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Next Generation Marine Wireless Communication Networks

Springer

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Preface

In the past decades, we have witnessed the rapid development of marine programs in many countries. Marine communication and networking, as an important cornerstone of the delivery of maritime services, is deeply integrated into production and life of people in coastal countries. The next generation Marine Wireless Communication Networks (MWCNs) are expected to incorporate advanced communication and networking technologies to meet the ever-increasing demand of maritime services, and to enable many new intelligent maritime applications such as environment-adaptive navigation, intelligent cargo storage management, underwater inspection and surveillance, telemedication, and maritime emergency rescue. However, marine communications are faced with many fundamental challenges such as complex marine environments, fast-changing maritime channels, and limited spectrum resources. These challenging issues may greatly degrade the quality of service of MWCN in terms of latency, reliability, and scalability.

This book aims to address these challenges in the design and development of next generation MWCNs. Specifically, we will explore the key technologies in the following general categories to improve the network performance, including (1) the network deployment, (2) the physical layer channel coding, (3) the link layer resource management, and (4) the network layer routing design. The objective of the book is to provide a comprehensive guide for the audience to understand the design principle and development of MWCNs in support of numerous maritime services.

The book is organized as follows. An overview of MWCNs is first presented, including maritime applications and a comprehensive survey of existing MWCNs, followed by a detailed discussion of challenges of maritime communications and networking in different layers. In order to address these challenges, e.g., high deployment costs of marine sensors in a large-scale three-dimensional space, and long propagation delay of underwater acoustic channel, we first study the network deployment and management of next generation MWCNs with a multi-tier hierarchical network architecture that includes three sub-networks, namely, the underwater acoustic sub-network, the sea-surface wireless sub-network, and the air wireless sub-network. Then, a novel Orthogonal Frequency Division Multiplexing (OFDM)

autoencoder featuring CNN-based channel estimation is presented for marine communications with complex and fast-changing environments. Next, the energy sustainable performance of an underwater sensor network using a random-access protocol is analytically studied, taking into consideration the stochastic nature of energy harvesting and the unique feature of the acoustic communication channel. Furthermore, in order to monitor the marine environment and surveil the sensor ecosystem, an Energy-efficient Depth-based Opportunistic Routing Algorithm with Q-learning (EDORQ) is proposed for marine wireless sensor networks to guarantee the energy efficiency and reliable data transmissions. Finally, we summarize the book and outline the possible further research directions.

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Contents

Abbreviations

AANet	Adaptive aggregation network
AIS	Automatic identification system
ANO	Average network overhead
AoA	Arrival of angle
AP	Access point
APD	Average packet delay
AR	Augmented reality
ARN	Aerial relay node
ARQ	Automatic repeat request
ASM	Application specific messages
AUVs	Autonomous underwater vehicles
BDS	BeiDou navigation satellite system
BLER	Block error rate
BnB	Branch and bound
BSs	Base stations
CE	Channel estimator
CIRs	Channel impulse responses
CL	Candidate location
CNNs	Convolutional neural networks
Co-DNAR	Cooperative DNAR
CoEERD	Cooperative effective energy and reliable delivery
COSPAS/SARSAT	International satellite system for search and rescue services
CP	Cyclic prefix
CSI	Channel state information
CSMA/CA	Carrier-sense multiple access with collision avoidance
CTS	Clear to send
DART	Deep-ocean assessment and reporting of tsunamis
DBR	Depth-based routing
DEADS	Depth and energy aware dominating set based algorithm
Dense-Net	Dense convolutional neural networks

DFT	Discrete Fourier transform
DL	Deep learning
DNAR	Depth and noise-aware routing
DSC	Digital selective calling
ECN	Edge computing node
EDORQ	Energy-efficient depth-based opportunistic routing algorithm with Q-learning
EE-DBR	Energy-efficient depth-based routing algorithm
EERD	Effective energy and reliable delivery
ELF	Extremely low frequency
ELT	Emergency locator transmitter
eMBB	Enhanced mobile broadband
EPIRB	Emergency position indicating radio beacon
ESONET	European Seas Observatory Network
EW	Electromagnetic waves
FC	Full connected
FCL	Feasible candidate location
FDMA	Frequency division multiple access
FSK	Frequency-shift keying
GEO	Geostationary Earth Orbit
GMDSS	Global Maritime Distress and Safety System
GOES	Geostationary Operational Environmental Satellite
GOOS	Global Ocean Observing System
GX	Global Xpress
HAPs	High-altitude platforms
HD	High definition
HF	High frequency
HH-VBF	Hop-by-Hop vector-based forwarding algorithm
IALA	International Association of Maritime Aids to Navigation and Lighthouse Authorities
IDFT	Inverse discrete Fourier transform
IMO	International Maritime Organization
INMARSAT	International Maritime Satellite
IoV	Internet of vessels
ISI	Inter-symbol interference
ITU	International Telecommunication Union
LEO	Low Earth orbit
LMMSE	Linear minimum mean square error
LS	Least squares
LUT	Local user terminal
MASS	Maritime autonomous surface ship
MCC	Mission Control Center
MDP	Markov decision process
MEC	Mobile edge computing

MEO	Medium Earth orbit
MF	Medium frequency
MMN	Marine monitoring network
MO	Multi-objectives optimization
MSI	Maritime safety information
MWCNs	Marine wireless communication networks
NAVTEX	Navigational Telex
NBDP	Narrow band direct printing
NCC	Network Control Center
NCS	Network Coordination Station
NFV	Network functions virtualization
NS2	Network simulator version 2
OFDM	Orthogonal frequency division multiplexing
OR	Opportunistic routing
OVAR	Opportunistic void avoidance routing
PDR	Packet delivery ratio
PLB	Personal locator beacon
QDAR	Q-learning based delay-aware routing
QELAR	Q-learning-based energy-efficient and lifetime-aware routing
QKS	Q-Learning with additional kinematics and sweeping features
QoS	Quality of service
RCC	Rescue coordination center
Res-Net	Residual network
RF	Radio frequency
ROVs	Remote operated vehicles
RSS	Received signal strength
RTS	Request to send
SAGSIN	Space-air-ground-sea integrated networks
SCS	Special communications systems
SDN	Software defined network
SIFS	Shortest interframe space
SOLAS	International Convention for the Safety of Life at Sea
SOTDMA	Self-organized time division multiple access
SSN	Sea-surface node
TEC	Total energy consumption
ToA	Time of arrival
TRITON	TRI-media Telematic Oceanographic Network
UAN	Underwater acoustic network
UAVs	Unmanned aerial vehicles
UNCTAD	United Nations Conference on Trade and Development
URLLC	Ultra-reliable and low latency communication
URN	Underwater relay node
UWSNs	Underwater wireless sensor networks
VAPR	Void-aware pressure routing

VBF	Vector-based forwarding
VDE	VHF data exchange
VDES	VHF data exchange system
VDL	VHF data links
VHF	Very high frequency
VLF	Very low frequency
VR	Virtual reality
VSAT	Very small aperture terminal
WiMAX	World Interoperability for Microwave Access
WISEPORT	Wireless broadband access project
WSN	Wireless sensor network