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TRENDS AND DEVELOPMENTS IN ICT INDUSTRY: NEW CHALLENGES FOR PERFORMANCE ANALYSTS

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Abstract
In the next few years the landscape of the information and communications technology (ICT) industry will be subject to many changes. New and advanced ICT services will be brought to the market, offered over large and highly distributed infrastructures consisting of a heterogeneity of information systems and communication networks, each owned by different parties. The business of many companies will increasingly depend on the performance of their ICT systems. The unbundling of the telecommunications world will become reality, the classical role models and value chains will be subject to change, and third party service providers will enter the market. Network and service providers will need to negotiate Service Level Agreements (SLA's) in order to offer high and predictable service levels to their customers in a cost-effective manner. In this paper we give an overview of trends and development in the ICT industry, and address new research challenges for performance analysts, both for practitioners and theorists.

Keywords
performance analysis, telecommunications industry, trends, developments

1. TRENDS AND DEVELOPMENTS IN ICT INDUSTRY

Unbundling of the ICT market: The unbundling of the telecom world is becoming reality, separating functional roles in the telecom and information domain. Examples of unbundling can be found in the emerging market of mobile internet access services, where services are realized over a multitude of domains owned by different parties, such as radio network operators, core network operators, gateway owners, service providers and content providers. This

unbundling leads to heterogeneous, multi-domain infrastructures over which new services and applications are supported. In this context, we will observe an increasing business importance of Service Level Agreements (SLA's) between different parties.

Third party service provisioning: The unbundling of the ICT market leads to business opportunities for so-called third parties: Third-party service provisioning (3PSP) is the concept where network operators provide open interfaces for third-party service providers to build services on top of communication networks.

Device- and location-independent information access: Demand for device- and location-independent access to information and services that are presented according to user specified preferences will be growing strongly. In conjunction with this growing demand and boosted by the opportunities enabled by the Internet, the variety of offered services and user-devices will grow tremendously. For these services, the end users typically have access to information servers via a heterogeneous mix of wired and wireless access networks and backbone infrastructures.

Emergence of distributed applications and middleware architectures: Many new applications will combine and integrate information from logically and geographically distributed information systems connected by a multitude of communication networks. To support this type of applications that cover a wide range of features, functionalities and open interfaces in multi-domain environments, software infrastructures will become increasingly complex. This will lead to an increasing importance of middleware technology that enables to manage this heterogeneity by abstracting details of lower-layer communication protocols for application programmers.

Heterogeneity of services: We observe that new user demands emerge with the technological advances in distributed system architectures. Typically, in order to stay in business service providers have to offer a wide range of these services, such as E-mail, information downloading, on-line banking, ticketing, remote access to a company intranet and streaming services. In addition, new and advanced will be brought to the market by third parties. Each of these services has its own traffic characteristics and performance requirements, depending for example on the type of content and the level of user interaction.

Demand for Quality of Service differentiation: We will observe a growing demand for differentiation of the Quality of Service of ICT services: customers are

willing to more for better quality, both in the consumer market and the business market.

Business relies increasingly on the performance of ICT: The business of many companies will be increasingly dependent on the performance of their ICT systems. For example, consider companies that automate their sales by E-commerce applications: customer dissatisfaction about overly long response times or unavailable servers will directly cause a decrease in revenue and customer churn. This development underlines the relevance of performance analysis.

2. NEW CHALLENGES FOR PERFORMANCE ANALYSTS

The trends and developments addressed above raise new challenges for performance analysts, both for theorists and practitioners. A few challenging areas and some research suggestions are addressed below.

Paradigm shift in performance bottlenecks: In the context of the increasing complexity of software architectures, we observe a growing impact of server and software performance on the end-to-end performance observed by the end user (see also [2]). This addresses a fundamental paradigm shift that has received relatively little attention in the performance modeling community, which traditionally has focused on performance aspects of communication networks, rather than servers and software architectures. Realistic modeling of end-to-end performance requires combined knowledge of performance modeling of communication and information technology.

New concepts for modeling end-to-end performance of ICT systems: The unbundling of the ICT market, 3PSP and the emergence of distributed applications ranging over multiple domains raises many questions regarding how to realize end-to-end performance. The end-to-end performance of applications offered over distributed system architectures is a complex interplay between many components, such as the specifics of the hardware, software, Operating Systems, middleware architecture, network architecture, object models, threading models, system load, amongst many others. In the literature several model-based methodologies to assess the performance of ICT systems have been studied, see for example [4, 6, 1] (and references therein). Despite these efforts none of these performance modeling approaches is flexible enough for modeling all the relevant features of today's ICT systems (see [3] for details). For this reason, Gijsen et al. [3] develop a new and promising modeling approach, called PerfICT, combining merits from existing modeling approaches and particularly focused on modeling distributed ICT

applications. PerfICT is a hierarchical modeling approach, with sub-models at the application level, the logical resources level and the platform level.

Performance evaluation techniques for multi-layered performance models: The increased impact of server and software architectures raises many challenges for the development of analysis techniques for performance models that include the *combined* impact of both software contention (e.g., threading and software concurrency models), and hardware contention (e.g., processing power, network capacity) simultaneously. This generally leads to the analysis of multi-layered performance models, for which only a limited number of exact results are available (see for example [6, 4, 3]).

Increased importance of performance monitoring capabilities: The emerging scenarios of a broad range of applications running over multi-domain and heterogeneous infrastructures impose new performance monitoring challenges. The increasing impact of ICT performance on business and the multi-domain aspect increases the importance of verification of performance specified in SLA's between administrative domains. Also, the multi-domain infrastructures complicate the overview and control over *end-to-end* performance. Further, the diversity in traffic and performance characteristics of emerging services require the ability to monitor and control the traffic and performance of services both in isolation and on aggregate level.

Development of integrated performance and capacity management process: Since the performance of ICT systems is becoming more business critical it is important to control and manage it. In general, managing ICT performance involves many activities, such as performance testing in lab environments, performance monitoring, analysis of the functional application behavior, the development of QoS enabling mechanisms, and performance modeling and evaluation, amongst others. In practice, most of these activities are performed by different research groups in relative isolation. What is needed, however, is an integrated performance and capacity management *process* in all these activities are *integrated* in a multi-disciplinary approach [5].

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