LMI Based Switching Congestion Controller for Multiple Bottleneck Packet Switching Networks

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Abstract: In this paper a new Linear Matrix Inequality (LMI) based switching controller for multiple Bottleneck packet switching Network has been considered. The main goal is to illustrate the effects of the Switching Control methodology on the congestion control problem of the packet switching Networks with dynamically varying parameters such as Link capacity and time delays. The congestion dynamic for congested network is presented and LMI based switching controller is being discussed. Then, the proposed control method has been applied on a case study in ATM Congested Network and simulations are conducted, and simulation results will be compared with old method..

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1. Introduction

High-speed computer communication networks are generally store-and-forward backbone networks consisting of switching nodes and communication links based on a certain topology. All the links and all the nodes are characterized by their own capacities for packet transmission and packet storing, respectively. A node which reaches its maximum storing capacity due to the saturation of its processors or one or more of its outgoing transmission links is called congested. Some of the packets, arriving at a congested node, cannot be accepted and have to be retransmitted at a later instance. This would lead to a deterioration of the network's throughput and delay performance or even the worst situation—network collapse. Therefore, congestion control is an important problem arising from the networks management. It follows that congestion is essentially a result of a mismatch between the network resources and the amount of traffic admitted for transmission. Consequently, congestion control can be linked to the classical problem of feedback control in which the main aim is to match the output to the input of dynamical systems [1].

Many algorithms have been proposed for computing explicit rates in single congested node. In general, these algorithms are of two types: the queue length and arrival rate of queue. The stability of the closed-loop system is critical in any congestion control scheme due to the fact that propagation delay encountered in high-speed networks may cause the controllers and the whole network to operate at an unstable point. This yields the notorious oscillation problem that greatly degrades the network performance [2]. But many of these algorithms are not shown to be asymptotically stable in steady state situation, and also these algorithms cannot able to use of full capacity of resources in transient states [3-6]. In [7] an analytical method for a design of a congestion control scheme in multiple congested nodes in packet switching network is presented .The control method is rate based with a local feedback controller associated with each switch node. The controller is a generalization of the standard proportional-plus-derivative controller. It is shown that there exist a set of control gain that result in applying asymptotic stability of the linearized network model for delay in networks.

In this paper a new LMI based switching controller for multiple Bottleneck packet switching Networks has been considered. The main goal is to illustrate the potential impact of the Switching Control methodology [8], [9] on the congestion control problem of the packet switching Networks with dynamically varying parameters and time delays.

2. Congestion Dynamics

Three types of dynamic equations are defined:

1. The equations which are related to the trend of x on which the input rate to the congestion link has affect and its difference with the link transition capacity is c. With only one bottle-neck node there is only one x but when there are multiple bottle-neck nodes (i.e. when multiple nodes are congested), for each x_i, $i \in N$ there is a equation for the changes of

the queue length in buffer. x_i , $i \in N$, denote the number of packets buffered for transmission on link i and $N = \{1, 2, K, N\}$ denote the set of links in network.

2. The calculating allowed sending rate q, and its changes made new equations. This is the control algorithm equations. If there were multiple bottle-neck nodes, there would be separate suggested source sending rates calculations – according to the queue length and the implemented control algorithm – for each of them and the signals are sent to different traffic-sending nodes.

3. All the information about the suggested sending rates are sent to the source by control packets and the applicable traffic rate would be the minimum of the suggested rates and the rate of the source. The point here is that there is delay between calculating the suggested allowed sending rate and their delivery to the source. According to what mentioned above, for multiple bottle-neck nodes congestion equations are more complicated than single bottle-neck node but they follow the same concept. Generally, regardless of the complexity of the model, it is suitable to benefit from the concepts used in single bottle-neck node models in cases of multiple bottle-neck nodes and therefore it is worth investigating both together. The three equations of the network for multiple bottle-neck nodes are as follows [2]:

$$x_i^{ab}(n+1) = x_i^{ab}(n) + \min\left\{\psi_{\bar{i}}^{ab}(n-\tau_{\bar{i}}^{ab}), \frac{\psi_{\bar{i}}^{ab}(n-\tau_{\bar{i}}^{ab})}{f_i(n)}(X - x_i(n) + \psi_i(n)\right\} - \psi_i^{ab}(n)$$

$$q_i(n+1) = \mathrm{Sat}_{q^o}\{q_i(n) - \sum_{j=0}^{J_i} a_{ij}(x(n-j) - x^o) - \sum_{k=0}^{K_i} b_{ik} q_i(n-k) \qquad (1)$$

$$\psi_{\bar{e}_{ab}}^{ab}(n) = r_{ab}(n) = \min\{q_m(n+1-d_{ma}^{ab}), m \in p(ab); r_{ab}^o(n)\} i \in N \quad (ab) \in C(i)$$

Where a_{ij} and b_{ij} are the controller gains and $x_i^{ab}(n)$ is the queue length for (ab) connection traffic stored in buffer link i in the moment n, $\psi_i^{ab}(n)$ is the passing traffic of connection (ab) on link i on a time interval of $[n, n+1)$. The feedback delay d_{ma}^{ab} is equal to $\lceil \tau_{ma}^{ab} \rceil$. $\lceil \tau_{ma}^{ab} \rceil$ is smallest integer greater or equal to τ_{ma}^{ab} .

Since q_m is generated in time T, the most updated feedback information in node a in the moment n is $q_m(n-1+d_{ma}^{ab})$ which may be arrived any time in the interval time $(n-d_{ma}^{ab}, n+1-d_{ma}^{ab})$. It is important to know that the equations are not closed with respect to the variables because in the equations, ψ_i^{ab} is not expressed in terms of the state variables x_i^{ab}, q_i and the applied traffic r_{ab}^o . We can simplified network dynamic equations as below[7]:

$$x_i(n+1) = \mathrm{sat}_X\{x_i(n) + \sum_{k=0}^{D_i} l_i^k(n) q_i(n+1-k) + f_{\bar{i}\bar{i}}(n) - c\}$$

$$q_i(n+1) = \mathrm{sat}_{q^o}\{q_i(n) - \sum_{j=0}^{J_i} a_{ij}(x_i(n-j) - x^o) - \sum_{k=0}^{K_i} b_{ik} q_i(n-k)\} \quad (2)$$

Then network can be divided into two sections: bottle-neck sub-network (the links in which congestion occurs) and non-bottle-neck sub-network. Equations (3) are for bottle-neck sub-network $(i = 1, \Lambda, N1)$:

$$x(n+1) = \mathrm{sat}_X\{x(n) + \sum_{i=0}^{D} l_i(n) q(n+1-i) + r^o(n) - c\} \quad (3)$$

$$q(n+1) = \mathrm{sat}_{q^o}\{q(n) - \sum_{j=0}^{J} a_j(x(n-j) - x^o) - \sum_{k=0}^{K} b_k q(n-k)\}$$

$l_i^k(n)$ is the number of passing connections from i, limited by i, with a RTD delay of k and $f_{\bar{i}}(n)$ is the summation of the connection traffic rates passing from i which are not limited by i (this kind of traffic may be limited by another bottle-neck link). Here, limited means a link creates a minimum suggested sending rate for a specific connection. Queue equations for link i is:

$$x_i(n+1) = \mathrm{Sat}_X\{x_i(n) + f_i(n) - c\}, i \in N \quad (4)$$

Where $x_i(n)$, $f_i(n)$ are the total occupancy of the buffer of link i and the aggregate input flow to link respectively and x is buffer size [7].

3. Problem definition

Since congestion control methods are inefficient in confront of variation in Network condition and directly depends on input traffic rate and network uncertainty, the multiple switching-based logic controllers are used to reduce the inefficiency and also improve the performance of the network. In addition in order to solve the problems caused by unknown system parameters, robust controllers are used. The goal of congestion control in a network is to queue length (x) to be achieved to desire value of x_0. If a buffer becomes full, it is saturated. Here, the controller objective is to control the number of the packets entering the buffer in order to keep it in a desired value. Suppose that a part of a network is congested. This part may include a number of connected links which are affected by several data streams. Figure 1 shows a part of a network affected by $r_A, r_B, r_C, r_D, r_E, r_F$ connection data stream.

4. Material and Methods

4.1. Proposed Method

In the proposed method for all network conditions a controller based on LMI should be determined. When network condition changed, then working area changed then controller should be changed. In this paper uncertainty in the number of the transfer packets which causes some changes in the parameters of the equations is considered. In order to design a controller some areas should be defined. These working areas are defined according to the buffer saturation. For each working area a dynamic equations can be defined according to how the buffers are saturated. The best tool for designing the controller that guarantees the robustness of the network is LMI [10].

During the congestion control of the network the areas change and make different dynamics then switching control is used for stabilizing the system [8], [9]. In such type of switching, it is assumed that the system remains in a single working area for a certain period of time. The Switching Control system based on the LMI theory, used for the design of congestion control scheme, is described In Figure 2. The set of candidate controllers is taken to be LMI should be selected by switching index function that recognized the network area based on network feedback.

4.2. Switching

Plant models are inherently inaccurate, and controllers regulating processes described by such models must be able to ensure satisfactory closed-loop performance in the presence of exogenous process disturbances which cannot be measured. Modem linear control theories (e.g., pole placement/ observer theory, linear quadratic theory, H ∞ theory, …) are very highly developed and can be used to design controllers with such capabilities. Processes admitting linear models, provided the model uncertainties are time invariant and "sufficiently small." But for "large" model uncertainties derived from real-time changes in plant dynamics, common sense suggests and simple examples prove that no single, fixed-parameter linear controller can possibly regulate in a satisfactory way. Such large uncertainties might arise in real time because of changes in operating environment, component aging or failure, or perhaps a sudden change in plant dynamics due to an external influence.

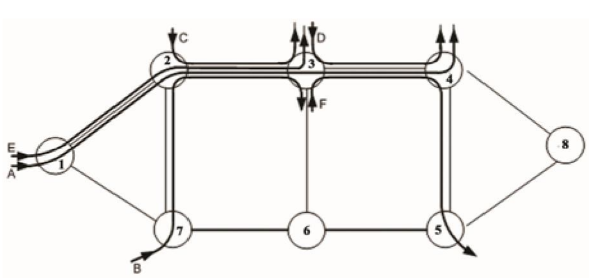

Fig. 1. A network with several bottle-neck nodes.

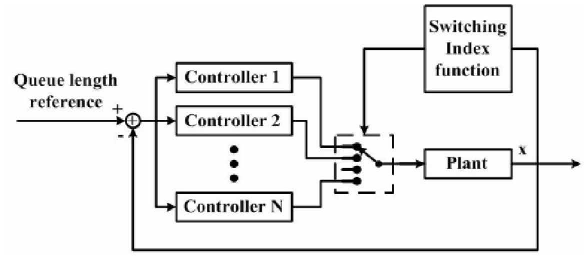

Fig. 2. congestion control structure

To deal with these types of uncertainties a controller better than linear feedback theory can provide, is obviously required. What is needed is a controller which can change or be changed in response to perceived changes in plant dynamics. If plant changes can be predicted in advance or can be directly measured when they occur, then controller gain scheduling will be often sufficient. But if plant changes cannot be predicted or directly measured, online controller selection or "tuning" must be carried out.

The aim of this paper is to describe a simply-structured "high-level" controller called a "supervisor" which is capable of switching into feedback for congestion control of a communication packet switching networks. A sequence of linear positioning controllers from a family of candidate controllers should be identified in order to output of the network approach and track x_0.

4.3. LMI Theory

Linear Matrix Inequalities (LMIs) and LMI techniques have emerged as powerful design tools in areas ranging from control engineering to system identification and structural design. Three factors make LMI techniques appealing: A variety of design specifications and constraints can be expressed as LMI. Once formulated in terms of LMI, a problem can be solved exactly by efficient convex optimization algorithms (the "LMI solvers"). While most problems with multiple constraints or objectives lack analytical solutions in terms of matrix equations, they often remain tractable in the LMI framework. This makes LMI-based design a valuable alternative to classical "analytical" methods. See[10] for a good introduction to LMI concepts.

Theory [11], [12]: undetermined closed loop system equation (6) with the input signal mentioned in equation (5), is totally exponentially stable if symmetric and positive definitive matrix X and a set of matrices Q_l can be found such that equation (8) holds. The feedback gain needed for stabilizing the closed loop system is expressed in equation (9).

$$u(t) = \sum_{l=1}^{m} \mu_l K_l x(t) \qquad (5)$$

$$x(t+1) = \sum_{j=1}^{m}\sum_{l=1}^{m}\mu_j\mu_l(A_l + B_l K_j)x(t) \qquad (6)$$

$$V(x) = x^T X^{-1} x \qquad (7)$$

$$\begin{bmatrix} -X & XA_l{}^T + Q_j{}^T B_l{}^T \\ A_l X + B_l Q_j & -X \end{bmatrix} < 0 \qquad (8)$$

$$K_l = Q_l X^{-1} \qquad (9)$$

5. Applying the proposed control method

The Figure (1) shows a network with several nodes. The traffic applied to each buffer is presented in Table 1 and Table 2. The reason for selecting the second and third type of the applied traffic is to investigate the efficiency of previously discussed method in the case of changing the working area. In this paper uncertainty in link capacity (c) which causes some changes in the parameters of the equations is considered. The goal of this paper is definition of the problem and the investigation of the proposed method in comparison to the one presented in [2], the addition of uncertainty is not considered.

Table. 1. Traffic applied to A

The applied traffic rate	End time	Start time	Link
0.6	3000	20	1
0.1	2500	50	2
0.1	3000	500	3
0.7	2500	1000	4
0.1	3000	1500	5
0.7	3000	2000	6

Table. 2. The applied traffic to B

The applied traffic rate	End time	Start time	Link
0.9	3000	20	1
0.8	2500	50	2
0.9	3000	500	3
0.9	2500	1000	4
0.9	3000	1500	5
0.8	3000	2000	6

According to the system equations of the multiple bottle-neck node network presented in [7] and the conditions in the following table also by ignoring the waiting time in the buffer, the initial value of system equations is $x_0 = 30, c = 60, \tau_{pr} << \tau_s$, RTD- Sampling time = T, x=100 and $10 \times \tau_s =$ Propagation delay τ_p^1.

Now by considering the network in figure (1) the working area have been defined according which buffers are saturated as below:

no buffer is saturated
buffer 2 is saturated
buffer 3 is saturated
buffer 1 and buffer 2 are saturated
buffer 2 and buffer 3 are saturated
all buffers are saturated

These are all working areas, in the following the details of proposed method for all of working area have been presented.

If no buffer is saturated

In this working area $x_i(n) + f_i(n) \le c$, i.e., the buffer capacity is not full so the equations are as follows:

$$x_i(n+1) = Sat_X\{x_i(n) + f_i(n) - c\}, i \in \{1,2,3,4\}$$
$$\Rightarrow x_i(n+1) = 0,\ i \in \{1,2,3,4\} \qquad (10)$$

It can be seen that input traffic affects the performance of the system and the network traffic behavior is much more desirable and no control is needed.

If buffer 2 is saturated

Buffer 2 being saturated, a new working area is created in which $x_2(n) + f_2(n) > c$ and for other buffers, $x_i(n) + f_i(n) \le c,\ i = \{1,3,4\}$. The fact that the saturation in one buffer may result in saturation in other buffers is not considered here, because if another buffer becomes saturated due to saturation of buffer2, another working area is created. Here, the control goal is that this working area, $x_2(n)$, converges to x_0. It should be noticed that the possibility of other buffers become saturated due to convergence of $x_2(n)$ to x_0 is not the point because in this case a new working are is created. Assuming that buffer 2 is saturated, the dynamic equations is as follows:

$$x_i(n+1) = 0, \quad i = 1,3,4$$
$$x_2(n+1) = x_2(n) + r_B + r_C + r_A + r_E - c \qquad (11)$$

In order to achieve the control objective in this area, a dynamic error is added to the system which expressed by the following equation:

$$e_2(n+1) = e_2(n) + x_0 - x_2(n) \qquad (12)$$

Since there is no uncertainty in the governing equations of the network, convergence of $e_2(n)$ to zero is sufficient to achieve the control objective. In order to do, pole placement method and the control rule $u = kx$ should be applied where the state vector is $x = [x_2, e_2]$.

$$K_{10} = \begin{bmatrix} 0.075 & -0.005 \\ 0.075 & -0.005 \\ 0.075 & -0.005 \\ 0.075 & -0.005 \end{bmatrix}$$

If buffer 3 is saturated

Saturation of buffer 3 creates a new working area in which $x_3(n) + f_3(n) > c$ and for other buffers we have $x_i(n)+f_i(n)\le c,\ i=\{1,2,4\}$. According to Figure 5, the input $r_D(n)$ and $r_F(n)$ enter the third buffer immediately and the input $r_A(n)$ can enter the buffer either immediately or with delay. The bi-aspect behavior of $r_A(n)$ makes us consider it as an uncertainty. The dynamic equations of the network for this working area are as follows:

$$x_i(n+1)=0,\quad i=1,2,4$$
$$x_3(n+1)=x_3(n)+r_B+r_C+r_A+r_E-c \quad (13)$$

where $\Delta r_A(n)$ represents the uncertainty in $r_A(n)$ which may appear as:

$$r_A(n-4),r_A(n-3),r_A(n-2),r_A(n-1) \quad (14)$$

Design of a controller for this working area should be based on robust control theories such as LMI. In order to design the dynamic control, the buffer error of x_3 from x_1 and the delays related to $\Delta r_A(n)$, considered as uncertainty, should be added to the dynamic equations of the system. Therefore, the uncertainty in $\Delta r_A(n)$ is implicitly taken into account in the controller design.

$$\begin{aligned}
&x_3(n+1)=x_3(n)+r_D(n)+r_F(n)+r_A(n)-c+\Delta r_A(n)\\
&x_3(n-1+1)=x_3(n)\Rightarrow x_3(n-2+1)=x_3(n-1)\\
&e_3(n+1)=e_3(n)+(x_0-x_3(n)) \qquad (15)\\
&r_A(n-1+1)=r_A(n)\Rightarrow r_A(n-2+1)=r_A(n-1)\\
&\Rightarrow r_A(n-3+1)=r_A(n-2)\Rightarrow r_A(n-4+1)=r_A(n-3)
\end{aligned}$$

Hence, system dynamic matrices are:

$$A=\begin{bmatrix}1&0&0&0&p_1&p_2&p_3&p_4\\1&0&0&0&0&0&0&0\\0&1&0&0&0&0&0&0\\-1&0&0&1&0&0&0&0\\0&0&0&0&0&0&0&0\\0&0&0&0&1&0&0&0\\0&0&0&0&0&1&0&0\\0&0&0&0&0&0&1&0\end{bmatrix},B=\begin{bmatrix}w&1&1\\0&0&0\\0&0&0\\0&0&0\\1&0&0\\0&0&0\\0&0&0\\0&0&0\end{bmatrix}$$

Where $w\in\{0,1\}$ is the uncertainty of matrix B. If one of the p_i is equal to 1, other p_i and w is are zero. In other words, in set $\eta\in\{w,p_i\}$ only one of the members can be 1 at the same time. Therefore, the control input is considered in the form of $u=kx$ to ensure the robustness of the system. Then, the state vector X is defined as follows:

$$[x_3(n),\ x_3(n-1),\ x_3(n-2),\ e(n),\ r_A(n-1),\ r_A(n-2),\ r_A(n-3),\ r_A(n-4)]$$

By using LMI, K is:

$$K_{01}=\begin{bmatrix}-0.0149&-0.0094&-0.0005&-0.0280&-0.4312&-0.3027&-0.0469&-0.0022\\0.7730&0.0251&0.0011&-0.0927&0.2518&0.1811&0.0291&0.0014\\0.7730&0.0251&0.0011&-0.0927&0.2518&0.1811&0.0291&0.0014\end{bmatrix}$$

If both buffer 1 and buffer 2 are saturated

In this case, for buffer 1 we have $x_1(n)+f_1(n)\ge c$ and since the all the data stream passing through buffer 1 enters buffer 2, then buffer 2 becomes saturated and the dynamic equations of the system considering the buffer error dynamics of x_2 from x_0 is as follows:

$$\begin{aligned}
&x_1(n+1)=x_1(n)+r_1+r_5-c\\
&x_2(n+1)=x_2(n)+r_3+r_2-c\\
&x_i(n+1)=0\quad i=\{3,4\} \qquad (16)\\
&e_2(n+1)=e_2(n)+(x_0-x_2(n))
\end{aligned}$$

This system does not contain any uncertainty. buffer 2 cannot be controlled while buffer 1 is still saturated and therefore, this working area should be omitted. In order to exit this working area it is assumed that buffer 2 is saturated. The design of this controller in this case is similar to the case in which buffer 2 is saturated. Since only buffer 2 is saturated.

If both buffer 2 and buffer 3 are saturated

In this case, for buffer 2 we have $x_2(n)+f_2(n)\ge c$ and for buffer 3 we have $x_3(n)+f_3(n)\ge c$. Therefore, by adding the new variables, buffer error integral x_2 from x_0 and x_3 from x_0, the governing equations of the system are as follows:

$$\begin{aligned}
&x_i(n+1)=0\quad i=\{1,4\}\\
&x_2(n+1)=x_2(n)+r_A+r_B+r_C+r_E-c \qquad (17)\\
&x_3(n+1)=x_3(n)+r_D+r_F+\delta-c
\end{aligned}$$

where δ is the uncertainty of buffer 3 which can be defined as follows:

$$\delta=\left(\frac{(x_2^A+r_A(n-i))}{x_2(n)+r_A+r_E+r_C+r_B}\right)\qquad i=0,1,2,.... \qquad (18)$$

By adding the new equations we have:

$$\begin{aligned}
&e_2(n+1)=e_2(n)+(x_0-x_2(n)) \qquad (19)\\
&e_3(n+1)=e_3(n)+(x_0-x_3(n))
\end{aligned}$$

As it can be seen in the above equations, the input to buffer 2 and buffer 3 are independent and therefore, distributed controller design methods can be applied for designing the controller. Hence, first for buffer 2 and then for buffer 3 controllers are designed separately. Because in the dynamics of buffer 3, some deterministic terms appear, LMI is used for controller design. In this case, the coefficient of buffer 2 and the coefficient of buffer 3 are as follows. Since in this problem the uncertainty has the form of noise and causes instability in the closed loop system, only if it is unbounded, decentralized controller is used for x_2 and the uncertain norm which is a part of x_2 is bounded. Therefore, the problem is to design a decentralized controller for which the state feedback gain is as follows:

$$K_{11}=\begin{bmatrix} 0.075 & 0 & -0.005 & 0 \\ 0.075 & 0 & -0.005 & 0 \\ 0.075 & 0 & -0.005 & 0 \\ 0 & 0.15 & 0 & -0.01 \\ 0.075 & 0 & -0.005 & 0 \\ 0 & 0.15 & 0 & -0.01 \end{bmatrix}$$

If all buffers are saturated

In this case, the working area in buffer 1 is c, in buffer 2 is $x_2(n)+f_2(n)\geq c$ and in buffer 3 we have $x_3(n)+f_3(n)\geq c$. Therefore the governing equations of the system by adding the new variables, buffer error integral of x_2 from x_0 and x_3 from x_0 are obtained as follows:

$$\begin{aligned} &x_1(n+1)=x_1(n)+r_A(n)+r_E(n)-c \\ &x_2(n+1)=x_2+r_C(n)+r_B(n) \qquad (20) \\ &x_3(n+1)=x_3(n)+r_D(n)+r_E(n)+\delta-c \\ &x_4(n)=0 \end{aligned}$$

where δ is the uncertainty related to buffer 3 and may have the following form:

$$\delta=\left(\frac{\left(x_2^A+\dfrac{x_1+r_A(n-i)}{x+r_A(n)+r_E(n)}\times c\right)}{x_2+c+r_B(n)+r_C(n)}\times c\right) \quad i=1,2,.... \qquad (21)$$

By adding the new variable we have:

$$\begin{aligned} &e_2(n+1)=e_2(n)+\left(x_0-x_2(n)\right) \qquad (22) \\ &e_3(n+1)=e_3(n)+\left(x_0-x_3(n)\right) \end{aligned}$$

In this case, similar to the case in which buffers 1 and 2 are saturated, we assume that only buffer 2 is saturated and since saturation of buffer 3 is taken into account, the controller design is the same as the design for the case mentioned before.

If there is no space in the buffer, the system will be saturated, i.e. if $X-x_i(n)+\psi_i(n)<f_i(n)$ then definitely $x_i(n)+f_i(n)>c$ because since $X>>c$, we have $c<X+\psi_i(n)<f_i(n)+x_i(n)$. In this case the equations are as follows:

$$x_i(n+1)=x_i(n)+\left(x_0-x_i(n)+\psi_i(n)\right)-c\Rightarrow x_i(n+1)=x_0 \quad (23)$$

which shows that there is no need for analysis because in this case the system does not obey the input and therefore, this should be prevented.

6. Simulation

Considering above, for the presented example there are four working areas: The working area in which only the second buffer becomes saturated, the working area in which only the third buffer becomes saturated, the working area in which the second and third buffer become saturated and the working area in which none of buffers become saturated. For each of these working areas the appropriate controller is designed based on the robust control theory and by applying the silence time switching logic the appropriate controller is selected and used.

Since if there isn't available any saturated buffer, transition rate will be upper limit i.e. full capacity of link ,therefore using of controller isn't necessary and for other working area following control signal is applied: r_A, r_B, r_C, r_D, r_E, r_F=c.

By applying these controllers and using the silence time switching logic, the following results for the applied traffic are presented in Table 1 and Table 2. Figure 3 – 7 depict the results of comparison between the obtained results and the response of the closed loop system controlled by a single controller. The comparison criteria is the response of the closed loop system according to the output performance and the control signal.

Figures 3 and 4 shows the response of the closed loop system when the traffic in Table 1 is applied. By considering the output response of the closed loop system it is obvious that the proposed design method results in an enhancement in the performance of the closed loop system and by using the proposed controller the control signal is enhanced (Figure 5).

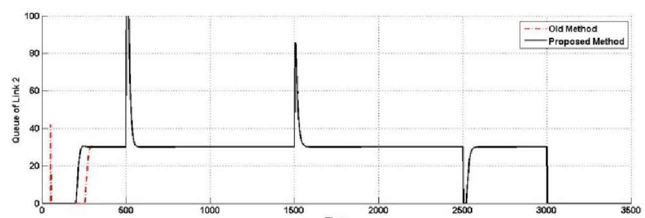

Figure 3. The output of the second queue lentgh.

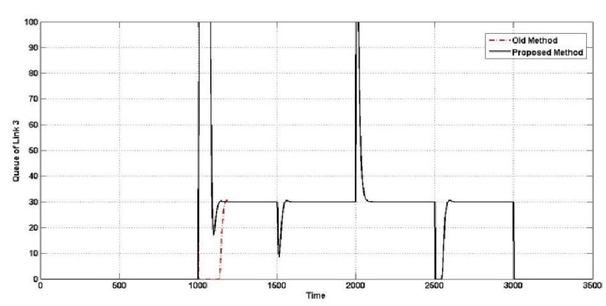

Figure 4. The output of the third queue lentgh.

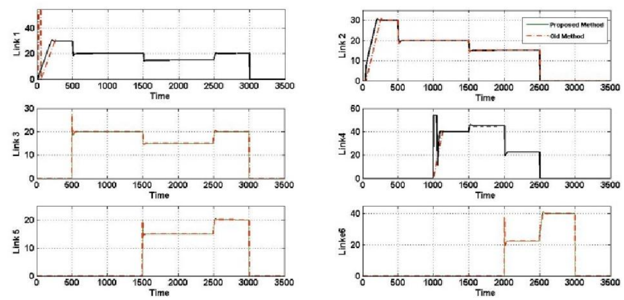

Figure 5. The control signals.

Figure 6 depicts the response of the closed loop system when the traffic is applied according to Table 2. By comparing between the closed loop system response, it is obvious that the performance of the closed loop system is improved by using the proposed method and the controller signal is also enhanced (Figure 7).

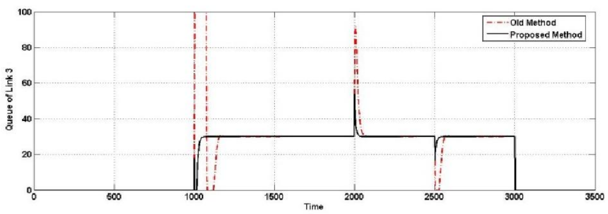

Figure 6. the output of the third buffer

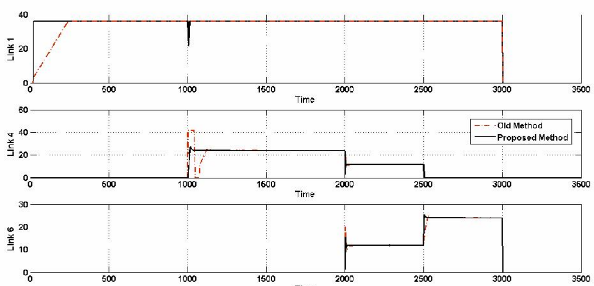

Figure 7. The resulted control signal

7. Conclusion

In this paper a new LMI based switching controller for multiple Bottleneck packet switching Networks was presented. The main goal was to illustrate the impact of the Switching Control methodology on the congestion control problem of the packet switching Networks with dynamically varying parameters such as link capacity (c)and time delays. Depends on network condition different working area defined and for each of these working areas the appropriate controller was designed based on the robust control theory. By applying the silence time switching logic the proposed method has been stable because there is no interference between controllers. Simulation result depicts that by considering the output response of the closed loop system, it is obvious that the proposed design method results in an enhancement in the performance of the closed loop system and by using the proposed controller the control signal is enhanced.

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