Measurement-based Admission Control Using Wavelets for Broadband Networks

Baek-Young Choi, Zhenhai Duan, Zhi-Li Zhang, and David H.C. Du

Department of Computer Science & Engineering

University of Minnesota, Minneapolis, MN 55455

{choiby, duan, zhzhang, du}@cs.umn.edu

Abstract

The current broadband networks allow a number of widely disparate traffic streams to share common resources through statistical multiplexing. How efficiently the resource sharing can be managed depends critically upon the analysis of statistical characteristics of the traffic. Numerous analyses of traffic measurements have shown that a large variety of network traffic, in WAN as well as in LAN, exhibits self-similar bursty behavior or long-range dependency (LRD). Self-similar traffic shows structural similarities across a wide range of time-scales (milliseconds, seconds, minutes, etc) and can be characterized by just one parameter (Hurst parameter). Many studies have shown that self-similar network traffic may have a detrimental impact on network performance, including increased queuing delay and packet loss rate under traditional queuing analysis and simulations [8].

It has been shown that network traffic traces exhibit only asymptotically self-similar behavior rather than strict self-similarity. Furthermore, the multifractal nature of WAN traffic was recently revealed [5]. With multifractal nature of traffic, buffer queueing prediction may be over-optimistic even when taking LRD into consideration [4]. The implications of those complex traffic behaviors add increased difficulty to optimizing resource usage such as call admission control. We also believe that analyzing large rapid variations (local singularity) of the traffic i.e. short range dependency (SRD) of traffic is also important particularly for call admission control which determines whether to accept a call or not depending on the rapidly changing traffic stream and its available resource.

Admission control algorithms for guaranteed service in the integrated service model or premium service in the differential service model use *a priori* characterization of sources to calculate the worst case behavior of all the existing flows in addition to the incoming one. This may, however result in low utilization especially when flows are bursty. Better network utilization can be achieved by providing statistical service guarantees based on a statistical characterization of controlled load service in integrated service or assured service in differential service model. In general, it is hard for a source to pre-specify its behavior precisely. Thus measurement-based call admission control may potentially accomplish higher resource utilization with knowledge of ongoing traffic.

In this paper, we develop a measurement-based call admission control algorithm using *wavelet* analysis for resource allocation to achieve a high level of network utilization while attaining reasonable packet loss rate dealing with multifractal traffic as well as SRD, LRD and self-similar traffic in broadband networks. In our call admission control algorithm, wavelet analyses are used to compute an *effective capacity*. Wavelets transform a signal from the time domain into the frequency domain. Unlike Fourier transform, temporal analysis and frequency analysis can be done in wavelet transform at the same time by dealing with the input signal at different scales or resolutions. I.e. on a large scale, it focuses on rough features, whereas on a small scale, minor features are of interest. Because of the weighted filters and dual localization in time and frequencies the wavelets are a more appropriate tool for signal/noise separation than a Fourier transformation. Haar wavelet transform effectively decorrelate LRD data as well as SRD data and are able to predict how a particular workload measured over large-

time scales is distributed over smaller time scales. With Haar wavelets, the burst traffic noise can be detected faster and only at spots where noise really occurs. It turns out to be a powerful tool for characterization of traffic including self-similar, multifractal traffic and also captures local singular behavior of traffic.

In the proposed algorithm, traffic measurements of transmission rates are taken periodically and based on the partially overlapping traffic sampling measurements, the wavelet analyzer calculates the effective capacity which is a value summarizing resource usage depending on statistical properties and QoS requirement of sources of the class. It determines the trade-off between statistical gain and a certain packet loss rate. A call is admitted to a source if the effective capacity would be less than the allocated bandwidth for that class with the addition of the new connection. The effective capacity is responsible for how well the traffic is characterized. The effective capacity can still be computed in $O(N)$ worst case.

The wavelet-based partition function $S(q,j)$, which is defined by summing across the q-th moments(with $q > 0$) of the absolute value of the normalized wavelet coefficients at level j, is evaluated and the tendency of decreasing rate is checked. If the partition function is not decreasing more than the previous level, the transform stops at that level and it finds the maximum of the approximate coefficients which becomes the effective capacity for the traffic measurement. Thus the wavelet transform does not need to be done for every whole iterative steps.

We performed simulation on various kinds of traffic including real LAN, WAN traces as well as Pareto and exponential ON/OFF data. The proposed method can deliver significant gain in utilization even though the effective capacity is not computed often which implies that it fulfills efficient traffic characterization.

The proposed measurement-based call admission control algorithm does not require pre-assumptions of the traffic as in traditional statistical traffic characterization. It is more adaptable to changing traffic with multifractal as well as long-range dependent traffic through wavelet analysis, which captures characteristics of the burstiness, and scaling of higher order moments.

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