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Application of Petri Nets to Communication Networks

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Preface

The development of telecommunication systems dates back to the last century with the development of the electric telegraph, telephone, and the transmission, switching and signalling systems to support them. The forerunner of the Internet, the computer communications network ARPAnet, originated in 1969, when the US Department of Defence Advanced Research Projects Agency (ARPA) initiated experiments in resource sharing. Convergence of the two technologies has now occurred with the development of integrated digital networks to support multimedia applications involving voice, data, images and video. This application area, which covers a vast range of systems embodying traditional telecommunication systems and computer networks, is of utmost importance in the development of new and advanced information systems and services. The next ten years will see enormous changes in the way the world operates. For example, the increase in the use of the Internet as a means of communication (via electronic mail and bulletin boards) and for information discovery and advertising, using the World Wide Web, has been breathtaking. These systems will continue to expand and to influence most economic activity. Examples of the latter include the development of electronic commerce, advanced intelligent manufacturing systems comprising multiple co-operating agents, flexible delivery of global education products, online banking and trading, complex military command and control systems, space systems and transport control systems. This is an area of intense research worldwide, as is demonstrated by the many international conferences and countless journals that deal specifically with telecommunications, computer communications, networks, and advanced information services.

These systems will become vitally important to the operation of the global economy. The consequences of the failure of this new information infrastructure will range from minor annoyance to major disruption, costing millions of dollars (ECUs, Yen, etc.), such as in failures in networks supporting financial systems, or to loss of life in safety critical applications (such as air traffic control, the nuclear power industry, military operations, transportation, space and medicine). It is therefore vitally important that the communications systems that are built to support the information economy are engineered to rigorous standards of functionality and performance. To do this requires the use of rigorous methods for the specification, design, verification, performance evaluation, implementation, testing and maintenance of networks. These methods depend on the use of mathematical techniques, computer aided tools and methodologies.

Networks are inherently distributed and comprise systems with concurrently operating components. Petri nets offer a mathematically defined technique for the specification, design, analysis, verification and performance evaluation of concurrent distributed systems. They not only offer precise semantics and a theoretical underpinning, but also a graphical form that assists in understanding information and control flow within the same formalism. This is important for network specification and design. Petri net tool development during the last 15 years has also been invaluable in the management of large industrial applications. It is not

surprising then, that Petri nets have been used in this domain for the last 25 years. The earliest work, which dates back to Merlin's work in 1974, seems to have been in the area of modelling and analysis of communication protocols. Communication protocols are the procedures used by software and hardware entities within networks to transfer not only user information (in several forms) between network customers, but also control information for managing connections and the network. They are the life blood and nervous system of the network.

This volume assembles a selection of the latest advances in the use of Petri nets for the modelling and analysis of communication networks and systems. The work on protocols is still very significant, and in this volume, is addressed directly by 4 of the 10 papers. However, Petri nets are now being used more generally in the modelling of communication systems, including high speed (asynchronous transfer mode (ATM)) packet switches and multiplexers, optical network receivers, intelligent network architectures (including call state models), feature interactions (conflicts) between different services (such as call forwarding and call waiting), bandwidth allocation policies, network management and local area networks. The papers in this volume cover most of these topics.

The book is structured into three sections.

The first section is concerned with functional modelling of communication systems and comprises three papers. The first, by Capellmann et al., shows how high-level nets and their associated tools can be applied to three aspects of the Intelligent Network. Lakos and Lamp provide an approach, using high-level nets with object oriented extensions, to the incremental modelling of an information retrieval protocol (Z39.50), illustrating how the evolution of standards can be handled. In the last paper of this section, Wheeler provides an extensive coloured Petri net model and a partial analysis of the IEEE 802.6 Metropolitan Area Network configuration control protocol.

The second section of the volume uses time extensions of Petri nets to examine performance. The first of these, by Mnaouer et al., uses Design/CPN's timed hierarchical coloured Petri nets to model and analyse the Fieldbus protocol used for factory automation. Moon et al. use Merlin's time Petri nets to analyse the logical link control procedures of IEEE 802.2 to establish appropriate parameter values. The final paper of this section, by Reid and Zuberek, provides a timed Petri net model for the analysis of layered protocols, using their university's ATM local area network and its higher layer protocols as an example.

The third section comprises a set of four papers that are concerned with the use of variants of stochastic Petri nets (SPNs) to analyse system performance. Haverkort provides an overview of polling mechanisms that are relevant to communication systems and the SPN models that are useful for the evaluation of their performance. These include token-bus and token-ring local area networks, and also an ATM multiplexer. In a second paper, SPNs are also used by Haverkort and Idzenga to investigate the cell-loss ratio of an ATM switch, using a structural decomposition approach. An extension to SPNs, called COSTPN

(controlled SPNs) is introduced by de Meer et al. to allow for dynamic optimization. Their technique is applied to a multimedia server. The final paper of this volume, by Franceschinis et al., provides a stochastic well-formed net model of a multi-receiver system for an optical network. Optical networks are at the forefront of research for providing very high speed services. This paper examines packet loss due to contention for optical receivers, in an all-optical network, using state space reduction techniques.

This volume illustrates the extent of the use of Petri nets to the specification, modelling, analysis and performance evaluation of a range of communication systems, where some very useful results have been obtained. The volume has not been exhaustive in its presentation of the use of Petri nets for communication network applications (some notable exceptions being rigorous testing methods and network management), but it does provide a very good starting point for those interested in this rapidly evolving area.

All the papers selected for this volume have undergone an extensive refereeing process, involving at least three reviews and then a revision cycle if needed. For this, we are indebted to the referees who have given very generously of their time and expertise. Finally, we would like to thank the authors for their contributions and their patience with the reviewing and production processes. This volume is testimony to their insights, originality, creativity, analytical ability and communication skills.

January 1999

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