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# QUALITY OF SERVICE IN IP AND WIRELESS NETWORKS

Quality of service (QoS) has been a frequently used term and hot research topic in the past few years. However, IP networks and wireless cellular systems have been looking at QoS provisioning from rather different perspectives. In IP and computer networks, researchers mainly concentrated on those techniques that could enable migrating traditional best effort Internet service with no guarantee on delay or throughput or even reliable delivery of packets into a more predictable architecture. Differentiated services (DiffServ), integrated services (IntServ), and various combinations of the two techniques have tried fulfilling QoS in the Internet by defining different architectures and reservation techniques. While research on these and other alternative techniques is still ongoing, due to the large-scale architecture of the global Internet and the diversity in Internet nodes, routers, and hosts, Internet QoS still has a long way to go to become a reality. One implication issue in providing QoS over the Internet, arising from the fact that QoS should be maintained on an end-to-end basis and without a mutual commitment from all intermediate links and networks, is that QoS cannot be guaranteed. Such commitment is even difficult for a small private network, not to mention for the widespread Internet where each packet may travel on a different path from other packets of the same message.

For cellular systems, traditionally service quality has been guaranteed for certain measures, including call dropping probability, call blocking probability, security, and, more important for voice communications, delay limits. With the introduction of data services, cellular providers have tried to accommodate a certain level of service guarantee to data transactions, mainly those that used the traditional circuit-switched network to deliver data packets.

As we head toward large volumes of data packet communications over cellular systems and look forward to interconnecting all telecommunication networks through a common IP core network, the issue of QoS becomes more challenging. Different from circuit-switched networks, packet-switched networks and their current commonly used IP networks do not dedicate any resources to message delivery unless a certain mechanism such as a reservation protocol is implemented. To guarantee QoS over integrated IP-cellular, therefore, it is necessary to look at the requirements of applications running over the both systems.

The main application of a cellular system is voice communications, which requires strict delay and delay variation constraints. Delivering voice packets over an IP network by means of techniques such as voice over IP then requires mechanisms that guarantee such delay requirements. On the other hand, for IP networks, with data applications such as email, Web, and file transfer, other QoS measures such as reliable and error-free data transfer and high throughput are more critical than the delay requirement. The combination of different QoS requirements for different applications makes the problem even more challenging.

Modern cellular systems such as the Universal Mobile Telecommunications System (UMTS) have approached this issue by introducing a few traffic classes and handling them with different priorities. A similar approach has been taken in IP and computer networks by giving different levels and priorities and classifications to different traffic types and labeling them by using a few bits at the IP header. While the similarity between IP and wireless cellular initiatives in guaranteeing QoS on an end-to-end basis is more or less over at this stage, we need to find more harmonized architectures to support QoS in future generations of wireless IP networks.

Therefore, in order to solve the issue of QoS provisioning in integrated IP-cellular systems (i.e., the forecast next-generation mobile communications networks) we must not only look at the individual techniques that satisfy particular service quality indicators, but more than that, look at architectural improvement that melds IP well inside cellular systems and vice versa. By architectural improvement we mean that all traffic, regardless of its originating applications, real-time or non-real-time, voice or data, should be treated in a common way. Such improvement will make it easier to classify packets and service them based on their quality requirements.

This feature topic is an attempt to gather related information on the topic of QoS in IP networks and wireless networks. The guest editors have tried to come up with a collection of tutorial papers from many submissions we received to the open call for papers of this issue so that a balanced view of the activities in different parts of the world as well as in academia and industry could be accommodated within our limited space. The paper selection process of this issue, therefore, focused on QoS optimization with many constraints.

We would like to thank all the authors who responded to the call for papers, regardless of whether their paper has been included in this issue or had to be rejected due to space limitations. We would also like to express our sincere thanks to all the reviewers who did an excellent job. The result of all those efforts is the following six articles that passed the requirements.

The first article, "Quality of Service Signaling for Next-

Generation IP-Based Mobile Networks" by Joachim Hillebrand, Christian Prehofer, Roland Bless, and Martina Zitterbart, addresses a novel end-to-end QoS architecture that enables seamless services over heterogeneous wireless access networks. The article tries to integrate resource management with mobility management in a mobility-aware IP network. The QoS architecture discussed in this article tries to find a solution to QoS provisioning in heterogeneous networks, where a user is able to connect to another network when it becomes available and therefore make efficient use of the available resources at the new point of attachment. The signaling requirements for different types of handovers are discussed in this article.

The second article, "End-to-end QoS Specification Issues in the Converged All-IP Wired and Wireless Environment" by S. Maniatis, E. Nikolouzou, and I. S. Venieris, proposes a process of establishing end-to-end QoS and focuses on the specification of QoS at the service level. During session establishment, the QoS requirements are negotiated through an intelligent automatic mapping algorithm that selects the most appropriate service class in each domain. It also determines the controls that need to be initiated to support the required QoS, including admission control, policing, and scheduling. In addition to the proposed QoS architecture for heterogeneous networks, this article provides a thorough discussion on relevant standards.

In the third article, "Individual QoS Rating for Voice Services in Cellular Networks," Algimantas Kajackas, Vaidas Batkauskas, and Arturas Medeisis point out a concept of individual QoS rating for voice services in cellular networks. The article tries to shift the usually accepted network-level QoS management into end-user QoS management. So instead of looking at overall network performance and average user QoS support, individual QoS can be assessed, and consequently appropriate billing done. Software implemented in the end-user terminal collects all information required to evaluate the actual service received by a user, which can include poor service reception due to wireless channel impairment or unavailability as well as network congestion. This information will then be used to adjust any charge to a user. Overall, the proposed scheme does not try to improve QoS in mobile networks but to increase the level of end-user satisfaction with QoS. This satisfaction could be included as a new QoS measure.

The fourth article, "An Investigation of Multilevel Service Provision for Voice over IP Under Catastrophic Congestion" by Yang Xu, Martin Westhead, and Fred Baker, looks at the classification of voice-over-IP traffic in order to guarantee voice-quality service over IP networks. The article looks at three different DiffServ strategies to be used in conjunction with the aforementioned traffic classification. These are WRED Dropper, PQ Meter, and Multiple Differentiated Meter (MDM). By classifying VoIP traffic, it is possible to make discriminatory decisions in handling real-time packets, thereby achieving reasonable delay and jitter limits comparable to those seen in traditional telephony networks. It is also possible to service several VoIP traffic classes using a single priority queue. Simulation results show that MDM would be a better option under catastrophic congestion scenarios.

The fifth article, "Providing Sustainable Quality of Service in Next-Generation Networks" by Gero Schollmeier and Chris Winkler, provides another view to the issue of voice-over-IP quality of service in next-generation Networks (NGNs). While the authors confirm that delay and delay variations are the most critical QoS parameters when the Internet is used to carry voice packets, they insist that delay would be short anyway in high-speed networks as long as the following two constraints are met. First, the link should be available most of the time; that is, link failures should be kept to a minimum. Second, there should be some traffic control mechanism in place so that the traffic load can be distributed evenly among available networks, thus avoiding network congestion and long delays. The first requirement is not supported by the current Internet routing algorithm as it takes a long delay before a link failure is discovered and the packet is rerouted. The second requirement also needs sophisticated admission control policies in place to avoid network overload. After exploring the above two criteria in NGNs, the authors propose a new routing algorithm that accommodates them efficiently in IP networks with slightly increased complexity from that of traditional routing schemes.

This Feature Topic concludes with the article "Load Balancing Routing with Bandwidth-Delay Guarantees" by Kartik Gopalan, Tzi-cker Chiueh, and Yow-Jian Lin, which looks again at the importance of delay requirements of the next-generation networks because of the increasing number of real-time applications, in addition to the usually considered bandwidth guarantee and congestion avoidance techniques. A new network resource management technique, Link Criticality Based Routing (LCBR), is proposed in this article. The authors state that the proposed algorithm provisions primary and backup routes for aggregate real-time flows with end-to-end delay, bandwidth, and reliability guarantees while maintaining high resource usage efficiency of the network infrastructure. The proposed algorithm relies on the concept that load balancing may lead to higher resource utilization efficiency and applies a simple but very effective notion of link criticality to maintain load balance across the network. LCBR can improve the amount of admitted network traffic by up to a factor of 1.8 compared to schemes that use route selection criteria from state-of-the art traffic engineering approaches.

As the guest editors of this Feature Topic, we hope readers find it interesting and consider it a useful guide to research and development activities toward QoS provisioning in next-generation IP and wireless networks. This is not the first special issue on this important topic, nor is it the last. The topic of quality of service provisioning will remain an important and strategic challenge for all researchers in the field of computer and telecommunications engineering for years to come.

## Biographies

PASCAL LORENZ [SM'00] (lorenz@ieee.org) received his Ph.D. from the University of Nancy, France. Between 1990 and 1995 he was a research engineer at WorldFIP Europe and Alcatel-Alsthom. He is a professor at the University of Haute-Alsace and responsible for the Network and Telecommunication Research Group. His research interests include QoS, wireless networks, and high-speed networks. He was the Program and Organizing Chair of IEEE ICATM '99, ECUMN 2000, ICN '01, ECUMN '02, ICT '03, and ICN '04. Since 2000 he is a Technical Editor of *IEEE Communications Magazine*. He is the secretary of IEEE ComSoc Communications Systems Integration and Modeling Technical Committee. He is a member of many international committees programs and he has served as a guest editor for a number of special issues, including *Telecommunication System*, *IEEE Communications Magazine*, and *Lecture Notes in Computer Science*. He is a member of many conference technical program committees, and has organized and chaired several technical sessions. He has given tutorials at major international conferences. He is the author of two books and 90 international publications in journals and conferences.

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