차등화 서비스 네트워크의 슬라이딩 모드 혼잡 제어

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Sliding Mode Congestion Control of Differentiated-services Networks

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Abstract - In this paper, we propose sliding mode congestion controller for differentiated-services network. Two important issue in differentiated-services architecture are bandwidth guarantee and fair sharing of unsubscribed bandwidth among TCP flows with and without bandwidth reservation. We use tight upper and lower bounds for various settings of differentiated-services parameters using the loss-bounded model. The Sliding mode congestion controller scheme is designed using nonlinear control theory based on a nonlinear model of the network that is generated using fluid flow consideration. The methodology used is general and independent of technology, as for example TCP/IP or ATM. The sliding mode congestion controller methodology has been applied to an TCP network. We use NS-2 simulation to demonstrate that the proposed control methodology achieves the desired behavior of the network, and possesses important attributes. as e.g, stable and robust behavior, high utilization with bounded delay and loss, together with good steady-state and transient behavior.

Ⅰ. INTRODUCTION

Differentiated services were proposed as a compromise for the quality of service(QoS) problem in internet networks. Differentiated services assigns each packet a predetermined QoS and aggregates traffic to a small number of classes [1]. From the router perspective, the tools for providing differentiated services are based on the following operations that should be done at high speeds: packet classification, buffer management and packet scheduling. In this work we in investigate the second aspect. Over the past few years differentiated services has attracted a great deal of research interest in the networking community[2].

This paper proposes a generic scheme for congestion control based on nonlinear and sliding mode control ideas. It uses an Sliding mode congestion controller approach. A specific problem formulation for handling multiple differentiated classes of traffic. Sliding mode congestion controller is derived from nonlinear control theory using a simple fluid flow model. The fluid flow model is developed using packet flow conservation considerations and by matching the queue behavior at equilibrium. This paper is organized as follows. Section Ⅱ presents the loss bounded analysis, Section Ⅲ fluid flow model for differentiated services, and Section Ⅳ Proposed sliding mode congestion controller design. The attributes above discussed above are demonstrated using simulation Section Ⅴ . Section Ⅵ presents our conclusions.

Ⅱ. LOSS BOUNDED ANALYSIS

We use a FIFO buffer that can hold B packets. Packets may arrive to the queue at any time and send events are synchronizes with time. Each packet p has corresponding benefit, $b(p)$. The system obtains the benefit of the packets it sends, and its aim is to maximize the benefit of the transmitted packets. In loss bounded analysis, the loss of an online policy is upper bounded by the loss of the optimal offline policy plus a constant fraction of the benefit of the optimal offline policy. This fraction constant be the loss bounded ratio of the online policy.

- Loss bounded analysis provides throughput competitive guarantee.
- One can either maximize the throughput of the policy or minimize its loss.

Definition 1. For a sequence of packet S and online policy A denote:

- The Subsequence of packets with benefit b by S_b
- The benefit of A on S by $V_A(S)$ and the loss of A on $L_A(S)$ $V(S) = V_A(S) + L_A(S)$.

Definition 2. Policy A is loss bounded iff every sequence of packets S.

$$L_A(s) \le L_{optimal}(S) + c_{loss\ bounded}\, V_A(S)$$

In the worst case scenario, A benefit at least $V_{optimal}(S)/\alpha$, of the optimal gain. And so A losses the maximum possible minus What A gain:

$$V_{optimal}(S) - V_{optimal}(S)/\alpha.. \tag{1}$$

where α is benefit. Then from **Definition 2**

$$L_A(S) \le L_{optimal}(S) + (\alpha - 1)/\alpha\, V_{optimal}(S) \tag{2}$$

Therefore $(\alpha-1)/\alpha$ becomes upper loss bounded ratio of the greedy policy. The loss bounded ratio of the $\sqrt{\alpha}$-preemptive greedy policy is developed using the model (3) as follows.

$$L_A(S) \le L_{Aextra}(S_1) + L_{Aovfl}(S_\alpha), \tag{3}$$

$$L_A(S_1) \le (1/\sqrt{\alpha})\, V_A(S_1) + L_{optimal}(S_1),$$

$$L_A(S_\alpha) \le (1/\sqrt{\alpha})\, V_A(S_\alpha) + L_{optimal}(S_\alpha),$$

Therefore $1/\sqrt{\alpha}$ become upper loss bounded ratio of the $\sqrt{\alpha}$ -preemptive greedy policy. Our TCP network model is shown in Fig. 1.

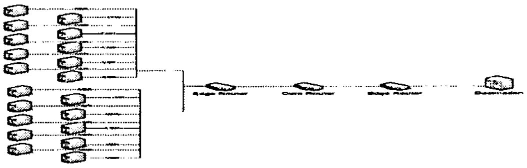

Fig. 1 Simulation Network Topology

We have implemented the differentiated services in greedy policy and $\sqrt{\alpha}$-preemptive greedy policy in NS-2 simulator. For purposes of comparison, we employ the network configuration parameter use in Table 1. A typical time evolution of the queue state from NS-2 simulation is presented in Fig. 2. Table 2 shown parameter of network model.

<Table 1> Network Parameter

Parameter	Value	Parameter	Value
CIR0	3000 ms	Edge router	10 Mb dsRED/edge
CIR1	3000 ms	Core router	10 Mb dsRED/edge
Packet size	8 Kbyte	Destination	10 Mb DropTail
Number flows	160 packet	CBR	25 Mb/s
Duration	2000 ms	VBR	480000 pixels/frame

<Table 2> Packets Statistics (simulation time 4000 ms)

CP	TotPkts	TxPkts	ldrops	edrops
All	38203	36377	1826	0
10	1586	1507	79	0
11	36617	34807	1747	0

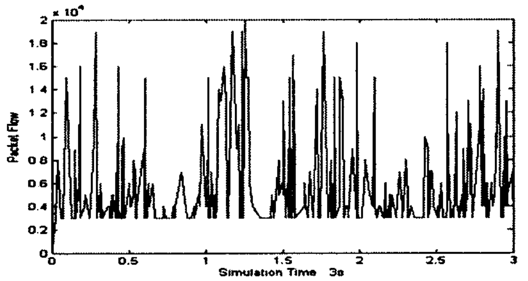

Fig. 2 Simulation Network NS-2 in RED/RIO Mechanism

Ⅲ. FLUID FLOW MODEL FOR DIFFERENTIATED SERVICES

A dynamic model is sought, in a form suitable for a distributed control solution. Using the flow conservation principle, for a single queue and assuming loss bounded, the rate of change of the average number of cells queued at the link buffer can be related to the rate of cell arrivals and departures by a differential equation of the form

$$\dot{x}(t) = -f_{output}(t) + f_{input}(t). \tag{4}$$

where $x(t)$ is the state of the queue, given by the ensemble average of the number of cells $N(t)$ in the system at the time t, $x(t)=$

$E\{N(t)\}$; $f_{output}(t)$ is the ensemble average of cell flow out of the queue at time t; and $f_{input}(t)$ is the ensemble average of cell flow into the queue at time t. Assuming that the queue storage capacity is unlimited and the customers arrive at the queue with rate $\lambda(t)$, then $f_{input}(t)$ is just the offered load rate $\lambda(t)$ since no packets are dropped. The flow out of the system, $f_{output}(t)$, can be related to the ensemble average utilization of the link $\rho(t)$ by $f_{output}(t)=C(t)\rho(t)$, where $C(t)$ is defined as the capacity of queue server[3].

Thus, the dynamics of the single queue can be represented by a nonlinear differential equation of the form

$$\dot{x}(t)=-G(x(t))C(t)+\lambda(t),\quad x(0)=x_0 \tag{5}$$

$\rho(t)$ can be approximated by a function $G(x(t))$, $0 \le x(t) \le x_{buffer\ size}$ and $0 \le C(t) \le C_{server}$. Assume that the link has a FIFO buffer discipline and a common buffer. The illustrate derivation of the state equation for an $M/M/1$ queue following, then from the $M/M/1$ queueing formulas, for a constant arrival rate to the queue the average number in the system at steady state is $\lambda/(C-\lambda)$.

$$\dot{x}(t)=-\frac{x(t)}{1+x(t)}C(t)+\lambda(t),\quad x(0)=x_0 \tag{6}$$

Ⅳ. SLIDING MODE CONGESTION CONTROLLER DESIGN

Ⅳ-1. Premium service strategy

It is based on the fluid model (6) used to model the input-output characteristics of the premium traffic, as follow:

$$\dot{x}_p(t)=-C_p(t)\left(\frac{x_p(t)}{1+x_p(t)}\right)+\lambda_p(t). \tag{7}$$

Let $\overline{x_p}(t)=x_p(t)-x_d(t)$, then $\dot{\overline{x_p}}(t)=\dot{x}_p(t)$ where x_d is the desired average state of the premium traffic. then from (7)

$$\dot{\overline{x}}_p(t)=-C_p(t)\left(\frac{x_p(t)}{1+x_p(t)}\right)+\lambda_p(t). \tag{8}$$

where $\lambda_p(t) \le \hat{k}_p \le C_{server}$ and $\hat{k}_p$ is a constant indicating the maximum rate that could be allocated to incoming premium traffic and C_{server} is the physical capacity of the server. The control objective is to choose the capacity $C_p(t)$ to be allocated to the premium traffic under the constraint that the incoming traffic rate $\lambda_p(t)$ is unknown but bounded by $\hat{k}_p$ so that the averaged buffer size $x_p(t)$ is as close to the desired value x_d as possible. In mathematical terms we need to choose $C_p(t)$ so that $\overline{x_p}(t)\rightarrow 0$ under the constraints that $C_p(t) \le C_{server}$ and $\lambda_p(t) \le \hat{k}_p < C_{server}$ The sliding mode surfaces are designed as:

$$s=\overline{x_p}(t),\qquad \dot{s}=\dot{\overline{x_p}}(t)\,. \tag{9}$$

If the sliding surface satisfies the reachability condition it attracts the system towards the sliding surface from any intial condition. The sliding surface will be attractive if $s\dot{s}<0$. Once system is attracted, it enters the sliding surface boundary and sides along the sliding surface. We choose the control input capacity $C_p(t)$, as

$$C_p(t)=\rho_p(t)\frac{1+x_p(t)}{x_p(t)}[\alpha_p\overline{x_p}(t)-Ksgn(\overline{x_p}(t))]. \tag{10}$$

where Lyapunov candidate as

$$V=\overline{x_p^2}/2 \tag{11}$$

(10) into (11)

$$\dot{V}=-\alpha_p\overline{x_p^2}+\lambda_p\overline{x_p}-Ksgn(\overline{x_p})\bullet\overline{x_p}\,. \tag{12}$$

It can be shown that $\lambda_p\overline{x_p}-Ksgn(\overline{x_p})\bullet\overline{x_p}\le 0$.

$$\dot{V}\le-\alpha_p\overline{x_p^2}\,. \tag{13}$$

where $\hat{k}_p<K$, $\overline{x_p}\rightarrow 0$ as $t\rightarrow\infty$ by Barbalat's Lemma [4].

Ⅳ-2 . Assured service strategy

$$\dot{x}_r(t)=-C_r(t)\left(\frac{x_r(t)}{1+x_r(t)}\right)+\lambda_r(t). \tag{14}$$

where $x_r(t)$ is the measured state of assured traffic buffer, $C_r(t)$ is the capacity allocated to the assured traffic and $\lambda_r(t)$ is the rate of the incoming assured traffic. The control strategy is developed using fluid model as follow.

$$\dot{\overline{x}}_r(t)=-C_r(t)\left(\frac{x_{r(t)}}{1+x_r(t)}\right)+\lambda_r(t). \tag{15}$$

Let $\overline{x_r}(t)=x_r(t)-x_f$, then $\dot{\overline{x_r}}(t)=\dot{x}_r(t)$ where x_f is the desired average state of the assured traffic buffer.

The control objective is to choose $C_r(t)$ and $\lambda_r(t)$ so that the average buffer size $x_r(t)$ remains close to the desired value x_f, chosen by the operator or designer. The value of $C_r(t)$ given by

$$C_r(t)=\max[0,(C_{server}-C_p(t))]. \tag{16}$$

The capacity allocated to the outgoing assured traffic is whatever is left after allocation to the premium traffic. We choose the controlled traffic input $\lambda_r(t)$ as

$$\lambda_r(t)=\max[0,\min C_r(t),g(t)]. \tag{17}$$

$$g(t)=C_r(t)\left(\frac{x_r(t)}{1+x_r(t)}\right)-\alpha_r\overline{x_r}(t). \tag{18}$$

where $\alpha_r>0$ is a design constant. Note that to achieve decoupling of the stability and transient properties of the system from time varying parameter, such as the number of connection $N(t)$, the calculated common rate $\lambda_r(t)$ is divided by $\hat{N}$, an estimation of $N(t)$:

$$\lambda_r^c(t)=\lambda_r/\hat{N}. \tag{19}$$

Ⅴ. SIMULATION RESULT

Using the simulation model we evaluate the performance of TCP network. At the beginning we set the reference point to 2000 packets. After $t=0.5s$ it is set to 5000 packets and after $t=1.0s$ it is again raised to 2000 packets. In this way, we not only shot that our controller can match the reference values but that it can also cope with dynamic changes that occur in the network.

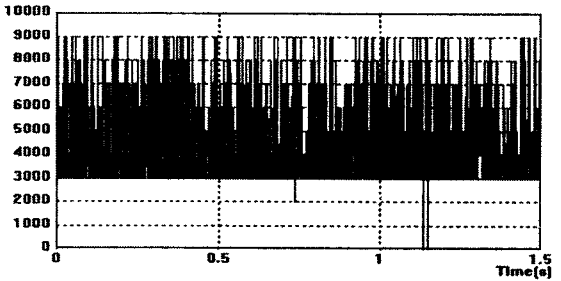

Fig.3 Packets Flow into Queue Buffer (sampling time 0.0005)

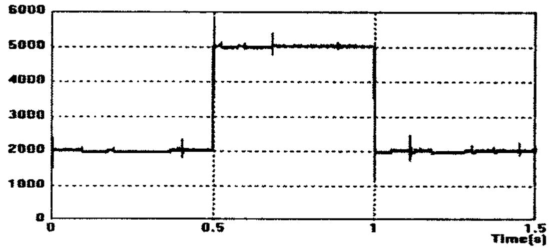

Fig.4 Queue Buffer Management Using Sliding Mode Control

We set control design constant as follow:

$\rho=0.68$ (worst case TCP flow), $\alpha=5000$, $C_{server}=200000$, sampling time 0.0005, window size 3000.

We observe that queue buffer management is well controlled with no packets drop. But sliding mode controller have chattering problem. The chattering effect that is a representative disadvantage of the sliding mode control is avoided by using second order sliding mode control instead of the first order sliding mode control. We future works are design second order sliding mode control of differentiated services network.

Ⅵ. CONCLUSIONS

This paper proposes a generic scheme for network congestion control. Generic scheme uses a sliding mode congestion controller approach. A sliding mode congestion controller is derived from nonlinear control theory using fluid flow model.

The propose controller algorithm possesses a number of important attributes such as admission congestion control and robust behavior, with high utilization and loss bounded and delay. In this paper, Robust reservation limits are an effective way to protect oneself against bursty connection arrivals and still maintain high bottleneck link utilization. Network simulation by NS-2 and RED/RIO control scheme are offered admission control. Theses attributes make the proposed control algorithm appearing for implementation in real, large scale heterogeneous network.

[References]

[1] Y. Bernet, A. smith, S. blake, D. grossman, "A conceptual model for Diffserv routers", Internet Draft 2000.

[2] C. Dovrolis, D. Stiliadis, P. Ramanathan, "Proportional Differentiated Services: Delay differentiation and packet scheduling", in Proc. ACM SIGCOMM'99.

[3] J. Filipiak, "*Modeling and control of dynamic Flows in Communication Networks*", New York: Springer-Verlag, 1998.

[4] V. I. Utkin, "*Sliding Modes in Control Optimization*", Springer-Verlag, 1992.