

行政院國家科學委員會補助專題研究計畫成果報告

寬頻網際網路之允入控制與訊務排程 (III)

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計畫主持人： 楊啟瑞 教授

共同主持人：

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行政院國家科學委員會專題研究計畫成果報告

寬頻網際網路之允入控制與訊務排程 (III)

Admission Control and Traffic Scheduling in Broadband Internet

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主持人：楊啟瑞 國立交通大學資訊工程研究所

一、中文摘要

今年，我們設計了一個運用在 broadband local/access 網路上，具QoS保證的MAC層通訊協定(QMAC)，其中運作的原理是藉由動態控制granularity (frame size) 的大小，在依然保持最大的throughput的情況下，提供隨用頻寬(bandwidth-on-demand) 的功能。QMAC支援三種ATM訊務 - CBR, VBR, ABR, 另外還有建立連線註冊用的訊務 - Reservation Request (RVR)。CBR/VBR/ABR的訊務是以reservation access的方式，在reservation bandwidth上傳送；RVR則是以random access的方式，在contention bandwidth上傳送。QMAC以動態的方式，決定每個由contention和reservation bandwidth所組成的訊框大小。對於reservation bandwidth的大小，以滿足所有已完成註冊CBR/VBR/ABR訊務的QoS為先決條件，頻寬的分配是將上述的條件加上weight-based的排程機制來決定。此外，基於neural-fuzzy 訊務推估技術，我們可以決定contention bandwidth的大小，仍以不破壞已完成註冊CBR/VBR/ABR訊務的QoS為先決條件。透過系統模擬的結果顯示，在現行數種不同的MAC通訊協定之中，以M/Pareto和動態的訊務輸入之下，QMAC在throughput, access delay, 和blocking probability上皆有很好的表現。所以，我們可以證明QMAC在broadband access 和local 網路上，不論在訊務排程或頻寬控制都有很好的效能。

關鍵詞：媒體存取控制，服務品質保證，類神經網路訊務預測技術。

Abstract

In the project of this year, we have proposed a QoS-guaranteed MAC protocol (QMAC) augmented with dynamic granularity (frame size) control for broadband local/access networks, aiming to provide bandwidth-on-demand while retaining maximal throughput. QMAC supports three types of ATM traffic - CBR, VBR, ABR, along with Reservation Request (RVR) traffic for making connection reservation. While CBR/VBR/ABR is governed by reservation access over the reservation bandwidth, RVR is conducted by random access over the contention bandwidth. QMAC essentially exerts dynamic granularity control on per-frame-based allocation of the reservation and contention bandwidth. The reservation bandwidth is allocated following a weight-based scheduling policy. For the allocation of the contention bandwidth, based on a neural-fuzzy traffic prediction technique. Simulation results demonstrate that, compared to a set of MAC alternatives under M-Pareto-distributed and dynamic traffic settings, QMAC invariantly achieves superior performance with respect to throughput, access delay, and blocking probability. Ultimately, QMAC facilitates traffic scheduling and bandwidth control for broadband access and local networks.

Keywords: Medium Access Control (MAC), Quality-of-Service (QoS), Neural-fuzzy traffic prediction.

二、緣由與目的

It is envisioned that next-generation broadband local/access networks should be capable of supporting integrated multimedia services with a wide range of service rates and different Quality-of-Service (QoS) requirements. Expected supported services include Constant Bit Rate (CBR), Variable Bit Rate (VBR), and Available Bit Rate (ABR). Examples of QoS requirements for VBR and ABR traffic are bounded delay and Minimum Cell Rate (MCR), respectively. A major challenge pertaining to such wireless ATM networks is the design of traffic scheduling, namely a Medium Access Control (MAC) protocol achieving multiple access efficiency and QoS guarantees.

Existing MAC classes, such as Time-Division Multiple Access (TDMA) [1,2,3] and Code-Division Multiple Access (CDMA) [1,3], exhibit various performance merits and weaknesses. TDMA can be further categorized as either Frequency-Division-Duplex (FDD) [1], in which uplink and downlink traffic are carried by two distinct carrier frequencies, or Time-Division-Duplex (TDD) [2], where only one common carrier frequency is used. In this paper, we focus on the design of a TDMA FDD-based MAC scheme. Moreover, TDMA operates in one of three different manners: reservation-based, random-access-based, or the combination (hybrid-based). Compared to the former two schemes, the hybrid-based TDMA [1] has been considered most promising. In essence, reservation access is indubitably favorable for guaranteed (e.g. CBR/VBR) services, whereas random access is suitable for making reservation. Such reservation traffic is hereinafter referred to as Reservation Request (RVR) traffic.

Furthermore, medium bandwidth is generally shared on a frame basis. Most schemes proposed in the literature advocate the use of a fixed [4,5,6], or variable but unrestricted [7] sharing granularity (frame size). Using a simple fixed-size frame, PRMA and companions [4] considered the QoS guarantee for traditional CBR voice traffic only. Aiming to provide dynamic bandwidth allocation

among CBR/VBR/ABR traffic via fixed granularity, PRMA/DA [5] unfortunately suffered from a noticeable increase in VBR delay in the presence of heavier CBR loads. Likewise, using fixed granularity, the scheme proposed in [6] separately considered QoS guarantees for CBR/VBR traffic and fair access for ABR traffic. Adopting a variable but unrestricted-length frame structure, RMAV [7] was shown viable for local networks supporting data traffic only. Essentially, we believe dynamic granularity facilitates a finer bandwidth control and would result in improved performance. This is the first primary feature of our MAC design.

Random access inevitably undergoes collisions, resulting in a decrease in network utilization and increase in access delay. To alleviate the problem, existing schemes have exerted various syntheses of the following three basic policies: collision avoidance (CA) [8,9], collision reduction [10], and collision resolution [8,11,12]. The former two policies engage in collision prevention by making the collision occurrence unlikely and less likely, respectively. Examples are the 802.11 CSMA/CA protocol [8] and controlled-ALOHA [10], respectively. The last policy undertakes collision correction should collisions have occurred. Examples are exponential backoff [8], feedback-based controlled retransmission [11], or dynamic tree splitting [12]. Unlike these policies, we tackle the problem by allocating the so-called “favorable bandwidth” suggesting maximal utilization, based on a novel neural-fuzzy traffic prediction technique. This is the second primary feature of our system design.

三、結果與討論

The major challenge we have encountered is the allocation of the Contention Bandwidth (CB). To approach it, we have designed a dynamic granularity control mechanism working in conjunction with a neural-fuzzy traffic prediction technique. Initially, dynamic granularity control predicts the normalized offered load of RVR traffic contending for bandwidth within the next

contention period. Based on a closed-form formula, granularity control then derives the FB. If the FB is less than the remaining unreserved bandwidth, the final CB to be allocated is set as the FB. Due to more bandwidth to be supplied than demanded in this case, every MT is allowed to access bandwidth unconditionally by randomly contending for a slot uniformly distributed among the CB. This type of access is called uncontrolled-ALOHA (parameterized with $p_{AL}=1$).

If the FB exceeds the remaining unreserved bandwidth, only the remaining bandwidth is allocated as the final CB. Unlike the previous case, owing to insufficient bandwidth, each MT can only access bandwidth with probability p_{AL} aiming to attain maximal throughput. This type of access is called controlled-ALOHA parameterized by $p_{AL} < 1$. Notice that the CB size and parameter p_{AL} are broadcast to MT's prior to the beginning of the contention period. In the sequel, we describe the detailed design of dynamic granularity control particularly on CB.

Essentially, the CB allocation process is performed serially in three phases: Neural-Fuzzy Traffic Prediction (NFTP), FB/CB determination, and learning data construction. Figure 1 depicts the three-phase process of determining CB allocation for frame n , namely CB_n , at time t_c .

In the first phase, the NFTP network predicts \hat{g}_n at time t_c , based on a set of m input values ($m=3$, in Figure 2) taken from m most-recent g_k values ($k=n-1$ to $n-m$). In the second phase, based on \hat{g}_n , the system derives the FB_n and ultimately determines the CB_n . In addition to prediction, at the end of contention period of frame n , NFTP has to perform the learning operation using the learning data constructed in the third phase. This is indicated in Figure 2 by the dotted link pointing back to the NFTP network.

We undertook event-based simulation for a set of MAC schemes under two different traffic settings. The MAC schemes include CBF (Fixed CB)- x , CBV (Variable CB)-FF (Fixed-Frame), CBV-WP (With Prediction), and QMAC. The CBF- x schemes used fixed

CB of x slots in length. The CBV-FF scheme, based on a fixed frame structure, designated variable-size remaining unreserved bandwidth as the CB. Employing variable-size frames and the CB, CBV-WP was furnished with coarse traffic prediction based on the traffic characteristic from the previous frame. Finally, QMAC adopted variable-size frames and CB, but used NF-based traffic prediction (NFTP). In particular, NFTP is a correlation-based [12] network accepting twelve inputs respectively corresponding to twelve exponential-averaging k -lag correlations, where $k=1$ to 12.

The two traffic settings were static M-Pareto-distributed traffic, and dynamic traffic. In the static setting, for any given load, we generated M-Pareto-distributed traffic [16] parameterized by a Hurst parameter, $H=0.9$. Simulation was terminated after reaching 95% confidence interval. In the dynamic setting, aiming to emulate realistic traffic with no priori distribution, for a given load, we generated Poisson arrivals of ten different loads, yielding the average load identical to the given load. For example, for a given load of 0.5, the load generated is $u \cdot x$, where u is an integer uniformly distributed between 1 and 10, and $x = 0.5 \times 10 / \sum_{k=1}^{10} k$. Simulation was terminated

after an execution of 10^4 different sample paths, each of which elapsed for 100 frames long. Simulation results demonstrate that, compared to a set of MAC alternatives under M-Pareto-distributed and dynamic traffic settings, QMAC invariantly achieves superior performance with respect to throughput, access

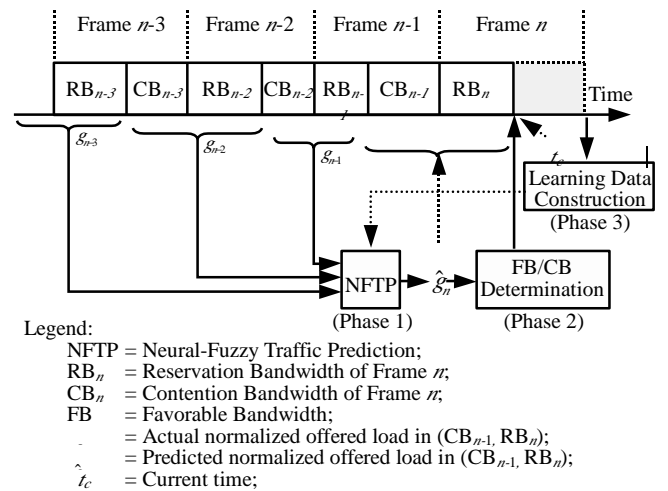


Figure 1. Dynamic granularity control on contention bandwidth allocation.

delay, and blocking probability.

四、計畫成果自評

Simulation results demonstrated that QMAC is superior to five other MAC schemes, with respect to throughput, access delay, and blocking probability, under both static M-Pareto-distributed and dynamic traffic settings. Significantly under dynamic traffic, QMAC is at least two orders of magnitude better than static-granularity-based MAC schemes in access delay and blocking probability. Finally, QMAC achieves much improved throughput and access delay than the MAC scheme using coarse traffic predication under dynamic traffic. A formal form of this report has been accepted and published in IEEE ICC 2001. Finally, the basic design and architecture is under patent application.

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