

Shengming Jiang

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# Wireless Networking Principles: From Terrestrial to Underwater Acoustic

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 Springer

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*To my wife, my son and my daughter*

# Preface

Today, wireless networking technologies deeply affect many social sectors and people's daily life. For example, mobile personal communication networks such as 4G and beyond as well as WiFi networks are the enabling technologies for mobile Internet used by almost everyone at anytime in terrestrial environments. These wireless networks provide the users with a great convenience for personal communication, social activities, shopping, and traveling as well as education, since many traditional activities and organizations now can be carried out simply through mobile smart terminals. The wireless networking technology as a whole is still developing. For example, mobile personal communication is under development toward 5G, aiming at providing much faster and reliable communications than the currently available one to eliminate the gap in service quality between wireless and wired networks. On the other hand, some wireless networks are still in early development stages. For example, a huge number of sensors and actuators as well as various types of vehicles have been deployed underwater, and this number is still growing. These underwater things usually equipped with communication facilities are able to construct an Internet of Underwater Thing (IoUT) [1]. How to link these nodes to cover large underwater areas and transfer the collected data to the surface processing center faces many challenges. Many issues are necessarily addressed for underwater wireless networks, which are still in enfant ages.

Since the radio wave cannot propagate long enough but only acoustic signal can in underwater environments to satisfy application requirements, currently most underwater wireless networks are based on acoustic waves. Therefore, in this book we call this kind of network underwater acoustic networks (UWANs), which include underwater acoustic sensor networks. UWANs have some special features not present in most terrestrial radio wireless networks (RWNs), such as much long propagation delays, very limited channel capacities, low channel reliability, and high dynamics of communication environments. These features greatly affect the design of underwater networking protocols and schemes, preventing those well-developed for RWNs from being used directly in UWANs.

Despite many differences in networking environments between RWNs and UWANs, they still have many similar issues to be addressed by both, and many approaches and design strategies developed for RWNs can be used as references in designing UWAN protocols, and some of them can be used in UWANs after proper modifications. Therefore, a good understanding of the well-developed RWN technologies can be helpful to understand network protocols and algorithms proposed for UWANs. There are several books systematically describing RWN technologies in the literature such as [2, 3, 4], while a couple of UWANs are also available such as [5, 6]. This book is unique in terms of discussing networking technologies for both RWNs and UWANs in one.

This book aims to highlight the key networking issues and explain the basic ideas of typical networking technologies, in which the principal challenging issues and research topics are addressed and discussed in detail. The book consists of thirteen chapters. The first chapter (Chap. 1) introduces the typical wireless networks and fundamental networking issues. The remaining chapters are divided into two parts. The first part will systematically describe the well-established RWN technologies that have been standardized or applied in practice, covering the following topics: error control (Chap. 2), medium access control (MAC) protocols (Chaps. 3 and 4), routing protocols (Chap. 5), end-to-end transmission control (Chap. 6), mobility (Chap. 7), and network security (Chap. 8). The majority of this part except TCP and vertical handoff in mobile networks are relatively mature and can provide a foundation to understand the counterparts of UWANs. The second part discusses the up-to-date networking technologies for UWANs, including underwater acoustic channels (Chap. 9), UWAN MAC protocols (Chap. 10), UWAN routing protocols (Chap. 11), UWAN transfer reliability control covering both error control and end-to-end transmission control (Chap. 12), and UWAN security (Chap. 13). This part is mainly based on the author's surveys on the related topics [7, 8, 9, 10].

I hope that the book can become a useful resource for new learners, researchers, and practitioners in RWNs and UWANs.

Shanghai, China  
January 2018

Shengming Jiang

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# Acronyms

3GPP	Third Generation Partnership Project, 176 <sup>1</sup>
AAA	Authentication, Authorization and Accounting, 208
ABE	Available bandwidth estimator, 156
ABR	Associativity-based routing, 149
ACK	Acknowledgement, 22
ADA	Adaptive delayed acknowledgement, 154
AES	Advanced Encryption Standard, 221
AIFS	Arbitration IFS, 88
AIMD	Additive increase and multiplicative decrease, 141
AKM	Authenticated key management, 226
ANC	Analog network coding, 349
AOA	Angle of arrival, 281
AODV	Ad hoc on-demand distance vector, 114
AP	Access point, 2
ARQ	Automatic Repeat reQuest, 22
ATCP	Ad hoc TCP, 155
ATM	Asynchronous transfer mode, 19
ATP	Ad hoc transport protocol, 155
AVP	Attribute–value pair, 200
AUV	Autonomous underwater vehicle, 12
AUC	Authentication center, 181
BER	Bit error rate, 60
BCH	Bose–Ray-Chaudhuri–Hocquenghem, 34
BO	Backoff, 59
BP	Beacon period, 91
BPSK	Binary phase shift keying, 351
BSC	Base station controller, 172
BSS	Basic service set, 216

---

<sup>1</sup> It is the number of the page on which the corresponding acronym first appears.

BSS	Base station subsystem, <sup>2</sup> 173
BTMA	Busy tone multiple access, 82
BTS	Base transceiver station, 172
BU	Binding update, 185
B-ACK	Block acknowledgement, 93
CA	Certificate authority, 204
CA	Collision avoidance, 72
CA	Congestion avoidance, 140
CAC	Call admission control, 186
CAP	Contention access period, 20
CBP	Call blocking probability, 186
CBR	Constant bit rate, 78
CC	Channel carrying, 186
CCH	Control channel, 78
CCMP	CCM protocol, 224
CCMP	Counter mode with CBC-MAC protocol, 222
CCP	Call completion probability, 186
CD	Collision detection, 73
CDM	Code division multiplexing, 27
CDMA	Code division multiple access, 59
CDP	Call dropping probability, 185
CFP	Contention-free period, 92
CHAP	Challenge plus response pair, 209
CIR	Carrier-to-interference ratio, 169
CL	Connectionless, 19
CO	Connection-oriented, 19
CoA	Care-of-address, 183
COPAS	Contention-based path selection, 154
CR	Communication round, 159
CRC	Cyclic redundancy check, 22
CS	Carrier sensing, 58
CSI	Channel state information, 240
CSMA	Carrier Sensing Multiple Access, 59
CSMA/CD	CSMA with collision detection, 253
CTR	Counter mode, 224
CTS	Ciphertext stealing, 356
CTS	Clear-to-Send, 52
CW	Contention window, 252
cwnd	Congestion window, 138
DAG	Directed acyclic graph, 322
DBF	Distributed Bellman Ford, 103
DCAC	Distributed CAC, 186

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<sup>2</sup>An acronym may refer to different definitions.

DCC	Dedicated control channel, 64
DCCP	Datagram congestion control protocol, 137
DCF	Distributed coordination function, 88
DCH	Data channel, 84
DCA	Dynamic channel allocation, 188
DDoS	Distributed DoS, 204
DIFS	DCF IFS, 89
DoA	Direction of arrival, 356
DoS	Denial of service, 204
DP	Data period, 97
DRP	Distributed reservation protocol, 97
DSDV	Destination-sequenced distance vector, 115
DSN	Destination sequence number, 124
DSR	Dynamic source routing, 117
DSSS	Direct-sequence SS, 60
DTLS	Datagram transport layer security, 212
DTN	Delay- and disruption-tolerant network, 11
EAP	Extensible Authentication Protocol, 215
EAPOL	EAP Over LANs, 216
ECAES	Elliptic curve authenticated encryption scheme, 342
ECC	Elliptic curve cryptography, 342
ECDLP	Elliptic curve discrete logarithm problem, 342
ECDSA	Elliptic curve digital signature algorithm, 342
ECN	Explicit congestion notification, 156
EIFS	Extended IFS, 90
ELFN	Explicit link failure notification, 151
ESP	Encapsulating security payload, 215
ETSI	European Telecommunication Standards Institute, 2
EU	European Union, 92
FAMA	Floor acquisition multiple access, 54
FCA	Fixed channel allocation, 188
FCC	Federal Communications Commission, 96
FCS	Frame check sequence, 38
FDD	Frequency-division duplex, 319
FDM	Frequency-division multiplexing, 60
FDMA	Frequency-division multiple access, 63
FEC	Forward error control, 21
FFD	Full function device, 94
FHSS	Frequency-hopping SS, 60
FIFO	First in, first out, 247
FS	Frame sensing, 62
FTP	File transfer protocol, 137
GC	Guard channel, 188
GEO	Geostationary Earth orbit, 4
GKH	Group key handshake, 226

GoS	Grade of service, 187
GSM	Global system for mobile communication, 20
GTK	Group temporal key, 226
GTS	Guaranteed time slot, 94
HARQ	Hybrid ARQ, 321
HiperLAN	High-performance radio local area network, 2
HLR	Home location register, 175
HMAC	Keyed-Hashing for Message Authentication, 214
HS	Handshaking, 62
ICI	Interchannel interference, 275
ICV	Integrity check value, 223
ID	Identity, 105
IETF	Internet Engineering Task Force, 117
IFS	Interframe space, 89
IP	Internet Protocol, 80
IPN	Interplanetary Internet, 11
IPSec	IP security, 187
IPv4	IP version 4, 23
IRTF	Internet Research Task Force, 117
ISDN	Integrated service data network, 27
ISI	Intersymbol interference, 239
ISM	Industrial, scientific, medical, 30
ISO	International Organization for Standardization, 16
ITCP	Indirect TCP, 148
ITS	Intelligent transportation system, 9
IV	Initialization vector, 220
JTCP	Jitter-based TCP, 149
KCK	Key confirmation key, 227
KEK	Key encryption key, 227
L3MP	Layer 3 or higher mobility protocol, 181
LAN	Local area network, 54
LBL	Long baseline, 239
LDPC	Low-density parity-check code, 38
LED	Light-emitting diode, 14
LEO	Low Earth orbit, 4
LLC	Logical link control, 61
LOS	Line-of-sight, 14
LT	Luby transform code, 324
LTE	Long-term evolution, 3
MAC	Medium access control, 17
MACA	Multiple access collision avoidance, 54
MACsec	IEEE 802.1AE MAC security protocol, 217
MAHO	Mobile-assisted handoff, 175
MAI	Multiple access interference, 252
MANET	Mobile ad hoc network, 5

MAS	Medium access slot, 96
MAU	Medium access unit, 57
MCHO	Mobile-controlled handoff, 175
ME	Messaging, 62
MEO	Medium Earth orbit, 4
MF	MAC frame, 58
MFSK	Multi-frequency shift keying, 253
MIC	Message integrity code, 225
MIH	Media-independent handover, 180
MIHF	MIH function, 180
MIMO	Multi-input–multi-output, 275
MM	MAC mechanism, 58
MPDU	MAC protocol data unit, 224
MPR	Multipoint relay, 125
MS	Mini-slot, 58
MSC	Mobile switching center, 175
MSDU	MAC service data unit, 224
MSR	Mobility support router, 148
MSS	Maximum segment size, 142
NAS	Network access server, 211
NAV	Network allocation vector, 91
NCC	Non-channel-carrying, 190
NCHO	Network-controlled handoff, 175
NDP	Neighbor discovery protocol, 187
NF	Notification packet, 263
NH	Next hop, 109
NIC	Network interface card, 216
NLOS	Non-line-of-sight, 303
NSS	Network and switching subsystem, 175
OC	Operation cycle, 57
OFDM	Orthogonal FDM, 60
OFDMA	Orthogonal FDMA, 252
OLSR	Optimized link state routing, 125
OSI	Open system interconnection, 316
OSS	Operation subsystem, 175
PAN	Personal area network, 93
PAP	Password pair, 212
PCA	Prioritized contention access, 97
PCF	Point coordination function, 88
PCS	Personal communication system, 176
PDA	Personal digital assistant, 3
PIFS	PCF IFS, 89
PKI	Public key infrastructure, 207
PMK	Pairwise master key, 226
PO	Polling, 62

PPK	Per-packet key, 222
PPP	Point-to-point protocol, 212
PR	Prioritization, 64
PRMA	Packet reservation multiple access, 60
PRoPHET	Probabilistic Routing Protocol using History of Encounters and Transitivity, 121
PSK	Pre-shared key, 222
PTK	Pairwise transient key, 226
PTSP	Partial tree-sharing protocol, 128
QoS	Quality of Service, 26
RA	Registration authority, 207
RADIUS	Remote Access Dial-in-User Service, 211
RC4	Rivest cipher 4, 220
RD	Route discovery, 122
RE	Reservation, 62
RED	Random early dropping, 25
RERR	Route error, 125
RFC	Request for comments, 117
RFD	Reduced function device, 94
RFN	Route failure notification, 152
RI-BTMA	Receiver-initiated BTMA, 84
RL	Reinforcement learning, 306
RM	Route maintenance, 122
RN	Reported node set, 129
RREP	Route reply, 123
RREQ	Route request, 123
RRN	Route re-establishment notification, 152
RRP	Route request packet, 122
RS	Reed–Solomon, 38
RSA	Ron Rivest, Adi Shamir and Leonard Adleman, 375
RSNA	Robust Security Network Association, 223
RSS	Received signal strength, 171
RSS	Radio subsystem, 175
RT	Reported subtree, 130
RTT	Round-trip time, 79
RTO	Retransmission timeout, 138
RTS	Request-to-Send, 54
rwin	Receiver window, 141
RWN	Radio wireless network, 337
RWN	RF wireless network, 29
SA	Slot access, 61
SACK	Selective ACK, 157
SAK	Secure association key, 217
SAP	Service access point, 181
SC	Scheduling, 62

SC	Shadow cluster, 188
SCTP	Stream control transmission protocol, 134
SI	Signaling, 59
SIC	Successive interference cancellation, 273
SIFS	Short IFS, 83
SIR	Signal-to-interference ratio, 189
SISO	Single-input–single-output, 174
SL	Slot, 56
SN	Sequence number, 113
SNIR	Signal-to-noise-plus-interference noise ratio, 341
SNR	Signal-to-noise ratio, 14
SS	Slow start, 140
SS	Spread spectrum, 54
SSH	Secure shell, 134
SSID	Service set identifier, 216
SSL	Secure socket layer, 211
ST-CG	Spatiotemporal conflict graph, 264
S-FAMA	Slotted FAMA, 255
TBRPF	Topology dissemination based on reverse path forwarding, 118
TC	Topology control, 123
TCP	Transmission control protocol, 18
TCP-AP	TCP with adaptive pace, 153
TCP-DCR	Delayed congestion response TCP, 146
TCP-F	TCP with feedback, 149
TDD	Time-division duplex, 314
TDM	Time-division multiplexing, 54
TDMA	Time-division multiple access, 59
TKIP	Temporal key integrity protocol, 219
TLS	Transport layer security, 210
TS	Time slot, 53
TSC	TKIP sequence counter, 222
TTL	Time-to-live, 120
UDP	User datagram protocol, 134
ULB	Underwater locator beacon, 234
URI	Uniform resource identifier, 116
UUV	Unmanned underwater vehicle, 12
UWAN	Underwater wireless acoustic network, 25
UWB	Ultra-wideband, 6
UWSN	Underwater wireless sensor network, 12
VANET	Vehicular ad hoc network, 10
VLR	Visitor location register, 272
VoIP	Voice over IP, 176
VPN	Virtual private network, 184
WAP	Wireless access protocol, 213
WBAN	Wireless body area network, 6

WEP	Wired equivalent privacy, 216
WiMAX	Worldwide Interoperability for Microwave Access, 4
WLAN	Wireless local area network, 2
WMAN	Wireless metropolitan area network, 3
WMN	Wireless mesh network, 8
WPA	Wi-fi Protected Access, 216
WPAN	Wireless personal area network, 6
WSN	Wireless sensor network, 8
WTLS	Wireless transport layer security, 213
WWAN	Wireless wide area network, 176

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