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THE DELAY ANALYSIS IN DISSIPATED RAILWAY MANAGEMENT AND CONTROL SYSTEMS

The paper deals with estimation of safety measures for complex multicomputer systems applied to railway management and control. In such systems the safety criteria must respect the real transmission process with delays and queues. The proposed boundary probabilities correspond to railway systems implemented now in EU with respect to ERTMS.

ANALIZA OPÓŹNIEŃ W ROZPROSZONYCH SYSTEMACH ZARZĄDZANIA I STEROWANIA RUCHEM KOLEJOWYM

Praca dotyczy wyznaczenia miar bezpieczeństwa w złożonych wielokomputerowych systemach zarządzania i sterowania ruchem kolejowym. W systemach tych kryteria bezpieczeństwa powinny uwzględniać faktyczny proces transmisji z kolejkami i opóźnieniami. Zaproponowane graniczne prawdopodobieństwa zostały odniesione do systemów wdrażanych obecnie w UE w ramach projektu ERTMS.

1. INTRODUCTION

The previous works [1], [2] show that problem of delays and queues has a great influence to system safety and disposability. (It is obvious, because the fail-safe action after detection of fault must be done as soon as possible.) The models of real systems are sophisticated, for Monte Carlo simulation the Markov process and Petri net are applied.

The main aim of this paper is the estimation of delays and probability of waiting for messages in general multi-state models.

The new systems, introduced to EU railways from last ten years are typical dissipated controllers connected via cable or radio network. The typical examples in Polish railways are:

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> ➤ central interlocking (ESTW) co-operating with local controllers (local crossing, small station)
> ➤ disputcher monitoring (WSKR) coupling many station computers
> ➤ remote control (METRO) corresponding to protection of safety movement of many trains in the underground lines
> ➤ management of trains in given area (ERTMS / ETCS) using mobile communication GSM-R.

In each from above system the situation when some messages are waiting for processing by one of coupled computers may appear. Because the safety measure is related to probability of fail safe state and time of reaction after failure the analysis of such transient state are necessary.

2. DELAYS IN THE SAFETY SYSTEM

For evaluation purpose the well-known Markov model of safety system [3] has been adapted. Corresponding to Fig.1a, we can add the transitions from state 1 (correct work) and 2 (fail-safe work). Now the transition for state of catastrophic failure 3 is omitted (corresponding to fail-safe reaction of existing railway control systems where computers switch-off), but in furture the link to state 1' corresponding to waiting for message processing may be included. From safety analysis this model may be transformed to scheme from Fig.1b because λ' (messsage transfer rate) is significant grater than λ (failure rate) and message processing rate μ' is greater than μ. Because the probability of correst work is significant grater than probability of fail-safe work:

$$P_1(t) >> P_3(t)$$

(1)

we can assume:

$$\frac{dP_{1'}(t)}{dt} = -\mu' P_{1'}(t) + \lambda' P_1(t)$$

(2)

detailed analysis gives following estimation:

$$P_1(t)\big|_{t \to \infty} = \frac{\mu'}{\lambda' + \mu'} P_{13\infty}$$

(3)

$$P_{1'}(t)\big|_{t \to \infty} = \frac{\lambda'}{\lambda' + \mu'} P_{13\infty}$$

(4)

when $P_{13\infty}$ is a probability of controlled working state 1 and 3 (near 1, $P_{13\infty} \approx 1$)

$$P_{13\infty} = 1 - P_2(t)\big|_{t\to\infty} = 1 - \frac{\mu_s\lambda(1 - P_{FS})}{\mu_s\mu_d + \lambda[\mu_s + \mu_d(1 - P_{FS})]}$$

(5)

The probability of occurrence in the state of waiting in 1_k state (k messages waiting for processing) may be estimated as:

$$P_k = P_k(t)\big|_{t\to\infty} = P_{13\infty}\left(1 - \frac{\lambda'}{\mu'}\right)\cdot\left(\frac{\lambda'}{\mu'}\right)^k \approx \left(1 - \frac{\lambda'}{\mu'}\right)\cdot\left(\frac{\lambda'}{\mu'}\right)^k\bigg|_{P_{13\infty}\approx 1}$$
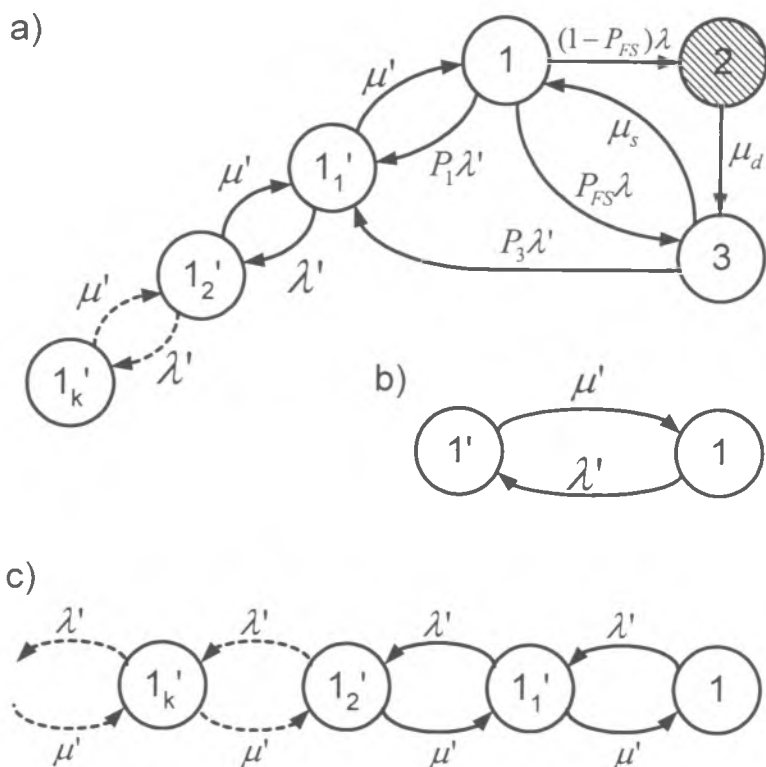
(6)

Fig.1. The models of safety system with delay

3. SAFETY COMPUTER SYSTEMS MODELLING

In an analysis of a safety system using graph method, we have a model composed of several states. We can find the solution of such graph using analytical approach. The problem appears when the model has a lot of states, sometimes even hundreds and more. In such situation the best solution is using a computer simulation. Monte Carlo methods proved especially useful for conducting such simulations. The typical simulation consists of [8]:
- ➢ implementation of so called random walk, i.e. generation of a large quantity of system histories (series of state systems state transitions)
- ➢ calculation of interesting system function along each of the generated histories, i.e. calculation of the estimating function value
- ➢ averaging along all the histories, i.e. calculation of the estimator for the interesting system indicator

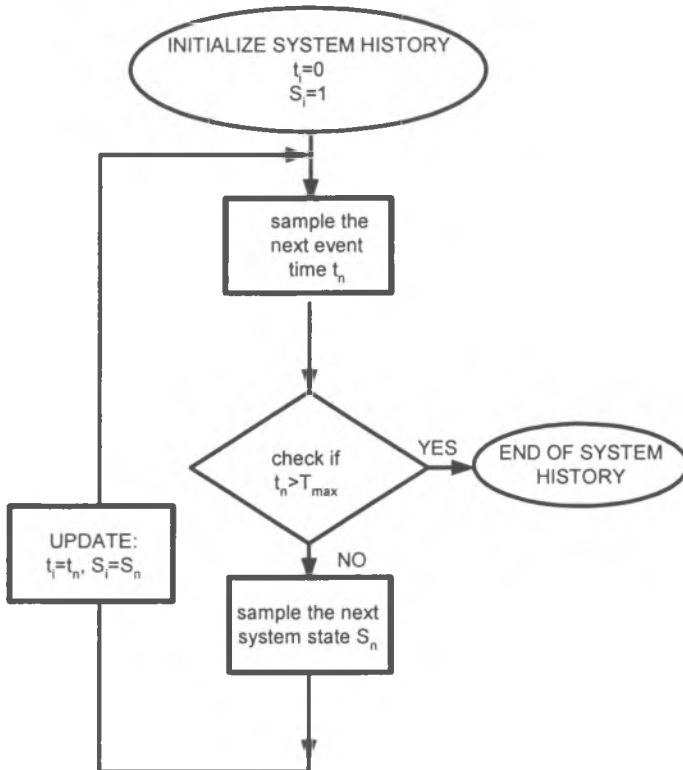The simulation algorithm is presented on the Fig.2.

Fig.2. Algorithm of program

The real railway systems are modelled corresponding to characteristics of applied computer systems including software. For example, Fig.3 shows the Markov models of two systems:

> ➤ triple system (without repair) connected with ESTW (Fig.3a)
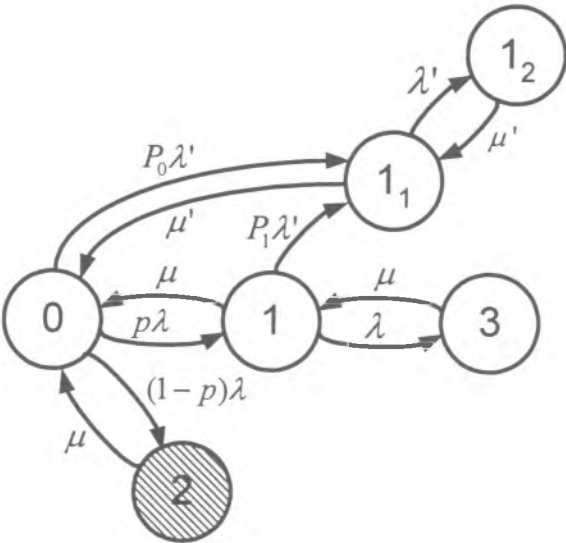> ➤ duplex system (with repair) connected with WSKR. (Fig.3b)

a)
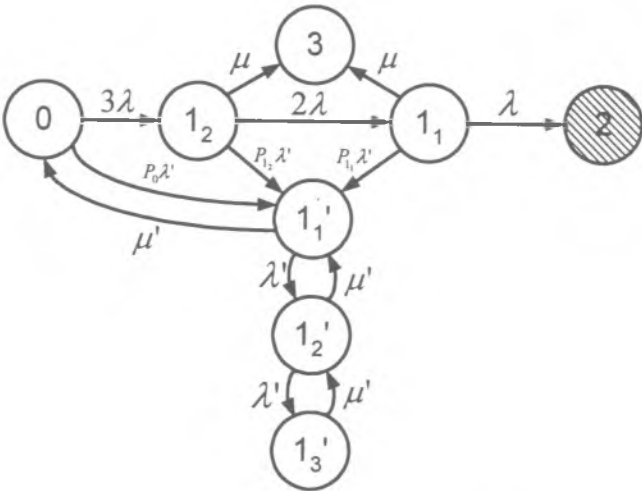
b)

Fig.3. The models of railway systems for Monte Carlo simulation, a) ESTW, b) WSKR

4. CONCLUSIONS

The estimation of probatility related to occurrence in given state is rather difficult by analythic way. The simulation method (especially Monte Carlo) is one of useful tool in this case. These models may be extended to Petri net including multi processing and synchronisation (generating the natural delays).

BIBLIOGRAPHY

[1] LEWIŃSKI A., PERZYŃSKI T., „The modelling of computer networks for railway control and management", IV Konferencja Naukowa Telematyka Systemów Transportowych Katowice – Ustroń, TST 2004.
[2] LEWIŃSKI A. I, PERZYŃSKI T., „Analiza parametrów sieci komputerowych w bezpiecznych systemach transportu kolejowego", Konferencja Naukowa TRANSCOMP 2004, Prace Naukowe TRANSPORT 1(15) 2004, Wydawnictwo Politechniki Radomskiej.
[3] LEWIŃSKI A., „Problemy oprogramowania bezpiecznych systemów komputerowych w zastosowaniach transportu kolejowego", Seria Monografie Nr 49, Wydawnictwo Politechniki Radomskiej, Radom, 2001.
[4] LEWIŃSKI A., SOKOŁOWKSA L.: „The simulation of computer networks for railway control and management ", IV Konferencja Naukowa Telematyka Systemów Transportowych, Katowice–Ustroń, TST 2004.
[5] LEWIŃSKI A., SOKOŁOWSKA T., „Symulacja sieci komputerowych w systemach sterowania i zarządzania ruchem kolejowym", Telekomunikacja i Sterowanie Ruchem, 4/2004.
[6] TANENBAUM A.S. „Computer Networks", Prentice Hall PTR, New Jersey 1996.
[7] JAŹWIŃSKI J., WAŻYŃSKA-FIOK K.: „Bezpieczeństwo systemów", PWN, Warszawa 1993r.
[8] DUBI A.: „Monte Carlo application in system engineering", John Wiley & Sons, 2000r.

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