行政院國家科學委員會專題研究計畫成果報告

ATM 網路 ABR 訊務管理及訊務源模型之研究

ABR Traffic Management and Source Traffic Modelling

計畫編號 : NSC88-2213-E-009-085
執行期限 : 87 限 8 限 1 日至 88 限 7 限 31 日
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一、中文摘要

本計劃有兩個目標: ABR 傳輸率的控制與 self-similar 訊務評估。這篇報告主要在說明 ABR 傳輸率控制的設計與結果。目果在 ATM 網路中支援 Available Bit Rate (ABR) 服務的回饋式傳輸率控制, 都是在每一個交換點上, 採用單一靜態的緩衝區門檻來當作其阻塞的預警。去年我們提出一個 continuous-based adaptive 的控制器機制, 而這個機制邏輯上來說, 可以使用無限個數的門檻。這個方法, 可以證明確實在資料流量大時能達到 high-utilization 到 low cell loss probability 的要求。但是頻繁地調整允允的傳輸率, 會使得訊號傳輸的負擔大為增加。為了降低負擔, 在本計劃中, 我們提出一個低為 stepwise-based rate control 的機制, 來使用有限個數的門檻。這些門檻，形成一個門檻的集合, 並且可以上下調整以反映離開速率的增減。透過模擬的結果，到 continuous-based control 相比，stepwise-based control 的確有較佳的效率，並能精確使用較少且合理的門檻個數。甚至從模擬結果中顯示，stepwise-based 的機制比示有 single-static-threshold-based 的方法在 cell-loss probability 到 link utilization 上有較好的表示。

Abstract

The goal of the project is two-fold: ABR rate control, and self-similar traffic estimation. This report mainly presents the design and results of the ABR rate control. To support the ABR service in ATM networks, existing feedback-based rate control schemes mostly employ a single static buffer threshold at each switching nodes as the forewarning of congestion. Last year, we proposed a continuous-based adaptive rate control mechanism which employs, logically, an infinite number of thresholds. The scheme was shown to achieve high utilization and low cell loss probability under highly bursty traffic, but at the expense of a drastic increase in signaling overhead due to frequent adjustment of permitted rates. To reduce overhead, in this project, we propose a so-called stepwise-based rate control mechanism adopting a limited number of movable thresholds, referred to as the threshold set. The threshold set ships up (down) reflecting the increase (decrease) in departures rates. Compared to continuous-based control via simulation, stepwise-based control is shown to be efficient and accurate using a reasonably low number of thresholds.

Moreover, we also display simulation results, which demonstrate that the stepwise-based mechanism outperforms existing single-static-threshold- based schemes in terms of cell-loss probability and link utilization.

Keywords: Available Bit Rate (ABR), Quality of Service (QOS), Feedback-based rate control, Explicit Rate (ER), Binary rate control, Cell Loss Probability (CLP), Fluid model.

二、Motivation and Objective

The Available Bit Rate (ABR) [1] service in ATM networks has been deployed to allow efficient use of available bandwidth without degrading the Quality of Service (QOS) of admitted traffic. While the QOS of admitted traffic is guaranteed through admission control and bandwidth allocation, the ABR service has been realized via the feedback-based rate control [2,3]. Feedback-based rate control deals with the dynamic adjustment of the granted rates of ABR sources as network loads fluctuate in an attempt to minimize the performance degradation of QOS-guaranteed services. Existing rate control mechanisms operate either on an end-to-end [6,8,11] or hop-by-hop [7] basis. While both classes of control mechanisms possess individual performance merit, hop-by-hop-based control has been considered to be more promising due to its speed reaction to the fluctuation of network loads [9-10].

Most hop-by-hop-based schemes adopt static buffer threshold [7,9] at each switching node as the forewarning of congestion. In these schemes, a switching node sends feedback messages to its immediate upstream nodes should the buffer occupancy exceed the pre-determined threshold. The up-stream nodes in turn adjust the cell departure rates on either a simple binary rate (i.e., start and stop)[7] or a specified rate [9] basis. Mishra, *et al.* [9] proposed a predictive rate control scheme for determined the permitted rate and illustrated that the buffer occupancy and throughput of a control connection converge to a desired operating point. Kawahara, *et al.* [7] developed an analytical model based on binary rate control and showed significant performance improvement, in terms of Cell Loss Probability (CLP) and resource utilization, of the congested node but at the expense of signaling overhead.

Exhibiting various performance credits, these schemes, however, result in improper rate determination due to the employment of one static threshold. The goal of the project is to propose a feasible feedback-based rate controller augmented with the precise ER determinator.

Last year, we presented the architecture of our newly-designed feedback-based rate controller. Each switching node on which feedback-based rate control operates consists of a finite buffer and a Rate-Based Controller (RBC). In principle, in accordance with the buffer occupancy, the RBC of a switching node at each time unit determines the Updated Permitted transfer Rate (UPR) for all immediate up stream nodes through sending feedback messages incorporating such rates. This rates then becomes the Outbound Permitted Rate (OPR) of those immediate upstream nodes or the Inbound Permitted Rate (IPR) of this current node throughout the next time unit. The RBC is composed of a Flow Estimator, a Rate Determinator, and a Rate Regulator. At each time unit, the Flow Estimator predicts the aggregate flow of future incoming traffic based on the previous UPR and the current buffer occupancy. The Rate Determinator in turn determines the new UPR achieving two performance criteria, based on a rate control flow. Finally, the Rate Regulator ensures that the transfer rate never exceeds the granted OPR.

We also designed the Rate Determinator. We have proposed a continuous-based adaptive rate control mechanism which employs, logically, an infinite number of the thresholds. Each node periodically determines the precise permitted rate of immediate upstream nodes based on a simple fluid model aiming at satisfying both loss-free and starvation-free criteria.

The scheme was shown to achieve high utilization and zero CLP under deterministic traffic and low CLP under highly bursty traffic. The prize paid was, however, a drastic increasing in signaling overhead due to frequent adjustment of permitted rates.

三、Approach and Results

This year, we propose a so-called stepwise-based rate control mechanism adopting a limited number of movable thresholds, referred to as the threshold set. The threshold set ships up (down) reflecting the increase (decrease) in departures rates. Compared to continuous- based control via simulation, stepwise-based control is shown to be efficient and accurate using a reasonably low number of thresholds.

In stepwise-based rate control, each node, for example, node i, assigns a set of evenly distributed ($P+1$) UPR's, namely, $\{0, R_{i-1}/P, 2R_{i-1}/P, \ldots, R_{i-1}\}$, to respective $P+1$ partitions of the buffer space, delimited by a set of P movable thresholds. Basically, the threshold set is altered should the granted OPR or IPR be modified. Upon receiving the signaling of the reduction (increase) of the OPR, the threshold set shifts down (up) reflecting more (less) stringent constraint on the departure rate. On the other hand, as the granted IPR is reduced (increased), the threshold set shifts up (down) reflecting more (less) stringent constraint on the arrival rate. Fig. 1 depicts the threshold sets and legitimate UPR's with respect to the alteration of the granted OPR and/or IPR at node i.

As shown at the right side of Fig. 1, the legitimate UPR set shifts up as the OPR declines and/or the IPR rises due to the reduction of prositive thresholds. On the other hand, the legitimate UPR set shifts down as the OPR increases and/or the IPR declines, as shown at the left side of Fig. 1. Accordingly, at the beginning of each superslot, a new UPR is reassigned and notified to immediate upstream nodes only when the current buffer occupancy is altered to a different partition (this may occur when either the buffer occupancy or the threshold set is changed). Thus, if the buffer occupancy settles in the same partition, the granted UPR remains the same, resulting in the elimination of transferring feedback messages and, thus, the reduction in signaling overhead.

The stepwise-based rate control algorithm is formally presented in detail as follows.

```
Input: buffer size size- B (cells);
        number of partitions- P;
        maximum transfer rate- R (cell/slot);
Variable: x: buffer occupancy (cells);
        TH_n: nth threshold (cells) where
           1 ≤ n ≤ P;
        UPR_old: previous UPR (cell/slot);
        UPR_new: new UPR (cell/slot);
        OPR: outbound permitted rat (cell/slot)
-------------------------------------------------
Initiation: Δ : the inter-threshold width (cells);
        TH_0 = 0;
        TH_P+1 = B;
-------------------------------------------------
For super-slot k
  Do
  { (i). If UPR_new is received from immediate
         downstream node then
      {  set OPR = UPR_new;
         Calculate TH_1 based on Equation(16);
         For n=2 to P do TH_n=TH_n-1 + Δ ;  }
    (ii). For n = 0 to P do
        {   If (TH_n ≤ x < TH_n+1) then
              { UPR_new = (1 - n/p)R ;   }   }
    (iii). If ( UPR_new ≠ UPR_old ) then
         Notify UPR_new to immediate upstream
         nodes;                                  }
```

四、Merit Review of the Project

We proposed the stepwise-based rate control mechanism, adopting a limited number of movable thresholds. Simulation results justified the performance compatability of stepwise-based control to continuous-based control with signaling overhead much reduced. Moreover, simulation results also demonstrated the superiority of the stepwise-based mechanism over the existing single-static-threshold-based scheme in terms of cell loss probability and link utilization at the expense of torable signaling overhead.

五、References

[1] T. M. Chen, S. S. Liu, and V. K. Samalam, "The available bit rate service for data in ATM networks," in *IEEE Commun. Mag*,. May 1996, pp. 56-71.

[2] F. Bonomi and K. W. Fendick, "The rate-based flow control framework for the available bit rate ATM service," in *IEEE Network Mag*., March/April 1995, pp. 25-39.

[3] P. Newman, "Backward explicit congestion notification for ATM local area networks," in *Proc. IEEE GLOBECOM'93*, 1993, pp. 719-723.

[4] K. K. Ramakrishnan and R. Jain, "A binary feedback scheme for congestion avoidance in computer networks," in *ACM Trans. Comput. Sys*., vol. 8, No. 2, 1990, pp. 303-313.

[5] K. W. Fendick and M. A. Rodrigues, "Asymptotic analysis of adaptive rate control for diverse sources with delayed feedback," in *IEEE Trans. On Information Theory*, vol. 40, No. 6, Nov. 1994, pp. 2008-2025.

[6] F. Bonomi, D. Mitra and J. B. Seery, "Adaptive algorithms for feedback-based flow control in high-speed, wide-area networks," in *IEEE J. Select Areas Commun.*, vol. 13, No. 7, 1995, pp. 1267-1283.

[7] K. Kawahara, Y. Oie, M. Murata and H. Miyahara, "Performance analysis of reactive congestion control for ATM networks," in *IEEE J. Select Areas Commun.*, vol. 13, No. 4, 1995, pp. 651-661.

[8] L. Benmohamed and S. M. Meerkov, "Feedback control of congestion in packet switching networks: the case of a single congested node," in *IEEE/ACM Trans. On Networking*, vol. 1, No. 6, Dec. 1993, pp. 693-708.

[9] P. P. Mishra, H. Kanakia, and S. K. Tripathi, "On hop-by-hop rate-based congestion control," in *IEEE/ACM Trans. On Networking*, vol. 4, No. 2, Apr. 1996, pp. 224-239.

[10] G. Ramamurthy and B. Sengupta, "A predictive hop-by-hop congestion control policy for high speed networks," in *IEEE INFOCOM'93*, 1993, pp. 1033-1041.

[11] Y. Gong anf I. F. Akyildiz, "Dynamic traffic control using feedback and traffic prediction in ATM networks." In *IEEE INFOCOM'94*, 1994, pp. 91-98.

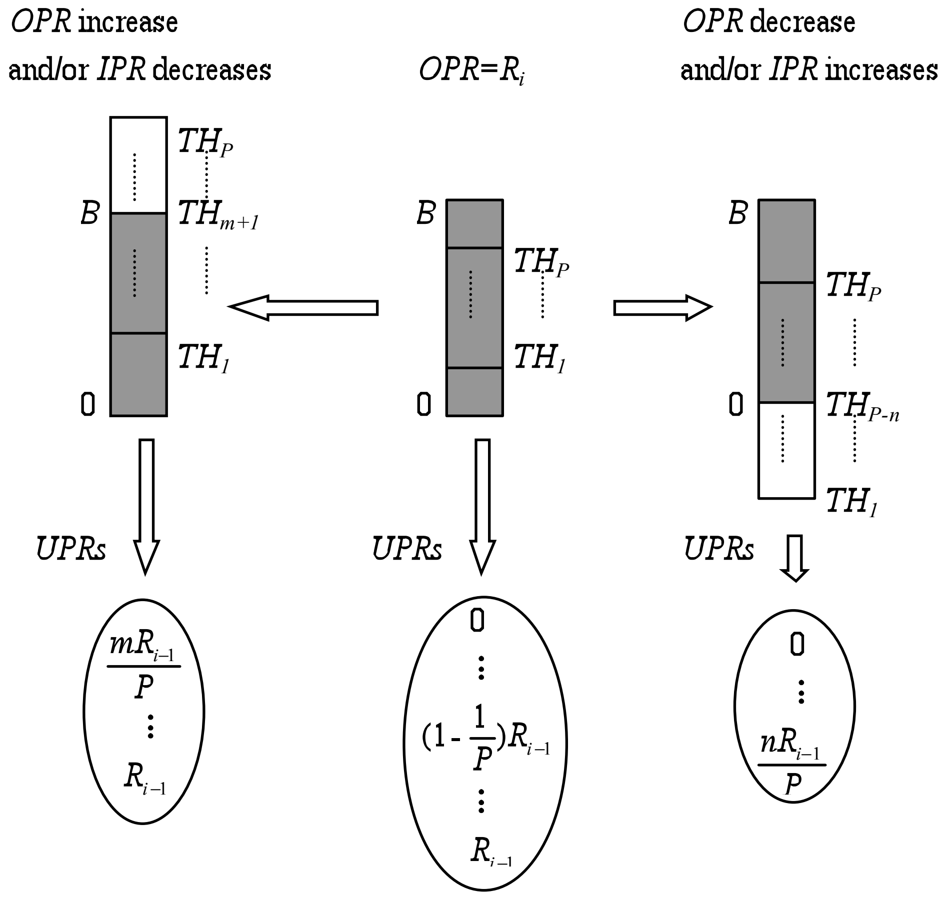

Figure 1. Sets of movable thresholds and UPR's at node *i*..