Quality of service in heterogeneous networks: current status, examples, and open issues

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ABSTRACT

The present telecommunication environment is an amalgamation of a large number of networks, administrative domains, and different access technologies. In particular, wireless access proliferation and increased user mobility introduce a new set of challenges and opportunities for Quality of Service (QoS) research and deployment. Multimedia applications (both streaming and real-time), video conferencing, and voice over IP (VoIP) require higher bandwidth, smaller delays, and session continuity in addition to demands placed by more traditional applications, such as email, web browsing, file transfer, and instant messaging. Although there are several QoS frameworks for homogeneous networks, or networks under a single administrative domain, heterogeneous networks lack a widely deployed mechanism that ensures end-to-end QoS. Differentiated services, although standardized and well-supported by network equipment vendors, are not deployed on the public Internet and thus still cannot be relied upon to provide true end-to-end QoS to applications accessing arbitrary resources over wired-only paths, let alone applications aimed for a mobile user.

This tutorial contemplates the value of network overprovisioning discussing examples from other domains, including civil engineering and computer science, where overprovisioning is not shunned. It addresses misconceptions about overprovisioning, QoS and charging schemes, and motivates the need for QoS for pragmatic applications.

Next, we introduce QoS frameworks standardized for cellular/wide and local area networks (WCDMA 3G/UMTS and IEEE 802.11a/b/g/e, respectively) and provide an example of a vertical handover while maintaining session continuity for streaming audio. Moreover, we highlight terminal handover session continuity based on results from the IST Ambient Networks project. We also present results from the IST PHOENIX project. After introducing tools for monitoring QoS and explaining the importance of subjective and objective QoS in evaluating network services and applications, we make the case for QoS throughout the protocol stack. We show, for example, how adaptive video coding can improve the gaming on demand user experience. In addition, we present new standardization efforts at the transport layer that can play an important role in diffusing QoS awareness throughout the stack. Based on recently published results we show that signal-to-noise ratio or simply detecting the presence of another available network is not sufficient to trigger a vertical handover while maintaining quality of service at the appropriate level. The tutorial continues with an overview of the Differentiated Services (DiffServ) architecture and specification, traffic classification and conditioning. We address the issues of whether DiffServ is still relevant and why it has not been widely deployed, surveying recent trends and discussing the path forward for end-to-end QoS mechanisms.

The open issues section addresses who needs QoS and who is willing to pay for it. QoS with flat pricing, the operational complexity introduced by QoS frameworks and new methods for dynamically traffic classification are also discussed. Finally, the

last section brings the whole presentation together discussing the value and role of service level agreements, the lack of end-to-end QoS frameworks, and how it can be dealt with.

The tutorial puts an emphasis on real-world examples, which are presented interwoven with more theoretical material. It focuses on recent developments and research efforts based on both the literature and our experience for several past and current large-scale QoS-related projects. It illustrates QoS measurement tools, QoS-aware gaming-on-demand applications, and seamless application and session continuity in heterogeneous networks. Open issues are introduced along with the speaker opinions on technical, deployment, and business aspects aiming to stimulate the audience and increase active participation, leading to a lively discussion at the end of the presentation. Finally yet importantly, the research efforts in the EUREKA/ITEA Easy Wireless and IST PHOENIX projects are portrayed.

RECOMMENDED AUDIENCE

Scientists and engineers; telecom researchers and practitioners; network managers, service developers, and R&D staff; students.
Tutorial Level: Intermediate. Basic background in networking is highly recommended.

ABOUT THIS TUTORIAL

A two-hour earlier version of this tutorial (also titled "Quality of service in heterogeneous networks") was presented at *APNOMS 2005*, Okinawa, Japan; at the VTT Wireless Services seminar, Oulu, Finland; and at the Institute of Informatics & Telecommunications, NCSR Demokritos, Athens, Greece. The expanded version proposed herein aims for a 3.5-hour slot. It includes more examples, details several issues that were summarily mentioned before, and presents exclusive new material.

SPEAKER BIOGRAPHIES

Kostas Pentikousis studied computer science at Aristotle University of Thessaloniki (BSc 1996, First Class Honours) and Stony Brook University (MS 2000, PhD 2004). He is the primary author of more than a dozen refereed journal and conference papers and has served as a reviewer for *IEEE Communications Letters*, *IEEE/ACM Transactions on Networking*, IEEE ICC (2000, 2006) and ICN (2001). He was the recipient of the Best Teaching Assistant Award in 2002 (Department of Computer Science, Stony Brook University), and an ERCIM Fellowship in 2005. Dr. Pentikousis is currently a Senior Research Scientist at VTT Technical Research Centre of Finland. His work at VTT revolves around 3G/UMTS wireless WANs and transport & application layer protocol performance. Of particular interest are issues pertaining to maintaining QoS levels in heterogeneous networks.

Milla Huusko received her Master of Science in applied mathematics and information processing sciences from the University of Oulu, Finland, in 2000. She started working for VTT in 1998 and, during 2003-2004, spent six months as a visiting lecturer and researcher at the University of Waikato, New Zealand. Ms. Huusko is familiar with wireless image and video transmission, image and video compression and internet related technologies. Her current research interests lie in the area of end-to-end Quality of Service (QoS) in heterogeneous networks, especially measuring QoS and network optimization, based on the measurement information, for multimedia communications according to the measured information is under research. She is the project manager for the Finnish sub-consortium, in the EUREKA/ITEA Easy Wireless project.

OUTLINE

- QoS research interest fades and overprovisioning dominates
  - Overprovisioning in other domains and disciplines
  - Overprovisioning vs. QoS
- QoS vs. charging
- QoS as a business enabler
  - Pragmatic QoS
  - Example: maxinetti (triple-play service provider in Helsinki)
- QoS in cellular networks
  - 3G/UMTS
  - Example: The 3G test platform at VTT
  - Beyond 3G
- QoS in WLANs
  - IEEE 802.11a/b/g
  - IEEE 802.11e
  - Example: Easy Wireless – streaming audio and vertical handovers (WLAN-3G-WLAN)
- QoS monitoring
  - Subjective vs. objective QoS
  - Tools
  - Example: QoSMET (one-way e2e QoS monitoring tool)
  - Example: VoIP over WLAN (measurements and insights)
- QoS throughout the stack
  - Terminal mobility and session continuity
  - Example: MAGELLAN – QoS-aware gaming on demand
  - Banking on the video codec development cycle
  - Transport protocols: new options for TCP, DCCP
  - Example: Why SNR or link layer metrics are not enough in order to maintain QoS? The first connection goodput effect in 3G/UMTS
- The “proper” IP QoS
  - Quick overview of DiffServ: motivation, architecture, specification
  - Traffic classification and conditioning
  - DiffServ – still relevant?
- Open issues
  - Who needs QoS and who is willing to pay for it?
  - QoS with flat pricing
  - QoS and operational complexity: a view for the NOC
  - Dynamic traffic classification
- QoS in heterogeneous networks
  - SLAs and end-to-end standardization
  - QoS-aware stacks
  - The EUREKA/ITEA Easy Wireless project
    - Motivation, partners, work accomplished, goals
  - The IST PHOENIX project
    - Motivation, partners, work accomplished, goals
- Synopsis
- Acknowledgements
- Further Reading
- Discussion