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Machine-Type Communication for Maritime Internet-of-Things

From Concept to Practice

Springer

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This book is dedicated to my wonderful children, to the memory of my beloved parents, and to all my diligent students.

Michael Mao Wang

Preface

Internet of Things (IoT) can be viewed as a global infrastructure for the information society, enabling applications and services in the fields such as energy, health, and transportation by seamlessly interconnecting and integrating "things" into the information network. The IoT technology is expected to burgeon in the coming decade. The same situation abounds in the maritime domain, as manifested by the recent effort by the United Nations chartered International Maritime Organization (IMO) to modernize the maritime industry under the name "*e*-Navigation," involving the harmonized collection, integration, exchange, presentation, and analysis of maritime information to enhance berth-to-berth navigation and related services for safety and security at sea as well as the protection of the marine environment.

The backbone of IoT is the machine-type communication technology that provides wireless connectivity for massive IoT devices or "things." It can be deemed the framework that the IoT network is hinged on. Machine-type communication (MTC), also known as machine-to-machine communication (M2M), is automated data communication among machines or things and, in principle, does not need human intervention. The communication may occur between an IoT device and an application server or directly between two or more IoT devices. A distinguishing characteristic of MTC from traditional human-type communication (HTC) is that the communication destination is typically not the "person of interest" but the "service of interest." Maritime MTC is a special type of MTC with a specific application in maritime IoT. Like in the general IoT scenarios, most maritime applications and services require little or no human involvement and work even in the absence of human operators, particularly in adverse conditions. Compared to most terrestrial MTC systems, maritime MTC is more complex in coverage, deployment environment, and radio spectrum allocation.

However, it is not an overstatement to say that maritime communication technology has been literally "crushed" by its land counterparts in the past few decades, in large part because of their mass markets and profits that have lured investments and research efforts in information and communication technology (ICT), virtually unchallenged for decades, depleting genuinely experienced maritime ICT professionals. Today's reality is that maritime communication technology has lost traction and fallen far behind, struggling to meet the emerging maritime service demand. This book is intended to fill this gap by pointing out the key challenges and requirements in maritime IoT, presenting a maritime MTC concept to address the challenges and requirements, and providing a comprehensive design example of a practical maritime MTC system, focusing on network architecture, air interface, and radio spectrum. The primary readers of this book include maritime communication engineers, maritime IoT professionals, maritime academia, and the general MTC and IoT communities.

Overall, this book can be partitioned into two parts. The first half, consisting of Chaps. 1, 2, 3, 4 and 5, identifies the challenges and requirements of maritime MTC, delineates an MTC concept—a portrait of a maritime MTC system from an architectural perspective, and describes an MTC framework along with definitions of the fundamental components and functionalities. In the second half, Chaps. 6, 7, 8, 9 and 10, we tie together all discussed in the first part and demonstrate how to apply it on a realistic radio spectrum. Particularly, we deal with more specific aspects through a practical design example based on an international maritime mobile spectrum, which stresses the unified approach introduced in the first part to address the various requirements. Throughout the book, we focus on describing the ideas behind the design using explanatory arguments and simple mathematical treatments to guide readers to an easier understanding of the provided material. A sequential reading of these chapters is recommended, although each chapter is reasonably self-contained.

Specifically, Chap. 1 introduces the Internet of Things and machine-type communication with a focus on maritime applications. It briefly reviews the maritime communication history and describes the challenges and requirements of maritime MTC. Chapter 2 overviews the maritime MTC system architecture and describes the associated network topology and components. It then examines the characteristics of various wireless communication techniques and networks pertinent to maritime MTC, such as proximity, terrestrial, and satellite communication networks. Chapter 3 defines the protocol layers, protocol channels, and layer interfaces for a maritime MTC system. Chapter 4 describes the network structure and the control and application planes to enable service-centric networking and interworking with the Internet protocol or the IP-based network. Chapter 5 reviews the elements of radio communication techniques most relevant to MTC and serves as a basis for the following chapters. It explains the basic concepts of the radio spectrum, modulation, baseband and passband signals, bandwidth, propagation, transmission, and reception to provide the reader with a technical foundation to understand the radio communication techniques used in the maritime MTC air interface design.

For materialization of the concept portrayed in the first half, Chap. 6 introduces a VHF maritime mobile band, recently assigned to *e*-Navigation by ITU. It then examines the individual frequency bands devoted to different maritime MTC scenarios regarding regulations, sharing, and interference mitigation. Chapter 7 deals with the proximity air interface design for proximity-based maritime IoT services operating on this VHF maritime mobile band. Chapter 8 provides an in-depth treatment of a terrestrial air interface for nearshore maritime services. Chapter 9 deals with the issues unique to a satellite air interface for global coverage of maritime services. Finally, Chap. 10 considers the open issues and highlights the potential pitfalls to watch out for in ongoing and future development and standardization of maritime MTC technologies.

This book is an outgrowth of our teaching activities on wireless networking and research work on the maritime Internet of Things. In writing this book, many people have contributed in many ways, and we acknowledge those whose efforts should not go unnoticed. Credit is due to Professor Xiaohu You of Southeast University for originally suggesting and funding the research that uncovered the material in this book. The authors are grateful to Professor Cong Shen of the University of Virginia and Professor Min Dong of Ontario Tech University for thoughtfully and constructively sharing their perspectives, insights, and expertise. We want to thank Mr. Ross Norsworthy, a delegate from the United States to ITU and IEC, for sharing his considerable knowledge of writing and maintaining technical standards for maritime communications and navigation, which has enriched Chap. 6. We also want to pay special thanks to Mr. Hans Christian Haugli of Space Norway, Mr. Yoshi Miyadera of Japan Radio Company (JRC), Dr. Ronald Raulefs of German Aerospace Center, and Dr. Krysztof Bronk of the Polish National Institute of Telecommunications for many valuable discussions and suggestions. Several gifted young minds—the graduate students of the authors have also helped with simulations and critical reading or proofing. In this regard, the efforts of Tingting Xia and Lei Wang and their continual assistance are invaluable and greatly appreciated.

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