Outage Analysis/SER of A Cooperative Wireless Network Based on Opportunistic Relaying

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ABSTRACT— In this paper, an adaptive relay node selection algorithm based on the opportunity is proposed to balance the network energy consumption. we analyze the SER and outage probability of opportunistic relay selection in a set-up using decode and forward and where the available channel state information (CSI) is not available. The relay is selected opportunistically to maximize the end-to-end signal to noise ratio received at the destination. At destination Maximal Ratio Combining(MRC) is done to exploit diversity. The statistics in terms of (PDF) and (CDF) have been derived and used for determining outage probability for varying channel conditions. The outage performance and SER with fixed and opportunistic relaying have been compared. It has been shown that the proposed algorithm can improve the network performance by deferring the earliest death time of the nodes, balancing the energy consumption of each node, and extending the network life cycle.

Keywords--- *pro-active relaying,Channel state information, WSN, cooperative relaying, outage probability.*

I. INTRODUCTION

In recent years, there has been a rapid development in building and deploying sensor networks which is promoted by the recent advances in MEMs-based technologies and low-power short range radios. With the advantage of broadcast in wireless medium, cooperative communication is proposed, which allows multiple nodes to simultaneously transmit the same packet to the receiver so that the combined signal at the receiver can be correctly decoded. Since the cooperative communication [1] can reduce the transmitter power and extend the transmission coverage, it has been widely advocated in terms of increased capacity, improved transmission reliability, spatial diversity. The research of classical cooperative relay communication technology has focused on the improvement of system performance, but takes no account of the energy efficiency of the system. At present, from an energy efficiency stance, the literature [2, 3] demonstrated that the energy consumption of the wireless communication network can be improved by cooperative diversity techniques. This paper proposes an adaptive relay node selection algorithm based on opportunity with the purpose of balancing node energy consumption, making the node to be more efficient and working in longer hours, and improving the performance of wireless sensor network (WSN), which can effectively and greatly achieve a balance of network energy consumption and extend the life cycle of the wireless sensor network.

Received: 27 Feb 2019 | Revised: 20 Mar 2019 | Accepted: 30 Apr 2020

II. RELATED WORKS

In [6], it has been shown that a decentralized relay selection protocol based on opportunistic feedback from the relays yields good throughput performance in dense wireless networks. This selection strategy supports a hybrid-ARQ transmission approach where relays forward parity information to the destination in the event of a decoding error. Such an approach, however, suffers a loss compared to centralized strategies that select relays with the best channel gain to the destination. This paper closes the performance gap by adding another level of channel feedback to the decentralized relay selection problem. It is demonstrated that only one additional bit of feedback is necessary for good throughput performance.

In [7], a fully opportunistic relay selection scheme to study cooperative diversity is employed in a semi analytical manner. In the framework, idle Mobile Stations (MSs) are capable of being used as Relay Stations (RSs) and no relaying is required if the direct path is strong. The relay selection scheme is fully selection based: either the direct path or one of the relaying paths is selected. Macro diversity, which is often ignored in analytical works, is taken into account together with micro diversity by using a complete channel model that includes both shadow fading and fast fading effects. The results show that the relay selection gain can be significant given a suitable amount of candidate RSs.

In [8], the authors develop a framework to analysis the reliability-reliability tradeoff (RRT) and security-reliability tradeoff (SRT) in the random CRNs, where the security and reliability are quantified in terms of secrecy outage probability and connection outage probability. The RRT evaluates performance tradeoff between the primary and the secondary networks and the SRT evaluates the performance tradeoff inside the secondary network. Furthermore, they propose an opportunistic relay selection (ORS) scheme to enhance the secondary confidential transmission. It is demonstrated that the ORS scheme significantly improves the RRT and SRT as the density of relays increases, and outperforms the conventional direct transmission when the density of relays is larger than a certain value.

Wireless Sensor Networks (WSNs) consists of a large no. of sensor nodes which are usually battery powered and designed to operate for a long period of time .Consequently, minimizing the energy consumption is a very important consideration in WSNs. In this paper the focus is on the usage of opportunistic relay selection algorithm for the purpose of improving the performance of cooperative network. The outage probability analysis of the proposed relay selection algorithm has been compared with fixed relaying system and it has also been shown that the network performance is improved by extending network life cycle.

III. SYSTEM MODEL

We assume that wireless sensor cooperative communication network [5,6] contains n sensor nodes and a destination node, in which n sensor nodes can work as a source node to send data,

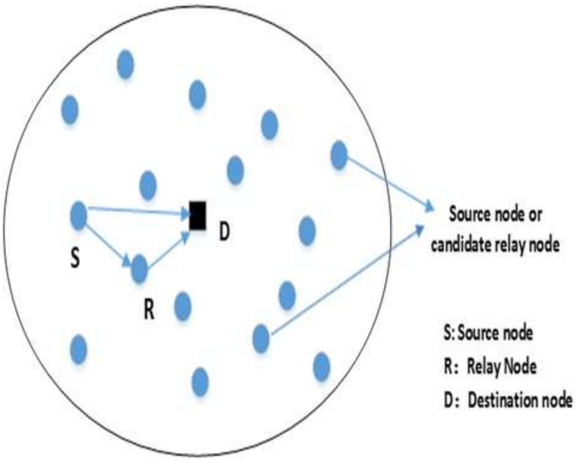

Figure 1: System Model

and also function as a relay node to forward data, as is shown in Fig. 1. We assume that the relay node is selected from the candidate relay nodes. According to the requirement of the bit error rate (BER) threshold, we select the relay node that BER is lower to assist the source node to send information to the destination node. The BER threshold is the direct link BER.

In this system, besides the channel between the source node (S) and destination node (D), there also exist channels between the source node and each relay node (R) and each relay node and destination node. dsd represents the distance from S to D, dsri between S and R, and drid between R and D. In the model above, the entire relay process can be divided into two time slots [7].

In time slot 1, S sends the information data to R and D, then the received signals $Y_{s,r}(t)$ and $Y_{s,d}(t)$ come, respectively, from R and D:

$$Y_{s,r}(t) = \sqrt{P_A} h_{s,r} x(t) + n_{s,r}$$

$$Y_{s,d}(t) = \sqrt{P_A} h_{s,d} x(t) + n_{s,d} \qquad (1)$$

P_A is the transmission power of S, $h_{s,r}$ and $h_{s,d}$ are the channel coefficients of S to R and to D, and $n_{s,r}$ and $n_{s,d}$ are the corresponding Gauss white noise.

In time slot 2, R will forward the message to D, at which D receives the signal $Y_{r,d}(t)$ from the relay node that is given:

$$Y_{r,d}(t) = \sqrt{P_R} h_{r,d} x(t) + n_{r,d} \qquad (2\text{-}1)$$

P_R means the transmission power of R, $h_{r,d}$ represents the channel coefficient of R to D, and $n_{r,d}$ shows the corresponding additive Gauss white noise. Without loss of generality, we suppose that $n_{s,r}$, $n_{s,d}$, and $n_{r,d}$ are subject to a Gaussian distribution with a mean of zero and a variance of N_0. If the relay node adopts the AF relaying mode, then there is

$$Y_{r,d}(t) = \beta h_{r,d} Y_{s,r}(t)) + n_{r,d} \qquad (2\text{-}2)$$

β is the relay amplification factor. If D adopts the maximum ratio combination, the received signal of the destination node is

$$Y(t) = \omega_1 Y_{s,d}(t) + \omega_2 Y_{r,d}(t) \qquad (3)$$

ω_1 and ω_2 are weighted factors. This paper assumes that the transmission adopts the BPSK modulation method.

IV. PROPOSED OPPORTUNISTIC RELAY SELECTION ALGORITHM

We assume that all the nodes are half duplex; hence the transmission between s-d takes place in two time slots. At the start of each coherence time a relay r_* is opportunistically selected from the set of relays and this method is called proactive relay selection which is more energy efficient and outage optimal method [4]. We assume that each terminal is equipped with a single antenna. Here h_{sd}; h_{sri} and h_{rid} are denoted as fading coefficients of the channels between the source s and destination d, the source s and the i^{th} relay and the i^{th} relay and destination d, respectively. The channel is modeled as at fading Rayleigh distributed with variances σ^2_{sd} ,σ^2_{sri} , and σ^2_{rid} respectively. We assume that the additive noise is zero-mean complex Gaussian with variance N0 in all channels.

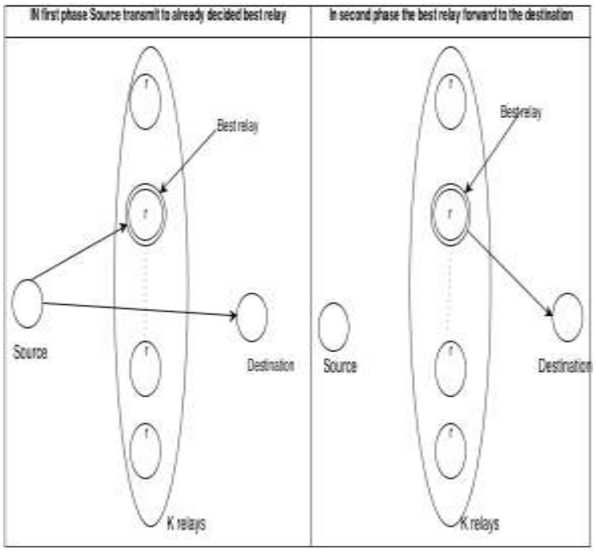

Figure 2: Proactive Opportunistic Relaying

The basic description of Proactive opportunistic relaying here best relay is known to all before the communication starts and in 2nd phase the best relay cooperates by forwarding the information signal to destination.

The flow chart of the OAR selection algorithm proposed in this paper is shown in the Fig. 2. In this paper, such a cycle is called a round number or a wheel. The OAR selection algorithm is considered from the goal of meeting the minimum BER requirement [8, 9]. That is to say, the BER of the data transmission from *S* to *D* is calculated firstly, and set it as the threshold for selecting candidate relay nodes. Then, the relay node calculates the average BER at the time of forwarding data, and automatically determines whether the average BER is less than the BER threshold. If so, these relay nodes constitute a set of candidate relay nodes that assist the source node to complete data transmission efficiently.

In AF relay mode, the SNR (signal to noise ratio) of the receiver with its maximum ratio is

$$\gamma_d = \gamma_{s,d} + \sum \frac{\gamma_{s,r}\gamma_{r,d}}{\gamma_{s,r}+\gamma_{r,d}+1} \quad (4)$$

$\gamma_{s,d} = P_A|h_{s,d}|^2/N_0$ represents the SNR of the direct link, $\gamma_{s,r} = P_A|h_{s,r}|^2/N_0$ represents the receiver SNR of R, $\gamma_{r,d} = P_R|h_{r,d}|^2/N_0$ represents the receiver SNR of D from R.

Under the circumstances of high SNR, 1 in formula (10) can be ignored and be approximated as

$$\gamma_d = \gamma_{s,d} + \sum \frac{\gamma_{s,r}\gamma_{r,d}}{\gamma_{s,r}+\gamma_{r,d}} \quad (5)$$

According to the basic knowledge of communication theory, the BER formula based on SNR can be expressed as [11] $P_e = Q\sqrt{k\gamma_d}$.

The constant k is related to the modulation mode.

Symbol Error Rate Analysis

Symbol Error Rate is a metric which signifies that out of transmitted symbols, what is the probability of getting information signal in error at the receiver[12].

The constant k is related to the modulation mode. In binary phase shift keying, the value of K is 2,

$$Q(x) = 1/\sqrt{2\pi}\int_x^{+\infty} e^{\frac{-t^2}{2}}dt \, .$$

In this way, the BER formula can be used to calculate the direct transmission link. That is, the BER of S to D is

$$P_e(d) = Q\left(\sqrt{k\gamma_d}\right) \quad (6)$$

Similarly, we can calculate the BER from S to the candidate relay node R_i, that is

$$P_e(S, R_i) = Q\left(\sqrt{k\gamma_{s,r}}\right). \quad (6.1)$$

The candidate relay node has two kinds of cases: correct reception and incorrect reception.

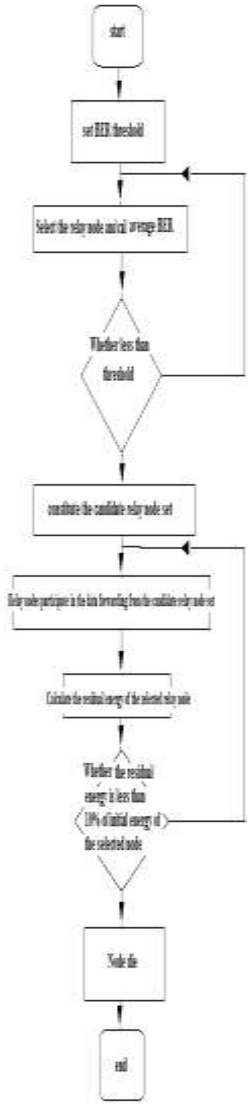

Figure 3: The flow chart of the Opportunistic relay selection algorithm

When the candidate relay node R_i receives correctly, with the help of a single R_i, the BER from *S* to *D* can be expressed as

$$P_e(S, R_i, D) = Q\sqrt{K\left(\gamma_{s,d} + \gamma_{r,d}\right)} \quad (6.2)$$

When the candidate relay node R_i receives incorrectly, it does not transmit power, which means that it does not assist in transmitting information. At this time, the BER between *S* and *D* can be expressed as

$$P_e(S, D) = Q\left(\sqrt{k\gamma_{s,d}}\right). \quad (6.3)$$

Thus, when a single relay node R_i is selected, its average BER can be expressed as

$$P_e(i) = \left(1 - P_e(S, R_i)\right) * P_e(S, R_i, D) + P_e(S, R_i) * P_e(S, D)$$

(7)

In this Opportunistic relay selection algorithm, the relay nodes that meet the requirement of BER $P_e(i) < P_e(d)$ making up the candidate relay nodes assist the source node to complete the efficient transmission of data together.

It has been shown that [8] the average SER can be determined using Moment Generating Function(MGF) based approach. The average SER expressions obtained are tight lower bounds for the average SER

MGF can be expressed by using PDF as

$$M_Z(s) = \int_0^{\infty} f_z(x)\, e^{-sx} dx \qquad (8)$$

Where $f_z(x)$ is the PDF of the SNR. And with the help of SNRs MGF average SER for M-ary PSK modulated signal can be determined as

$$SER = \frac{1}{\pi} \int_0^{\frac{(M-1)\pi}{M}} M_z\left(\frac{g}{sin^2\theta}\right) d\theta \qquad (9)$$

Where M is for M-ary PSK modulation and

$$g = Sin^2\left(\frac{\pi}{M}\right).$$

SER for threshold opportunistic relaying (from this paper)

$$SER_{OR} = P_{out}(\gamma_{sr})P_{er}(\gamma_{sd}) + \left(1 - P_{out}(\gamma_{sr})\right)P_{er}(\gamma_{\beta}) \qquad (10)$$

WhereΥ_{sd} and Υ_{β} denotes the SNR of link s - d and end-to-end SNR respectively. The term $P_{out}(\Upsilon_{sr})Per(\Upsilon_{sd})$ denotes the event of error, when threshold at relay is not met means the link s-r_* is in outage and so at destination the only available signal is from source. While the term $(1-P_{out}(\Upsilon_{sr})P_{er}(\Upsilon_{\beta})$ signifies the event of error, when at relay the threshold criteria is met means the instantaneous SNR of the link s-r_* is greater than the threshold, and so it cooperates by forwarding the signal to destination and now the signals available at destination are from source and relay both.

V. OUTAGE PROBABILITY ANALYSIS

The Outage probability [13] is defined as the probability that the end-to-end SNR falls below a certain threshold value Υ_{th} as

$$Pout = P_r(\gamma \leq \gamma_{th}) = F_{\gamma}(\gamma_{th}) = \int_{-\infty}^{\gamma th} f_{\gamma}(x) dx \qquad (11)$$

Where $f_{\Upsilon}(x)$ is the PDF of SNR.

VI. SIMULATION RESULTS

The plot in Fig 4 the SER of opportunistic relay selection algorithm and Fixed relaying is compared and has been Plotted. The SER expression derived in section IV. The results shown are for k(no.of relays)=5.

Received: 27 Feb 2019 | Revised: 20 Mar 2019 | Accepted: 30 Apr 2020

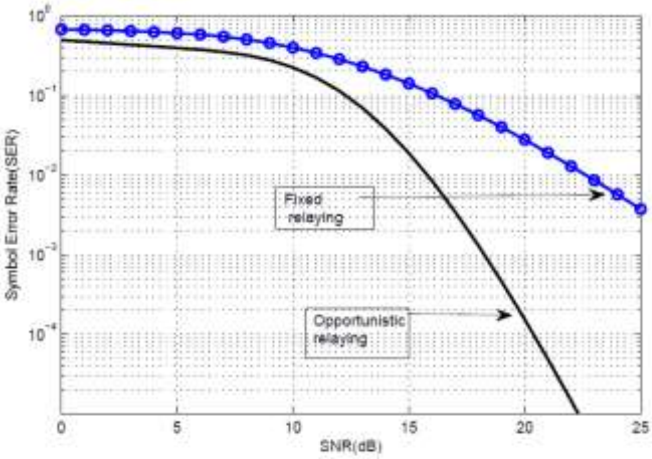

Figure 4: Comparison of Symbol Error rate for opportunistic relaying and fixed relaying

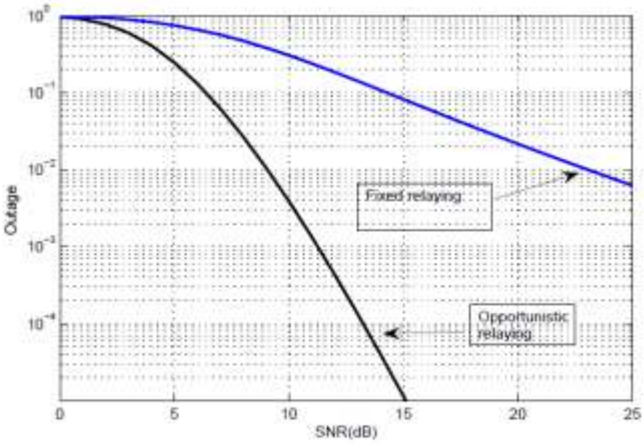

Figure 5: Comparison of Outage Probability performance for opportunistic relaying and fixed relaying.

The plot in Fig 5 the Outage probability of opportunistic relay selection algorithm and Fixed relaying is compared and has been Plotted. The results shown are for k(no. of relays)=5.

The plot in Fig 6 aims to show that how is our system performance going to change if the numbers of relays are different here for the same channel condition different number of relays have been taken into account. Here result has been shown for 3; 4 and 5 number of relays are cooperating in opportunistic relaying. For increase in the number of relays the system performance improves approximately by an order of more than 1 dB for increase in number of relays BPSK modulation.

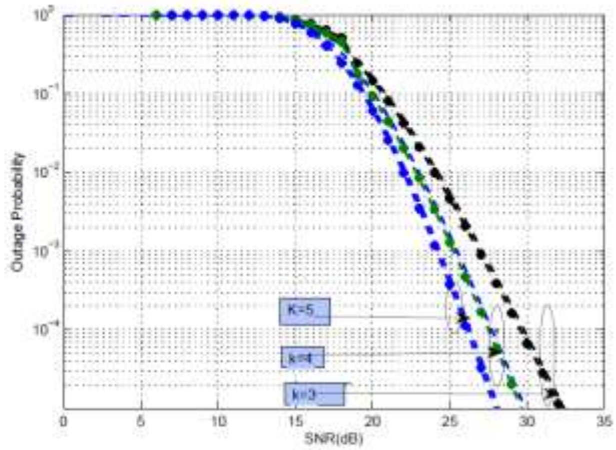

Figure 6: Outage Probability of opportunistic relaying with varying number of relays.

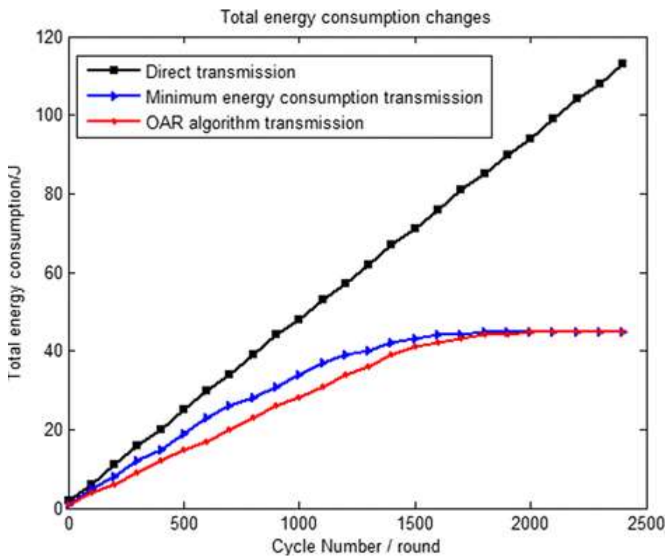

Figure 7: The number of Dead nodes.

In order to verify the validity of the proposed OAR selection algorithm, the number of network dead nodes of three algorithms is compared under the same initial energy. As shown in Fig 7, since the direct transmission is not taken into account of the adaptive adjustment process of the node based on the opportunity, the number of dead nodes in the direct transmission is more than the minimum energy consumption transmission and OAR selection algorithm transmission. At the same time, the minimum energy consumption standard to select relay node, it does not count the average energy consumption of all nodes, thus accelerating the death time of the first node.

VII. CONCLUSION

Opportunistic relaying is one of the best relaying protocol to get diversity it provides with a diversity gain of K+1, where K is number of relays. Only one relay is engaged in cooperation and only one additional time slot is required for the overall communication and thus it increases the network efficiency and bandwidth efficiency.

The threshold based opportunistic relaying performs better than non-threshold based opportunistic relaying as propagation error is minimized in former. It is found that the proposed OAR algorithm can improve the network performance by deferring the earliest death time of the nodes, balancing the energy consumption of each node, and extending the network life cycle.

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Received: 27 Feb 2019 | Revised: 20 Mar 2019 | Accepted: 30 Apr 2020

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