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Optimal Power Allocation and Relay Selection for Energy Harvested Cooperative Wireless Sensor Network

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Abstract— **Mobile wireless communication has experienced an unprecedented growth in recent years in which communication using wireless sensor network has attracted much interest where minimizing the problem of power allocation and relay selection in many areas is a major challenge to deal with. In this paper, an energy efficient cooperative wireless sensor network is considered in which optimal power allocation and relay selection strategies are discussed and energy is harvested from the available energy and thus creating a Green cooperative communication scenario in energy harvesting wireless sensor networks(EH-WSN).The problems addressed above will be solved by using clustering based algorithm.**

Keywords — **Energy harvesting; cooperative networks; Energy harvesting-wireless sensor networks (EH-WSN); Clustering.**

1. INTRODUCTION

In recent years, energy harvesting based coopera-tive communication network have attracted signifi-cant attentions because of their intrinsic capability of self-sustainability which can scavenge energy from environment (solar, wind, vibrations, etc.). These networks may be wireless sensor networks which are made up of many tiny wireless sensor nodes which are operating on small batteries for which replacement if possible is difficult and ex-pensive. Hence, it is desired to minimize the power consumption in different functional layers of a sen-sor node which is a challenging design considera-tion. For improvising the performance of sensor nodes energy constraint is the main limiting factor which calls for solutions for maximizing the work-ing performance under energy harvesting con-straints.

2. RELATED WORKS

Recently, many researchers have shown that EH-WSN is using cooperative communication strategies to improve working performance under total power utilization constraints [2, 3]. For example, in [4], Yinlong et al. proposed an energy-efficient scheme for relay selection and also provided strategy for allocation of opti-mal power with optimal number of relays selected. In [5], Ahmed and Aazhang propose a power allocation method on partial feedback channel state information (CSI) and also discussed finite rate feedback methods. Their works shows that for large power improvements it is required to have feedback for each realization of channel state. In [6], Host-Madsen and Zhang discussed power allocation strategy for maximizing channel capacity which also requires feedback of communication channel state for every channel realization and derive bounds on ergodic capacity for fading relay channels.

K. Singh et al. in [7] proposed a scheme for joint source selection and allocation of power in relay transmission for maximizing system throughput. Songtao Guo et al. [8] has considered a technique for power transfer and applying a simultaneous wireless information for clustered wireless sensor networks in coopertive mode. To maximize the energy efficiency of the system, they developed a distributed iterative algorithm for power allocation, power splitting, and relay selection and they find that power splitting ratio plays an imperative role in the relay selection.

Close loop power allocation schemes require channel state information of transmitter and their realization in practical applications may create some problems. In [9], Hasna and Alouini investigated the problem of optimal power allocation for an open-loop transmission scheme (channel state information is available only at the receiver side) for outage probability minimization. Their results for Amplify and Forward relaying are restricted to multi-hop systems without diversity advantages.

The remainder of the paper is organized as follows. Section III presents a transmission model; Section IV analyzes transmission model; Section V introduces methodology for energy harvesting; Section VI gives methodology for energy efficiency; Section VII gives methodology for power allocation; Section concludes the paper with future work and references in section VIII and IX respectively.

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3. TRANSMISSION MODEL

The transmission model considered in this paper is based on cooperative communication protocol in clustering EH-WSN in which clustering routing protocol is used.This model is illustrated in Figure 1, in which a set of distributed homogeneous sensor nodes are grouped into di erent cooperative clusters. In the transmission procedure the EH node transmits its data to the to its cluster head which is also a sensor node with capabil-ity of selection of relay nodes for further transmission. Every node within cluster acts as relay and cooperates with each other. Then, the cluster head uses the best relay node (optimum cooperating relay) within its cluster to collaboratively transmit the data to the neighboring cluster head (i.e., next hop). This process continues in a multi-hop manner until the data are received by a fusion center or nal destination. In this process, if the relay is placed at optimal place and optimal power is allocated to the system, a minimum BER can be achieved at the destination.Since, there is predetermined knowledge of the position of each cluster head, finding the optimal place for relay that provides the source (transmitting cluster head) and the destination (fusion center) is feasible with the best cooperative link in terms of the BER performance.

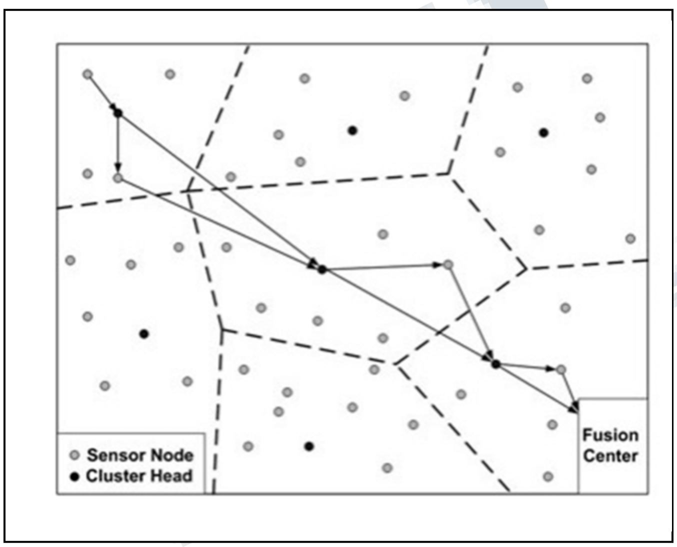

Fig. 1: Cluster-based cooperative relaying. Dashed lines reveal the boundaries of the clusters and bold dots show the cluster head.

In Fig. 2, a simplified network model is depicted. In which R_i is the optimum relay, S represents the source cluster head, and D is the destination cluster head. All sensor nodes are having the capability of energy harvest-ing and are of single antenna type. The communication procedure consists of two transmission slots: in the first slot, source cluster head S broadcasts its data as byte x and the received signal is as shown below in equation (1):

$$y_{S,D} = \sqrt{P_S}\, h_{S,D} x + n_{S,D} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

All the relay node R_i and destination cluster head D can hear this message, and their received signals are shown below in equation (2):

$$y_{S,R_i} = \sqrt{P_S}\, h_{S,R_i} x + n_{S,R_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, P_S is transmission power of Source and $n_{S;D}$, and $n_{S;Ri}$ represent the additive Gaussian noise of S to D and S to R_i respectively. In second slot: the selected relay retransmits the signal received in the first slot in a DF (decode-and-forward) [10] scheme, it will transmit at power P_R. After a maximal ratio combining procedure, the recovered signal should be given by equation (3):

$$y'_{S,D} = \sqrt{P_S}\, h_{S,D} y_{S,D} + \sqrt{P_R}\, h_{R_i,D} y_{R_i,D} \ldots\ldots\ldots (3)$$

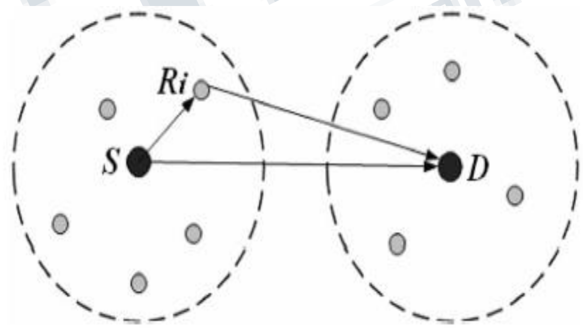

Fig.2: Simplified cooperative relay network.

4. PERFORMANCE PARAMETERS

a. Bit Error Rate

The bit error rate or bit error ratio (BER) is the ratio of number of bit errors to the total number of transferring bits during in selected time interval. BER has no unit and often expressed in percentage. A low BER implies an error less transmission.

$$BER = \frac{No.of\ Bit\ Errors\ Received}{Total\ No.of bits\ transmitted} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

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b. Signal-to-Noise Ratio (SNR)

Signal-to-noise ratio (SNR or S/N) is defined as the ratio of signal power to the noise power. It is a mea-sure that compares the amount of desired signal to the amount background noise. It is usually measured in decibels (dB). An SNR value greater than 1 indicates more signal than noise. In other towards, signal-to-noise ratio is defined as the ratio of signal power to noise power. A high SNR value shows low noise is present in the communication system.

$$\text{SNR} = \frac{P_{Signal}}{P_{Noise}} \ldots\ldots\ldots\ldots \text{(5)}$$

5. METHODOLOGY FOR ENERGY HARVESTING

The energy model discussed in [1] deduces the energy consumption per bit for cooperative as well as non cooperative diversity is considered and energy harvested at each node is calculated in equation (6):

$$E_i(t) = E_i(t-1) + P_{(EH,i)}(t) - I(a_i(j))E_{TX} + E_{RX} \ldots\ldots\ldots\ldots \text{(6)}$$

$E_i(t)$ is the residual energy of node i at the end of time slot t, $P_{(EH,i)}(t)$ is the harvested energy of node i at time slot t, I(.) is binary indicator function, $E_{(TX)}$ is energy consumption of data transmission and $E_{(RX)}$ is energy consumption of data reception.

A positive energy saving efficiency value (i.e., shown in equation (7)) in cluster based EH-WSN will harvest energy efficiently in cooperative scenario.

$$\boldsymbol{\epsilon_{saving}} = 100.\frac{\boldsymbol{E_{(Non-Coop)}} - \boldsymbol{E_{(Coop)}}}{\boldsymbol{E_{(Non-Coop)}}} \ldots\ldots\ldots\ldots \text{(7)}$$

Where, $\boldsymbol{\epsilon_{saving}}$ is energy efficiency saving, $\boldsymbol{E_{(Non-Coop)}}$ is energy consumption per bit in non cooperative communication scene and $\boldsymbol{E_{(Coop)}}$ is energy consumption per bit in cooperative communication scene.

6. METHODOLOGY FOR ENERGY EFFICIENCY

a. Relay Selection Based On Energy Efficiency

The relays used in cooperative communication are selected based on their energy efficiency. The energy efficiency is a metric denoted as the ratio of the end-to-end capacity and the transmitted energy consumption. The energy efficiency of the DT (Direct Transmission) mode can be expressed in equation (8):

$$EE_m = \frac{C_{SD}}{P_{DT}} \ldots\ldots\ldots\ldots \text{(8)}$$

The energy efficiency of the DF (Decode and Forward) mode can be expressed in equation (9):

$$EE_m = \frac{C_m}{P_{DF}} \ldots\ldots\ldots\ldots \text{(9)}$$

Where the P_{DT} and P_{DF} are the power consumed by the DT mode and DF mode, respectively. C_{SD} and C_m are the channel capacity of the DT case and cooperative case.

7. METHODOLOGY FOR POWER ALLOCATION

In this section, power allocation scheme of multi-relay cooperative system under energy efficient principle [4] is presented. A simple multi-hop (MH) protocol is considered which is based on where partial CSI at the source and the relay is known and the transmission takes place according to MH protocol. In this condition, both the number of the relays participating in the transmission and the P_{opt} (i.e.Optimal power) alloted to the relay will be determined by using energy efficiency of the system as shown in equation (10):

$$\boldsymbol{\gamma} = \frac{\mathbf{R}((\mathbf{1} - \mathbf{P_{DT}}\,(\mathbf{Outage})) * \mathbf{P}(\mathbf{EE_{DT}} > \mathbf{EE_{DF}})}{\mathbf{P}}$$

$$\mathbf{P}$$

$$+ \frac{\mathbf{R}((\mathbf{1} - \mathbf{P_{DT}}\,(\mathbf{Outage})) * \mathbf{P}(\mathbf{EE_{DT}} > \mathbf{EE_{DF}})}{\mathbf{P}} \ldots\ldots\ldots\ldots \text{(10)}$$

Where, P_{DT}(outage) is system outage probability in DT mode and P_{DF}(outage) is the system outage probability in DF mode. R is transmission rate. P is the energy consumed in the entire transmission process. Optimal Power allocated in DT mode is shown in equation (11):

$$P_{(Opt)} = \min\left(\frac{(2^{R-1})No}{\delta\sigma_{SD}^2}\right) \ldots\ldots\ldots\ldots \text{(11)}$$

8. CONCLUSION

In this paper, strategies for optimal power allocation and relay selection is discussed for cooperation in a clustering based EH-WSN. Various performance parameters are defined for measurement and analysis of performance of the network when clustering based algorithm is used.

9. FUTURE WORK

In the future the efficiency will be enhanced by using a multi objective algorithm for node placement and coverage of cooperative EH-WSN. Various application cases, including energy harvester-sharing networks and structural health monitoring etc will use these results for better performance and further innovations.

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