PERFORMANCE EVALUATION AND APPLICATIONS OF ATM NETWORKS

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PERFORMANCE EVALUATION AND APPLICATIONS OF ATM NETWORKS

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To Mihalis and Maria

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Preface

Information Highways are widely considered as the next generation of high speed communication systems. These highways will be based on emerging Broadband Integrated Services Digital Networks (B-ISDN), which - at least in principle - are envisioned to support not only all the kinds of networking applications known today but also future applications which are not as yet understood fully or even anticipated. Thus, B-ISDNs release networking processes from the limitations which the communications medium has imposed historically. The operational generality stems from the versatility of Asynchronous Transfer Mode (ATM) which is the transfer mode adopted by ITU-T for broadband public ISDN as well as wide area private ISDN. A transfer mode which provides the transmission, multiplexing and switching core that lies at the foundations of a communication network.

ATM is designed to integrate existing and future voice, audio, image and data services. Moreover, ATM aims to minimise the complexity of switching and buffer management, to optimise intermediate node processing and buffering and to bound transmission delays. These design objectives are met at high transmission speeds by keeping the basic unit of ATM transmission - the ATM cell - short and of fixed length. However, to support such diverse range of services on one integrated communication platform, it is necessary to provide a most careful network engineering in order to achieve a fruitful balance amongst the conflicting requirements of different quality of service constraints, ensuring one service does not have adverse implications on another. Thus, performance evaluation and quantitative analysis of ATM networks are of extreme importance to both users and operators.

Experimental ATM networks have now been established worldwide, based on commercially available ATM products and switch architectures. Although the suitability and cost effectiveness of ATM to provide the B-ISDN core has been the subject of public debate, the authoritative endorsement of ATM by ITU-T and the subsequent investments in commercial ATM technology ensure that ATM will - in all likelihood - hold a place of prominence in the world of communications well into the new millennium!

Performance modelling, evaluation and prediction of ATM networks are very important in view of their ever expanding usage and the multiplicity of their component parts together with the complexity of their functioning. Over the recent years a considerable amount of effort has been devoted, both in industry and academia, towards the performance analysis of ATM networks. However, there is still a set of many interesting and important performance related research problems to be addressed and resolved before a global integrated broadband network infrastructure can be established. This includes traffic modelling and characterisation, flow and congestion control, routing and optimisation, ATM switch architectures and internetworking, IP/ATM networks integration, resource allocation and the provision of specified quality of service. Thus, it seems most essential both to comprehend recent advances made in the field and also to search for new evaluation techniques and tools for the performance optimisation of these future high speed networks.

The principal objective of the tutorial book 'Performance Evaluation and Applications of ATM Networks' is to present an overview of recent results, applications, future directions and comprehensive bibliographies relating to the fundamental performance evaluation and application issues of ATM networks. The book maintains an effective balance between descriptive and quantitative approaches towards the presentation of important ATM mechanisms and associated performance modelling techniques and applications. Moreover, it offers a fundamental source of reference on ATM networks' performance within both academic and industrial environments.

The book includes 17 tutorial papers by eminent researchers and practitioners in the field from industry and academia worldwide. All papers are invited works which were evaluated and selected, subject to rigorous international peer review. The tutorial papers can be used as essential introductory state-of-the-art material for both education and further research in the performance modelling and analysis field of ATM networks. In particular the tutorial book aims to unify ATM performance modelling material already known but dispersed in the literature, introduce readers to unfamiliar and unexplored ATM performance research areas and, generally, illustrate the diversity of research found in the ATM field of high growth.

The tutorial papers are broadly classified into six parts covering the following topics:

Part One ATM Traffic Modelling and Characterisation

Part Two ATM Traffic Management and Control

Part Three ATM Routing and Network Resilience

Part Four IP/ATM Networks Integration

Part Five ATM Special Topics: Optical, Wireless and Satellite Networks

Part Six Analytical Techniques for ATM Networks

An overview of the proposed tutorial papers of the book is presented below:

Part One on "ATM Traffic Modelling and Characterisation" includes three tutorial papers and is concerned with modelling, characterisation and performance implications of multiplexed streams of bursty and correlated ATM traffic in ATM networks. The first paper by John Cosmas (Brunel University, UK) on 'Stochastic Source Models and Applications to ATM' describes the theory of the relationships between the main statistical and model parameters of voice, data and video sources and how they relate to Usage Parameter Control (UPC) mechanisms in ATM networks. The second paper by Mark Bromirski and Wieslaw Lobejko (Military Communication Institute, Poland) on 'Fractals and Chaos for Modelling Multimedia ATM Traffic' explores the fractal and chaotic properties of multimedia ATM traffic and their performance impact. The third paper by Timothy X. Brown (University of Colorado, USA) on 'Adaptive Statistical Multiplexing for Broadband Communication' focuses on the ststistical multiplexing of traffic sources and reviews adaptive multiplexing in terms of statistical-classification-based decision functions and their applications.

Part Two on "ATM Traffic Management and Control" brings together five tutorial papers addressing fundamental objectives such as guaranteed network performance, traffic control and congestion schemes, traffic management and contracted quality-of-service (QoS).

The first paper by Chris Blondia (University of Antwerp, Belgium) and Olga Casals (Polytechnic University of Catalunia, Spain) on 'Traffic Management in ATM Networks: An Overview' provides a comprehensive overview of traffic service categories and transfer capabilities for ATM traffic managements together with some essential control and congestion schemes in ATM networks. The second paper by Khaled M. Fuad Elsayed (Cairo University Egypt) and Harry G. Perros (North Carolina State University, USA) on 'A Comparative Performance Analysis of Call Admission Control Schemes in ATM Networks' carries out a comparative study of the performance analysis of Call Admission Control (CAC) mechanisms devised to meet certain QoS requirements expressed in terms of cell loss probability and maximum delay. The third paper by Nikolas Mitrou (National Technical University of Athens, Greece) on 'Traffic Control in ATM: A Review, an Engineer's Critical View and a Novel Approach' reviews the main ATM control functions and describes an alternative approach to the traffic control problem, based on burst-level modelling. The latter explores the buffering gain and proposes the use of the M/D/1 model as a unified tool for engineering all necessary control mechanisms. The fourth paper by Gunnar Karlsson (Swidish Institute of Computer Science, Sweden) on 'Video over ATM Networks' is concerned with quality requirements posed on network transfers of video information and presents a review of video communication over ATM networks which includes source coding, bit rate regulation and quality constraints. The fifth paper by Michael Logothetis (University of Patras, Greece) on 'Optimal Resource Management in ATM Networks based on Virtual Path Bandwidth Control' discusses the impact of the optimal call-level virtual path bandwith (VPB) control towards the analytic minimisation of the worst call blocking probability of all virtual paths (VPs) of an ATM network.

Part Three on "ATM Routing" consists of two tutorial papers addressing inherent routing problems frequently encountered during the design and management of complex multiservice ATM networks involving information transfer from one to one or one to many recipients for multimedia applications. The first paper by John Crawford and Gill Waters (University of Kent at Canterbury, UK) on 'ATM Multicast Routing' reviews heuristics for multicast routing which support multimedia services in high speed networks such as B-ISDNs based on ATM, by minimising the multicast tree cost whilst maintaining a bound on delay. Relative performance comparisons

involving different multicast heuristics are carried out and recommendations are made towards efficient solutions for a wide range of flat and hierarchical networks. The second paper by Paul Veitch (BT Labs., UK) on 'Embedding Resilience in Core ATM Networks' deals with the embedding of resilience mechanisms in core ATM network elements in order to provide restoration mechanisms and, thus, mitigate the impact of outages caused by cable breaks and node failures.

Part Four on "IP/ATM Networks Integration" includes a single tutorial paper by Andreas Skliros on 'IP Switching over ATM Networks'. The paper addresses performance and reliability problems associated with the unprecedented growth of IP traffic and reviews various approaches for integrating the flexibility of IP software with the high transmission speed and QoS guarantees of ATM networks. Particular emphasis is given on the new cost-effective IP switching architecture, its functionality and the management of QoS issues.

Part Five on "ATM Special Topics: Optical, Wireles and Satellite Networks" presents three tutorial papers dealing with some contemporary topics in the ATM field. The first paper on Maurice Gagnaire and Saso Stojanovski (ENST, France) on 'An Approach for Traffic Management over G.983 ATM-based Passive Optical Networks' focuses on a new generation of access networks aiming to provide end-to-end broadband services. The state of the art in this field is presented by addressing both feeder networks and access networks with particular reference to ATM traffic management over passive optical networks. The second paper by Renato Lo Cigno (Politecnico di Torino, Italy) on 'Wireless ATM: An Introduction and Performance Issues' reports an overview of the main characteristics of wireless ATM networks with radio access, network architecture and management. Moreover, performance issues and application areas are identified together with MAC protocols, handover implementation procedures and experimental projects. The fourth paper by Zhili Sun (Surrey University, UK) on 'Satelite ATM Networks' presents an overview of the major issues and recent developments of satellite systems for ATM networks (and broadband communication) including ATM satellite system structure and architecture, management and control over satellite, performance aspects of ATM over satellite, satellite bandwidth resource management, multimedia applications including current projects and future research issues on satellite constellations and convergence of ATM and Internet.

Part Six on "Analytical Techniques for ATM Networks" presents three tutorial papers reviewing exact and approximate analytic methodologies for the performance modelling, evaluation and prediction of ATM switching nodes and networks involving multistreams of bursty and /or correlated traffic under different buffer management policies. The first paper by Gilberto Mayor and John Silvester (University of Southern California, USA) on Performance Modelling and Network Management for Self-Similar Traffic' highlights the long-range dependence phenomenon exhibited by real network traffic and provides an overview of self-similar traffic models, based on a fractional Brownian motion envelope process. Moreover, analytical tools capable of computing bandwidth and buffer requirements in ATM are included, driven by aggregate, heterogeneous and self-similar processes. The second paper by Sabine Wittevrongel and Herwig Bruneel (University of Ghent, Belgium) on 'Discrete-Time ATM Queues with Independent and Correlated Arrival Streams' presents analytical techniques for the solution of discrete-time queueing models of ATM multiplexers and switching elements with either independent or correlated arrival streams and dedicated-buffer output queueing schemes. The Third paper by Demetres Kouvatsos (Bradford University, UK) on ' An Information Theoretic Methodology for Queueing Network Models (QNMs) of ATM Switch Architectures' reviews an information theoretic methodology for the credible and cost-effective approximate analysis of queueing models of some ATM switches and networks with short range dependence (SRD) correlated traffic streams and either cell-blocking or cell-loss, as appropriate. The methodology has its roots on the information theoretic principle of maximum entropy (ME) and implies a decomposition of the queueing network into individual finite capacity queues each of which can be solved in isolation.

Some of these papers are based on tutorial themes presented during the recent series of the International Federation of Information Processing (IFIP) Workshops on the 'Performance Modelling and Evaluation of ATM Networks' which were organised by Bradford University at Ilkley, West Yorkshire, England, UK and generated enormous international support from both industry and academia. I, therefore, wish to end this foreword by expressing my thanks to the IFIP TC6 on Communication Systems and all other supporting organisations, such as the Performance Engineering Groups of the British Computer Society (BCS) and British Telecom (BT). My

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