defined and Functions Explained. https://support.microsoft.com/en-us/help/103884/the-osi-model-s-seven-layers-defined-and-functions-explained.

[4] C.Kalloniatis, Innovative Information Systems Modelling Techniques, InTech, ISBN 978-953-51-0644-9.

[5] Q.Han, J.Li, A semantic integration mode for heterogeneous system, *IEEE Computer Design and Applications (ICCDA)*, 2010, DOI: 10.1109/ICCDA.2010.5541213.

[6] A.E.Govorskii, O.Ja.Kravets, Mathematical Modeling of Inhomogeneous Traffic in a Heterogeneous Integrated Corporate Data Control Systems, *Automation and Remote Control*, **73**(2012), no. 7, 1269–1278.

[7] K.Hyseni, N.Frasheri, Low Cost SOA Based Platform Independent Back-End Data Acquisition System, *International Journal on Information Technologies and Security*, **8**(2016), no. 3, ISSN 1313-8251, 53–64.

[8] Sh.I.Aihara, M.Ishikawa, Y.Sunahara, On the optimal control for stochastic one phase Stefan problem, Decision and Control, 25th IEEE Conference, 1986, DOI: 10.1109/CDC.1986.267329.

[9] B.Filipowicz, J.Kwiecien, Queueing systems and networks. Models and applications, *Bulletin of the Polish Academy of Sciences. Technical Sciences.* **56**(2008), no. 4, 379–390.

Проблемы и особенности моделирования интегральных систем обслуживания неоднородного трафика

Олег Я. Кравец
Факультет гражданского строительства
Университет Тон Дук Тханг
19 Нгуен Хуу Тхо, район 7, 700 000, Хошимин
Вьетнам
Олег Н. Чопоров
Воронежский государственный технический университет
Московский проспект, 14, Воронеж, 394026
Россия

Рассмотрены проблемы и особенности моделирования и рационального проектирования интегральных систем обслуживания неоднородного трафика. Цель работы — провести сравнительный анализ существующих технологий моделирования распределенных систем с неоднородной средой в составе подсистемы управления процессами моделирования и модернизации рассматриваемых систем. Объектом исследования является система, состоящая из эфирной и кабельной подсистем множественного доступа.

Использована методология концептуального и математического моделирования в рамках теории систем массового обслуживания. Даны: модель представления структуры неоднородных подсистем; постановка оптимизационной задачи многокритериального выбора вариантов построения системы; интегральные протоколы функционирования системы; математическая модель на основе z-преобразований ряда распределения времени доставки и интервала обслуживания.

Результаты применимы как для статической, так и для динамической реконфигурации гетерогенных (по передающей среде) информационных систем.

Ключевые слова: неоднородная среда, коммуникационная система, математическая модель, оптимальное проектирование.