An Extensive Survey on Energy Optimization Techniques Based on Simultaneous Wireless Data and Energy Transfer to Wireless Sensor Network

Ankit Gambhir and Rajeev Arya

Abstract Wireless sensor networks (WSN) have involved many research scholars in recent years.WSN are significantly confined by their limited energy. Energy expenditure is a major concern in the designing and implementation of routing protocols and algorithms for wireless sensor networks because of limitation of power supply. There are many research articles available on optimization of wireless sensor network (WSN), mostly rely on energy-efficient routing protocols such as ant colony optimization, genetic algorithm, etc. However, with the advancement of antenna technology and wireless power transfer through microwaves, the issue of limited energy can be addressed by transmitting power as well as data at the same time. In this paper, authors have presented a wide survey of such optimization techniques that rely on simultaneous transfer of power as well as data to the wireless sensor nodes.

Keywords WSN · Energy · Optimization techniques

1 Introduction

In the recent years, WSN have got consideration from many research communities. A great number of applications, such as medical care, military target tracking, disaster relief, etc., are using this technology. Limited power supply is one of the major concerns as sensor nodes are generally battery-powered devices [1]. The main challenge is to how to decrease the energy utilization of nodes, so that the

A. Gambhir (✉)
GGSIP University, Delhi, India
e-mail: er.ankit.gambhir@gmail.com

R. Arya
Delhi Technical Campus, GGSIP University, Delhi, India
e-mail: rajeev.arya.iit@gmail.com

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network life span could be extended. Energy utilization is also a key issue in the designing and implementing algorithms and protocols for WSN. Hence, most research is happening in WSN area which is related to energy optimization. Many routing algorithms are specifically designed for the optimization of energy in WSN and have been proposed. Some algorithms like ant colony optimization (ACO) that take idea from the social behavior of ants [2] and genetic algorithm (GA) which is based on the concept of Darwin‘s evolution of biological systems that use arbitrary search in the decision space via selection, crossover, and mutation operators in order to reach its destination [2] are designed and used for energy optimization. However, with the advancement of antenna technology and wireless power transfer through microwaves, the issue of limited energy can be addressed by transmitting power as well as data at the same time. Wireless powered communication network eliminates the requirement of frequent replacement of battery or charging thus perk up the performance [3]. In this paper, an extensive survey of energy optimization techniques based on simultaneous transfer of data and power has been presented. Furthermore, recent advances and future research challenges have been discussed.

2 Simultaneous Wireless Data and Energy Transfer (SWDET)

Nikola Tesla first envisage the idea of wireless power transmission (WPT) and demonstrated “the transmission of electrical energy without wires” that rely on electrical conductivity in 1891 [4]. In 1893, lighting of vacuum bulbs had been shown by Tesla without the use of wires for transmission of power, at the World Columbian Exposition [4]. The Wardenclyffe tower that is also called as Tesla tower was constructed by Tesla primarily for electrical power transmission without wires instead of telegraphy [4]. Later in 1961, William C. Brown an American electrical engineer published the foremost paper regarding microwave energy for transmission of power; later on in 1964, he demonstrated a helicopter that received power required for flight from a microwave beam of frequency 2.45 GHz [5]. In 2007 a research group of Massachusetts Institute of Technology (MIT) showed illumination of a light bulb of 60 W using wireless power with efficiency of 40% at a two-meter distance by using a couple of diameter coils of 60 cm [6]. The Same concept has been applied in simultaneous transfer of energy and data to wireless sensor nodes. The recent advances in microwave-based wireless transmission of power open a new way to deal with the issue of limited energy and frequent battery replacements. Any signal that is used for data transmission also bears energy that can be harvested by the node at receiver. This is the principle of simultaneous transfer of energy and data technique. The wireless devices (WD) can use this harvested energy to send out information to or from other nodes. It improves the experience of user and can provide a high throughput in comparison to

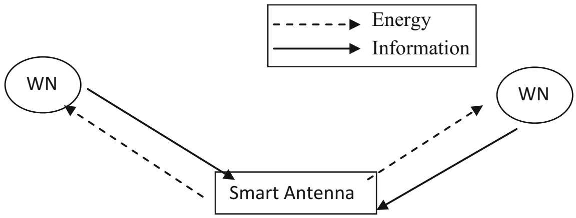

Fig. 1 A model for wireless powered communication

conventional battery-powered wireless sensor networks. Furthermore, with the recent advances in antenna technology and much higher microwave power with an adequate efficiency can be transferred [7] (Fig. 1).

3 Literature Survey

(See Table 1).

Table 1 Literature survey

Authors	Literature	Main contribution
Ioannis krikidis et al.	Simultaneous wireless information and power transfer in modern communication systems [3]	• Discussed techniques such as spatial switching time switching, antenna switching, and power splitting, for SWIPT • Aspects of resource allocation algorithm design for SWIPT systems such as joint power control, user scheduling, energy scheduling, information scheduling, and interference management have been presented • Path loss, energy security, and hardware development have been also discussed
Suzhi Bi et al.	Wireless powered communication: opportunities and challenges [8]	• Outline of high-tech RF-enabled wireless energy transmission (WET) technologies • Comparative analysis of rate as well as energy trade-offs of SWDET receivers • Introduction to harvest-then-transmit protocol and doubly-near-far problem

(continued)

Table 1 (continued)

Authors	Literature	Main contribution
Pulkit Grover et al.	Shannon meets Tesla: wireless information and power transfer [9]	• Considered the case of SWDET across a noisy coupled-inductor circuit with frequency selective channel and AWG noise • Provided solution in discrete and continuous version • Trade-off between information rate and power
Suzhi Bi et al.	Wireless powered communication networks an overview [7]	• Provided an outline on the fundamental model of wireless powered communication model • Presented idea of cognitive WPCN and green WPCN • Performance comparison of various operating WPCN models
Emily Adams et al.	A wireless sensor network powered by microwave energy [10]	• Demonstrated a prototype of a system enables a transfer of wireless energy to nodes • Analysis of node voltage as a function of time has been shown • A complete functional decomposition of the system (prototype) has been presented
Xun Zhou et al.	Wireless information and power transfer: architecture design and rate-energy tradeoff [11]	• Proposed, *dynamic power splitting* (DPS) receiver operation that splits the received signal with adaptable power ratio for energy conservation and data decoding, unconnectedly • Exceptional cases of DPS, on–off power splitting (OPS) power splitting (SPS) and time switching (TS), were examined
Lav R. Varshney	Transporting information and energy simultaneously [12]	• The elementary balance between the rate of energy and information that can be sent over a noisy line has been presented • A coding theorem and a capacity-energy function were also defined
Amin Enayati et al.	3D-antenna-in-package solution for microwave wireless sensor network nodes [13]	• Implemented a 3D antenna-in-package solution for microwave WSN • Designed an antenna in a modular way and its structure and dipole shape pattern have been shown

(continued)

Table 1 (continued)

Authors	Literature	Main contribution
Luca Catarinucci et al.	Switched-Beam Antenna for Wireless Sensor Network Nodes [14]	• Proposed a flexible beam-steering antenna for WSN in ISM band • Demonstrated an inexpensive realization on an FR4 substrate
Giuseppe Anastasi et al.	Energy conservation in wireless sensor networks: a survey [15]	• Presented a systematic and comprehensive nomenclature of the energy-efficient schemes • Different approaches like data-driven and mobility-based schemes for energy conversation have been presented
Seunghyun Lee et al	Cognitive wireless powered network: spectrum sharing models and throughput maximization [16]	• Proposed cognitive radio (CR) WPCN consisting of one single H-AP and distributed wireless powered users, which uses the common spectrum for down-link WET and up-link wireless data transmission (WDT) • Provided analysis as well as simulation results and compared the sum-throughput of the CWPCN (cognitive) with coexisting models
Xiaoming Chen et al.	Enhancing wireless information and power transfer by exploiting multi-antenna techniques [17]	• Performance enhancement by using multi-antenna techniques • Investigated trade-offs based on inadequate feedback multi-antenna techniques for small distance and large-scale MIMO technique for long distance • To improve power transfer efficiency, techniques like energy beamforming by exploiting spatial degree of freedom have been discussed
Yueling Che et al.	Multi-antenna wireless powered communication with co-channel energy and information transfer [18]	• Obtained optimum solutions for the issue of co-channel interference • Achieved best energy-interference trade-off
Ioannis Krikidis et al.	A low complexity antenna switching for joint wireless information and energy transfer in MIMO relay channels [19]	• Investigated a technique for SWDET in MIMO relay channels • The proposed technique was applied to interference in more than one user, where zero-forcing receiver was employed at the relay node

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Table 1 (continued)

Authors	Literature	Main contribution
Qian Sun et al.	Joint beamforming design and time allocation for wireless powered communication networks [20]	• A multi-input single-output WET model under the protocol of first harvest-then-sent was investigated • Considered integrated time allocation and beamforming designing to make the most of the system sum-output

4 Conclusion

In this paper, we have presented a comprehensive overview of research going on in the domain of wireless powered communication. Recent research articles on energy optimization techniques based on simultaneous transfer of data and power have been considered for the survey. Some authors have worked in the domain of antenna technology and exploited spatial characteristics. Various switching techniques such as time switching, antenna switching, power splitting, etc. have been presented by many authors. Optimization of energy in WSN is a challenging issue and a key area of research. Simulation results and comparative analysis of various parameters have been shown by authors. Trade-off between energy and interference was also discussed by many authors. This paper has provided a summary of recent advancement in the area of transmitting power as well as data to wireless sensor network at the same time. This paper summarizes and organizes recent research results in a way that adds understanding to work in this domain.

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