ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2012. No. 6(122)
ELEKTRONIKA IR ELEKTROTECHNIKA

T 180 TELECOMMUNICATIONS ENGINEERING
TELEKOMUNIKACIJŲ INŽINERIJA

Router Resource Management Research

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crossref http://dx.doi.org/10.5755/j01.eee.122.6.1825

Introduction

In modern competitive conditions the telecommunications technologies and systems are constantly under improvement to ensure a better quality of service (QoS) as is required by the total aggregate services (multiservice) as well as increasing requirements of the users. Due to that efficient performance of the network nodes is extremely important for service providers. It is possible to describe the following tasks: the management of the optimal communication channels, their bandwidth capacity, protocols' selection, the router's memory, and the processes management. The traffic management methods in the information technology (IT) are based on the conventional procedures, such as: *Traffic Shaping*, *CB Policing*, *GCRA* and similar [1]. Queuing control mechanisms (*WFQ, CBWFQ*, *WRR*) are used in the flow packets for the equivalent resource allocation algorithms, e.g. max-min fair-share allocation, *GPS*, and others. The routing protocols *RIP*, *OSPF*, *IS-IS*, *BGP* in the IT equipment use minimum path determination methods [2]. These methods do not assess real time flow dynamics and this leads to routing flow anomalies in the transit and marginal IT nodes. It can be avoided installing the priority flows recalculation in the IT nodes in the real-time by assessing the state of the current IT node (e.g. the occupation of the input/output packet buffers, service packet duration, and the processor computing capability). The random Markov processes are usually used to describe the IT node resources dynamic properties. This solution requires substantial computing resources with complex technical implementations. It is known that the key resources for the IT nodes are the input / output packets' buffer capacity and computing resources. They can be generally evaluated as the resource value depending on their use coefficients. Therefore, the effective models can be applied for the IT resource management component analysis, i.e. evaluating resource value, which is variable, depending on the supply and the demand at current time [3]. The objective of this work is to investigate application of stability conditions in the routers taking into account the variable delay time.

The description of IT network node functional scheme

The next generation (NGN) IT networks provide various multiservice, e.g. *Triple Play*, which is controlled by the routers. The resources of the IT node are limited and depend on the technical realization characteristics. Providing services the node's functioning becomes unstable, when the resource use coefficient approaches to the maximum value. It is possible to predict this because the lack of used algorithm resource properties in the IT networks becomes close to the critical value. For this purpose the IT network node simplified functional scheme is shown in Fig. 1. Routing algorithms are installed in the IT network node *R*. They use the receivable information about the status condition of the input / output buffers and the connection ports, which are characterized by the following parameters: relative channel spacing *L*, transfer rates V_c, and the delay time τ. It is known that the average servicing time of the flow queues in the systems (e.g. *M/G/1*) is expressed by the *Littl* equation [4]

$$\bar{\tau}_q = \frac{\bar{q}}{\lambda} = \bar{t}_s[1 + p\frac{1+C_s^2}{2(1-p)}], \tag{1}$$

where $\bar{t}_s$ is the mean time of the datagram's service in the system, λ is the flow intensity, p is the busyness of the system , C_s^2 is the variation coefficient of the delay.

Let assume that the service flows *Str* entering IT *R* nodes are random and independent, and the resources of the nodes R_s are constantly changing due to the serving flow intensity at the given time. Let the IT resources of a node are expressed as follows: $R_s = \xi(T_{buf} + T_{proc})$, where T_{buf} is the input / output buffer capacity, T_{proc} is the time required for the performance of the calculation process. The quantity of resources has to meet the condition $R_s \in [0, R_{s\max}]$.

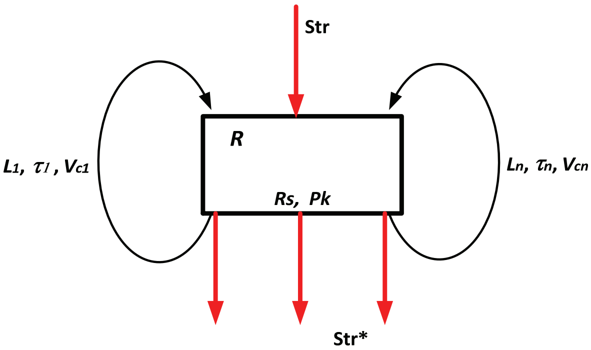


Fig. 1. The simplified functional scheme of IT network node

The demand of the IT node resources $P_k(t)$ necessary for the service of the random *Str* is constantly changing. The quantity of the node free resources $R_s(t)$ will decline with the increasing demand for resources $P_k(t)$, i.e. it can be said that the value of resources $P_r(t)$ will change. The value of the IT node resources $P_r(t)$ is an important parameter and it is possible to manage effectively the IT equipment's resources $R_s(t)$ in order to avoid the reaching of the critical limit of free available resources $R_{s\max}$. Based on the above presented assumptions that these IT node *R* resource demand is $P_k(t)$, supply is $R_s(t)$, and the resources value is $P_r(t)$ and given that the IT node R will receive information about the resource states with the relevant delays τ_1, τ_n, it is possible to use the L. Walras dynamic model when $\tau_1 = \tau_n$ [3].

Then the value of IT network node resources, using this model, can be expressed as a functional dependence on the supply and demand

$$\frac{dP_r(t)}{dt} = \gamma(P_k(P_r(t)) - R_s(P_r(t-\tau)), \quad (2)$$

where $P_r(t)$ is the value of the resources at the moment t, $P_k(P_r(t))$ is the demand of the resources, $R_s(P_k(t-\tau))$ is the supply of the resources. Let us accept the condition that $P_k(P_r(t))$ depends on t and $R_s(P_k(t-\tau))$ depends on the $P_k(t)$ prior period, which is delayed by the value τ ($t-\tau$). If the resource supply and demand varies linearly, the equilibrium system point is found by the condition

$$P_k(P^*) = R_s(P^*) = PR. \quad (3)$$

However, those relations are valid in the following conditions:

$$P_k(P_r) = PR - \alpha(P_k - P^*), \quad (4)$$

$$R_s(P_r) = PR - \beta(P_r - P^*), \quad (5)$$

where $\alpha > 0$, $\beta > 0$ are the slope coefficients of the curves. The values of the resources supply are chosen in the interval $P_{\min} \le P \le P_{\max}$ in the real IT equipment.

The equation (2), taking into account (4) and (5), can be expressed by a linear differential equation with the variable delay time τ depending on the speed of the channel reversible bandwidth and the management information collection intervals. The supply and demand of the resources can be expressed in relative terms

$$\frac{1}{P_k(t)}\frac{dP_k(t)}{dt} = -\gamma(\alpha(P_k(t) - P^*) + \beta(P_k(t-\tau) - P^*))/P^*. \quad (6)$$

It is necessary to define the initial conditions in order to find the solutions of the differential equations with the variable argument in this case initial conditions are defined as $P_k(t_0) = P_{k0}$ and the initial function is $P_k(t) = P_{kprad}(t)$. The analysis is performed in the interval $[t_0 - \tau, t_0]$. Let be assumed that the IT node is in equilibrium state, when the resources were distributed in interval t_0. Node status can change abruptly after moment t_0, i.e. $P^* \ne P_{k0}$. Then the initial conditions can be expressed as follows

$$P_k(t_0) = P_{k0}, \quad P_k(t) = P^*, \quad t \in [t_0 - \tau, t_0]. \quad (7)$$

The operation of the IT node in the range $t \in [t_0 - \tau, t_0]$ evaluating the initial conditions when dimension $\tau > t_0$ will be analysed. The management's information access the node with the constant delay time τ is constant, i.e., when the *Str* is uniform then the solution of the equation (6) can be obtained using known integration by steps method [3]. The best solution is to use a generalized method of Eilers if the delay time τ is variable [5– 7].

The description of the IT network node with variable delay

Let's consider the distribution of the IT node resources, which is described by equation (5), where $\tau = \tau(t)$. For this purpose, the time interval T is divided into the small time intervals n, i.e. $h = (T - t_0)/n$. The following condition must be satisfied

$$t_0 < t_1 < t_2 .... < t_n = T, \text{ when } t_j = t_0 = jh, \ j = \overline{1,n}. \quad (8)$$

According to the initial conditions (6), after the integration of equation (7) in the interval $[t_0, t]$, it is obtained

$$P_k(t) = P_{k0} + \int_{t_0}^{t} f(P_k(t), P_k(t - \tau(t)))dt. \quad (9)$$

Taking into account that $t_0 = t_i$ and $t = t_{i+1}$ it is obtained

$$P_k(t_{r+1}) = P_k(t_i) + \int_{t_i}^{t_{i+1}} f(P_k(t), P_k(t - \tau(t)))dt. \quad (10)$$

It is assumed that $f(P_k(t), P_k(t-\tau(t)))dt$ is a continuous function for the arguments when the trapezoid integration method (9) is used. (10) is expressed as follows, when t is small enough and if to take into account that $P_{k(i)} = P_k(t_i)$, $\tau_i = \tau(t_i)$, and initial conditions, (10) can be expressed as follows

$$P_{k(i+1)} = P_{k(i)} + \frac{h}{2}(f(P_{k(i)}, P_k(t_i - \tau_i)) + \\ + f(P_{k(i+1)}, P_k(t_{i+1} - \tau(t_{i+1}))). \qquad (11)$$

This is acceptable when the initial conditions P_{k0} at time t_0 and P^* at the time $t_i - \tau_i < t_0$ and $t_{i+1} - \tau_{i+1} < t_0$ are met. The equation (9) satisfies the Eiler's generalized equation when the value τ_i is variable. It is possible to use a simple iteration method for the each fixed i in respect of $P_{k(i+1)}$ in order to find the solution of this equation. The value τ_i can get the nonnegative various no repetitive to the step h values at the time moments $t_i - \tau_i$. The linear interpolation will be used in order to find the solution in the borders of the interval h

$$P_k(t_{i+1} - \tau_{i+1}) \cong \left(1 - \frac{t_{i+1} - \tau_{i+1} - t_\mu}{h}\right) P_l + \frac{t_{i+1} - \tau_{i+1} - t_\mu}{h} P_{\mu+1}, \quad (12)$$

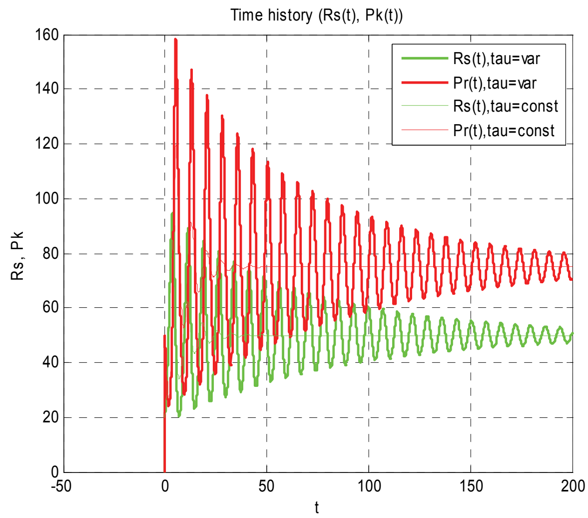
when the following conditions are: $h \le \tau_{i+1} \le t_{i+1} - t_0$, $t_{i+1} - \tau_{i+1} \in \lfloor t_\mu, t_{\mu+1} \rfloor$, $P_k(t_{i+1} - \tau_{i+1}) = P^*$, $\tau_{i+1} < t_i - t_0$.

The evaluation of IT node resource stability

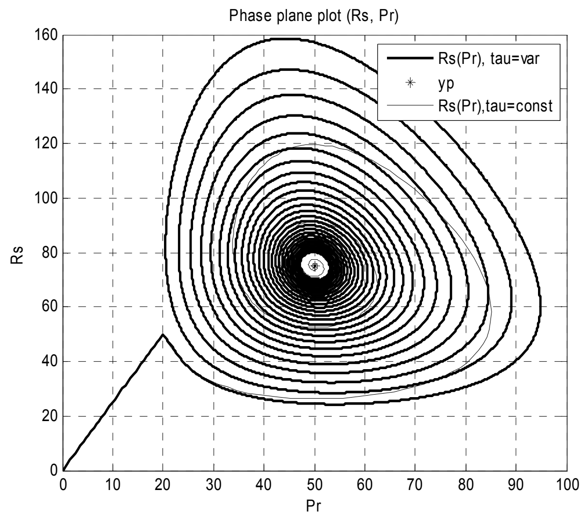
The evaluation of numerical IT network resource model (5) and (10) according to the initial conditions will be described. For this purpose the stability of the IT network node resources will be evaluated in the discrete time t_k when the delay is constant $\tau = const$ or variable $\tau \neq const$ with the expression $\tau_i = \bar{\tau} + rnd(2\Delta\tau) - \Delta\tau$, when $\Delta\tau > 0$ and $rnd(x)$ is the set of the random values from the interval $[0, x]$. $PR = 1$ when $P^* = 1$, i.e. the equilibrium is between resource supply and demand. Let us accept that: $\gamma = 0.9$, $\alpha = 0.5$, , $P_{\min} = 0.1$, $P_0 = 1$, and $\beta = 1.0$, the integration step $h = 0.005$, the integration accuracy $\xi = 0.01$. The equation (10) of the iterative calculation is chosen $\varepsilon = 0.0001$. t_0 is the start of the system monitoring, $T = 100$.

The uniform distribution in the interval $[\bar{\tau} - \Delta\tau, \bar{\tau} + \Delta\tau]$ for the modeling of the IT network resources allocation $R_s(t) = \xi(T_{buf}(t) + T_{proc}(t))$ is chosen because this allocation is the random process, where $\bar{\tau}$ is the mean value of the delay, $2\Delta\tau$ is the delay variation interval. The non random constant delay $\tau = \bar{\tau}$ is when $\Delta\tau = 0$. The IT network resource allocation is unstable, i.e., the Hopf's oscillations occur (*Hopf bifurcation*) at the certain values τ_{rib} of the delay. That fact can be observed from the results presented in Fig. 2 (a). As it can be seen, the character of these oscillations is periodic and extinguishing fading when $\tau < \bar{\tau}_{rib}$. The values of R_s and P_k in the phase plane are below the limit values (Fig. 2, b). This means that the system with the chosen parameters is working steadily.

The obtained results in the case $\tau > \bar{\tau}_{rib}$ are shown in Fig.3. As it can be seen, the vibration characteristics are periodical and growing. The R_s and P_k values in the phase plane are close to the limit values (Fig. 3, b). This means that the system with these parameters works unstable. The system's cut-off delay time is $\tau = \bar{\tau}_{rib} = 0.17$ for the chosen parameters. During the calculation it was found that the largest influence on the IT node's distribution of resources has the delay time value $\tau(t)$.



a)



b)

Fig. 2. Comparison of recourse supply and demand, and price: a) Rs(t) and Pk(t) time history, b) Rs(t) and Pr(t) phase plane, with the parameters: $\gamma = 0.9$ is the proportionality factor, $\alpha = 0.5$ is the coefficient of variation Pk(t), $\beta = 1.0$ is the coefficient of variation Rs(t), $P_{\min} = 0.1, P_0 = 1$, the delay $\tau = \bar{\tau} = 0.16$

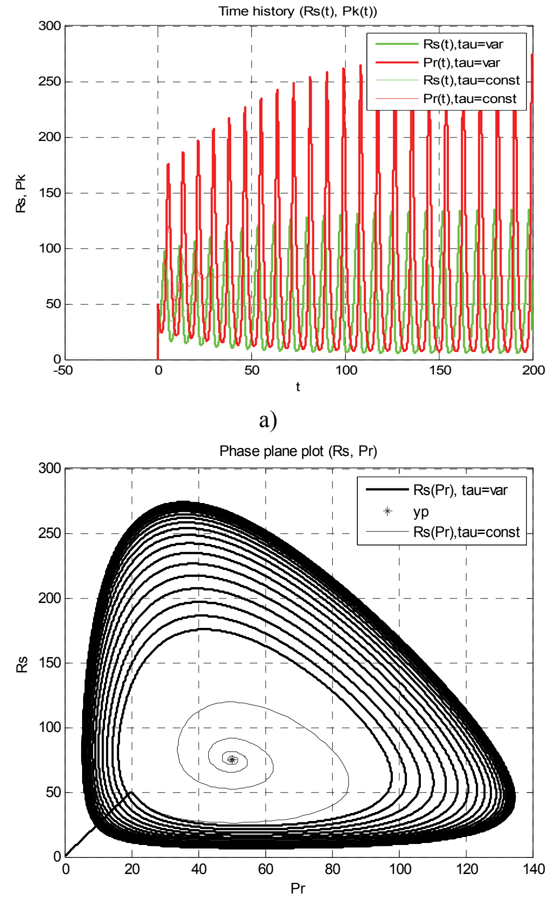


Fig. 3. Comparison of recourse supply and demand, and price: a) Rs(t) and Pk(t) is time history, b) Rs(t) and Pr(t) is phase plane with the parameters: $\gamma = 0.9$ is the proportionality factor, $\alpha = 0.5$ is the coefficient of variation Pk(t), $\beta = 1.0$ is the coefficient of variation Rs(t), $P_{\min} = 0.1$, $P_0 = 1$, the delay $\tau = \overline{\tau} = 0.19$

Conclusions

The investigation of the IT node resources R_s and P_k dependency from P_r when delay was constant $\tau(t) = const$ and variable $\tau(t) \neq const$ was carried out. The results show that in the system when the resource's demand and supply are described by L. Walras dynamic model, there are the oscillations of the demand and supply. The character of these oscillations much depends on the delay value and the slightly depends on the parameters which of the system of the model. The given results in the phase planes characterize the character of the oscillating. The smaller oscillation amplitude is obtained at the constant delay τ, i.e. the system better meets the resource demand. Conversely, the oscillations in the system increase when the delay time τ approaches to $\tau(t) \Rightarrow \overline{\tau}_{rib}$. This means that the IT node system fails to ensure the demand R_s of the resources in time and that will affect QoS. The probability that the system reaches a critical state will decrease having evaluated the IT network node resources distribution according its value.

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Received 2012 03 19
Accepted after revision 2012 05 28

G. Cincikas, S. Japertas. Router Resource Management Research // Electronics and Electrical Engineering. – Kaunas: Technologija, 2012. – No. 6(122). – P. 79–82.

The problem of resource management of the network node is analysed in the paper. It is offered to apply the L. Walras dynamic model for the solution of this problem. The stability of the resource management of network node in the cases of content and variable delay is investigated. It is expected that having applied the offered model of the system resource management, the system will be capable to change its state smoothly without reaching the critical one. Ill. 3, bibl. 7 (in English; abstracts in English and Lithuanian).

G. Činčikas, S. Japertas. Maršrutizatoriaus išteklių valdymo tyrimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 6(122). – P. 79–82.

Straipsnyje nagrinėjami IT tinklų maršrutizatoriaus išteklių valdymo klausimai. Ištekliams valdyti siūloma taikyti L. Walraso dinaminį modelį. Išnagrinėtas sistemos stabilumas, esant pastoviam ir kintamam vėlinimui, atsirandantis dėl valdymui reikalingos informacijos surinkimo kitimo. IT sistemos ištekliams valdyti panaudojus išnagrinėtąjį modelį, tikimasi, kad sistema sugebės dinamiškai keisti savo būseną ir šuoliškai nepasieks kritinės būsenos reikšmių. Il. 3, bibl. 7 (anglų kalba; santraukos anglų ir lietuvių k.).