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BUFFER AIDED RELAYING SYSTEM WITH ENERGY HARVESTING NODES

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ABSTRACT

In this paper, a optimal power allocation for buffer aided relaying systems with Energy Harvesting (EH) node, where EH means source communicates with destination via EH Decode-and-Forward relay over the fading channels. A new relaying protocol employing adaptive link selection, i.e., in any given time slot, based on the channel information of the source to relay and the relay to destination link a decision is made whether the source or the relay transmits. In order to avoid data loss at the relay, adaptive link selection requires the relay to be equipped with a buffer such that data can be queued until the relay to destination link is selected for transmission. The main aim of this paper, is to maximize the system throughput and SNR of the system. In this work, the propose offline and online power allocation. For offline power allocation case, the source and relay transmit the powers along with the link sekection result in a mixed integer non linear non linear program which the spatial branch and bound method used to solve optimally. For online power allocation case, a Dynamic Programming (DP) approach is use. To alleviate the complexity inherent to DP, several suboptimal online power allocation scheme is propose. Furtermore, a modified link selection protocol which avoids buffer overflow by limiting the queue size. Also introducing the RSS technique with buffer aided relaying system. The analytical and numerical result show that buffer aided relaying with RSS adaptive link selection achieves significant throughput gain compared to without RSS buffer aided relaying system where the relay employs a fixed schedule for reception and transmission.

KEYWORDS: Adaptive link selection, buffer aided relaying, energy harvesting, power allocation, RSS, throughput..

INTRODUCTION

A source and number of relay expend their energy for processing and transmitting data in cooperative communication systems. For some application, power grid is connected to source and relay but this is not possible for all the condition. So the pre-charged battery are overcome some of the problem.

But, still the problem occurs. In practice, the limited storage capacity of battery and high transmit power may result in quick drain the battery. As the result replaced/recharged the battery periodically which can be sometime impractical. An alternative solution is deployment of Energy Harvesting(EH) nodes. EH node harvest the energy from their surrounding environment to carry out their function. Energy can be harvest from solar, thermal, wind etc. EH nodes no need to replace the battery periodically. It will give the long lifetime of the network. EH source and EH relay during the data transmission at random tine and random amount of energy harvest independently. EH nodes expend the energy from their storage and only the unused energy remains in the battery during the data transmission and other signal processing in the network.

In a source and relay act as a energy harvesting nodes, the type relay used here is Decode and Forward (DF) relaying system. The two types of relaying mechanism is offline and online methods. To compare their performance for both method. In buffer aided relaying, for offline case result in a mixed integer non-linear program to solve by spatial branch and bound method and for online case dynamic programming is used to solve. To eliminate the complexity of dynamic programming, the several suboptimal power allocation online scheme is proposed. Also in this protocol, relay having a buffer to store the received signal until relay to destination selected for transmitting. In [2] a single source-destination non-cooperative link with an EH source is considered and an optimal offline along with an optimal and several sub-optimal online transmission policies is provided for allocation transmit power to source according to random

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variation of the channel and energy storage condition. In this paper, the point to point data transmission with an energy harvesting transmitters, but it have a limited amount of battery capacity is considered. The two main objectives are: 1)maximizing the throughput by the deadline, and 2)minimizing the transmission completion time sequence of the communication session. Then introduce a *directional water-filling* algorithm, it will gives a simple and short interpretation of necessary optimality condition. Also propose offline and online optimal policies under the various configuration.

In [3], the same system model is considered, where the dynamic programming to allocate the source transmit the power for the case when causal channel state information(CSI) was available. Two type of side information(SI) on the channel condition and harvested energy are assumed to be available: 1) Casual SI is consist of the past and present slots of channel condition, in terms of SNR, and amount of energy harvest in the past slots 2)Full SI is consist also of the past and present slot, in addition to that future slots of the channel condition and amount of energy harvested.

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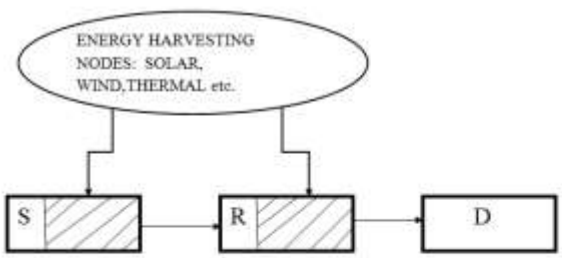

Fig. 1. System model for single link S-R-D

The use of EH relays in cooperative communication is introduced in [4], where the performance analysis is performed for relay selection in cooperative network employing EH relay. The concept of energy constrained and energy unconstrained relay and analytically characterize the symbol error rate of the system. Further gained by asymptotic analysis that consider the case where signal to noise ratio or number of relays are large. The analysis based on the EH relays used and its availability for relaying. It does not depends only a relay energy harvesting process, but also on its transmit power setting and other relay in the system. A deterministic EH model for the Gaussian relay channel is consider [5], here delay and no-delay constrained traffics were studied. 1) Delay-Constrained (DC) traffic: The destination is required to decode the i-th source data, i=1,...,N, immediately after it receives the signal from the source in the i-th block and from relay in the (i+1)-th block and then forwarded to destination. 2) No-delay Constrained (NDC): Decoding delays provided that all source messages are decoded at the end of each N-block transmission.

In [6] the power splitting receiver which dynamically splits the received power into two power streams for information decoding and energy harvesting.The design of power allocation algorithms maximizing the spectral efficiency (bits/s/Hz) of the data transmission. In this the constraint on the minimum power delivered to the receiver. The suboptimal algorithm will produce the excellent performance. In summary the contribution of this paper are follows:

The optimal offline, online and sub optimal online power allocation scheme for EH nodes employing the buffer-aided relaying protocols in the fading channel. The optimal offline joint power allocation and link selection scheme is formulated as an MINLP problem, which is solved optimally by the sBB method. The optimal online power allocation is formulated as an DP problem. To reduce the complexity of optimal online scheme, several sub optimal online power allocation, low complexity online scheme is proposed.

SYSTEM MODEL

An EH relay system, where the source S communicates with destination D via a cooperative relay R (Decode-and-Forward) relaying system as shown in Fig. 1. Both S and R are the EH device and are equipped with battery, which have limited storage capacity and store the harvest the energy for the future uses. The S and R in the signal transmission and processing depends on the amount of harvested energy stored in their battery. The harvested energy can be in any form for example solar, wind, thermal. S has perfect knowledge of the channel SNR and energy harvested at R.

A. Channel model

The time is divided into slots of equal lemgths. In the ith time slot, the transmit powers of source and relay are denoted by $P_S(i)$ and $P_R(i)$ respectively. The instantaneous channel gains of the S-R and R-D links denoted by $h_S(i)$ and $h_R(i)$ respectively. $h_S(i)$ and $h_R(i)$ are modeled as mutually independent, non negative, stationary. The ergodic random process with expected values $E\{ h_S(i)\}= \Omega_S$ and $E\{ h_R(i)\}=\Omega_R$, where E{.} denotes expectation.The channel gains are constant during one time slot but change from one time slot to

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the next due to e.g. th mobility of the involved npdes and frequency hopping.

The instantaneous link Signal to Noise Ratio (SNR) of the S-R and R-D channels in the ith time slot is given by $s(i)=\gamma_S(i)h_S(i)$ and $r(i)=\gamma_R(i)h_R(i)$ respectively. Here, $\gamma_S(i)=P_S(i)/\sigma^2_{ns}$ and $\gamma_R(i)=P_R(i)/\sigma^2_{nr}$ denote the transmit SNR of the source and the relay , respectively. σ^2_{ns} and σ^2_{nr} are the variances of the Additive White Gaussian Noise(AWGN) at the relay and the destination respectively. The average link SNRs are denoted by $\Omega_S=E\{s(i)\}$ and $\Omega_R=E\{r(i)\}$.

B. Buffer-Aided Relaying Adaptive Link Selection

The link adaptive transmission protocol, one of the nodes of the network is responsible for deciding whether the source or the relay should transmit in the given time slot i. This node is reffered to as the central node in the following. The central node broadcasts its decision to the other nodes before transmission in the time slot i begins. If they are selected for transmission, the source and the relay adapt their transmission rates to the capacity of the respective link and transmit codewords spanning one time slot. Assume that source and relay employ capacity achieving codes. For both link selection and rate adaptation, the nodes require CSI knowedge as will be detailed in the following.

CSI requirements: The central node require knowledge of the instantaneous channel gains $h_S(i)$ and $h_R(i)$. In addition, regardless of which node is the central node, if the S-R link is selected, the source and the relay require knowledge of $h_S(i)$ for rate adaptation and decoding respectively. On the other hand, if the R-D link is selected, the relay and destination require knowledge of $h_R(i)$ for rate adaptation and decoding respectively. Nodes can obtain the instantaneous channel gains through estimation based on the piolt symbols emitted by other nodes and/or CSI feedback from other nodes. Futhermore, assume that the central node knows the noise variances σ^2_{ns} and σ^2_{nr}, and regardless of which node is the central node, source, relay and destination knows σ^2_{ns}, (σ^2_{ns}, σ^2_{nr}), and σ^2_{nr}, respectively. Also, if the transmit power is a priori fixed, i.e., $P_S(i)=P_S$ and $P_R(i)=P_R$, the central node requries knowledge of P_S and P_R, and source, relay and destination require knowledge of P_S, (P_S,P_R), and P_R, respectively. If the power allocation is employed, $P_S(i)$ and $P_R(i)$ are computed by the nodes based on their respective knowledge of the instantaneous channel gains and statistical CSI knowledge.

Node serves as the central node depends on the network architecture. For example, in the downlink of a cellular network, the source can serve as the central node as it typically acquire the full CSI of all links anyways and can afford the complexity of performing adaptive link selection and power allocation. On the other hand, if the relay serves as the central nodes,source and destination have to acquire only the CSI of the S-R and R-D link respectively.

For convenience the number of bits transmitted in one time slot by the number of symbols per time slot. Thus, the number of bits refers to the number of bits divided by the number of symbol in the codeword.

Source transmit: If the source is selected for transmission in time slot i, it transmits with rate

$S_{SR}(i)= \log_2(1+s(i))$ (1)

Hence, the relay receives $S_{SR}(i)$ data bits from the source and appends them to queue in its buffer. The number of bits in the buffer of the relay at end of the time slot i is denoted by Q(i) and given by

$Q(i)=Q(i-1)+ S_{SR}(i)$ (2)

Relay transmits: If the relay transmits in time slot i, the number of bits transmitted by the relay is given by

$R_{RD}(i)= \min\{\log_2(1+r(i)), Q(i-1)\}$, (3)

where the take into account that the maximal number of bits that can be send by the relay is limited by the number of bits in its buffer and the instsntsneous capacity of the R-D link. The number of bits remaining in its buffer at the end of time slot i is given by

$Q(i)=Q(i-1)- R_{RD}(i)$ (4)

which is always non negative because of (3).

Because of the half duplex constraint, $R_{RD}(i)=0$ when the source transmits and $S_{SR}(i)=0$ when the relay transmits.

c) Throughput

Since, assume the source has always data to transmit, the average number of bits that arrive at the destination per time slot is given by

$$\tau = \lim_{N\to\infty} \frac{1}{N} \sum_{i=1}^{N} R(i) \quad (5)$$

i.e., τ is the throughput of the considered communication system. The goal of the following section is the maximization of τ by optimizing the adaptive link selection protocol and the transmit power allocated power allocated to source and relay.

Power Allocation And Link Selection For Buffer-Aided Relaying

A. Offline Power Allocation

The main goal is to maximizing the total number of transmitted bits (from S to D) delivered by a target of K time slots for the link adaptive transmission protocol. The offline information about the full CSI and the energy arrivals at S and R in each time slot are assumed to be identified in proceed. The consequential maximization problem is subject to a causality control

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on the harvest energy and the storage control for the battery at both S and R. The major problem is non-convex MINLP due to binary variable d_k and non-convex and non-linear constraint. Then, the propose two optimal method to solve the buffer-aided link adaptive offline optimization problem.

1) Exhaustive Search: This method of searching the cost function is maximizes. This approach cannot be adopted for large value of K. The exhaustive search can be effective for small K

2)Spatial Branch-and-Bound(sBB): The feasible lower bounds are chosen to be local minimizes of the problem whereas the upper bounds are obtained from convex relaxation .

B. Online Power Allocation

In practice, only fundamental information about channels and harvested energy is available for power allocation . Therefore , the offline power allocation scheme is not eagerly related as, at a given time slot, the future CSI and upcoming harvested energy are not know in proceed. To this end, the formulate an optimal online method using stochastic DP. Unfortunately, this approach leads to a very high computational complexity because of the adaptive link choice in every time slot and may not be implementable in practice. Therefore, the propose two efficient suboptimal online scheme which have low complexity.

1) Suboptimal Harvesting Rate(HR) Assisted Online Power Allocation: The propose an efficient online power allocation scheme referred to as "HR Assisted". To this end, to create an optimization problem which is based on the average data rate, the average energy causality constraints at S and R, and the average buffering constraint .

2) Suboptimal Online Power Allocation: In the suboptimal power allocation scheme for link adaptive relaying, at every time slot, K, S and R consider the total of energy stored in their batteries as their transmit power. Based on the transmit power , S and R calculate their capacity. The buffer status should be taken into account in the computation of the capacity of R. The S-R (R-D) link is selected if the capacity of S is greater (smaller) than that of R.

POWER ALLOCATION AND LINK SELECTION FOR BUFFER AIDED RELAYING WITH RSS

In this section, an offline and several online power allocation scheme for the considered EH system with buffer aided relaying with Received Signal Strength (RSS) is proposed.

A. Offline Power Allocation

Like for buffer-aided relaying, for buffer aided relaying with RSS, our goal is to maximize the total number of transmitted bits delivered by a deadline of K time slots. Assume offline information of full CSI and the energy arrivals at S and R in each time slot. The offline optimization problem for maximization of the throughput of the considered system of K time slot.

B. Online Power Allocation by DP

Unlike buffer-aided link adaptive relaying, the link selection policy is pre-defined for the buffer aided relaying with RSS, i.e., $d_{2k-1} = 0$ and $d_k = 1$, K ε {1,2,..... k}. This feature of the buffer aided relaying with RSS reduce the complexity of stochastic DP compared to link adaptive relaying. Therefore, for buffer aided relaying with RSS, a stochastic DP approach for optimum online power allocation is considered.

$$RSS = \frac{T_p G_t G_r H_t^2 H_r^2}{d^4}$$

Where,

T_p is Transmission Power
G_t isTransmitter Gain
G_r is Receiver Gain
H_t is Height of the transmitter antenna
H_r is Height of the Receiver antenna
d is Distance between source and destination.

SIMULATION RESULTS

In this section, evaluate the performance of the proposed offline and online power allocation schemes for buffer-aided link adaptive with and without RSS relaying protocols. The simulate 10^4 randomly generated realizations of the S-R and the R-D channel and harvestd energies at S and R to obtain the average throughput and SNR.

1. *Throughput*

In this subsection, shows the throughput performance of the proposed power allocation scheme for buffer aided relaying with and without RSS.

In Fig. 2 shows that in various time period, number of received packets efficiently. To compare the performance of both offline and online relaying

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system for buffer aided link adaptive with and without RSS. The result shows offline method performance better than online method for both relaying techniques. Hence, offline buffer aided link adaptive with RSS shows the best result.

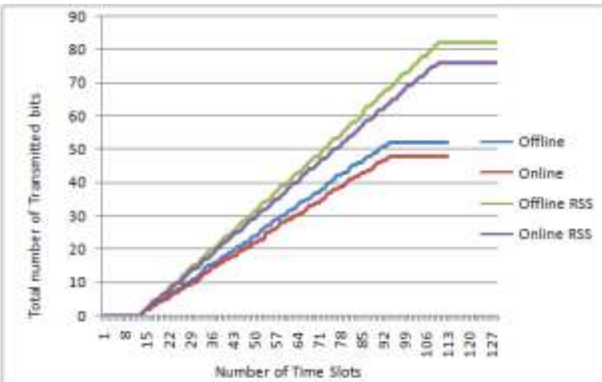

Fig. 2 Number of Time Slots vs. Total number of Transmitted bits

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B. Harvesting Energy

In this subsection, shows the harvesting energy performance of the proposed power allocation scheme for buffer aided relaying with and without RSS.

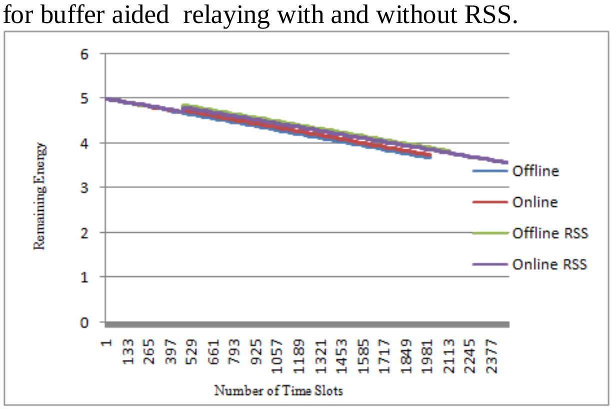

Fig. 3. Number of Time Slots vs. Remaining Energy

In Fig 3 shows that plotted for time versus remaing energy. During the transmission of data, it losses their energy from the battery. Continuouly transmitting the data to the destination. If the battery power is low, its suddenly stop the transmission and starts to harvest the energy for their surroundings for transmiting the data. Again, its start to transmit the remaining data. Finally send all the data to destination successfully. The energy harvesting for offline buffer aided link adaptive relaying with RSS shows the best result.

Performance of Offline

In this subsection, shows the offline throughput performance of the proposed power allocation scheme for buffer aided relaying with and without RSS.

In Fig. 4 show, to compare the offline for buffer aided relaying system with and without RSS. Hence, the result shows that offline with RSS is received more number of packets within the short number of time slots.

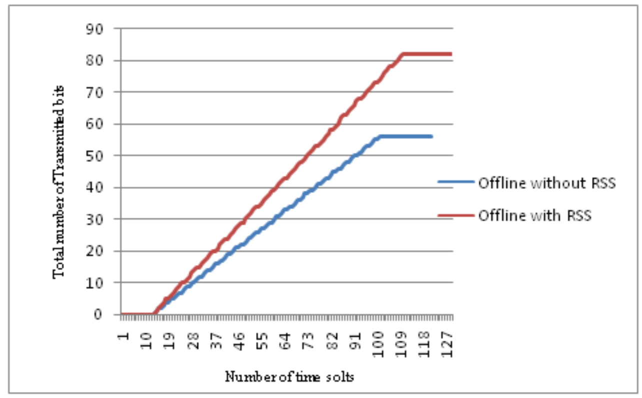

Fig.4 Number of Time Slots vs. Total number of Transmitted bits.

D. *Performance of Online*

In this subsection, shows the online throughput performance of the proposed power allocation scheme for buffer aided relaying with and without RSS.

In Fig. 5 show, to compare the online for buffer aided relaying system with and without RSS. Hence, the result shows that online with RSS is received more number of packets within the short number of time slots.

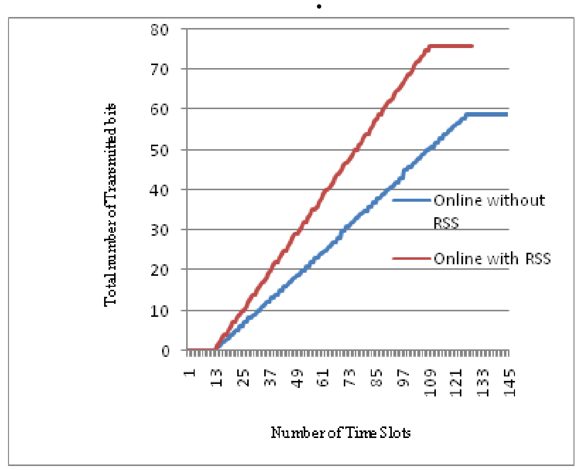

Fig.5 Number of Time Slots vs. Total number of Transmitted bits.

E. Signal to Noise Ratio(SNR)

In this subsection, shows the SNR performance of the proposed power allocation scheme for buffer aided relaying with and without RSS.

In Fig. 5 shows plotted for Packets versus SNR and to compare the SNR for buffer aided link adaptive relaying system with and without RSS protocol both offline and online methods. It measure the quality of a transmission channel through the wireless network. The SNR for offline buffer aided link adaptive relaying with RSS shows the best result.

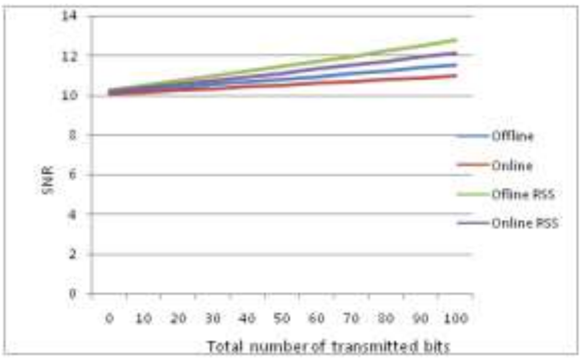

Fig. 6 Total number of transmitted bits vs. SNR

Table1.Comparison table for throughput power allocation buffer-aided link adaptive relaying system with and without RSS value of the different number of time slots

Number of Time Slots	Number of Transmitted bits			
	Without RSS		With RSS	
	Offline	Online	Offline	Online
10	0	2	0	3
25	8	8	10	10
40	17	15	20	20
50	25	25	30	30
65	30	30	40	40
80	40	40	50	60
90	50	50	60	76
105	55	50	82	76

Table 2. Comparison table for SNR power allocation buffer-aided link adaptive relaying system with and without RSS value of the different number of time slots

Number of Transmitted bits	SNR			
	Without RSS		With RSS	
	Offline	Online	Offline	Online
10	10.25	10.1	10.45	10.35
20	10.3	10.22	10.65	10.55
30	10.35	10.55	10.9	10.75
40	10.60	10.57	11.1	10.9
50	10.8	10.6	11.4	11.1
60	10.9	10.6	11.65	11.3
70	11.05	10.7	11.95	11.45
80	11.2	10.8	12.2	11.7
90	11.35	10.95	12.45	11.9
100	11.5	10.95	12.75	12.1

In Table 1 show the compare the throughput offline and online power allocation for the buffer aided link adaptive relaying system with and without RSS calculation of different number of time slots. Among that, offline power allocation for buffer aided link adaptive with RSS gives the best performance result.

In Table 2 show the compare the signal to noise ratio offline and online power allocation for the buffer aided link adaptive relaying system with and without RSS calculation of different number of time slots. Among that offline power allocation for buffer aided link adaptive with RSS gives the best performance result.

CONCLUSION

In this paper, the problem is transmit power allocation for multi relay networks, where harvest the energy needed for transmission from the surrounding atmosphere is source and relay. Two different relaying mechanism, namely buffer aided link adaptive relaying with and without RSS, have been measured. The several optimal and suboptimal offline and online power allocation schemes maximizing the system throughput of the measured EH systems. Simulation result showed that the proposed suboptimal online scheme have a good complexity performance. Moreover, showed that, for both offline and online optimization, adopting the link adaptive protocol radically improves the throughput compared to without RSS. Especially for asymmetric link qualities, and buffer-aided link adaptive relaying with RSS is more robust to changes in the EH profile than without RSS. Finally, offline buffer aided link adaptive with RSS simulation result will give the best performance compare to other relaying system.

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