Preface

Communication techniques and services are changing rapidly, and so are the techniques for the design and analysis of communicating systems and networks transporting and processing information: both in terms of data or images generated in a professional environment and – increasingly – in a personal environment (personal terminals: computers and mobiles). We have felt the need to reconsider basic mathematic tools, usually known by engineers but seldom presented as a whole, in the context of communication technologies. So, this book presents the major mathematical techniques in use in the field of telecommunications and more generally in the domain of information and communication technologies. Engineers, as well as students, will be led to tackle problems related to various subjects, such as signal and information processing, traffic or performance analysis, reliability, etc. Possibly they will become specialists, or responsible for one or several of these domains. We attempt here to provide the mathematical basis necessary to open constructive exchanges with experts, and also to efficiently begin the study of specialized publications.

The present publication has naturally been constructed around the notion of probability. Indeed, we should not be surprised that random variables play a major role in the mathematics deployed to solve problems related to the processing and transport of "information", in essence an unknown quantity. This has naturally guided the structure of this book, providing something of a framework for a unified theoretical approach of communications, with the following chapters.

Probability theory is naturally the subject of Chapter 1, as it constitutes the basis of numerous developments in all the fields addressed by this book, from simple combinatorics to queueing theory, signal processing, statistics or reliability. The chapter presents the main theorems and introduces the notion of random variables and their handling. Transform properties, and their use, are also detailed. Indeed, transforms happen to offer an essential tool for the solution of numerous problems

arising when dealing with linear systems, birth and death systems or stochastic relationships. They will find many applications in each of the following chapters.

Chapter 2 complements Chapter 1 and presents the major *probability distributions* we should encounter when describing or modeling the events observed in systems and networks. This refers to, for instance, the analysis of a signal, the volume of data to process, or the reliability of a piece of equipment. All these distributions will be of constant use in the later chapters.

Statistics constitute the object of Chapter 3. Engineers face uncertainty at every step – in observation, measurement, modeling – and have to rely on statistical techniques in order to support their decisions. Estimation will be a constant necessity, e.g. when observing traffic flows, measuring equipment reliability or recognizing a signal.

Chapter 4 presents *signal theory* and its *digital processing*. Every communication relies on signals, and more and more sophisticated methods guarantee the quality of its transport and reconstruction. Sampling makes it possible to represent the actual analog signal in the form of a digital signal. The latter can then be easily stored or transported. Finally, digital processing techniques allow signal filtering in order to restore it as accurately as possible, or even to synthesize new signals. The complex variable, the Fourier and z-transforms, as well as correlation analysis are the major tools for these operations.

Chapter 5, devoted to *information and coding theory*, is the natural successor of Chapter 4. Considering the random nature of information and its perturbations, digitalization and coding bring considerable improvements, both for its transmission (error correction) and for resource optimization (thanks to compression techniques). The chapter first presents a probabilistic model of the information (measure of information and notion of entropy, source and channel modeling, Shannon's theorems), then the major theoretical and practical aspects of coding algorithms are introduced (detecting codes and correcting codes, data compression, for text, image and sounds). For this, probabilities, transforms and modulo 2 algebra will be used.

Chapter 6 presents *traffic and queueing theory*. In networks, traffic represents the information transported globally, its volume, time characteristics (arrival epochs, duration of resource seizing). Here we encounter the well-known *Erlang* concept and the associated dimensioning procedures. Traffic and queueing theory are the essential tools for performance analysis of networks and computers, in order to guarantee the fulfilment of quality of service constraints, through systems and protocols modeling. This is above all the area of Markov processes, of stochastic relations as well as Laplace transforms, generating and characteristic functions.

Chapter 7 presents *reliability theory*. Facing all defects present in any equipment and software involved in a given communication task, and given the catalectic

(random) nature of failures, studying their reliability makes it possible to evaluate the probability that the mission will be successful. Observation and statistical processing of the observed events allows us to collect all the data needed to forecast the reliability of systems under design. Using statistical laws will then allow a judicious dimensioning of spare parts, for an acceptable probability of stock outage.

Finally, Chapter 8 presents the theoretical bases of *simulation*, which offers an essential complement to analytical methods. Whatever the approach, Monte Carlo or discrete-event, it aims at reproducing the random aspects of events of interest, and at estimating probabilities of interest, by observing a large number of their occurrences.

To complete these topics, the reader will find a mathematical refresher in the Appendix, recalling a few "elementary" results relevant to the proofs.

As complete as it strives to be, this book cannot pretend to present all the details and ramifications of these theories. However, besides the tools to solve most of the problems he/she could encounter, the reader should find here the essential background information allowing them to tackle specific topics, and for which purpose a bibliography is provided.

Obviously all the subjects presented in this book have a wider application field than pure communications (i.e. carrying information through a media), even if most examples belong to this field. For instance, signal processing plays a major role in medicine, climatology and astronomy, as well as entertainment. Equally, birth and death processes are at the basis of financial mathematics. The same comment holds for statistics, simulation or reliability. All these mathematical techniques cover a wider range of applications, and it is our belief that this book meets the needs of numerous students as well as practitioners in many fields involved with probabilities – communications, and much besides.

Writing this book has given us the opportunity for fruitful exchanges with specialists in various domains. In particular, it is our pleasure to address our thanks to A. Gilloire and M. Joindot, France Télécom R&D, and also to N. Moreau, Telecom-ParisTech (formerly GET/ENST), for their suggestions and for having re-read Chapters 4 and 5.