

Routing and QoS over Heterogeneous Networks

Today the Internet has become the most important communication infrastructure of our society. It enables world-wide users (individual, groups, and organizations) to access and exchange remote information scattered all over the world. Currently, due to the growing needs in telecommunications (Video on Demand, Video-Conference, VoIP, etc.) and the diversity of transported flows, the Internet still does not meet the requirements of integrated-service networks that carry multimedia data traffic with a high Quality of Service (QoS). The main drivers of this evolution are the continuous growth of the bandwidth requests, the promise of cost improvements, and finally the possibility of increasing profits by offering new services. First, the Internet does not support resource reservation which is primordial to guarantee an end-to-end QoS (bounded delay, bounded delay jitter, and/or bounded loss ratio). Second, flow packets may be subjected to unpredictable delays and thus may arrive at their destination after the expiration time, which is undesirable for continuous real-time media. In this context, to optimize the financial investment of their networks, operators must use the same underlying Internet infrastructure to transport all types of flows including those associated with strict QoS requirements. Therefore, we need to develop high quality control mechanisms that can support efficient end-to-end QoS requirements. It is clear that the integration and support of these QoS parameters increases the complexity of current QoS routing algorithms and models. Many QoS challenges still exist in emerging hybrid networks often consisting of a highly heterogeneous mix of several different types of networks (wireless, broadcast, mobile, fixed, etc.) especially during the routing process which is central to the delivery of optimal performances in hybrid network environments.

Providing a good Quality of Service in heterogeneous networks for irregular traffic flows remains a significant challenge. A general problem of large-scale, distributed systems is the ever-increasing complexity of their operations. This complexity is mainly driven by heterogeneity.

The wide variety of underlying technologies deployed within a network and their different, if not proprietary, operational paradigms make it hard for network operators to solve. Moreover network operations are typically handled by one or more human operators. Manual control is time-consuming, expensive, and error-prone. Nevertheless, both technologies and needs continue to develop and grow. The risk is thus that complexity and cost become limiting factors in the evolution of networks in the future and for the enriched services these networks are expected to deliver.

We have witnessed significant interests in recent years in the area of QoS routing algorithms that can support emerging value-added services through the integration of dynamic criteria (supported by each type of network) for heterogeneous networks. The most popular formulation of the optimal distributed routing problem in a data network is based on a multi-commodity flow optimization where a separate objective function is minimized with respect to the types of flow subjected to multi-commodity flow constraints. However, due to their high complexity, increased processing burden, only a few proposed routing schemes could be accepted for the Internet.

This special issue of *Annals of Telecommunications* focuses on QoS, control policies, traffic engineering and explores their effectiveness when deployed over heterogeneous networks. Increasing demands of real-time, multiservice traffic (such as data, video, voice, etc.) over IP-based networks require continuous QoS as well as scalability. The Special issue aims at providing the readers with a set of papers presenting the latest developments made in this area to support the requirements of emerging multimedia applications. State-of-the-art results presented in this issue will provide further insight into novel QoS approaches that support mobility, scalability, connectivity and safety over the heterogeneous

Internet infrastructure. They also put in evidence novel approaches for various architectural frameworks in Inter-domain traffic engineering, End-to-End QoS based on negotiation and market mechanism, and class-based multicast technologies is also discussed.

This special issue starts with a first set of papers which address QoS-based Routing in Inter-domain Heterogeneous Networks: Olivier Dugeon, Enzo Mingozzi, Giovanni Stea and Luca Bisti present an architectural framework that allows inter-domain Traffic Engineering Label Switched Paths with guaranteed QoS to be setup; Wojciech Burakowski, Andrzej Beben, Halina Tarasiuk, Jaroslaw Sliwinski, Robert Janowski, Jordi Mongay Batalla and Piotr Krawiec present a framework to provision end-to-end QoS integrating several classes of service supported in all domains by setting up an end-to-end QoS path. These two frameworks were tested in the context of the FP6 EuQoS project; Maria Joao Nicolau, Antonio Costa, Joaquim Macedo and Alexandre Santos look at the innovative multicast QoS routing strategy designed for the new class-of-service paradigm from a full end-to-end perspective. Their solution is based upon the construction of multiple trees, one per class of service available, while still allowing receivers to shift for source specific trees in its own class of service; Xuebing Pei, Guanxi Zhu, Qinqing Wang, Gan Lui and Wenpeng Yuan discuss a novel load balancing strategy for heterogeneous overlapping networks based on multi-hop routing protocols for ad hoc networks.

In addition, some papers address the problem of end-to-end QoS by using schemes based on negotiation and market mechanism: Dohoon Kim proposes an architecture that allows ISPs to trade Bandwidth in an open market and focuses on delivering end-to-end QoS; Helia Pouyllau and Stefan Haar investigate the design of a negotiation process needed before users' requests to establish services are received. The proposed negotiation process results in the selection of aggregated contract chains and a distribution among them; Artur Tomaszewski, Michal Piore and Mariusz Mycek evaluate a new iterative procedure where domains cooperatively determine an optimal flow of inter-domain traffic, with respect to a common utility function.

Another group of papers presents an overview and challenges in several areas of heterogeneous QoS environments: Hesham El-Sayed, Abdelhamid Mellouk, Laurent George and Sherali Zeadally presents an overview of QoS paradigms and models for heterogeneous networks and focus on the use of deterministic and probabilistic QoS for different types of wired, wireless and mobile networks (such as WiMAX, Wireless Mesh Networks, WPANs, WLANs, etc) and cellular-based networks; Anahit Martirosyan, Azzedine Boukerche and Richard Nelem Pazzi discuss two essential issues of routing protocols designed for Wireless Sensor Networks: energy-efficiency and QoS. They also present QoS-based routing protocols for Vehicular Ad Hoc Networks. Finally, Alexandre Fonte, Marilai Curado and Edmundo Monteiro provide an insight into the Inter-domain QoS Routing problem and they give a survey of the most relevant Inter-Domain QoS Routing approaches while focusing on the existing BGP protocol.

We thank all anonymous reviewers for their hard work, time, and support that greatly helped us select the best papers for this Special issue. We also thank all authors who submitted their papers for consideration for this issue. We express our gratitude to the staff of *Annals of Telecommunication* for their support and kind encouragements throughout the preparation of this work. Finally, we hope you will enjoy reading this selection of papers as we did.

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