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Quality of Service in the Emerging Networking Panorama

Fifth International Workshop on Quality of Future Internet Services, QofIS 2004 and First Workshop on Quality of Service Routing, WQoSR 200 and Fourth International Workshop on Internet Charging and QoS Technology, ICQT 2004 Barcelona, Catalonia, Spain, September/October 2004, Proceedings

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Preface

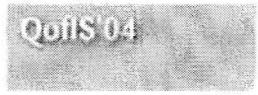
This volume of the Lecture Notes in Computer Science series contains the set of papers accepted for presentation at the 5th International Workshop on Quality of future Internet Services (QofIS 2004) and at the two one-day workshops co-located with QofIS 2004, namely the 1st International Workshop on QoS Routing (WQoSR 2004) and the 4th International Workshop on Internet Charging and QoS Technology (ICQT 2004).

QofIS 2004, the fifth international event, was organized under the umbrella of the E-NEXT Network of Excellence on "Emerging Networking Experiments and Technologies", which started its activities in January 2004. QofIS 2004 took place on September 29–30, 2004 at the Telefónica premises in Barcelona, and was arranged by the Universitat Politècnica de Catalunya (UPC). QofIS 2004 in Barcelona followed the highly successful workshops in Stockholm in 2003, Zürich in 2002, Coimbra in 2001, and Berlin in 2000. The purpose of QofIS 2004, as of all QofIS events, was to present and discuss design and implementation techniques for providing quality of service in the Internet.

The impact of emerging terminals, mobility and embedded systems is creating a new environment where networks are ambient. New challenges are opened by this new space where networks of interest ranging from personal networks to large-scale application networks need to be designed and often integrated. Protocol mechanisms for supporting quality of service at the different layers of the networks need to be assessed and eventually redesigned in such environments. In this context, the focus of the QofIS 2004 workshop was on the provisioning of *Quality of Service in the Emerging Networking Panorama*, assessed by results of experiments carried out in simulation platforms and test-beds, and given the progressive irruption of optical technologies.

QofIS 2004 contributed to this LNCS volume with 22 research papers selected from the 91 submissions received by the workshop, which address specific problems of quality-of-service provisioning in the fields of Internet applications, such as P2P and VoIP; service differentiation and congestion control; traffic engineering and routing; wireless LAN, ad hoc and sensor networks; and mobility in general. According to this, the workshop was organized in five sessions and featured two invited talks, by Prof. Ian F. Akyildiz of the Georgia Institute of Technology (USA) and Prof. David Hutchison of the University of Lancaster (UK), and was closed with a panel session, "New Face for QoS", featuring QofIS 2004 invited speakers and leaders of FP6 Networks of Excellence in networking and QoS provisioning.

August, 2004



Josep Solé-Pareta
Michael Smirnov

The 1st Workshop on Quality of Service Routing was motivated by the growing number of contributions on this topic within the papers submitted to previous QofIS editions. We thought it would be worth having a set of sessions focused on QoS routing aspects and we decided to organize it as a co-located workshop within QofIS.

Quality of service routing poses several challenges that must be addressed to enable the support of advanced services in the Internet, both at intra- and inter-domain levels. The challenges of QoS routing are related to the distribution of routing information and to path selection and setup throughout the network. Extensive research has been carried out on QoS routing in the past few years. New frontiers are opening up to QoS routing such as the introduction of QoS routing in ad hoc, wireless multihop, sensor and self-organized networks, in content delivery networks and in optical technologies.

The purpose of this workshop was to summarize current research in QoS routing, describing experimental and theoretical studies, and to point out new research directions leading to *Smart Routing*. We were glad to see that 28 papers were submitted to the workshop, with authors from 15 different countries and covering a wide range of topics focused on QoS routing. After the reviewing process, 8 papers were selected, those that are included in this LNCS volume. The final WQoSR 2004 program was structured in two technical sessions, respectively devoted to Algorithms and Scalability issues and to Novel Ideas and Protocol Enhancements, and an invited talk given by Prof. Ariel Orda from the Technion at Haifa (Israel).

We hope the reading of these selected papers might be appealing and stimulating for the research community and that this workshop will be continued in the future.

August, 2004

Piet Van Mieghem
Jordi Domingo-Pascual
Edmundo Monteiro

The International Workshop on Internet Charging and QoS Technology (ICQT 2004) was the fourth event in a series of very successful annual workshops on network economics and Internet charging mechanisms. After establishing ICQT in 2001 in Vienna, Austria, the workshop was co-located once before with QofIS in 2002 in Zürich, Switzerland. The 2003 workshop took place in Munich together with NGC 2003. In 2004, ICQT was again co-located with QofIS and provided further vivid proof of the stimulating interdisciplinary combination of economics and networking technology, which has made these workshops a success story.

As in previous years, ICQT 2004 received more than 20 submissions from 14 different countries. Our enthusiastic Technical Program Committee managed to provide between 3 and 5 reviews per paper. Eventually, 8 papers were selected for the final program and arranged to form sessions on Auctions and Game Theory,

Charging in Mobile Networks, and QoS Provisioning and Monitoring. Together with the traditional invited lecture, this program presented a broad view on current research work in the interesting area where economy meets technology, where theory meets application, and where *"QoS has its price"*, as is stated in the title of ICQT 2004.

August, 2004

Peter Reichl
Burkhard Stiller
Richard Gibbens

Acknowledgments

It is our pleasure to acknowledge the excellent work done by the members of the QofIS 2004, WQoSR 2004 and ICQT 2004 program committees, and by the reviewers assigned by them, in helping to select the papers for this LNCS volume from the respective submissions. It was work done in addition to the daily line of business and we were fortunate to have had such a committed and careful group of experts help us.

The arrangements for the workshop were handled with wonderful dedication by the local organization committee, with the inestimable help of Anna Cutillas and Lluïsa Romanillos of the *Servei de Relacions Institucionals i Internacionals* of the UPC.

The QofIS 2004 website was built and maintained by the staff of the *Laboratori de Càlcul de la Facultat d'Informàtica de Barcelona*, also of UPC, led by Rosa Maria Martín. In particular we thank Xavier Rica (our webmaster) for his dedication and care in fixing all the details of the QofIS 2004 website.

Finally, the administrative issues were carried out by the secretariat of the Computer Architecture Department, our special thanks to Mercè Calvet and Juani Luna.

Organization

QofIS 2004 was organized by the Advanced Broadband Communications Centre (CCABA) of UPC, the Technical University of Catalonia (Spain). The CCABA (http://www.ccaba.upc.es) is a multidisciplinary laboratory composed of researchers from both the Computer Architecture Dept. and the Signal Theory and Communications Dept. of the UPC.

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Performance Analysis of Peer-to-Peer Networks for File Distribution

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Abstract. Peer-to-peer networks have been commonly used for tasks such as file sharing or file distribution. We study a class of cooperative file distribution systems where a file is broken up into many chunks that can be downloaded independently. The different peers cooperate by mutually exchanging the different chunks of the file, each peer being client and server at the same time. While such systems are already in widespread use, little is known about their performance and scaling behavior. We develop analytic models that provide insights into how long it takes to deliver a file to N clients. Our results indicate that the service capacity of these systems grows exponentially with the number of chunks a file consists of.

1 Introduction

Peer-to-peer systems, in which peer computers form a cooperative network and share their resources (storage, CPU, bandwidth), have attracted a lot of interest lately. They provide a great potential for building cooperative networks that are self-organizing, efficient, and scalable.

Research in peer-to-peer networks has so far mainly focused on content storage and lookup, but fewer efforts have been spent on content distribution. By capitalizing on the *bandwidth* of peer nodes, cooperative architectures offer great potential for addressing some of the most challenging issues of today's Internet: the cost-effective distribution of bandwidth-intensive content to thousands of simultaneous users both Internet-wide and in private networks.

Cooperative content distribution networks are inherently *self-scalable*, in that the bandwidth capacity of the system increases as more peers arrive: each new peer requests service from, but also provides service to, the other peers. The network can thus spontaneously adapt to the demand by taking advantage of the resources provided by every peer.

We present a deterministic analysis that provides insights into how different approaches for distributing a file to a large number of clients compare. We consider the simple case of N peers that arrive simultaneously and request to download the same file. Initially, the file exists in a single copy stored at a node called *source* or *server*. We assume that the file is broken up into *chunks* and

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that peers cooperate, i.e., a peer that has completely received a chunk will offer to upload this chunk to other peers. The time it takes to download the file to all peers will depend on *how* the chunks are exchanged among the peers, which is referred to as peer organization strategy.

To get some insights into the performance of different peer organization strategies, we analytically study three different distribution models:

- A linear chain architecture, referred to as *Linear*, where the peers are organized in a chain with the server uploading the chunks to peer P_1, which in turn uploads the chunks to P_2 and so on.
- A tree architecture, referred to as $Tree^k$, where the peers are organized in a tree with an outdegree k. All the peers that are not leaves in the tree will upload the chunks to k peers.
- A forest of trees consisting of k different trees, referred to as $PTree^k$, which partitions the file into k parts and constructs k spanning trees to distribute the k parts to all peers.

We analyze the performance of these three architectures and derive an upper bound on the number of peers served within an interval of time t. We consider a scenario where each peer has equal upload and download rates of b. The upload rate of the server is also b. We focus on the distribution of a single file that is partitioned into C chunks. The time needed to download the complete file at rate b is referred to as *one round* or 1 unit of time. Thus, the time needed to download a single chunk at rate b is $1/C$. For the sake of simplicity, we completely ignore the bandwidth fluctuation in the network or node failures. We assume that the only constraint is the upload/download capacity of peers.

Several systems have been recently proposed to leverage peer-to-peer architectures for application-layer multicast. Most of these systems target streaming media (e.g., [1,2,3,4]) but some also consider bulk file transfers (e.g., [5,6]). Experimental evaluation and measurements have been conducted on real-world several peer-to-peer systems to observe their properties and behavior [7,8,9,10] but, to the best of our knowledge, there has been scarcely any analytical study of distribution architectures for file distribution. We are only aware of one other paper that evaluates the performance and scalability of peer-to-peer systems by modeling the propagation of the file as a branching process [11]. However, no particular distribution architecture is assumed. The results of this paper indicate that the number of clients that complete the download grows exponentially in time and are in accordance with our results.

The rest of the paper is organized as follows. Section 2 introduces the *Linear* architecture. In Section 3 we study $Tree^k$ and we evaluate $PTree^k$ in Section 4. We then presents a comparative analysis of the three distribution models in Section 5 and conclude the paper in Section 6.

2 *Linear*: A Linear Chain Architecture

In this section, we study the evolution over time of the number of served peers for the *Linear* architecture. We make the following assumptions: