ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

PERFORMANCE ANALYSIS OF WIRELESS CO-OPERATIVE NETWORK FOR DECODE-AMPLIFY AND FORWARD RELAYING WITH ENERGY HARVESTING CONSTRAINT

Dr.J.Raja*, M.Logeswari, Mr.K.Moorthi
***** Professor, ECE Department, Adhiparasakthi Engineering college, Melmaruvathur, Kanchipuram, India
M.E-Applied Electronics (final yr), ECE Department, Adhiparasakthi Engineering College, Melmaruvathur, Kanchipuram, India
Assistant Professor, ECE Department, Adhiparasakthi Engineering College, Melmaruvathur, Kanchipuram, India

ABSTRACT

Power management is significant criterion in Wireless Relay Networks (WRN) to increase the lifetime of the network. Energy harvesting is a recent emerging proficient method to attain the transmission power in a profuse level. So the use of energy harvesting is utilized for classic three node Gaussian relay channel with co-operative relaying of Decode-Amplify and Forward in order to achieve the superior energy levels thereby achieving the maximum throughput. In particular, two types of data traffic are compared to provide the best case which gives the maximum throughput. The source and relay nodes transmit with the power drawn from the EH source. Also the performance of co-operative relaying network is analyzed for both amplify- forward and decode- forward relaying.

KEYWORDS: amplify and forward, decode and forward, energy harvesting and Gaussian relay channel.

INTRODUCTION

A relay network is a broad class of network topology commonly used in wireless networks, where the source and the destination are interconnected by means of some other participating nodes in network so that the communication will not abrupt even when the distance between the source and the destination is greater than the transmission range of them.

In wireless communication, the main parameters that affects its lifetime are energy consumption and battery sources. While taking the conventional energy it does not provide the availability and reliability since it has low operational time. For real time application in forest, industries etc, the replacing and recharging of battery is quite difficult. Hence a new concept of energy source is developed which is called as ENERGY HARVESTING (EH). Energy scavenging is a tremendous technique that can be applied to energy constrained wireless communication since it provides unlimited energy supply and intermittent over time.

In EH technology, the nodes are able to harvest energy from the nature. The various resources of EH includes the solar power, wind turbines, thermal energy, vibration equipments, transducer, windmill, etc. The EH increases the power level that is required for transmission of data excessively. But the main goal here is not on how the energy is harvested instead it is on how to improve the performance and throughput of the network by assuming the EH constraint network. The power management strategies for WSNs is investigated with EH nodes in [1] and [2]. In [1], the solar powered WSN is considered. And also two modes of operation is considered i.e., sleep and active modes, the nodes switches between these two modes depends upon the available power. When the energy is available, the nodes are in active mode, and if the energy is less then the nodes switches into the sleep mode until the battery is recharged. In EH model, the AWGN channel capacity under the EH constraint was studied in an independent and identically distributed mode in [3]. Even with the time varying energy sources, the same capacity can be achieved as that for the conventional case and also achieving the constant power supply with the same total transmission energy consumed. In [4] it is considered the conventional time invariant energy sources with full duplex relay channel and the throughput maximization problem is exploited by the Gaussian two hop relay channel without considering the direct link between the source and the

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

destination. Node cooperation occurs to improve the system capacity and diversity. Two dimensional discrete memory less parallel relay channel is investigated in [5] where the source, relay and destination communicates with each other on two parallel (independent) links. The achievable rates for optimal and equal resource allocations are compared and proved that optimizing the resource allocation yields significant performance gain.

In Gaussian orthogonal relay channel, the source transmits to the relay and destination in channel 1, and the relay transmits to the destination in channel 2, with channels 1 and 2 being orthogonalized in the time–frequency plane .

The half duplex orthogonal Gaussian relay channel with EH source and relay nodes is considered here and it is shown in Fig.1. The orthogonal represents that the relay to destination link is orthogonal to both the source to relay and source to destination links, by assuming that the relay transmits and receives over two various frequency bands.

The finite horizon of N transmission blocks are considered and in each block, the source transmit a new message to the destination and relay.

Then the relay receives it and simply decode or amplify it based on the SNR factor and then forward it to the destination in the next one or more blocks.

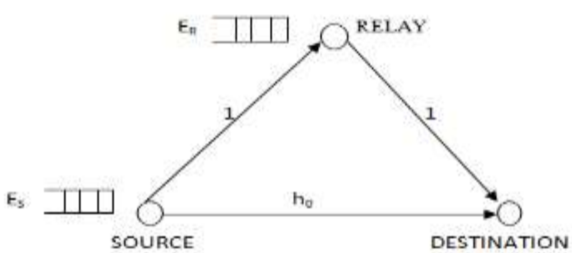

Fig.1: Half duplex orthogonal relay channel

The main objective is to maximize the total throughput by studying the optimal rate and power allocation of source and relay over different blocks. Specifically it is consider that the two types of data traffic based on different decoding delay and are Delay constraint(DC) and No Delay Constraint (NDC).

In DC case, there is a limitation on delay i.e., the destination is needed to decode or amplify the i-th message from the source immediately after it receives the message from the source and from the relay. The source involves in i-th block while relay in the (i+1)-th block where i=1,2,….,N. so when the relay received the message from the source in one block , it needs to forward it to the destination in the next block immediately.

While in the NDC case ,there is no limitation on decoding delay so that all the source messages are decoded at the end of each N-block transmission. The destination can tolerate the decoding delay. So even the relay receives the source message in one block, it can forward it to destination in any one of the remaining (i+1)-th to (N+1)-th blocks.

The DC and NDC cases also differs in power allocation methods. For the DC case the joint source and relay power allocation over time will be achieved. For the NDC case, the separation power allocation principle is used i.e., power allocation will be done for source and relay separately. From the explanation of the two cases, it is clearly noted that the NDC case allows more flexible relay operation when compared to the DC cases. It is expected that the NDC case achieves the larger throughput in general.

Notation:

- log(.) and ln(.) stands for base 2 and the natural logarithm respectively;
- The AWGN channel capacity is denoted by

$$\boldsymbol{c}(x) = \tfrac{1}{2}\log(1+x)$$

$(x)^+ = \max(0, x)$ where min(x, y) and max(x, y) are the minimum and the maximum between the two real numbers x and y respectively.

SYSTEM MODEL

In the classic three node relay channel it is assumed that the relay nodes operates in the half duplex over the two different orthogonal frequency i.e., source-relay and the relay-destination uses different band while source operates in same frequency i.e., source-relay and the source-destination (direct link) involves in same band.

The harvested amount of energy for source and relay i.e., $E_S(i)$ in the i^{th} block and $E_R(i+1)$ in the $(i+1)^{th}$ block are known prior to the transmission since the deterministic EH model is assumed. Here it is assumed that there is small consumed energy at the source and relay other than transmission energy while the battery capacity is assumed to be infinite so consumed energy other than involved in transmission is negligible.

Thus the amount of energy available for each of the transmission block is constraint by the following EH constraints conditions:

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

$$\sum_{i=1}^{K} P_s(i) \leq \frac{1}{B}\sum_{i=1}^{k} E_S(i), k=1,\ldots.N, \quad (1)$$

$$\sum_{i=1}^{K} P_R(i+1) \leq \frac{1}{B}\sum_{i=1}^{k} E_R(i+1), k=1,\ldots.N, \quad (2)$$

The channel input –output relationships for source and relay are given as

$$y_{sr}(i) = \sqrt{h}_{sr}\ x_s(i) + n_r(i), \quad (3)$$

$$y_{sd}(i) = \sqrt{h}_{sd}\ x_s(i) + n_d(i), \quad (4)$$

$$y_{rd}(i+1) = \sqrt{h}_{rd}\ x_r(i+1) + w_d(i+1), \quad (5)$$

where $x_s(i)$ is the i^{th} source transmitted signal and $x_r(i+1)$ is the $(i+1)^{th}$ relay transmission blocks with corresponding powers as $P_S(i)$ and $P_R(i+1)$; $y_{sr}(i)$ is the received signal at the at the relay from the source; $y_{sd}(i)$ and $y_{rd}(i+1)$ are the received signals at the destination from the source and relay respectively; h_{sr}, h_{rd}, and h_{sd} are the constant channel gain for source-relay, relay-destination and source – destination links respectively; $n_r(i)$, $n_d(i)$ and $w_d(i+1)$ are the additive white Gaussian noise (AWGN) with zero mean and unit variance.

The received signals to noise ratio (SNR) for the source –relay, relay-destination and source – destination are given as follows:

$$\gamma_{sr}(i)=P_S(i)h_{sr} \quad (6)$$

$$\gamma_{rd}(i)=P_R(i+1)h_{rd} \quad (7)$$

$$\gamma_{sd}(i)=P_S(i)h_{sd} \quad (8)$$

while the $\gamma_{sr}(i)$ is widely used to select the relaying types.

The new source and relay energy and power profiles are defined as

$$\tilde{E}_S(i)=E_S(i)h_{sr} \quad (9)$$

$$\tilde{E}_R(i+1)=E_R(i+1)h_{rd} \quad (10)$$

$$\tilde{P}_S(i)=P_S(i)h_{sr} \quad (11)$$

$$\tilde{P}_R(i+1)=P_R(i+1)h_{rd} \quad (12)$$

With the new channel gains as $\tilde{h}_{sr}= \tilde{h}_{rd}=1$ and $\tilde{h}_{sd} = \frac{hsd}{hsr}=h_0$. So without loss of generality, the equations in the (3), (4) and (5) are modified as

$$y_{sr}(i) = x_s(i) + n_r(i), \quad (13)$$

$$y_{sd}(i) = \sqrt{h}_0 x_s(i) + n_d(i), \quad (14)$$

$$y_{rd}(i+1) = x_r(i+1) + w_d(i+1), \quad (15)$$

SELECTION OF RELAYING TYPE

The co-operative relaying scheme is considered here, which requires the relay to successfully decode or amplify the source message. In this relaying, the selection of decode or amplify is based on the SNR value of source-relay link and given threshold SNR. The relay type selection process is given as follows:

- When $\gamma_{sr}(i) < \gamma_{th}$, then the relaying type is amplify and forward
- When $\gamma_{sr}(i) \geq \gamma_{th}$,then the relaying type is decode and forward

Where $\gamma_{sr}(i)$ represents the source-relay link SNR and γ_{th} represents the threshold SNR.

Thus if $\gamma_{sr}(i)$ is less than γ_{th}, then the relay chooses the amplify to avoid the error propagation, otherwise it chooses the decode to avoid the noise amplification.

Decode and Forward

During decode and forward relaying ,each N source transmission blocks, let take i^{th} block,$1\leq i \leq N$, the source transmit a new message w_i with rate R(i) and power $P_S(i)$. The relay upon receiving the source message, decodes w_i and generates a binning index for w_i based on 'Random binning' technique with rate $R_B(i+1)$. While in $(i+1)^{th}$,the relay transmit a message v_{i+1} with power $P_R(i+1)$ and rate $\boldsymbol{c}(P_R(i+1))$.

For the DC case ,v_{i+1} is the binning index of w_i only; while for NDC case ,v_{i+1} may contain the information of binning index for all message from source w_k where $k\leq i$.

Amplify and Forward

While amplify and forward relaying the source transmit the signal to relay in one block since SNR of source to relay link is less than threshold SNR ,the relay then amplify the signal and forward it to the destination in the immediate next block.

If the relay adopts the amplify protocol, then relay-destination link output signal (5) become modified as

$$y_{rd}(i+1) = \beta\sqrt{h}_{rd}\ x_r(i+1) + w_d(i+1) \quad (16)$$

where β is the amplification factor and it is given by

$$\beta=(P_R(i+1)/(P_S(i)h_{sr}+N_0))^{1/2} \quad (17)$$

with unit variance N_0.

PROBLEM FORMULATION

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

Delay-Constrained Case

For the DC case , in the i[th] transmission block ,the source transmits w_i message with power $P_S(i)$ and rate R(i) then the relay checks whether decodes or amplify if it is decode protocol then relay reliably decodes it only if

$R(i) \leq \boldsymbol{c}(P_S(i))$

In (i+1)[th] block the relay partitions w_i into number of bins with the equivalent rate $R_B(i+1)$ and transmit message v_{i+1} with the binning index to the destination with power $P_R(i+1)$ and at the destination it first decode v_{i+1} and then decodes the original message w_i.

If it is amplify protocol, then the relay amplify the message w_i and then forward it to the destination.

Considering the N block transmission, the average throughput in the unit of bits/sec/Hz (bps/Hz) is maximized by solving following equations:

$$\max_{\{P_S(i)\},\{P_R(i+1)\}} \frac{1}{2(N+1)} \sum_{i=1}^{N} \min\{\boldsymbol{c}(P_S(i)),\boldsymbol{c}(h_0P_S(i))+\boldsymbol{c}(P_R(i+1))\} \qquad (P1)$$

Such that (1),(2),$P_S(i)\geq 0, P_R(i+1)\geq 0, i=1,\ldots,N$

where the factor $\frac{1}{2}$ is due to the half duplex relaying and $\frac{1}{(N+1)}$ is due to the fact that each N block requires (N+1)-block duration.

No-Delay –Constrained Case

For the NDC case, the relay operates the same as in case of DC but only difference is that it is allowed to transmit the binning index for message w_i in message $v_{i+1},\ldots,v_{N+1}$ instead of v_{i+1} only as in the DC case. At the destination, the binning indices for all source messages can be successfully decoded if

$$\sum_{i=1}^{N} R_B(i+1)=\sum_{i=1}^{N} \boldsymbol{c}(P_R(i+1)) \qquad (18)$$

$$\sum_{i=k}^{N} R_B(i+1) \leq \sum_{i=k}^{N} \boldsymbol{c}(P_R(i+1)) \;,\; 2\leq k \leq N \qquad (19)$$

Where $R_B(i+1)=\min\{\boldsymbol{c}(P_R(i+1)), \boldsymbol{c}(P_S(i))-\boldsymbol{c}(h_0P_S(i))\}, i=1,..,N$

The average throughput for NDC case is solved by following equations:

$$\max_{\{P_S(i)\},\{P_R(i+1)\}} \frac{1}{2(N+1)} \sum_{i=1}^{N} \boldsymbol{c}(h_0P_S(i))+\boldsymbol{c}(P_R(i+1)) \qquad \textbf{(P2)}$$

Such that $\sum_{i=1}^{k} \boldsymbol{c}(h_0P_S(i))+\boldsymbol{c}(P_R(i+1))\leq \sum_{i=1}^{k} \boldsymbol{c}(P_S(i))$, $k=1,\ldots,N$

OPTIMAL SOLUTION FOR DC CASE

Here the problem P1 for DC case is solved by presenting the solutions to develop the optimal power allocation algorithm.

The Case with Direct Link

By considering the lagrangian of the problem P1 given below as (9)

$$(PI^*) \quad \max_{\{P_S(i)\},\{P_R(i+1)\}} \frac{1}{2(N+1)} \sum_{i=0}^{n} C\left(h_o P_S(i)\right) + C(P_R(i+1))$$

Such that $C\left(h_o P_S(i)\right) + C\left(P_R(i+1)\right) \leq C\left(P_S(i)\right), i = 1, \ldots, N.$

$$\mathcal{L}(P_S(i), P_R(i+1), \mu_K, \lambda_k, \gamma_i, \eta_{i+1}) =$$

$$\frac{1}{2(N+1)} \sum_{i=1}^{N} \min\{\boldsymbol{c}(P_S(i)),\boldsymbol{c}(h_0P_S(i))+\boldsymbol{c}(P_R(i+1))- \sum_{k=1}^{N} \mu_k(\sum_{i=1}^{k} BP_S(i)-E_S(i))- \sum_{k=1}^{N} \lambda_k(\sum_{i=1}^{k} BP_R(i+1)-E_R(i+1))+\sum_{k=1}^{N} \gamma_i P_S(i) +\sum_{i=1}^{N} \eta_{i+1}P_R(i+1). \qquad (20)$$

where μ_k, λ_k, γ_i and η_{i+1} are the non negative lagrangian multipliers.

By taking derivative of (9) w.r.t $P_S(i)$ and $P_R(i+1)$ then equating it to 0,we get the optimal solution for P1 as follows,

1) Case I: if $P_R^*(i+1) \geq \frac{(1-h_o)P_S^*(i)}{1+h_oP_S^*(i)}$,

$$\begin{cases} P_S^*(i) = \left(\frac{1}{4(N+1)\sum_{k=i}^{N}\mu_k} - 1\right)^+ \\ P_R^*(i+1) = \frac{(1-h_0)P_S^*(i)}{1+h_oP_S^*(i)} \end{cases};$$

2) Case II: if $P_R^*(i+1) \leq \frac{(1-h_o)P_S^*(i)}{1+h_oP_S^*(i)}$,

$$\begin{cases} P_S^*(i) = \left(\frac{1}{4(N+1)\sum_{k=i}^{N}\mu_k} - \frac{1}{h_o}\right)^+ \\ P_R^*(i+1) = \left(\frac{1}{4(N+1)\sum_{k=i}^{N}\lambda_k} - 1\right)^+ \end{cases}$$

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

The Case without Direct Link
Similar to the case with direct link, we obtain the optimal power solutions for without direct link given as below:
1) Case I: if $P_R^*(i+1) \geq P_S^*(i)$,

$$\begin{cases} P_S^*(i) = \left(\frac{1}{4(N+1)\sum_{k=i}^{N} \mu_k} - 1\right)^+ ; \\ \quad P_R^*(i+1) = P_S^*(i), \end{cases}$$

2) Case II: if $P_R^*(i+1) \leq P_S^*(i)$,

$$\begin{cases} P_S^*(i) = P_R^*(i+1) \\ P_R^*(i+1) = \left(\frac{1}{4(N+1)\sum_{k=i}^{N} \lambda_k} - 1\right)^+ \end{cases}$$

OPTIMAL SOLUTION FOR NDC CASE

In this section the problem P2 will be solved for NDC case. For that it is proved, a problem P2 will be solved by introducing the power allocation problem to the source and relay separately by two-stage strategy i.e,

1. Obtain the optimal source power allocation by ignoring the relay
2. Optimize the relay power allocation with the obtained source power solution.

Since for both cases with and without direct link, the separation principle can be applied, and analyzing the both cases as unified one.

Optimal Source Power Allocation
First consider the source power allocation by ignoring the relay given as follows:

$$\max \ \sum_{i=1}^{N} c(h\, p_S(i)) \qquad (P3)$$

$p_S(i) \geq 0, \forall_i$

s.t. $\sum_{i=1}^{K} P_S(i) \leq \frac{1}{B}\sum_{i=1}^{k} E_S(i)$, k=1,….N,

where h is a constant with 0<h≤1.

$$P_S(i) = \frac{\sum_{k=1}^{i_S} E_S(k)}{(i_S - i + 1)B}$$

Where $i_s = \arg \min_{i \leq j \leq N} \{ \frac{\sum_{k=i}^{j} E_S(k)}{(j-i+1)B} \}$, i ≤ N.

The optimal source power profile is given as
$P_S^*(n) = P_S(i)$, n=i,…,i_s and {set $i = i_s + 1$}

Optimal Relay Power Allocation
The optimal relay power profile can be determined by using the optimal source power profile $P_S^*(i)$ as follows:

$$\max \ \sum_{i=1}^{N} \boldsymbol{c}(P_R(i+1)) \qquad (P4)$$

$P_R(i+1) \geq 0, \forall_i$

Such that $\sum_{i=1}^{k} \boldsymbol{c}(P_R(i+1)) \leq \sum_{i=1}^{k} \boldsymbol{c}(P_S^*(i)) - \sum_{i=1}^{k} \boldsymbol{c}(h_0 P_S^*(i))$, k=1,..,N.

RESULT

The simulation result for the throughput comparison of delay constraint and no-delay constraint cases is given in Fig2.
For the purpose of exposition, assume a periodical energy profile for some predictable EH sources. Hence the source and relay energy profiles are given as

$E_S(i) = A_S \sin\left(\frac{i-1}{N} 2\pi + \frac{\pi}{2}\right) + A_S$,
$E_R(i+1) = A_R \sin\left(\frac{i-1}{N} 2\pi + \theta\right) + A_R$, $1 \leq i \leq N$

respectively, where $A_S, A_R > 0$ are the amplitudes of the sinusoidal energy profiles at the source and relay, respectively and θ is the phase shift between these two energy profiles. Here the parameters are chosen as B=100, N=40, $\theta = \frac{5}{4}\pi$ and $A_S = A_R = 200$.

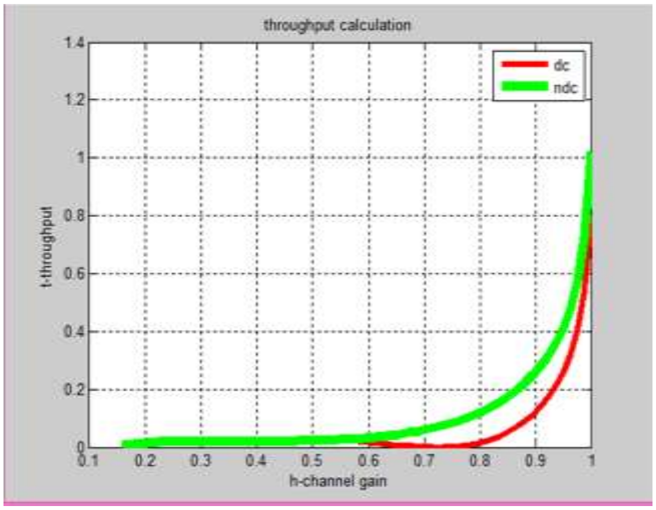

Fig 2: Throughput comparison of various power allocation schemes for relay channel

The DC and NDC are compared by using the following Table 3 by means of average throughput over the channel gain. The channel gain h0 should be within (0,1) interval since it is a probability distributed function and also it is maintained to make the link stronger.

Table 3: Comparison table for DC and NDC cases

CHANNEL GAIN h_0	AVERAGE THROUGHPUT	
	DC	NDC

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

0.1	0.0078	0.0078
0.2	0.0185	0.0197
0.3	0.0188	0.0233
0.4	0.0189	0.0254
0.5	0.0197	0.0388
0.6	0.0254	0.0544
0.7	0.006	0.1589
0.8	0.0912	0.1993
0.9	0.2602	0.5767
1	0.8023	1.0201

From the table, it is clear that at initial h0 of 0.1 both the cases have same throughput. But when h0 increases the NDC shows the more increases of throughput than the DC case. And also at maximum channel gain of 1, NDC case achieves the maximum throughput of 1.02 while DC achieves only 0.8023. Finally it is proved that the NDC case performs strictly better than the DC case for the throughput maximization problem.

The performance of co-operative relaying is also analyzed by deriving the end to end Symbol Error Rate (SER) for Gaussian relay channel.

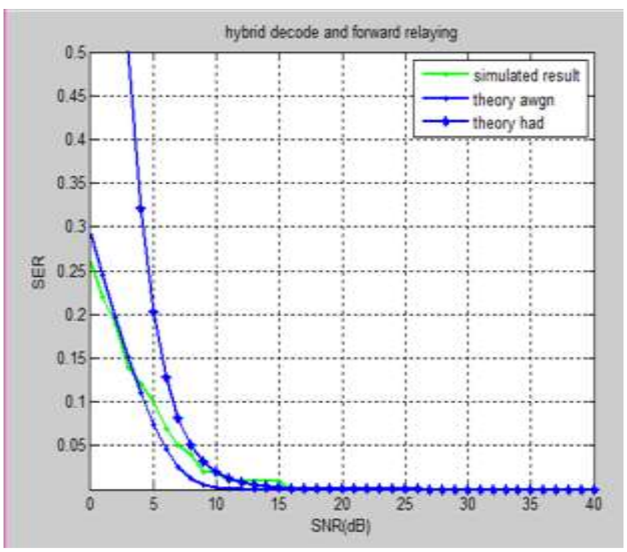

Fig 3: SER vs. SNR for Gaussian relay channel when amplify and forward relaying

In Fig 3, SER is plotted against SNR for the Gaussian relay fading channel when relay chooses the amplify and forward relaying protocol and also for theoretical values of hybrid decode and amplify relay communication and with added theoretical AWGN noise over the channel.

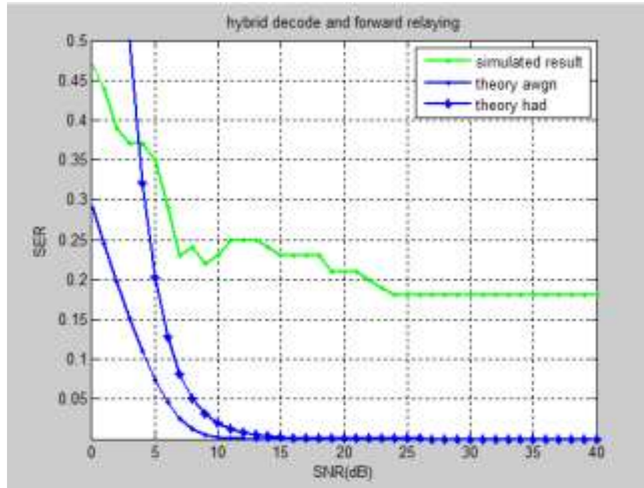

Fig 4: SER vs SNR plot when relay chooses decode and forward relaying

If the relay chooses the decode and forward protocol i.e., the theoretical SNR is smaller than the SNR of source to relay link, then the SER vs SNR will be plotted as Fig 4. These SER results for both amplify – forward and decode –forward relaying are also compared with theoretical values.

From the simulation results, it is observed that the NDC performs better than the DC. Since throughput increases with smaller value of channel gain for NDC but for DC it doesn't reach the throughput limit even when gain increases.

CONCLUSION

Here, the throughput maximization problem for the orthogonal Gaussian relay channel is solved by assuming it as deterministic model. Also the hybrid relaying is presented here i.e., the relay can choose any one from both decode and amplify protocol based on the threshold and source-relay link SNR values and forward it to the destination. The performance of cooperative relaying is also analyzed through the SER and SNR values. In addition, the source and relay optimal power profiles are efficiently computed. From the simulation results, at the maximum channel gain of 1, DC case obtain its maximum throughput as 0.802 bps/Hz only, but NDC obtain its maximum throughput as 1.02 bps/Hz. Finally it is proved that the NDC case performs strictly better than the DC case in terms of average throughput.

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

REFERENCES

1. D. Niyato, E. Hossain, and A. Fallahi, “Sleep and wakeup strategies in solar-powered wireless sensor/mesh networks: Performance analysis and optimization,” IEEE Trans. Mobile Comput., vol. 6, no. 2, pp. 221–236,Feb. 2007.
2. A. Kansal, J. Hsu, S. Zahedi, and M. B. Srivastava, “Power management in energy harvesting sensor networks,” ACM Trans. Embedded Comput.Syst., vol. 7, no. 4, pp. 1–8, Sep. 2007
3. O. Ozel and S. Ulukus, “Information-theoretic analysis of an energy harvesting communication system,” in Proc. IEEE Personal, Indoor Mobile Radio Conf. (PIMRC), Sep. 2010.
4. D. Gunduz and B. Devillers, “Two-hop communication with energy harvesting,” in Proc. 4th Int. Workshop Computational Advances Multi-Sensor Adaptive Process., Dec. 2011.
5. Y. Liang and V. V. Veeravalli, “Gaussian orthogonal relay channel: Optimal resource allocation and capacity,” IEEE Trans. Inf. Theory, vol.51, no. 9, pp. 3284–3289, Sep. 2005.
6. S. Boyd and L. Vandenberghe, Convex Optimization. Cambridge, UK: Cambridge University Press, 2004.
7. T. M. Cover and J. A. Thomas, Elements of information Theory, 2nd ed. John Wiley & Sons, Inc., 2006.
8. T. Q. Duong and H. J. Zepernick, “On the performance gain of hybrid decode–amplify–forward cooperative communications,” EURASIP J. Wireless Commun. Netw., vol. 2009, Article ID 479463, 10 pp.,2009.
9. H. Chen, J. Liu, C. Zhai, and L. Zheng, “Performance analysis of SNR -based hybrid decode–amplify–forward cooperative diversity networks over Rayleigh fading channels,” in Proc. IEEE WCNCW, Sydney,Australia, Apr. 2010, pp. 1–6.