Chapter 1

Introduction

Taking a single global IP based packet switched networks to carry all types of networks, telecommunication is moving toward a converged network to replace the traditional separated packet switched and circuit switched networks [1]. This revolutionary converged All-IP network not only reduces network deployment and management costs, but also offers a great opportunity to introduce various new services that are not possible on the traditional separated networks.

The idea of a single shared physical network that will support multiple heterogeneous applications, that is, applications with different traffic characteristics and different Quality of Service (QoS) requirements, is widely regarded as the way to meet the telecommunication challenges of the future [10], [20], [34]. Packet-switched networks have been proposed to offer the QoS guarantees in integrated-services networks, because in networks individual packets may exhibit a significant variation in network service quality.

Packet switched networks suffer three major quality problems in offering time-sensitive services: long delay time, jitter, packet loss. The Universal Mobile T-elecommunications System (UMTS) [1] has specified four different traffic classes according to their quality of service (QoS) requirements for different applications

Table 1.1: UMTS Service Classes

Traffic Classes	Examples of Applications	Sensitivity to Jitter	Sensitivity to Delay	Sensitivity to Packet Loss
Conversational	VoIP	high	high	low
Streaming	VoD	high	high	low
Interactive	WWW, Telnet	low	low	high
Background	E-mail, FTP	very low	low	high

as Table 1.1 shows.

Among various schemes used in practice, QoS routing ([12], [26], [31]) concerns the selection of a path satisfying the QoS requirements of a connection. The path selected most likely is not the traditional shortest path. Depending on the specifics and the number of QoS metrics involved, computation required for path selection can become prohibitively expensive as the network size grows. The path selection process involves the knowledge of the connection's QoS requirements and characteristics and (frequently changing) information on the availability of bandwidth. Resource allocation decisions in networks are concerned with the allocation of limited bandwidth so as to achieve the best system performances.

Telecommunication networks are facing the increasing demand for Internet services. Therefore, a problem of network dimensioning with elastic traffic [25] arises which requires to allocate bandwidth to maximize service flows with fair treatment of all the services. Fair resource allocation problems are concerned with the allocation of limited bandwidth among competing activities so as to achieve the best overall performances of the system but providing fair treatment of all the competitors. We introduce the methodology that allow the decision maker to explore a set of solutions that could satisfy users' preferences with respect to throughput and fairness (see [16], [18], [25], [27]). In various systems which serve many users, like in telecommunications systems, there is a need to respect the fairness rules, that is, to allocate resources equitably among the competing services. In this work, we will adopt the approach called Proportional Fairness (see [16], [18], [27]) to maximize the sum of logarithms of the bandwidth θ^i for each class i. The use of the logarithmic function makes it impossible to choose zero bandwidth for any pair of nodes, and, on the other hand, makes it not profitable to assign too much bandwidth to any individual demand. The optimization model of the Proportional Fairness method takes the following form:

$$\max \sum_{i=1}^{m} \log(\theta^i) \tag{1.1}$$

The challenge in integrated-services networks [31] is to determine general resource allocation and QoS routing schemes that have the following desirable features: (i) they meet the QoS requirements of the services provided by the network; (ii) they efficiently allocate resources by appropriately distributing the QoS among the various resources at each link along the path of a connection; (iii) they satisfy the user's preferences as simultaneously are social-welfare maximizing.

Different people have different objectives for the network QoS. There are a number of characteristics that qualify QoS [36], including minimizing delivery delay, minimizing delay variations, providing consistent data throughput capacity, etc. In a multiple-objective decision-making situation in the absence of uncertainty we often search for Pareto optimal solutions[1]. In a typical multiple-objective model of realistic size, especially one with more than two objectives, the range of efficient solutions can be enormous. One scheme [23] for dealing with multiple-objective models that permits more balanced handling of the objectives is simply to combine them in a weighted sum. Multiple objective functions can be combined into a single composite one by summing objectives with positive weights on maximizing and negative weights on minimizing [35]. Signs orient all objectives in the same direction, and weights reflect their relative importance. If a single weighted-sum objective model derived from a multiple-objective optimization produces an optimal solution, the solution is undominated by any other one; simply we call it a Pareto

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[1] A solution (say $\mathbf{x}$) to a multiple-objective problem is Pareto optimal if no other feasible solution is at least as good as $\mathbf{x}$ with respect to every objective and strictly better than $\mathbf{x}$ with respect to at least one objective. This means that each feasible decision vector for which one cannot improve any attribute value without worsening another is a Pareto optimal solution.

optimal solution of the multiple-objective model. In this work, we use the method of weighted sums to solve (1.1).

In short, we deal with the problem of dimensioning bandwidth for elastic data applications in packet-switched communication networks, which can be considered as a multiple-objective optimization model. In our work, we will focus on the following subjects:

i. How do we transform the different criteria measurement onto a normalized scale?

ii. How do we allocate resources with proportional fairness and find a routing scheme on All-IP communication networks?

iii. How do we modify the nonlinear multiple-objective problems as solvable Mixed-Integer programming models?

We present an approach for the fair resource allocation problem and QoS routing in All-IP networks that offer multiple services to users. The basic function of QoS routing [12] is to select a path that is likely to be able to meet the QoS requirements. Users' satisfaction is summarized by means of their achievement functions, and each user is allowed to request more than one type of service. The objective of the optimization problem is to determine the amount of required bandwidth for each class to maximize the sum of the users' satisfaction.

The contributions of this work are:

1. The construction of a achievement function that has the following features:
    (a) It can map different criteria onto a normalized scale.
    (b) It may be interpreted as a measure of QoS on All-IP networks.
2. The formulation of a general bandwidth allocation model with proportional fairness.

3. A scheme of the routing optimization problem with end-to-end QoS guarantees.

The remainder of this thesis is organized as follows. In the next chapter we introduce the concept of QoS on All-IP networks. In Chapter 3, we construct the achievement function to transform the different measurements onto a normalized scale. In Chapter 4, basic fair solution concepts for resource allocation are formally introduced, and the ordered outcomes are used to introduce Nonlinear Programming Pareto optimal implementable solution concepts allowing to model various fair allocation schemes. Next, we present a routing scheme under consideration of the delay. The optimal path provides the End-to-End QoS guarantees to each user. A numerical example is given in Chapter 5. Finally, in Chapter 6, we remark results of our work and suggest some future studies.