

Signals and Communication Technology

Hossam Mahmoud Ahmad Fahmy

Wireless Sensor Networks

Concepts, Applications, Experimentation
and Analysis

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*Dedicated to my family; parents, brothers
and sister with whom I grew up warmly...*

*wife and daughters who gave my life a caring
taste...*

*Dedication is not only for who are in our
world...*

Preface

Writing a book is tempting, many ideas and topics, idea after idea, and topic upon topic, what to elaborate, which to mention, the reader must find a satisfying answer, enough knowledge; overlooking or going-by are painful choices for the author, space is limited, a hard decision is to be made, without compromising what should be transferred to the audience. Writing a scientific book is navigating, across the Nile, the Mediterranean, the Atlantic, and the Indian oceans, in boat and in glass submarine, looking and searching for known and unknown species, appreciating diversified colors and a variety of sizes, collecting for a near benefit and for the future. I navigated, explored, day and night, when cold and hot, whether windy or breezing, without tolerating a least chance to know and learn.

Networking is a field of integration, hardware and software, protocols and standards, simulation and testbeds, wired and wireless, VLSI and communication; an orchestrated harmony that collaborates dependably, all for the good of a connected well-performing network. That is the charm of networking, of life in a civilization that recognizes differences and goes on.

In introductory computer networking books, chapters sequencing follows the bottom-up or top-down architecture of the seven layers protocol. This book is some more steps after, both horizontally and vertically, the view and understanding are getting clearer, chapters ordering is based on topics' significance to the elaboration of wireless sensor networks (WSNs), concepts, and issues.

This book focuses on the notions of WSNs, their applications, and their analysis tools; meticulous care has been accorded to the definitions and terminology. To make WSNs felt and seen, the adopted technologies as well as their manufacturers are presented in detail. With such a depth, this book is intended for a wide audience, it is meant to be helper and motivator, for senior undergraduates, post-graduates, researchers, and practitioners; concepts and WSN-related applications are laid out, research and practical issues are backed by the appropriate literature, and new trends are put in focus. For senior undergraduate students, it familiarizes with conceptual foundations and practical project implementations. For graduate students and researchers, testbeds and simulators provide a must follow emphasis

on the analysis methods and tools for WSNs. For practitioners, besides applications and deployment, the manufacturers and components of WSNs at several platforms and testbeds are fully explored.

Chapter 1 introduces the basics of sensors and WSNs, the types of WSNs, and the standards specifically innovated to bring WSNs to useful life. Chapter 2 presents the distinctive protocol stack in WSNs. Chapter 3 lays out the plentiful applications of WSNs in military, industry, environment, agriculture, health, daily life, and multimedia. Chapter 4 is devoted to exhibiting characterizing transport layer protocols in WSNs. Analysis tools of WSNs are prime methods and tools to study, analyze, and implement WSNs, this is the goal of Chaps. 5 and 6. Chapter 5 presents the testbeds as existing in research institutes and projects to investigate protocols and practical deployment. Chapter 6 takes care of exhaustively surveying and comparing the simulation tools existing in the WSN realm. Chapters 7 and 8 must be checked whenever a product or a manufacturer is mentioned in the text, they are meant to provide the full spectrum of the WSN industry, from a full variety of products and their specs, to a wide diversity of manufacturers. Chapter 9 motivates the takeoff in WSNs study, research, and implementation. Exercises at the end of each chapter are not just questions and answers; they are not limited to recapitulate ideas. Their design objective is not bound to be a methodical review of the provided concepts, but rather as a motivator for a lot more of searching, finding, and comparing beyond what has been presented in the book.

Talking numbers, this book extends over nine chapters, and embodies 232 acronyms, 127 figures, 29 tables, and above 750 references.

With the advance of technology writing a book is becoming easier, information is attainable; but it is certainly harder, details and depth are not to be missed. A book, any book, is a step in a long path sought to be correct, precise as possible, nonetheless errors are non-escapable, they are avoided iteratively, with follow up and care.

The preface is the first get-together between the author and the audience, it is the last written words, it is lying in the ground after the end line, to restore taken breath, to enjoy relaxing after long painful efforts, mentally and physically, to relax in preparation for a new game.

An author has his ups and downs, as everybody, but he is visible like nobody. Could he manage to hide some of his letdowns? He has to, unlike anybody, for the sake of his book, his readership.

If you find somebody talking to himself, tumbling, wearing a differently colored pair of shoes, don't laugh at him, he is probably writing a book...

Hossam Mahmoud Ahmad Fahmy

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Acronyms

ACA	Autonomous Component Architecture
ACC	Active Congestion Control
ACK	Acknowledgment
ADC	Analog to Digital Converter
AER	Address Event Representation
AFOSR	Air Force Office of Scientific Research
AM API	Aggregate Manager API
AmI	Ambient Intelligence
AMR	Anisotropic Magneto-Resistive
AoA	Angle of Arrival
AODV	Ad Hoc On-demand Distance Vector
API	Application Program Interface
APS	Ad Hoc Positioning System
ARQ	Automatic Repeat reQuest
ART	Asymmetric and Reliable Transport
ATM	Asynchronous Transfer Mode
BAN	Body Area Network
BGP	Border Gateway Protocol
BLE	Bluetooth Low Energy
BSD	Berkeley Software Distribution
CBR	Constant Bit Rate
CCA	Clear Channel Assessment
CCD	Charge-Coupled Device
ChSim	CHannel SIMulator
CIF	Common Intermediate Format
CMOS	Complementary Metal-Oxide Semiconductor
CODA	COngestion Detection and Avoidance
COM	Component Object Model
COOJA	COntiki Os JAva
COP	Computer Operating Properly
CORBA	Common Object Request Broker Architecture

COST	Component-Oriented Simulation Toolkit
COTS	Commercial Off-The-Shelves
CPLD	Complex Programmable Logic Device
CPU	Central Processing Unit
CSMA/CA	Carrier Sense Multiple Access/Collision Avoidance
CSS	Central Supervisory Station
DARPA	Defense Advanced Research Projects Agency
DCF	Distributed Coordination Function
DDR3	Double Data Rate Type Three
DiffServ	Differentiated services
DIMM	Dual In-line Memory Module
DOA	Direction of Arrival
DoS	Denial-of-Service
DSP	Digital Signal Processor
DSR	Dynamic Source Routing
DTC	Distributed TCP Cache
DTSN	Distributed Transport for Sensor Networks
DV-hop	Distance Vector-hop
DVR	Digital Video Recorder
ECG	Electrocardiogram
EEG	Electroencephalogram
EEPROM	Electrically Erasable Programmable Read-Only Memory
EIGRP	Enhanced Interior Gateway Routing Protocol
EKG	Electrocardiogram
EMI	Electromagnetic Interference
EPRB	Ethernet PRogramming Board
ERTP	Energy Efficient and Reliable Transport Protocol
ESM	Experience Sampling Method
ESN	Environmental Sensor Network
FFD	Full Function Device
FIFO	First-In First-Out
FOV	Field of View
FPGA	Field Programmable Gate Array
FPSLIC	Field Programmable System Level Integrated Circuit
FSK	Frequency-Shift Keying
GCP	Global Control Processor
GEAR	Geographic and Energy Aware Routing
GENI	Global Environment for Network Innovation
GFSK	Gaussian Frequency-Shift Keying
GloMoSim	Global Mobile Information System Simulator
GPIO	General-Purpose Input/Output
GPO	GENI Project Office
GPRS	General Packet Radio Service
GPS	Global Positioning System
GPSR	Greedy Perimeter Stateless Routing

GTS	Guaranteed Time Slots
GUI	Graphical User Interface
HIL	Hardware In the Loop
HOL	Head-Of-Line
IACK	Implicit Acknowledgment
ID	Identification
IDE	Integrated Development Environment
IDL	Interface Definition Language
IETF	Internet Engineering Task Force
IGRP	Interior Gateway Routing Protocol
IID	Independent and Identically Distributed
INET	Internetworking Framework
IP	Ingress Protection/Internet Protocol
JPEG	Joint Photographic Experts Group
JSP	JavaServer Pages
JTAG	Joint Test Action Group
LAN	Local Area Network
LCD	Liquid Crystal Display
LDO	Low Dropout Regulator
LOS	Line of Sight
LQI	Link Quality Indication
LR-WPAN	Low Rate Wireless Personal Area Network
MANET	Mobile Ad Hoc Network
MBD	Muzzle Blast Detection
MCC	Motor Control Center
MCSA	Motor Current Spectral Analysis
MCU	Micro-controller Unit
MEMS	Micro-Electro-Mechanical System
MF	Mobility Framework
MiNT	Miniaturized Network Testbed for Mobile Wireless Research
MITM	Man-In-The-Middle
MiXiM	MiXed siMulator
MMC/SD	Multimedia Card/Secure Digital
MOVIE	Mint-m cOntrol and Visualization InterfacE
MPR	Mote Processor Radio board
MTT	Multi-target Tracking
MURI	Multidisciplinary Research Program of the University Research Initiative
NACK	Negative Acknowledgment
NAM	Network Animator
NED	NEtwork Description
NFC	Near Field Communication
NFS	Network File System
NIST	National Institute of Standards and Technology
NPE	Network Processor Engine

NRT	Network Research Testbed
NSF	National Science Foundation
NTP	Network Time Protocol
OLSR	Optimized Link State Routing
OMF	ORBIT Management Framework
OML	ORBIT Measurement Framework and Library
OMNeT++	Objective Modular Network Testbed in C++
OPNET	Optimized Network Engineering Tool
OSPF	Open Shortest Path First
OTAP	Over-The-Air Programming
PAN	Personal Area Network
PARSEC	PARAllel Simulation Environment for Complex systems
PAWiS	Power Aware Wireless Sensors
PCB	Printed Circuit Board
PCCP	Priority-Based Congestion Control Protocol
PCFG	Probabilistic Context Free Grammar
PCMCIA	Personal Computer Memory Card International Association
PCR	Peak Cell Rate
PDA	Personal Digital Assistant
PF	Positif Framework
PHP	Hypertext Preprocessor
PHY	Physical Layer
PIR	Passive Infrared
PIR	Pyroelectric Infrared
PLL	Phase Locked Loop
PNC	PicoNet Coordinators
PNNI	Private Network-to-Network Interface
POC	Proof of Concept
PRNG	Pseudo Random Number Generator
PROWLER	Probabilistic Wireless Network Simulator
PSFQ	Pump Slowly Fetch Quickly
PSK	Phase-Shift Keying
PSRAM	Pseudostatic Random-Access Memory
QoS	QoS Quality of Service
RBC	Reliable Bursty Convergecast
RF	Radio Frequency
RFC	Request for Comment
RFD	Reduced Function Device
RHE	Radio Harsh Environment
RIP	Routing Information Protocol
RISC	Reduced Instruction Set Computing
RMASE	Routing Modeling Application Simulation Environment
RMI	Remote Method Invocation
RMST	Reliable Multi-segment Transport
RON	Resilient Overlay Networks

RS	Reservation System
RSS	Really Simple Syndication
RSSI	Received Signal Strength Indicator
RTC	Real-Time Clock
RTS	Request To Send
RTT	Round Trip Time
SAS	Safety and Automation System
SCU	Small Combat Unit
SDRAM	Synchronous Dynamic Random Access Memory
SDRT	Segmented Data Reliable Transport
SENS	Sensor, Environment, and Network Simulator
SENSE	SEnsor Network Simulator and Emulator
SF	Serial Forwarder
SFA	Slice-Based Federation Architecture
SIMD	Single Instruction Multiple Data
SIMM	Single In-line Memory Module
SINR	Signal-to-Interference-plus-Noise Ratio
SMA	Sub-Miniature version A
SMP	Sensor Management Protocol
SNAAs	Sensor Network Authentication and Authorization
SNMP	Simple Network Management Protocol
SNMS	Simple Network Management System
SNR	Signal-to-Noise Ratio
SNS	Sensor Network Server
SOA	Service-Oriented Architecture
SO-DIMM	Small Outline Dual In-line Memory Module
SPI	Serial Peripheral Interface
SPIN	Sensor Protocols for Information
SRAM	Static Random Access Memory
SS	Signal Strength
SSCS	Service-Specific Convergence Sublayer
STCP	Sensor TCP
STD	State Transition Diagram
SUE	System Under Examination
SUNSHINE	Sensor Unified aNalyzer for Software and Hardware in Networked Environments
SVM	State Vector Machine
SWD	Shockwave Detection
SW-GDS	Soldier Wearable Gunfire Detection System
SXGA	Super eXtended Graphics Array
TCP	Transport Control Protocol
TCP/IP	Transport Control Protocol/Internet Protocol
TDMA	Time Division Multiple Access
TDOA	Time Difference of Arrival
TOA	Time of Arrival

TORA	Temporally Ordered Routing Algorithm
TOSSF	TinyOS Scalable Simulation Framework
TS	Testbed Server
TSMP	Time Synchronized Mesh Protocol
TWIST	TKN Wireless Indoor Sensor network Testbed
UART	Universal Asynchronous Receiver/Transmitter
UASN	Underwater Acoustic Sensor Network
UDG	Unit Disk Graph
UDP	User Datagram Protocol
USART	Universal Synchronous/Asynchronous Receiver/Transmitter
USB	Universal Serial Bus
USRP	Universal Software Radio Peripheral
UWB	Ultra-Wide-Band
VC	Virtual Circuit
VGA	Video Graphics Array
VHDL	Verilog Hardware Description Language
VS	Virtual Sink
VSG	Vector Signal Generator
WARP	Wireless Open Access Research Platform
WINLAB	Wireless Information Network Laboratory
WLAN	Wireless LAN
WMN	Wireless Mesh Network
WMSN	Wireless Multimedia Sensor Network
WPAN	Wireless Personal Area Network
WSDL	Web Service Definition Language
WSN	Wireless Sensor Network
WT	Watchdog Timer
XML	Extensible Markup Language
XSM	eXtreme Scale Mote
XSS	eXtreme Scale Stargate
XTC	Extended C
ZC	Zero-Crossing