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Concave piecewise linear service curves and deadline calculations

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Abstract

The Internet is gradually and constantly becoming a multimedia network that needs mechanisms to provide effective quality of service (QoS) requirements to users. The service curve (SC) is an efficient description of QoS and the service curve based earliest deadline first policy (SCED) is a scheduling algorithm to guarantee SCs specified by users. In SCED, deadline calculation is the core. However, not every SC has a treatable deadline calculation; currently the only known treatable SC is the concave piecewise linear SC (CPLSC). In this paper, we propose an algorithm to translate all kinds of SCs into CPLSCs. In this way, the whole Internet can have improved performance. Moreover, a modification of the deadline calculation of the original SCED is developed to obtain neat and precise results. The results combining with our proposed algorithm can make the deadline calculation smooth and the multimedia Internet possible.

Keywords: Concave piecewise linear service curve; Deadline calculation; Quality of service; SCED; Differentiated services

1. Introduction

The Internet will be full of multimedia transmission in the future. Due to the diversities of multimedia traffic, different flows/classes should be treated differently to provide appropriate quality of service (QoS) required by users. For this purpose, the Internet engineering task force (IETF) has developed two service architectures: IntServ and DiffServ. A possible architecture suitable to the current Internet is depicted in Fig. 1 of [7], where the IntServ is applied to LAN (or intranet) and the DiffServ is applied to WAN (or the Internet). Furthermore, [7] reviewed some QoS issues and pointed out two essential implementation considerations in a multimedia QoS application: a user-oriented QoS specification and dynamic queue mapping. In addition to architecture, specification, and mapping discussed in [7], there are many approaches for solving QoS problems in the Internet, e.g., multicast routing protocols [10,16], active queueing management (AQM) [4,6,14], input-queue

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scheduling [1], (output-queue) scheduling [11–13], and so on. All the above methods cooperate to provide QoS to users. Scheduling is one of the most important methods to solve QoS problems and the service curve (SC) [2,13] is an efficient way to describe of QoS requirements. Furthermore, the concave piecewise linear SC (CPLSC) [13] is the most useful SC, because CPLSC offers time-variant service rates for users and possesses treatable deadline calculation for the scheduler with service curve based earliest deadline first policy (SCED) [13]. This motivates us to develop an algorithm for translating all kinds of SCs into CPLSCs.

The terminology service curve (SC) was first mentioned by Parekh [11]. The formal definition of SC was proposed by Cruz in 1995 for a discrete time (slot-based) model [2] and then extended by Boudec for a continuous case [8,9]. However, in Cruz's definition the SC is the curve that the system should provide to fulfill the users' request, while Parekh's SC is just the output curve from the system. In addition, there is a close relation between the SC and the network calculus. The network calculus was originally proposed by Cruz [3], and he performed the calculus of network delay without using SC. After the appearance of SC, Boudec combined the concept SC with the (min, +)-algebra to make network calculus easier, and it has become the standard scheme.

The above survey mainly focuses on the network calculus when the system/node can provide the required SC. However, a method to provide SC has not been reported yet. If an SC is assigned by a user, how can a system provide the service guarantee required by the SC? To solve this problem, Sariowan developed a scheduler called SCED to guarantee the SC [13]. In SCED, the key factor is to determine the packet's deadline and to use that as the base for scheduling. A recursive relation has been derived to find the deadline in [13], in which CPLSC is the only treatable SC and the determination of deadline is still a very difficult task for general cases. Two special cases are discussed in [13]: one for a partial linear SC, which is linear after a certain time, and the other for a CPLSC. Their algorithms for deadline calculation are shown in the Appendix for reference. Another special case of a partial linear SC is discussed in [12], where the SC is 0 before a certain time and is linear after that time. In fact, the case studied in [12] is a special case of the partial linear SC in [13] and the derivation of [12] is the same as that in [13].

On the Internet, the SC is specified by a user and is taken as the QoS parameter by routers, which are generally the main bottleneck of the Internet. One way to improve the performance of the Internet is to reduce the loads of routers. Since a non-CPLSC creates many loads for a router using an SCED scheduler, the SC should be simplified at the user ends or at the edge routers to improve the performance of the Internet.

In this paper, an algorithm, known as CPL Algorithm (CPLA), is proposed to translate all kinds of SCs into CPLSCs. The algorithm consists of two steps, in which the first step translates any kind of SC into a piecewise linear SC, not necessarily concave, and the second step translates the piecewise linear SC into a CPLSC. In addition, two related works are also mentioned in this paper. One is to re-derive the packet's deadline and to obtain a clearer and more compact recursive relation for CPLSC, and the other is to improve the SCED in [13]. Using these, a more precise SCED and an easier approach for the deadline will be obtained and, upon combining with CPLA, the deadline calculation will be less complex for any kind of SC. That is, the purpose of this paper is to make the networks, which use SCED policies, have treatable complexity. For this purpose, an algorithm is needed to translate a non-CPLSC to a CPLSC. It is also the importance of this work. Furthermore, some additional results are obtained in this paper, including some modifications and some enhancements to the SCED in [13]. When an SC has a treatable deadline calculation, it can be employed in a multimedia network. As stated in [13, p. 699], an SC can best match the QoS required by the user. In this way, the Internet can assign QoS to multimedia flows to facilitate the multimedia Internet, because the QoS requirements of multimedia flows can be properly described by SCs, which describe the required service quantities as the transmission time approaches.

This paper is organized as follows. Section 2 reviews and refines the SCED. The CPLA algorithm is described in Section 3. Section 4 re-derives the recursive relation of the deadline calculation for CPLSC and improves SCED. The paper is concluded in Section 5.

2. SCED

2.1. Reviewing SCED

We rewrite the necessary concepts and equations below for completeness.