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Review on Energy Harvesting for Wireless Communications

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Abstract: **In energy harvesting communications, user transmits messages using energy harvested from nature during the course of communication. In energy harvesting introduced the energy cooperation, where the user wirelessly transmits a portion of its energy to another energy harvesting user. where the transmitter sends one signal and receiver receives the received signal into two parts by either power splitting or time switching by using SWIPT (simultaneous wireless information power transmit). The energy cooperation save-then transmit (EC-ST) scheme is employed consider additive white Gaussian noise one-way channels with two-way energy transfer under a deterministic energy arrival rate. In this case, the optimal active ratio and the energy cooperation power are obtained in closed form to achieve the maximum throughput. Next, for Rayleigh block fading channels with a stochastic energy arrival rate, the optimal energy cooperation power for minimizing the outage probability. This paper concentrates on the optimal performance of the P2P wireless communications within T seconds. To begin with, the (EC-ST) scheme to additive white Gaussian noise (AWGN) one-way channels with two way energy transfer under a deterministic energy arrival rate.**

Index Terms- **Energy harvesting, energy cooperation save-then-transmit scheme, throughput maximization, outage probability minimization.**

I. INTRODUCTION

Energy harvesting for communication devices has emerged as a prominent research area due to its benefit of powering the devices through alternative energies instead of battery or hardwire power [1], [2]. By employing the piezoelectric, electromagnetic, photo-voltaic or other energy harvesting technologies, external sources, such as kinetic, solar energy and ambient radio waves, can be harvested to power the devices. Thus, energy harvesting becomes an attractive and effective solution for powering the energy-constrained devices and prolonging their lifetime. In an energy harvesting wireless communications system, the cumulatively consumed energy by the system is not allowed to exceed the cumulatively harvested energy at any time instant. [3], based on which a significant amount of works have investigated energy harvesting communications. Beginning with an energy harvesting transmitter design, [3] analyzes the communication channel capacity with random energy arrival from the information-theoretic view. [4] uses dynamic programming to maximize the system throughput over a finite horizon. For the energy harvesting receiver, Varshney introduced the concept of scavenging information and energy simultaneously [5]. This idea leads to the simultaneous wireless information and power transfer (SWIPT) proposed in [6] and [7], where the transmitter sends one signal and the receiver divides the received signal into two parts by either power splitting or time switching: one for information decoding and one for energy harvesting. Moreover,[8] applies the power splitting and time switching schemes at an energy harvesting relay in wireless cooperative networks, termed as cooperative SWIPT.

Rather than purely harvesting energy from the unintentional sources, energy cooperation allows the devices to intentionally transfer some energy to others to assist communications, which is inspired by the work of Brown on power transfer by radio waves [9]. Note that both SWIPT and energy cooperation involve the wireless information transmission and energy transfer. However, compared to the SWIPT technology that embeds the transferred energy into the information signal, an independent energy transfer channel is used in this paper for energy cooperation. Such approach provides more freedom to optimize the energy transfer design for higher efficiency and the direction of energy transfer can be different from that of the information flow at any time instant. Reference [10] proposes a one-way energy cooperation scheme under two-way and multiple-access communications system respectively, using a bidirectional water-filling algorithm to control the energy flows. The papers [11] and [12] investigate the unidirectional energy cooperation between the source node and relay node, while in [13] the downlink wirelss energy transfer is employed to assist the uplink information transmissions in a wireless powered communication network. The analysis of the bi-directional energy cooperation is given in [14], where two communication nodes are assumed to wirelessly exchange their energy. In addition, the energy cooperation between base stations in wireless cellular systems have been considered in [15] and [16].

The above-mentioned work all assume the power consumption of the hardware circuits can be ignored (ideal circuits). In fact, the power consumption of the hardware circuits (nonideal circuits) is a significant factor that influences the system's behaviors, like sleeping or keeping active. The papers [17] and [18] investigate the designs of such practical transmitters with non-ideal circuits: the former proposes both offline and online energy/power allocation algorithms for optimizing average throughput under a deterministic energy arrival profile, while the latter introduces a save-then-transmit (ST) protocol that the energy harvesting transmitter sleeps for a period of time to

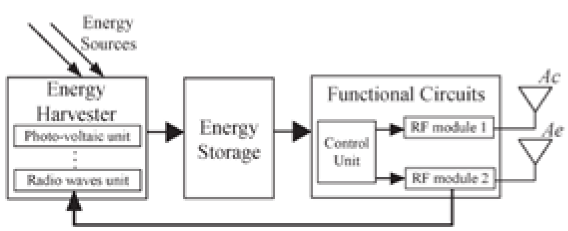

Fig. 1. Practical circuit model for energy harvesting device.

Save energy and then wakes up to communicate. The optimal save ratio of the ST protocol is derived in [19]. In this paper, both the energy harvesting transmitter and receiver with non-ideal circuits, based upon [17] – [19] which did not consider the design of the energy harvesting receiver. We assume that both the practical transmitter and receiver harvest energy from the external sources, and then employ the harvested energy to support communications as well as running the non-ideal circuits. We choose the ST scheme to handle the harvested energy and enable energy cooperation between the transmitter and receiver, which is termed energy cooperation ST (EC-ST) scheme. The EC-ST scheme allows the active transmitter and receiver to transfer some of their stored energy to each other to improve the communications performance by adjusting the transmission power and communication time, while the common ST scheme is merely applied to a transmitter without energy cooperation. Fig. 1 shows the circuit model for a practical energy harvesting device (applied to both the transmitter and receiver). The energy harvester contains several energy harvesting units for different energy sources, like photovoltaic and electromagnetic energy harvesting units. The rate (joules/second) of energy harvesting is called energy arrival rate. Functional circuits manage communications and energy cooperation through the control unit. Two antennas, Ac, Ae, are integrated into two RF modules respectively, where Ac is used to communicate while Ae transfers energy between the transmitter and receiver to realize energy cooperation. Moreover, Ae needs to feed the received energy transferred by another device to the electromagnetic energy harvesting unit for harvesting and storage.

II. RELATED WORK

William C. brown proposed the history of power transmission by radio waves. It is defines as being point – to – point transmission [1]. The free space power transmission has been development of components for the transmitting and receiving ends of the system that have sought to achieve the combined objectives of high efficiency low cost, high reliability and low mass. C. brown contributions to microwave generator and rectenna

Technology, and has pioneered microwave power transmitted by microwave beam to support a flying vehicle, and also contribute subsequent development of solar power satellite (SPS).

S. Priya Daiel J.Inman proposed the energy harvesting technologies [2]. A wide range of applications are targeted for the harvesters, including distributed wireless sensor nodes for medical applications, recharging the batteries of large systems, monitoring tire pressure in automobiles, powering unmanned vehicles, and running security systems in household conditions. Important energy harvesting technologies including piezoelectricity, inductive thermoelectric and micro batteries are addressed. Daniel J.Inman proposed the one - dimentional electro mechanical analytic model and for power optimization optimality of a parallel – RL circuit can be results the optimal energy harvesting from a vibration source using a piezoelectric stack.

Dibin Zhu and Steve Beeby proposed the normal kinetic energy harvesting and adaptive kinetic energy harvesting[3]. Kinetic energy harvesters are also known as vibration power generators.Tom J.Kazmiereski and Leran Wang proposed modeling, performance optimization and automated design of mixed – technology energy harvester system. It presents an automated energy harvester design flow which is based on a single HDL software platform that can be used to model, simulate, configure and optimize the complete mixed physical – domain energy harvester system.

Prakash chand, Rajarshi mahapatra and rishi prakash proposed the energy efficient coordinated multipoint transmission and reception techniques-saving power in base stations is therefore the primary focus in energy efficient operation. The heterogeneous network (Het Net) architectures to inter connect these different wireless technologies. The energy efficiency can also be achieved by coordinated transmits and receive at network level, this can be achieved by power saving protocols, energy aware cooperative base station power manager, cell zooming, link adaption and beam forming with comp.

Yeow – Khiang Chia proposed a model for energy cooperation in cellular networks with renewable powered base stations (BS) with individual hybrid power supplies. The online energy cooperation algorithm shows the optimality properties of this algorithm under certain conditions. Furthermore, the energy – saving performances of the developed offline and online algorithm are compared by simultaneous, and effect of the availability of energy state information (ESI) and performance gains of the BSs energy cooperation is investigated. Finally hybrid algorithm that can incorporate offline information about the energy profiles, but operates in an online manner.

Berk Gurakan, Omur Ozel, Jing Yang proposed the energy cooperation in energy harvesting communications with an optimum transmit policy, the energy cooperation enables shaping and optimization of the energy arrivals at the energy – receiving node and improves overall system performance. For maximize system through put, lagrangain formulation and the resulting KKT optimality conditions. So, for developed a two dimensional directional water – filling algorithm.

III. EXISTING SYSTEM

In table I X is fixed to 100 mW with $\alpha = 0.75$, and we compare the throughput performances under these three schemes. With that of the practical Tx ST scheme from $H = 15$ dB to $H = 25$ dB which is inside the no energy cooperation region of the EC-ST scheme. Outside this region, the EC-ST scheme outperforms by applying energy cooperation. Furthermore, the idealistic Tx ST scheme is consistently the worst performer.

Table I. Normalized throughput in AWGN channels as a function of the normalized channel power gain H

S.No	Schemes	Transfer efficiency (α)	random variables X
1 2	Practical TX-ST Ideal TX-ST	0.2 0.29	100mW 100mW

S.No	Schemes	Transfer efficiency (α)	Power gain H
1 2	Practical TX-ST Ideal TX-ST	0.75 0.75	60dB 60dB

Table II: Normalized throughput in AWGN channels as a Function of the energy arrival rate X,

Table II Compares the throughput performances under the practical Tx ST, and idealistic Tx ST schemes with $\alpha = 0.75$, $H = 60$ dB, by increasing the energy arrival rate X. Note that the energy transfer efficiency $\alpha = 0.75$ can be possibly achieved by the magnetic resonant coupling technique. Obviously, the EC-ST scheme outperforms the others. Failing to consider the power consumption of circuits, the performance of the idealistic Tx ST scheme is slightly degraded compared to the practical Tx ST scheme when $100 < X < 150$mWbecause the former cannot arrive at the proper transmission power Ps when ignoring the power consumption of circuits.

IV. ENERGY HARVESTING

Energy harvesting (also known as power harvesting or energy scavenging) is the process by which energy is derived from external sources (e.g. solar power, thermal energy, wind energy, salinity gradients, and kinetic energy), captured, and stored for small, wireless autonomous devices, like those used in wearable electronics and wireless sensor networks. Energy harvesters provide a very small amount of power for low-energy electronics. While the input fuel to some large-scale generation costs resources (oil, coal, etc.), the energy source for energy harvesters is present as ambient background and is free. For example, temperature gradients exist from the operation of a combustion engine and in urban areas, there is a large amount of electromagnetic energy in the environment because of radio and television broadcasting.

V. ENERGY COOPERATION FOR THROUGHPUT OPTIMIZATION BASED ON SAVE-THEN-TRANSMIT PROTOCOL

Green communication and energy saving have been a critical issue in modern wireless communication systems. The concepts of energy harvesting and energy transfer are recently receiving much attention in academic research field. In this paper, we study energy cooperation problems based on save-then-transmit protocol and propose two energy cooperation schemes for different system models: two-node communication model and three-node relay communication model. In both models, all of the nodes transmitting information have no fixed energy supplies and gain energy only via wireless energy harvesting from nature. Besides, these nodes also follow a save-then-transmit protocol. Namely, for each timeslot, a fraction (referred to as save-ratio) of time is devoted exclusively to energy harvesting while the remaining fraction is used for data transmission. In order to maximize the system throughput, energy transfer mechanism is introduced in our schemes, i.e., some nodes are permitted to share their harvested energy with other nodes by means of wireless energy transfer. Simulation results demonstrate that our proposed schemes can outperform both the schemes with half-allocate save-ratio and the schemes without energy transfer in terms of throughput performance, and also characterize the dependencies of system throughput, transferred energy, and save-ratio on energy harvesting rate.

VI. THROUGHPUT MAXIMIZATION

Cognitive radio network is the promising technology of the next generation communication networks which enables the secondary users (SUs) to use the free spectrum bands which are licensed originally to the primary users (PUs) without causing interference and utilize the spectrum more efficiently. Spectrum sensing should be carried out frequently in order to transmit the data successfully through SU without causing significant interference with the PU and to achieve the maximum throughput. In this paper we propose an artificial neural network model which is known as Levenberg-Marquardt (L-M) algorithm for predicting the propagation.

VII. OUTAGE PROBABILITY MINIMIZATION

The outage probability of cognitive relay networks with cooperation between secondary users based on the underlay approach, while adhering to the interference constraint on the primary user, i.e., the limited amount of interference which the primary user can tolerate. A relay selection criterion, suitable for cognitive relay networks, is provided, and using it, we derive the outage probability. It is shown that the outage probability of cognitive relay networks is higher than that of conventional relay networks due to the interference constraint, and we quantify the increase. In addition, the outage probability is affected by the distance ratio of the interference link (between the secondary transmitter and the primary receiver) to the relaying link (between the secondary transmitter and the secondary receiver). We also prove that cognitive relay networks achieve the same full selection diversity order as conventional relay networks, and that the decrease in outage probability achieved by increasing the selection diversity (the number of relays) is not less than that in conventional relay networks.

VIII. CONCLUSION

In energy harvesting capability on a simple wireless network with orthogonal DF cooperation, the network layer orthogonal cooperation uses the harvested energy with poor energy profile. In proposed method by using AWGN fading channels, the optimal normalized throughput can be obtained. The accuracy of analytical results will be verified by simulation.

In the optimal power allocation to minimize the averaged outage probability in fading channels. The outage capacity problem with practical observations. In proposed method, the optimal normalized throughput and outage probability are analyzed respectively in additive white Gaussian noise and Rayleigh block fading channels. One effective method for improving the communications performance between practical energy harvesting devices is to allow the energy folloow between the devices, and then find an optimal tradeoff between the transmission power and the active communications intervals.

This work demonstrates the benefits of an energy harvesting. Furthermore effective method for improving the communications performance between practical energy harvesting devices is to allow the energy flow between the devices, and then find an optimal tradeoff between the transmission power and active communication intervals.

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