Preface to the Second Edition

From the invention of the telegraph and of the telephone networks the importance of telecommunication technologies has been clearly evident. Human beings need to interact continuously. The exchange of information of different types is today an absolute necessity. Telecommunications favor the development of countries and the diffusion of knowledge, and they are playing and will play a pivotal role in the society.

Originally, telecommunication systems were simply conceived as links to transmit information between two points. At present, telecommunication systems are characterized by networks with nodes, where information is processed and correctly addressed to output links, interconnecting nodes.

The first telecommunication networks for telegraphy supported the transmission of messages. Then, telephone networks were conceived to establish a physical circuit at call set up in order to connect source and destination for the whole duration of the conversation. Today's networks are digital and based on the transmission of information organized in blocks, called *packets*, which are either independently routed along the nodes or forwarded through a virtual path from source to destination. Transmission media are typically differentiated on the basis of the network hierarchy; in particular, twisted pairs (copper) or wireless transmissions are used for the user access, whereas, optical fibers are adopted in the core network.

Telecommunication systems have reached a worldwide diffusion on the basis of the efforts of international and regional standardization bodies, which have done a significant work, allowing different pieces of hardware to interoperate on the basis of well-defined protocols and formats.

Instead of having a specialized network for each traffic type, the digital representation of information has made it possible to efficiently integrate different traffic types and then services (from voice, to video to data traffic, etc.) in the same network.

At present, the network of the networks, that is the Internet, has a tremendous worldwide-increasing diffusion. The outcome of this impressive process is that the Internet protocol has become the glue, unifying different network technologies, from mobile to fixed and from terrestrial to satellite.

The central issue for modern telecommunication networks is the provision of multimedia services with global-scale connectivity (also including mobile users), guaranteeing several Quality of Service (QoS) requirements, differentiated depending on the application the user is running (i.e., traffic classes). Network resources are precious and costly and must be efficiently utilized. On the other hand, digital information and data traffic worldwide are experiencing an exponential growth that represents a challenge to be addressed by the system designer and the network planners. In this scenario, wireless access will play a major role since from 2011 wireless connections have surpassed broadband wired ones.

The design of modern networks requires a deep knowledge of network characteristics, transmission media types, traffic demand statistics, and so on. On the basis of these characteristics, analytical methods can be adopted to determine the appropriate transmission capacity of links, the number of links, the management strategy for sharing resources among traffic classes, and so on.

The main interest of this book is in providing a basic description of important network technologies (in the first part of the book) as well as some analytical methods based on queuing theory to model the behavior of telecommunication systems (in the second part of the book). The aim and ambition is to provide the most important tools of teletraffic analysis for telecommunication networks.

As for Part I of this book, the focus is on network technologies (and related protocols) according to their time evolution. In particular, this part is mainly organized according to a *bottom-up approach*, referring to the ISO/OSI stacked protocol model, since we start from almost-layer 2 technologies (i.e., X.25, ISDN, Frame Relay based, ATM based) in Chap. 2 and then we address layer 3 and above technologies in Chap. 3 (i.e., IP routing, MPLS, transport-layer protocols, VoIP, satellite networks).

In Part II of this book, queuing systems are studied with a special interest in applying these analytical methods to the study of telecommunication systems. In particular, queuing models are adopted at different levels in telecommunication systems; they can be used to study the waiting time experienced by a given request instanced to a processor or the time spent by a message or a packet waiting to be transmitted on a given link or through a whole network. Note that the behavior of every protocol in every node of a telecommunication network can be modeled by an appropriate queuing process. Our analysis of queuing systems starts from Markov chains, such as the classical M/M/1 queuing model for message-switched networks and the M/M/S/S queue to study the call blocking probability in classical telephone networks. Then, the interest is on more advanced concepts, such as imbedded Markov chains (M/G/1 theory) with related models adopted to study the behavior of ATM switches as well as of IP routers.

This second edition has been enriched and updated for what concerns both new network technologies (Part I) and mathematical tools for queuing theory (Part II). As for Part I, the main improvements are in Chaps. 2 and 3 as follows: (1) better description of policers and shapers for ATM; (2) enriched contents on QoS support in IP networks (e.g., deterministic queuing is introduced to deal with QoS guarantees with IntServ); (3) detailed analysis of TCP congestion control behavior;

(4) satellite IP-based networks; (5) VoIP. As for Part II, Chap. 6 on M/G/1 has been substantially improved, detailing more general cases and the relations among different imbedding options. Moreover, Chap. 7 now contains a better explanation of the potential instability of Aloha protocols, updated details on Gigabit Ethernet, and more details on three different approaches for the analysis of random access schemes. Chapter 8 now provides a better description of the conditions for the applicability of the Jackson theorem to real networks. Finally, new exercises have been added to the first part of the book as well as to all the Chapters of the second part of this book. The solution of all the exercises have been removed from the book and provided in a separated *solution manual*, accessible online www.extras.springer.com. Finally, a *collection of slides* has been made available for downloading and represent a support and complementary tool for teaching based on this book www.extras.springer.com.

QoS provision is a key element for both users who are happy of the telecommunication services and network operators. The success of future telecommunication services is heavily dependent on the appropriate modeling of the networks and the application of analytical approaches for QoS support. This is the reason why the analytical teletraffic methods are of crucial importance for the design of telecommunication networks.

Siena, Italy Giovanni Giambene

Preface to the First Edition

From the invention of the first telecommunication systems (i.e., telegraph and telephone networks) the importance of these technologies has been clearly evident. Humans need continuously to interact; the exchange of information of different types at distance is today essential. Telecommunications favor the development of countries and the diffusion of knowledge, and they are playing and will play a pivotal role in the society.

Originally, telecommunications were simply conceived as links to transmit information between two points. At present, telecommunication systems are characterized by networks with nodes, where information is processed and properly addressed (i.e., switching), and links that interconnect nodes.

The first telecommunication networks due to telegraphy were based on the transmission of messages. Then, telephone networks have been based on the establishment of a physical circuit at call setup in order to connect (for all the duration of the conversation) the source and the destination. Today's networks are digital and based on the transmission of information organized in blocks, called *packets*, that are either independently routed along the nodes or forwarded through a virtual path connecting source and destination. Transmission media are distinguished according to a hierarchy in the network typology; in particular, twisted pairs (copper) or wireless transmissions are used for the user access, whereas optic fibers are employed for core network links.

Telecommunication systems have reached a worldwide diffusion on the basis of the efforts of international and regional standardization bodies that have done a significant work, allowing different pieces of hardware to interoperate on the basis of well-defined rules.

Instead of having a specialized network for each traffic type, the digital representation of the information has made possible to integrate efficiently in the same network different traffic types, from voice, to video to data traffic, etc.

At present, the network of the networks, that is the Internet, has a tremendous and ever increasing success. The outcome of this impressive process is that the Internet protocol results as the glue that can unify different network technologies, from mobile to fixed and from terrestrial to satellite.

The crucial point for modern telecommunication networks is the provision of multimedia services with global-scale connectivity (also including mobile users) and guaranteeing several Quality of Service (QoS) requirements, differentiated depending on the application the user is running (i.e., traffic classes). Moreover, network resources are precious and costly and must be efficiently utilized.

The design of modern networks requires a deep knowledge of network characteristics, transmission media types, traffic demand statistics, and so on. On the basis of these data, analytical methods can be adopted to determine the appropriate transmission capacity of links, the number of links, the management strategy for sharing resources among traffic classes, and so on.

The interest of this book is in providing the basic characteristics of current network technologies (i.e., X.25-based, ISDN, Frame Relay-based, ATM-based, IP-based, MPLS, GMPLS, and NGN) as well as some important analytical methods based on the queuing theory to be used to study the behavior of telecommunication systems. The aim is to contribute to providing the basis of teletraffic analysis for current telecommunication networks.

Queuing systems are studied in this book with a special interest in applying these analytical methods to the study of telecommunication systems. In particular, queues can be applied at different levels in telecommunication systems; they can be adopted to study the waiting time experienced by a given request instanced to a processor or the time spent by a message or a packet waiting to be transmitted on a given link or through a whole network. In particular, every protocol in every node of a telecommunication network can be modeled through an appropriate queuing process.

Our analysis of queuing systems will start from Markov chains, such as the typical M/M/1 queuing model to be used in message-switched networks and the M/M/S/S queue employed to characterize the call loss behavior of local offices in telephone networks. Then, the interest will be focused on more advanced concepts, such as imbedded Markov chains (M/G/1 theory) with the related models adopted to study the behavior of ATM switches.

QoS provision is a key element both for the users that are happy of the telecommunication service they are adopting and for the network operators. The success of future telecommunication services and networks is heavily dependent on appropriate modeling and analysis in order to achieve an optimized network design able to guarantee suitable QoS levels for different traffic classes. This is the reason why the analytical methods of teletraffic analysis are of crucial importance for telecommunication networks.

Siena, Italy Giovanni Giambene

http://www.springer.com/978-1-4614-4083-3

Queuing Theory and Telecommunications
Networks and Applications
Giambene, G.
2014, XXI, 516 p. 268 illus., 32 illus. in color., Hardcover
ISBN: 978-1-4614-4083-3