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Quantum Communication Networks

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Preface

Taking a quick look at this book, a reader might think: *Oh, here comes another book on quantum computing, quantum information theory, and quantum communications!* This may be partially true. Quantum mechanics was born at the beginning of the last century and, over the decades, has obtained huge popularity in mathematics and physics. Additionally, quantum mechanics has been applied to computing and information theory for the past 40–50 years. Recently, it has been also applied to communications.

Thus, by exploring the available scientific literature, it is possible to find plenty of books on quantum mechanics, quantum computing, and quantum information theory and some on quantum communications. So, the question is: *Is this book needed in the panorama of scientific literature?* The answer is yes, and there are some important reasons to support this.

First, many of the books are not very recent (especially from a communication perspective), so they miss some important recent updates. Furthermore, most of them are monographs, which focus on specific areas of research in quantum theory and its applications.

Second, to the best of the authors' knowledge, no book has considered the recent perspectives that communication networks have been gradually acquiring. In fact, communication networks are currently undergoing a paradigm shift that adds computing and storage to the simple transportation ideas of our first communication networks. These *softwarized* solutions break new ground in reducing latency and increasing resilience but have an inherent problem due to the introduced computing latency and energy consumption. This problem can be solved by hybrid classical-quantum communication networks.

This book inherits the existing paradigm of computing-in-networks, and it uses this to describe future quantum communication networks (which will not only be the Quantum Internet). The book focuses on quantum computing, quantum information theory, quantum error correction, and system-level architecture as various bricks that will build future *compute-and-forward* quantum communication networks. The approach, which is used for the presentation of the theory of quantum communication networks, borrows some viewpoints from the ongoing

work of the IETF Quantum Internet Research Group (qirg) (in which the authors are participating). However, this book also enhances and generalizes these views in order to leave the reader free to investigate and figure out new designs and solutions without architectural limits. This becomes especially important in a new field like quantum communication networks, where there are no existing standardized solutions yet.

Last but not least, this book addresses a topic in this field, which has never been presented before in books: the research problem of classically tested (via software simulations) quantum-mechanical systems. Because of this, at the end of the book, existing simulators of quantum communication networks are presented and their pros and cons are underlined. In this way, the reader will become aware of this important open issue when approaching research on quantum communication networks. Finally, some identified potential applications of quantum communication networks are also described. This also represents a practical viewpoint for the reader.

As authors who are experts in the fields of the research presented, we hope that the book conveys the importance of quantum-mechanical resources for the effective and efficient evolution of future communication networks. When we wrote this manuscript, we had in mind providing both physicists and engineers with a valuable reference for their research in quantum communication networks (and its subfields). Moreover, we planned the structure and the terminology to be both accurate and accessible, in order to become a helpful assistant for lectures in higher education and for training courses in the industry.

Dresden, Germany Riccardo Bassoli
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Contents

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