

Energy Harvesting Communications

Energy Harvesting Communications

Principles and Theories

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To my parents

Contents

Preface *xi*

Acronyms *xiii*

1	Introduction	<i>1</i>
1.1	Background	<i>1</i>
1.2	Relationship with Green Communications	<i>2</i>
1.3	Potential Applications	<i>3</i>
1.3.1	Energy Harvesting for 5G	<i>3</i>
1.4	Outline of Chapters	<i>4</i>
2	Energy Sources	<i>5</i>
2.1	Introduction	<i>5</i>
2.2	Types of Sources	<i>6</i>
2.2.1	Mechanical Energy	<i>6</i>
2.2.2	Solar/Light Energy	<i>8</i>
2.2.3	Electromagnetic Energy	<i>9</i>
2.3	Predictive Models of Sources	<i>9</i>
2.3.1	Solar Energy Modeling	<i>10</i>
2.3.2	Ambient RF Energy Modeling	<i>12</i>
2.4	Summary	<i>16</i>
3	Energy Harvesters	<i>19</i>
3.1	Introduction	<i>19</i>
3.2	Photovoltaic Panels	<i>19</i>
3.2.1	Principles	<i>20</i>
3.2.2	Models	<i>22</i>
3.3	Radio Frequency Energy Harvester	<i>25</i>
3.3.1	Principles	<i>26</i>
3.3.2	Efficiencies	<i>28</i>
3.4	Overall Models	<i>31</i>
3.5	Battery and Supercapacitor	<i>35</i>
3.5.1	Battery	<i>35</i>
3.5.2	Supercapacitor	<i>36</i>
3.6	Summary	<i>36</i>

4	Physical Layer Techniques	39
4.1	Introduction	39
4.2	Effect of Energy Harvesting	40
4.2.1	Distribution of Transmission Power	41
4.2.2	Transmission Delay and Probability	43
4.2.3	Bit Error Rate	47
4.2.4	Achievable Rate	52
4.2.5	General Information Theoretic Limits	54
4.3	Energy Harvesting Detection	55
4.4	Energy Harvesting Estimation	61
4.4.1	With Relaying	62
4.4.1.1	Scheme 1	62
4.4.1.2	Scheme 2	66
4.4.1.3	Scheme 3	68
4.4.1.4	Scheme 4	70
4.4.1.5	Scheme 5	71
4.4.1.6	Scheme 6	72
4.4.2	Without Relaying	79
4.5	Energy Transmission Waveform	83
4.5.1	Scenario	84
4.5.2	Energy Waveform Optimization	85
4.5.2.1	Linear Harvester	85
4.5.2.2	Non-Linear Harvester	86
4.6	Other Issues and Techniques	88
4.6.1	Circuit Power Consumption	88
4.6.2	Physical Layer Security	89
4.6.3	Non-orthogonal Multiple Access	91
4.6.4	Joint Detection and Estimation	92
4.7	Summary	98
5	Upper Layer Techniques	101
5.1	Introduction	101
5.2	Media Access Control Protocols	102
5.2.1	Duty Cycling	102
5.2.1.1	Wireless Power Transfer	103
5.2.1.2	Ambient Energy Harvesting	107
5.2.2	Other Issues in MAC Protocols	110
5.3	Routing Protocols	111
5.3.1	Ambient Energy Harvesting	112
5.3.2	Wireless Power Transfer	117
5.4	Other Issues in the Upper Layers	118
5.4.1	Scheduling	118
5.4.2	Effective Capacity	121
5.5	Summary	123
6	Wireless Powered Communications	125
6.1	Introduction	125
6.2	Types of Wireless Powered Communications	126
6.3	Simultaneous Wireless Information and Power Transfer	127

6.3.1	Ideal Implementations	128
6.3.2	Practical Implementations	130
6.3.2.1	Time Switching	130
6.3.2.2	Power Splitting	132
6.3.2.3	General Scheme	134
6.4	Hybrid Access Point	135
6.4.1	Rate-Energy Tradeoff	135
6.4.2	Fairness Issue	138
6.4.3	Channel Knowledge Issue	138
6.4.3.1	Average Achievable Rate	139
6.4.3.2	Average BER	141
6.4.3.3	Numerical Examples	144
6.5	Power Beacon	150
6.5.1	System and Design Problem	150
6.5.2	More Notes	152
6.6	Other Issues	153
6.6.1	Effect of Interference on Wireless Power	153
6.6.1.1	System and Assumptions	153
6.6.1.2	Performances with Interference	154
6.6.1.3	Performances without Interference	155
6.6.1.4	Numerical Examples	155
6.6.2	Effect of Interference by Wireless Power	157
6.6.2.1	System and Assumptions	158
6.6.2.2	Average Interference Power	159
6.6.2.3	Rate	159
6.6.2.4	Numerical Examples	161
6.6.3	Exploitation of Interference	163
6.6.4	Multiple Antennas	169
6.7	An Example: Wireless Powered Sensor Networks	172
6.8	Summary	172
7	Energy Harvesting Cognitive Radios	175
7.1	Introduction	175
7.1.1	Cognitive Radio	175
7.1.2	Cognitive Radio Functions	177
7.1.3	Spectrum Sensing	177
7.1.4	Energy Harvesting Cognitive Radio	178
7.2	Conventional Cognitive Radio	180
7.2.1	Different Types of Cognitive Radio Systems	180
7.2.2	Spectrum Sensing Methods	182
7.2.2.1	Energy Detection	182
7.2.2.2	Feature Detection	186
7.3	Types of Energy Harvesting Cognitive Radio	189
7.3.1	Protocols	189
7.3.2	Energy Sources	190
7.4	From the Secondary Base Station	192
7.5	From the Primary User	198
7.5.1	Conventional PU	198
7.5.2	Wireless Powered PU	204

7.6	From the Ambient Environment	210
7.7	Information Energy Cooperation	215
7.8	Other Important Issues	217
7.9	Summary	218
8	Energy Harvesting Relaying	221
8.1	Introduction	221
8.1.1	Wireless Relaying	221
8.1.2	Relaying Protocols	222
8.1.3	Energy Harvesting Relaying	223
8.2	Conventional Relaying	224
8.2.1	Amplify-and-Forward Relaying	224
8.2.2	Decode-and-Forward Relaying	225
8.2.3	Performance Metrics	226
8.2.3.1	Amplify-and-Forward	226
8.2.3.2	Decode-and-Forward	227
8.2.4	Relay Selection	229
8.2.4.1	Full Selection	231
8.2.4.2	Partial Selection	231
8.2.5	Two-Way Relaying	233
8.3	Types of Energy Harvesting Relaying	235
8.4	From the Ambient Environment	237
8.5	From the Power Transmitter	241
8.5.1	One User and Single Antenna	241
8.5.2	Multiple Users and Single Antenna	242
8.5.3	One User and Multiple Antennas	244
8.6	From the Source	246
8.6.1	Amplify-and-Forward Relaying	247
8.6.2	Decode-and-Forward Relaying	250
8.6.2.1	Instantaneous Transmission	251
8.6.2.2	Delay- or Error-Constrained Transmission	253
8.6.2.3	Delay- or Error-Tolerant Transmission	254
8.6.2.4	Numerical Examples	255
8.6.3	Energy Harvesting Source	260
8.7	Other Important Issues	270
8.7.1	Interference	270
8.7.1.1	Time Switching	271
8.7.1.2	Power Splitting	273
8.7.2	Multi-Hop	275
8.7.2.1	Time Switching	276
8.7.2.2	Power Splitting	280
8.7.2.3	Numerical Examples	282
8.7.3	Others	291
8.8	Summary	292
	References	293
	Index	307

Preface

Wireless communication has provided unprecedented convenience for our daily lives over the past few decades. This convenience largely comes from the replacement of data cables with wireless interconnections. However, the remaining power cables or batteries used in conventional wireless systems are still restricting their mobility or lifetime and hence, are preventing them from being deployed in more and wider applications. Meanwhile, wireless power has emerged as a recent innovation to substitute the power cable. Many breakthroughs have been made. The innovation is further boosted by green communications that aims to meet the governmental targets for emission reduction by harvesting solar energy, wind energy, and other renewable sources.

Given these recent development, it is reasonable to adopt wireless power or energy harvesting in communications so that the last cable in wireless systems can be removed to exploit the full potential of wireless communications. This leads to energy harvesting wireless communications, which is the topic and the motivation of this book.

The use of harvested energy brings big challenges to system designs. First and most importantly, the energy source becomes random or dynamic. This leads to fundamental changes to wireless system designs. Secondly, energy harvesting changes the characteristics of signals and channels utilized in system designs. On the other hand, the use of harvested energy also creates great opportunities. It allows perpetual and sustainable operations of wireless systems. Many conventional wireless systems can be upgraded by adding the energy harvesting functionality to improve their sustainability. For example, sensor networks can use energy harvesting to prolong their lifetime. Cognitive radios can exchange energy for transmission opportunities. Relaying networks can encourage more idle nodes to be involved in relaying by offering them wireless power.

Chapters 1–5 focus on the challenges brought by energy harvesting in wireless communications. Chapters 6–8 focus on different wireless applications enhanced by energy harvesting. Specifically, this book will follow the flow of energy from the energy source, to the energy harvester, to the wireless device, and then to the application. Chapter 1 gives a brief introduction of energy harvesting wireless communications. Chapter 2 discusses different energy sources harvested for wireless communications. Chapter 3 examines the energy harvesters used for two widely used sources. Chapters 4 and 5 study the physical layer and upper layer of the energy harvesting wireless device, respectively. Chapters 6–8 investigate wireless powered communications, energy harvesting cognitive radios and energy harvesting relaying as applications. The whole book focuses on principles and theories rather than systems and implementations.

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I apologize in advance for any errors that may have occurred and welcome any comments and suggestions for further improvements.

Yunfei Chen
Coventry, UK, May 2018

Acronyms

3G	Third Generation
4G	Fourth Generation
5G	Fifth Generation
AC	Alternating Current
AF	Amplify-and-Forward
AP	Access Point
AWGN	Additive White Gaussian Noise
BCR	Bit Correct Rate
BER	Bit Error Rate
BFSK	Binary Frequency Shift Keying
BPSK	Binary Phase Shift Keying
CDF	Cumulative Distribution Function
CDMA	Code Division Multiple Access
CR	Cognitive Radio
CSMA/CA	Carrier Sensing Multiple Access with Collision Avoidance
D2D	Device-to-Device
DF	Decode-and-Forward
DPS	Dynamic Power Splitting
DPSK	Differential Phase Shift Keying
EA-MAC	Energy Adaptive Media Access Control
EME	Average Energy to Minimum Eigenvalue
EWMA	Exponentially Weighted Moving Average
FCC	Federal Communications Commission
GSM	Global System for Mobile Communications
HAP	Hybrid Access Point
HE-MAC	Harvest-then-Transmit Media Access Control
LOS	Line-Of-Sight
MAC	Media Access Control
MB	Moment-Based
ME	Maximum Eigenvalue
MIMO	Multiple-Input-Multiple-Output
MME	Maximum-to-Minimum Eigenvalue
ML	Maximum Likelihood
MSE	Mean Squared Error
NLOS	Non-Line-Of-Sight

NOMA	Non-Orthogonal Multiple Access
NRMSE	Normalized Root Mean Squared Error
OFDM	Orthogonal-Frequency-Division-Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OMA	Orthogonal Multiple Access
OSI	Open Systems Interconnection
PAPR	Peak-to-Average-Power Ratio
PB	Power Beacon
PDF	Probability Density Function
PHY	Physical
PS	Power Splitting
PSK	Phase Shift Keying
PU	Primary User
PV	Photovoltaic
QoS	Quality of Service
RC	Resistor-Capacitor
RD	Relay to Destination
RF	Radio Frequency
RFID	Radio Frequency Identification
ROC	Receiver Operating Characteristics
SIR	Signal-to-Interference Ratio
SINR	Signal-to-Interference-plus-Noise Ratio
SNR	Signal-to-Noise Ratio
SR	Source to Relay
STC	Standard Testing Conditions
SWIPT	Simultaneous Wireless Information and Power Transfer
TCP/IP	Transmission Control Protocol/Internet Protocol
TDD	Time-Division-Duplex
TDMA	Time Division Multiple Access
TS	Time Switching
QoS	Quality of Service
WCMA	Weather Conditioned Moving Average
WPC	Wireless Powered Communications
WSN	Wireless Sensor Network