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Data and Energy Integrated Communication Networks

A Brief Introduction

Springer

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Preface

In order to satisfy the power thirsty of communication devices in the imminent fifth-generation (5G) and Internet of Things (IoT) era, wireless charging techniques have attracted much attention both from the academic and industrial communities. Although the inductive coupling and magnetic resonance based charging techniques are indeed capable of supplying energy in a wireless manner, they tend to restrict the freedom of movement. By contrast, RF signals are capable of supplying energy over distances, which are gradually inclining closer to our ultimate goal—charging anytime and anywhere. Furthermore, transmitters capable of emitting RF signals have been widely deployed, in TV towers, cellular base stations and WiFi access points. This communication infrastructure may indeed be employed also for wireless energy transfer (WET). Therefore, no extra investment in a dedicated WET infrastructure is required. However, allowing radio frequency (RF) signal based wireless energy transfer (WET) may impair the wireless information transfer (WIT) operating in the same spectrum. Hence, it is crucial to coordinate and balance WET and WIT for simultaneous wireless information and power transfer (SWIPT), which evolves to data and energy integrated communication networks (DEINs). This brief aims for providing a landscape picture of DEINs, while including latest research contributions in this promising topic.

To this end, we first provide an overview of DEIN in Chap. 1. We will look into the energy shortage of the electronic devices, compare the popular wireless charging techniques with one another and highlight the RF signal based WET and its distinctive features against the conventional wireless communication in the same spectral bands. Then, we will describe the ubiquitous architecture of DEINs.

In Chap. 2, we will focus on the fundamental of the physical layer for implementing the integrated WET and WIT of the point-to-point link. Key enabling modules of the generic transceiver architecture for the integrated WET and WIT will be introduced. Then, we will introduce several popular receivers equipped with multiple antennas for simultaneously information and energy reception, namely the ideal receiver, the spatial splitting based receiver, the power splitting based receiver and the time switching based receiver.

In Chap. 3, we consider a typical DEIN system consisting of a single H-BS and multiple DEIN users, who are eager to receive both information and energy simultaneously during the downlink transmission of the H-BS. The DEIN users then exploit the energy harvested from the downlink for powering their own uplink transmission. Both the downlink and uplink transmissions are time slotted in order to reduce the potential interference and transmission collision among the multiple users. Optimal time slot allocation schemes in the MAC layer are proposed for maximising the sum-throughput and the fair-throughput of the DEIN users' uplink transmissions, respectively.

In Chap. 4, a full-duplex aided H-BS is conceived in a multi-user DEIN for the sake of simultaneously transferring energy during its downlink transmission, while receiving the information uploaded by the multiple users. The uplink transmissions of the multiple users are powered by the energy harvested from the H-BS's downlink energy broadcast. In this full-duplex aided DEIN, a joint time allocation and user scheduling algorithm is proposed for the sake of maximising the sum-throughput of the users' uplink transmissions by further considering the users' actual information uploading requirements.

Finally, we conclude this brief in Chap. 5 by providing some emerging research topics in the DEIN.

This brief aims for boosting the joint effort from both the academia and industry so as to push the DEIN a step closer to the practical implementation. It is also suitable for the undergraduate/postgraduate students to be familiar with this cutting-edge technique.

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Acronyms

AC	Alternative Current
AWGN	Additive White Gaussian Noise
CDF	Cumulative Distribution Function
CDMA	Code Division Multiple Access
CICO-MC	Continuous Input Continuous Output Memoryless Channel
DC	Direct Current
DEIN	Data and Energy Integrated communication Network
DIDO-MC	Discrete Input Discrete Output Memoryless Channel
FDD	Frequency Division Duplex
H-BS	Hybrid Base Station
IoT	Internet of Things
KKT	Karush–Kuhn–Tucker
LPF	Low-Pass Filter
MAC	Medium Access Control
MIMO	Multiple Input Multiple Output
MISO	Multiple Input Single Output
mmW	millimetre Wave
NASA	National Aeronautics and Space Administration
NOMA	Non-Orthogonal Multiple Access
NSFC	National Natural Science Foundation of China
OFDMA	Orthogonal Frequency Division Multiple Access
PAPR	Peak to Average Power Ratio
PS	Power Splitting
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RF	Radio Frequency
SCMA	Sparse Code Multiple Access
SER	Symbol Error Ratio
SIMO	Single-Input-Multiple-Output

SISO	Signle-Input-Single-Output
SS	Spatial Splitting
SVD	Singular Value Decomposition
SWIPT	Simultaneous Wireless Information and Power Transfer
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TS	Time Switching
UE	User Equipment
UESTC	University of Electronic Science and Technology of China
WET	Wireless Energy Transfer
WIT	Wireless Information Transfer
WPCN	Wireless Powered Communication Network
5G	Fifth Generation