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Power Allocation Strategies for Wireless Relay Networks with Analog Network Coding: Survey

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Abstract– Relay aided communication with network coding can bring spectacular performance enhancements for wireless networks. The proper design of power allocated to each of the nodes involved in the communication is essential as it has impact on the performance when Analog Network coding (ANC) is used. This paper presents a survey on recent power allocation strategies, intended objectives, practical constraints that have been considered, and corresponding performances for networks with ANC protocol.

Index Terms *– ANC, Power allocation.*

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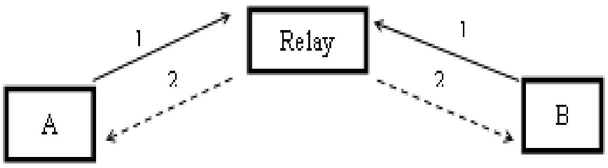
I. INTRODUCTION

Relay communication inherits many advantages but at the same time there are some challenges which make it difficult for the relay aided wireless communication to reach its full versatility. Relay provides a solution for increasing coverage area, combating fading effects but these advantages are accompanied by the challenges like increased overhead, resource consumption, and low spectral efficiency [1]. A two way relay channel has recently emerged as a promising approach to mitigate the spectral efficiency loss of conventional half duplex relaying systems [2]. This approach is known as network coding and wired network coding performance was improved with the introduction of network coding [3] and later it was shown to be effective for wireless networks [4]. In network coding two source nodes communicate bidirectionally via a half duplex relay in two time phases. This scheme is called as Analog Network Coding (ANC) where the relay employs Amplify and Forward strategy for the superimposed signals received from the sources in the first phase [5]. ANC is easier to implement it only requires coarse synchronisation at the packet level. For a wireless network there are several performance parameters like Bit Error Rate (BER), outage probability, data rate etc. It was proved in [6], that the data rate in conventional wireless networks can generally be maximised by setting the average transmission power of nodes to its maximum value, because in the case of zero interference, maximising the transmission power implies maximising signal to noise ratio (SNR) at the receiver and subsequently maximising achievable data rate .But this does not hold for the case for ANC. Consider the system model shown in figure 1.



2 Time slot Transmission Scheme

Let x_1 and x_2 be the signals transmitted by the signals transmitted by the *source A* and *source B* respectively. If the distance between the source A and the relay is significantly smaller than the distance between source B and the relay. Then x_1 will dominate the Amplified and Forwarded signal broadcast by the relay if both the source nodes transmit at the maximum transmission power, because the transmission power of the relay is also constrained to a maximum value. If x_1 is very large, it will suppress x_2. Consequently, x_2 will have small SNR at the destination node, which will lead to data rate reduction of both sessions, because only one packet from each session can be coded together. This implies that the data rate is affected by the interaction between simultaneously coded sessions and power adaptation is necessary for ANC [7]. Optimum Power allocation for ANC protocol is very crucial and useful because it can enhance the system performance such as outage probability [8]. Thus Power allocation is an important design issue which can address many performance parameters of a wireless network and can bring noticeable difference in the result.

In this paper we have considered a comprehensive survey of existing optimum power allocation strategies and adaptive power allocation strategies. Some of the most recent studies and research works have been considered for the survey and they have been analyzed from a perspective of the methodology followed, objectives, applications and their corresponding performance.

II. PREVIOUS WORKS

The impact of source power allocation on the performance of the one way Multiple Access Relay Channel (MARC) was analysed in [9]. The throughput of the one way ANC as well as the numerical analysis has been done. A feasible power allocation value is crucial for the enhancement of throughput. It was found that the outage probability is increasing with the power allocation factor. The outage probabilities are approximate solutions under the assumption of high signal to noise ratio.

In [10] a simple and generalised outage analysis of the ANC protocol by considering asymmetric traffic requirements over Rayleigh flat fading channel along with the optimal relay location and power allocation for minimizing the overall system outage probability was proposed. It was shown that the relay has to be located closer to one of the source nodes to handle asymmetric traffic optimally. And also to overcome this, an optimum power allocation with an objective that the system remains balanced even with a high level of traffic asymmetry has been presented.

A two phase ANC and power allocation scheme for the distributed relay nodes and terminals to enhance the security of the data exchange was proposed in [11]. Here three different approaches have been considered, when all instantaneous channel state information (CSI) is available, with full eavesdropper's CSI and with no eavesdropper's CSI. The physical layer security issue of bidirectional transmission with the help of multiple relay nodes in the presence of an eavesdropper has been addressed. Three different security schemes using two phase analog network coding and power control to enhance the security of the data exchange has been proposed and showed that both of these schemes can be mathematically transformed to convex optimisation problems and their solutions are unique and globally optimal.

Two-way relaying (TWR) system where two source nodes are equipped with multiple antennas and the relay has a single antenna was proposed in [12] and provided an observation that the relay location is more important than the relay power allocation when the numbers of source antennas are unequal. A more accurate upper-bound on the average sum rate (ASR) when the TWR consists of one AF relay and two source terminals employing the beamforming (BF) was derived.

A scheme which adaptively allocates the transmit power in order to make the instantaneous signal-to-interference plus noise power ratios (SINRs) of both up and down links identical and maximised was proposed in [13]. By computer simulations the distribution of bit error rate (BER) and throughput when the proposed power allocation was used was evaluated and it was shown that the proposed scheme can improve the BER and throughput performance compared to equal power allocation. It was shown that the proposed scheme can provide about 1.5 times higher uplink throughput than equal power allocation and about 10 times higher throughput than the direct transmission when P_T/N=20dB. The power allocation method which can control the up and downlink throughput was considered as the next work.

The power allocation for the practical analog network coding (ANC) for MARC was investigated in [14]. In this work optimal power allocation under the goal of maximizing the mutual information is proposed and the numerical results show that the proposed method achieves better mutual information than uniform power allocation.

The advantages offered by ANC makes it open for experimenting in different platforms. In [15] power allocation for the network coded cognitive cooperative networks (NCCCN) was proposed. A power allocation optimization problem has been considered that maximises the data transmission rate of the NCCCN under the total transmit and peak interference powers or the total transmit and average interference powers. This is a first attempt where power allocation considering ANC and interference constraint for OFDM base CCN has been considered and the power allocation in the underlay CCN is different from the conventional algorithms. The proposed system performs better than the CCN without network coding and higher data rate can be achieved by using power allocation and the work was extended considering channel coding and power allocation based on outage probability analysis.

Analytically determining the optimal power values at both nodes and at the relay that leads to a maximisation of sum rate under the fairness constraint with AF and DF relay strategy was investigated in [16]. Here fairness refers to the rate from node A to node B R_{AB}, must be equal to the data rate from node B to node A R_{BA}. Numerical results show that fair AF is more efficient than fair DF and fairness also improves the average data rate for AF.

In [17] an Orthogonal Frequency Division Multiplexing (OFDM) based multiple two-way relay system with ANC protocol was considered. A joint optimisation problem is formulated considering power allocation, relay selection and subcarrier pairing to maximise the sum capacity under individual power constraint on each node. Using dual decomposition method, the resource allocation problem is decomposed into per-subcarrier based subproblems. The proposed scheme which jointly optimises three types of resource outperforms conventional resource allocation scheme significantly.

ANC with three transmission phases (3P) was considered in [18] where an outage optimal relay power allocation (RPA) was derived. When a direct link (DL) is available a suboptimal RPA is proposed to avoid the requirement of the feedback of the DL quality. And simulation results show that 3P ANC with suboptimal RPA outperforms the optimal RPA with at a negligible loss.

The objective of minimizing the transmit power consumption at required end to end rates, energy efficient relay selection (RS) and power allocation (PA) scheme for TWRC with ANC was proposed in [19]. Best relay node is selected to minimize the transmit power. An energy efficient single RS and PA (E-SRS-PA) is proposed and it has been proved that E-SRS-PA is optimal energy efficient and power allocation scheme (OE-RS-PA). The closed form expressions for E-SRS-PA scheme are derived. The optimality has been confirmed through simulations and also the higher the data rate requirements the better the energy efficiency of ANC E-SRS-PA compared to other relaying schemes.

The problem of resource allocation from the perspective of outage probability has been studied in [20] and an optimal power allocation that minimizes an approximate outage probability is derived and shown to improve the performance up to 4.77 dB under the sum power constraint with perfect receiver side channel knowledge. And when the sum-power constraint is not useful one way AF in addition to/instead of ANC is suggested to be used in the proposed work. A cut set type bound is derived to understand how much the power allocation can make the ANC operate close to the fundamental limits of TWRC.

In [21] sum-power minimization for given signal to noise ratio (SNR) constraints has been considered. The optimality of energy efficient single relay selection and power allocation is proved under the gain requirements and the best worst relay selection and power allocation scheme is introduced and the best worst relay is selected according to best-worst relay selection criterion

A multi-pair two-way relay network with multiple user pairs simultaneously exchanging the information through a common multi-antenna relay station is considered in [22]. A relay precoding matrix that provides inter-pair interference free transmissions for a selected subset of users is designed also a power allocation optimisation at both RS and active users to maximize the network sum rate is considered.

The problem of joint and separate optimisation of power allocation and relay location in order to minimize the outage probability was considered in [23] for a two way relay system with multiple antenna sources employing beamforming to communicate through a single antenna relay over *Nakagami*-m fading channels. It was demonstrated through results that separate optimization of relay location is more significant than that of power allocation to improve the overall system outage. The outage performance improvement over unbalanced per-hop fading conditions and/or nonidentical antenna configurations is also emphasized in this work.

Energy efficiency (EE) enhancement for asymmetric analog network coding was investigated in [24]. The power allocation problem is formulated as the system EE maximisation problem with an objective function quantified by *Goodbit-per-energy* (GPE). A non linear fractional programming based algorithm is proposed and closed-form solution is obtained. The impact of traffic asymmetry has been taken into account particularly.

With an objective of minimizing the weaker link's outage probability under the total power constraint and interference power threshold (IPT) constraint to the primary user (PU) in a Rayleigh fading channel environment an optimum power allocation (OPA) scheme has been proposed in [25] for ANC protocol in cognitive radio (CR) network. OPA guarantees that the primary user will not be affected due to secondary transmissions while the secondary user achieves its maximum possible performance under some limitations.

A power allocation strategy to mitigate the negative impact of imperfect channel state information by minimizing the weaker link's individual outage probability under the sum power constraints from the perspective of secondary communication in cognitive radio was proposed in [26]. And it used only statistical CSI rather than instantaneous CSI which makes the scheme practically feasible and robust to the channel uncertainty and has a significant performance gain over the traditional scheme.

In [27] an optimal relay power allocation to minimize the overall system outage was proposed for two-way multi-relay system employing three-phase ANC with best relay selection over independent and non-identically distributed Nakagami-m fading channels. An overall system outage expression that gives important insights at high SNR based on which optimal relay power allocation to minimize the overall system outage has been presented.

ANC has been extended recently to broadband transmission undergoing frequency selective fading where Orthogonal Frequency Division Multiplexing (OFDM) is preferred as the radio access platform. In [28] time domain instantaneous power scaling and relay selection to improve the outage performance without equipping Discrete Fourier Transform (DFT) and Inverse DFT functions at the relay has been employed for the proposed two-phase (2P) and three-phase (3P)-ANC schemes for OFDM based multirelay networks. A relay power allocation factor has been devised. The proposed 3P-ANC with suboptimal relay power allocation is favourable in the asymmetric relay location while the proposed 2P-ANC is favourable in the symmetric relay locations.

The objective of the power allocation (PA) strategy can be to minimize the outage probability and to maximize the achievable sum rate for ANC based TWRC (A-TWRC). In [29] it has been theoretically proved that optimal PA problems in the sense of minimizing the outage probability and maximising the achievable sum rate are equivalent to each other. A unified optimal PA scheme for A-TWRC is proposed and it has been shown that the previous optimal PA schemes are special cases of the proposed unified scheme under certain conditions. Results show that proposed scheme obtains the optimal outage probability and achievable sum rate performance and the previous works approach the proposed unified PA scheme on either outage or achievable sum rate performance.

The objective of joint single relay selection (SRS) and power allocation schemes for energy efficient wireless communication systems with ANC for Time Division broadcast for a TWRC with two end nodes and N parallel relay nodes with an assumption of perfect channel state information (CSI) was investigated in [30]. The proposed work aims at minimizing the total system transmit power under the constraint of Quality-of-Service (QoS).

The error rate performance of MARC with ANC was analytically studied in [31]. A power allocation problem is formulated and a closed form expression of the optimal power to be allocated to the sources and relays for a Maximum-Likelihood (ML), Zero-Forcing (ZF), Minimum Mean Square Error (MMSE) receiver is provided. It has been shown that power optimization is beneficial as the number of sources increases and if the quality of source-relay links is better than the quality of the relay-destination link.

The throughput of the ANC scheme may not be doubled in practical wireless environments due to the poor channel quality of the overhearing links (OL). Hence in [32] a power allocation strategy and the relay locations which are to be varied under the quality of OL is proposed.

III. CONCLUSION

As we can see from the entire study that power is an important resource and its careful allocation can bring difference in the performance of different wireless communication networks with ANC. In this paper we have surveyed the recent works in the power allocation strategies for networks with ANC protocol, the objectives of the work, the constraints considered for the work and the performance outcomes.

Based on the review we can conclude that there have been significant research on power allocation strategies but there have been few works which have considered the impact of power allocation on the Bit Error Rate (BER) and Quality of Service (QoS) of the wireless networks with ANC. Hence there can be an intense work in this direction in future.

REFERENCES

[1] R. Pabst, B. Walk and D. Schultz," Relay-based deployment concepts for wireless and mobile broadband radio" *IEEE Commun Mag.,* Vol. 42, no.9, Sep. 2004.

[2] B. Rankov and A. Wittneben, "Spectral Efficient Protocols for half-duplex relay channels," IEEE J. Sel.Areas Commun.,vol.25,no.2,pp.379-389,Feb.2007.

[3] Ahlswede, R., et al., Network Information flow, Information Theory, IEEE Transactions on,2000.46(4):p.1204-1206.

[4] P Larsson, N.Johansson, K.E.Sunell, "Coded Bi-directional Relaying", in Vehicular Technology Conference, 2006. VTC 2006-Spring IEEE 63rd, 2006, pp. 851-855

[5] S. Katti, S.Gollakota, and D.Katabi, "Embracing wireless interference: analog network coding", in Proc. ACM. SIGCOMM, Aug. 2007, pp. 397-408

[6] A. Goldsmith, Wireless Communications, Cambridge, UK: Cambridge Univ. Press, 2005.

[7] S.Wang, Q.Song, X.Wang and Abbas Jamalipour, "Rate and Power Adaptation for Analog Network Coding", IEEE Transaction on Vehicular Technology, Vol. 60 no. 5, June 2011.

[8] Z. Yi, M. Ju and II-Min Kim, "Outage Probability and Optimum Power Allocation for Analog Network Coding", IEEE Transaction on Wireless Communications, Vol. 10, No. 2; Feb. 2011.

[9] Y.Ouyang, X.Jia, "Outage Probability Analysis on Multiple-Access Relaying Channel with Analog Network Coding", IEEE 2010.

[10] Prabhat K.Upadhyay, Shankar Prakriya, "Performance of Analog Network Coding with Asymmetric Traffic Requirements", IEEE Communications Letters, Vol. 15, No. 6, June 2011.

[11] Hui-Ming Wang, Q.Yin Xiang-Gen Xia, "Improving the Physical-Layer Security of Wireless Two-Way Relaying via Analog Network Coding", IEEE Globecom 2011.

[12] J.C.Parl, J.B.Park, Ji-Hye Lee, Jin Soo Wang and Yun Hee Kim, "Analysis on Average Sum Rate of Two-Way Relaying with Simple Analog Network Coding in Nakagami Fading Channels", IEEE 2011.

[13] H.Miyazaki, M.Nakada, T.Obara and F.Adachi, "Adaptive Power Allocation for Bi-Directional Single-Carrier Relay Using Analog Network Coding", IEEE 2011.

[14] M.Zhao, Y.Zhou, Y.Yang, "An Optimal Transmit Power Allocation for Multiple-Access Relay Channel with Analog Network Coding", ICCSIT 2011.

[15] M.Shamim Kaiser, "Power Allocation for the Network Coded Cognitive Cooperative Network", IEEE 2011.

[16] M.Pischella and D.Le Ruyet, "Optimal Power Allocation for the Two-Way Relay Channel with Data Rate Fairness", IEEE Communications Letter, Vol. 15 No. 9, Sept. 2011.

[17] Bin Han, W.Wang and M.Peng, "Optimal Resource Allocation for Network Coding in Multiple Two-Way Relay OFDM Systems", IEEE Wireless Communications and Networking Conference, 2012.

[18] J.Cheol Park, I.Song, Yun Hee Kim, "Outage-Optimal Allocation of Relay Power for Analog Network Coding with Three Transmission Phases", IEEE Communications Letters, Vol. 16 No. 6, June 2012.

[19] M.Zhou, Q.Cui, R.Jiantti, X.Tao, "Energy-Efficient Relay Selection and Power Allocation for Two-Way Relay Channel with Analog Network Coding", IEEE Communications Letters, Vol. 16, No. 6, June 2012.

[20] H. Bhageri, M. Ardakani and C. Tellambura, "Resource Allocation for Two-Way AF Relaying with Receive Channel Knowledge", IEEE Transactions and Wireless Communications, Vol. 11, no. 6, June 2012.

[21] E.S.Cetin, M.E.Celebi, "Two-Way Relay Networks with Analog Network Coding: Relay Selection under Total Power Minimization", IEEE 2013.

[22] M.Wang, P.Wang, Y.Li, Z.Zhong, F.Wang and B.Vucetic, "Transceiver Design for Multi-Pair Two-Way Relay Networks with Analogue Network Coding", IEEE Communications Letters, Vol. 17, No. 12, Dec. 2013.

[23] Prabhat K.Upadhyay, Shankar Prakriya, "Joint Power and Location Optimization for Analog Network Coding with Multi-Antenna Sources", IEEE Wireless Communications and Networking Conference (WCNC),2013.

[24] C.Zhang, J.Ge, Jing Li, Yun Hu, "Energy-Aware Power Allocation for Asymmetric Analog Network Coding with Statistical CSI", IEEE Wireless Communications and Networking Conference (WCNC), 2013.

[25] Mi Hu, J.Ge, X.Shi, "Optimal Power Allocation Scheme for the Two-Way Relay Channel Using ANC in Cognitive Radio", IEEE 2013.

ISSN: 2454-4248
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[26] M.Hu, J.Ge, X.Shi, "Outage Probability and Power Allocation for ANC with Channel Estimation Errors in Cognitive Radio", IEEE 2013.

[27] S.Yadav, Prabhat K.Upadhyay, "Performance of Three Phase Analog Network Coding with Relay Selection in Nakagami-m Fading", IEEE Communications Letter, Vol. 17, No. 8, Aug. 2013.

[28] J.B.Park, J.S.Wang, T.P.Du, I.Song, Y.H.Kim, "Pragmatic Analog Network Coding with Relay Selection for OFDM-Based Multirelay Networks", IEEE Transactions on Wireless Communications, Vol. 13, No. 10, Oct. 2014.

[29] Kui Xu, D.Zhang, Y.Xu, W.Ma, "On the Equivalence of Two Optimal Power-Allocation Schemes for A-TWRC", IEEE Transactions on Vehicular Technology, Vol. 63 No. 4; May 2014.

[30] B.M.Elhalawany, M.Elsabrouty, O.Muta, A.Abdelrahman, H.Furukawa, "Joint Energy-Efficient Single Relay Selection and Power Allocation for Analog Network Coding with Three Transmission Phases", IEEE 2014.

[31] K.Ntontin, M.D.Renzo, A.I.Perez-Neira, C.Verikoukis, "Analog Network Coding in the Multiple Access Relay Channel: Error Rate Analysis and Optimal Power Allocation", IEEE Transactions on Wireless Communications, Vol. 14, No. 6, June 2015.

[32] J.Lee, M.Rim and K.Kim, "Impact of Overhearing Link Quality on Power Allocation Strategy and Relay Location for Analog Network Coding", IEEE Transaction on Vehicular Technology, Vol. 65, No. 4, April 2016.