Wireless Networks

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Wireless Sensing

Principles, Techniques and Applications

Springer

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Preface

Motivation of This Book

Wireless signals play a crucial role in communication for people's daily lives. Without wireless signals, for example, Wi-Fi, Bluetooth, and radio-frequency identification (RFID) signals, people may not enjoy those convenient and joyful services. In the last decade, apart from the communication function, researchers have shown that wireless signals provide a new paradigm for sensing human activities and objects. Wireless sensing has many benefits and advantages over traditional sensing approaches. First, wireless devices are prevalent almost everywhere. Using existing wireless infrastructures can provide a ubiquitous and cost-effective way for sensing. Second, wireless sensing can be non-intrusive. People can get rid of the traditional bulky sensors and avoid being monitored by the camera.

The primary motivation of this book is to provide a comprehensive summary of common principles of wireless sensing, a systematic study about challenging issues in complex and practical scenarios, and critical solutions to tackle these challenges. In particular, we first present a systematic introduction for the development and the vision of wireless sensing technology. Second, we provide a comprehensive study about wireless signals, sensing principles, and applications. Third, we discuss the challenges of putting wireless sensing into tangible and practical use. Then, we introduce methods to tackle the challenging issues in wireless sensing. Finally, we share our experiences in designing wireless sensing systems for several essential applications.

What This Book Is About

This book provides comprehensive reviews of the wireless sensing technology, including the types of wireless signals used for sensing, the general principles and approaches for wireless sensing, the information that wireless signals can sense, and the key applications. This book presents an investigation of the critical challenges that need to be alleviated to achieve wireless sensing in complex and practical scenarios and how to tackle these challenges with concrete case studies

and examples. The book can be seen as a textbook and a practical guide for the reader.

How This Book Is Organized

This book is divided into six chapters:

Chapter 1: "Introduction". This chapter introduces motivations, basics, applications, and the framework of wireless sensing.

Chapter 2: "Wireless Signals and Signal Processing". This chapter introduces different kinds of wireless signals and signal processing methods utilized for wireless sensing.

Chapter 3: "Wireless Sensing System Configurations". This chapter introduces and compares different configurations of wireless devices in wireless sensing systems.

Chapter 4: "Wireless Sensing Methodologies". This chapter introduces and discusses representative methodologies to obtain sensing information from wireless signals.

Chapter 5: "Case Studies". This chapter showcases representative case studies of applying wireless sensing for different applications, including human respiration monitoring, exercise monitoring, and liquid sensing.

Chapter 6: "Conclusion". This chapter provides the summary and future directions of wireless sensing.

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Contents

List of Symbols and Abbreviations

a	Signal amplitude of a single path
A	Amplitude of overall received signal
B	Bandwidth
c	Light speed
d	Signal propagation distance
Δd	Change of signal propagation distance
f	Frequency
$h(t)$	Impulse response
$H(f)$	Frequency-domain representation of $h(t)$
v	Signal speed
$x(t)$	Transmitted signal
$X(f)$	Frequency-domain representation of $x(t)$
$y(t)$	Received signal
$Y(f)$	Frequency-domain representation of $y(t)$
φ	Signal phase
$\Delta\varphi$	Phase difference
ϕ	Azimuth angle of arrival
θ	Elevation angle of arrival
λ	Signal wavelength
τ	Time delay
$*$	Convolution operation
ADC	Analog-to-digital converter
AM	Amplitude modulation
AOA	Angle of arrival
AP	Access point
BSS	Blind source separation
CFO	Carrier frequency offset
CFR	Channel frequency response
CSI	Channel state information
CSS	Chirp spread spectrum
CW	Continuous wave

DAC	Digital-to-analog converter
DWT	Discrete wavelet transform
FFT	Fast Fourier transformation
FM	Frequency modulation
FMCW	Frequency-modulated carrier wave
HPA	High power amplifier
ICA	Independent component analysis
IFFT	Inverse fast Fourier transformation
IoT	Internet of Things
IQ	In-phase and quadrature
ISAR	Inverse synthetic aperture radar
LFM	Linear frequency modulation
LNA	Low noise amplifier
LOS	Line of sight
LPF	Low-pass filter
LTI	Linear time-invariant
MIMO	Multiple-input multiple-output
MUSIC	Multiple signal classification
OFDM	Orthogonal frequency-division multiplexing
PA	Power amplifier
PDD	Packet detection delay
PGA	Programmable gain amplifier
PPO	Phase-locked loop
RF	Radio frequency
RFID	Radio frequency identification
RSS	Received signal strength
Rx	Receiver
SFO	Sampling frequency offset
SNR	Signal-to-noise ratio
STFT	Short-term Fourier transformation
SVM	Support vector machine
TOF	Time of flight
Tx	Transmitter
UHF	Ultra-high frequency
UWB	Ultra-wide band