Analysis of Relay Selection Game in a Cooperative Communication Scenario

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Abstract. This paper analyzes the performances of a proposed set of functions that model the relay selection process in a cooperative communication scenario. The proposed behavior and influence functions create a mechanism for selecting the best relays to be used to send certain types of data. The mechanism is based on a Nash Equilibrium (NE) algorithm and on a marriage equation, that predicts the degree of satisfaction between married couples. We consider an opportunistic cooperative communication settings in which multiple nodes are competing for a poll of relay nodes. The performances are evaluated in terms of comparison between the bit error rate of the proposed mechanism and the direct communication, using Matlab.

Keywords: Relay selection · Nash Equilibrium · Marriage equation
Behavior function · Cooperative communication · Resource allocation

1 Introduction

When we are talking about cooperative communication we are talking about a field that was and is on the hot investigated areas. Even more, in the context of 5G rising there will be a need of transferring the information to relevant receivers as is the case of a poll of sensors that want to forward their information to a destination node that is several hops away. For this poll of sensors there should be a poll of relays to forward that information and the best relay for each sensor should be selected. Moreover, the poll of sensors of the poll of relays is not stable (i.e. a relay can be on or off conserving energy). Hence a mechanism that can be flexible and independent of the number of relays or the number of transmitters is required.

Current research papers presented the performances of cooperative communication (CC) in comparison with direct communication (DC). In [1] Lee et al. proposed a max-min-max cooperative relay selection based on the signal intensity. Thus, a higher diversity gain and a higher system throughput was achieved in comparison with DC. In [2] Guo and Carrasco proposed a MAC protocol for improving the transmission rate by using high rate station as an assistant for low rate ones. Moreover, relay networks are also used in mobility scenarios to dynamically select a relay for improving the delay and capacity of the transmitter. In [3] the authors proposed a routing algorithm for efficient resource allocation in MANET and in [4] a group two-hop CC algorithm is proposed for delay improvement.

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Another extensively used mechanisms for CC is the game theory in the context of relay selection. The research is concentrated on rate improvement by selecting the best relay from a poll of relays [5]. This problem is different formulated from the Chinese restaurant game (i.e. choose the best table such that the satisfaction is maximized) [6] or using the auction theory (i.e. efficient matching buyers with sellers) [7].

In this paper, we used the mechanism proposed by the authors in [9], and evaluated the improvements in BER against SNR for different scenarios in a cooperative communication model.

This paper is organized as follows. Section 2 describes the proposed mechanism algorithm and the mathematics behind it; Sect. 3 shows simulated results and Sect. 4 concludes this paper.

2 Relay Selection Mechanism

2.1 The Behavior Function

The following mechanism translate the behavior function, that models the relation between the partners of a married couple, to a selection relay behavior function.

The node that initiates the communication will be denoted as SN (source node). The node that is used to relay the communication is denoted as RN (relay node) The relationship between these two nodes is defined in (1) and (2) [9]:

$$B_{RN(\mathrm{n}+1)} = I_{SN \rightarrow RN}(B_{SN^{\mathrm{n}}}) + r_{n_1} B_{RN^{\mathrm{n}}} + a \quad (1)$$

$$B_{SN(n+1)} = I_{RN \rightarrow SN}(B_{RN^{\mathrm{n}}}) + r_{n_2} B_{SN^{n}} + b \quad (2)$$

In (1) we have the following notations: $B_{RN(n+1)}$ is the notation of the RN behavior at *n + 1*, and it is a score determined by the following values; *ISN* $\longrightarrow$ *RN* is the value of the Influence of the source node on relay node; the function is described in Sect. 2.2; r_{n_1} is a parameter, which considers the free resources of node RN at time *n*. It has values between [0; 0.9], where 0 means that 100% of the resources are occupied and 0.9 means that 100% of the resources are free; $B_{RN^{\mathrm{n}}}$ is the behavior function score at the previous moment of time; *a/b* is a constant defining the Device Class. The parameter takes its values as integer ones in the range [4; 20] [9]; *n* represents the current moment in time/number of iterations.

(2) is the mirrored imagine of (1) with the addition that RN is replaced by SN. This equation scores the behavior of the SN with regards of the RN.

As demonstrated in [9] "Theorem 1. The behavior function is convergent" is true, thus, concluding that the stability is achieved faster as the free resources are lower.

2.2 The Influence Function

The *Influence* (from (1) and (2)) is a function of the *Influenced Behavior*. It describes the influence that one node (RN or SN) has on the connected node (SN or RN) and its main usage is to evaluate the connection by rewarding beneficial partners and penalizes the non-beneficial ones.

The influence score is calculated based on (3). The different parameters values will be chosen by the CC system administrator. The values to choose from are defined in [9].

$$I = \alpha I_{\mathrm{L}} + \beta I_{CA} + \gamma I_{\mathrm{PE}} + \delta I_{\mathrm{S}} + \varepsilon I_{\mathrm{T}} + \eta I_{CH} + \lambda I_{\mathrm{EP}} + \mu I_{CP} \tag{3}$$

All the parameters from (3) are described in [9]. When searching for the best neighbors a node is sending its expectation and the weights of the above parameters can be relevant or 0, thus sending just the interest parameters in each context.

2.3 The Relay Selection Game

The relay selection game, described in [9] has the outcome of selecting the best relay such that the overall performance of the CC system is optimal.

The system has a M source nodes, denoted as {SN1, … SNM) each of them with selfish requirements (i.e. they want to choose the relay so that they maximize their requirements). Each of the sources will select one of the N relay nodes, denoted as {RN1 … RNN}, N >= M. Each source can have only one relay that relays its data and the relay can be assigned to only one source node. The optimal strategy (denoted as (*)) is the solution of a *Maximum Weighted Bipartite Matching* (MWBM) problem applied to a graph [10]. The game is described in [9].

The utility function is defined as in (4) and takes into consideration how much the current SN node selection deviates from the optimal strategy.

$$U(s_i, s_{-i}) = -\left|B_{RN_i^{n+1}} - B^*_{RN_i^{n+1}}\right| + \frac{\sum_{k \neq i}\left|B_{RN_k^{n+1}} - B^*_{RN_k^{n+1}}\right|}{M - 1} \tag{4}$$

The game has a Strictly Dominant Strategy Equilibrium and, thus, a unique NE strategy as demonstrated in [9].

2.4 The Relay Selection Algorithm

As described in [9] the results of Sects. 2.1, 2.2 and 2.3 are converted into the algorithm described by the diagram in Fig. 1. This algorithm is used for the relay selection results described in Sect. 3.

3 Results

For the simulations Matlab was used. Using the selection algorithm described in Sect. 3 we compared the performances, in terms of bit error rate (BER) of the overall CC system (with 50 relays and 40 source nodes) with a direct communication between a SN and a RN. Also, we compared the performances of the best and worst communication pair of nodes (SN-RN) from the CC system and a DC between random selected

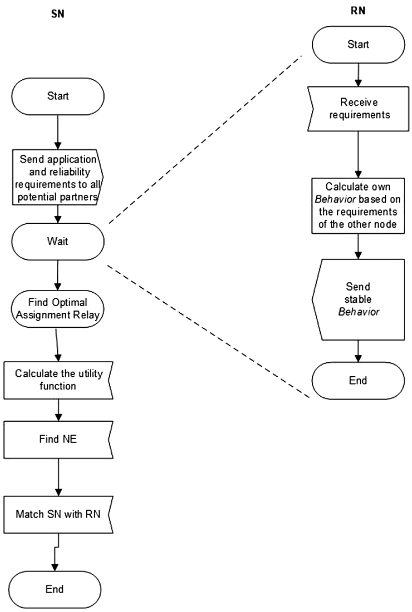

Fig. 1. The relay selection mechanism algorithm

nodes from the SN and RN poll. The communication is done using OFDM with 64 carriers and a CP length of 4 samples from the number of samples in the OFDM symbol, 64QAM for the modulation and 10^8 transmitted bits. The channel fading model adopted is Rayleigh. The source and relay nodes are situated on a 50 km x 50 km area. The sources are equally distributed on one edge of the area and the

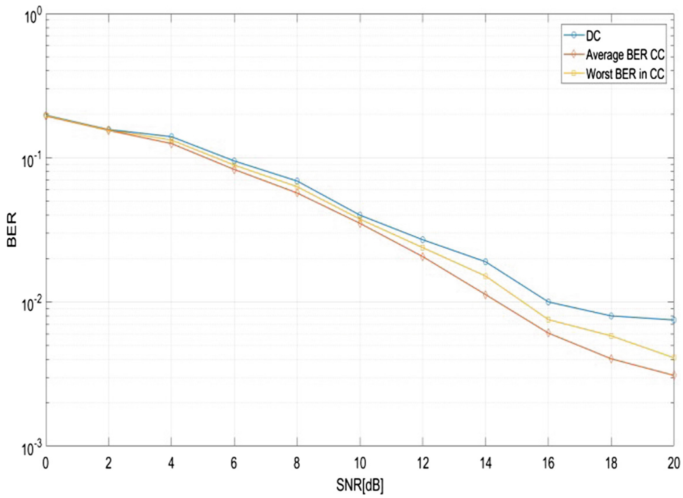

Fig. 2. BER curves for a direct communication (blue), average BER of the CC (red) and the worst BER of the CC pairs (yellow) (Color figure online)

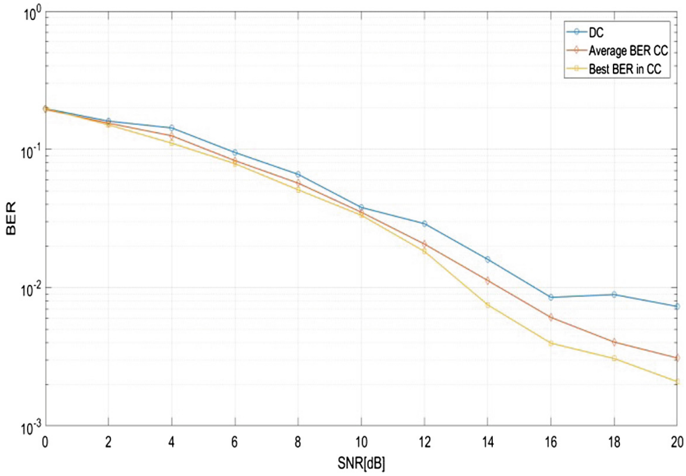

Fig. 3. BER curves for a direct communication (blue), average BER of the CC (red) and the best BER of the CC pairs (yellow) (Color figure online)

relays are scattered on the area. The closes relay is at 25 km away from the edge where the source nodes are positioned.

For Figs. 2 and 3 we can conclude that if we choose a random node pair (SN, RN) (the blue line) the performances are worst if we are going to compare them with the worst, average or best BER in the CC system. As the Signal to Noise (SNR) increases the difference between the CC and DC performances also increases. Hence, only in the case of a poor communication the systems behave the same. Even more, the usage of behavioral functions in corroboration with game theory improves even more the relay selection and the overall performances of a communication system [9].

4 Conclusions

In this paper, we presented the results of a game theory selection algorithm for relay selection. The authors presented a novel utility function based on a behavior and influence function and, demonstrated that using this utility function the game achieves a Strictly Dominant Strategy Equilibrium. The paper also demonstrated the results of 50 relays, 40 source nodes in comparison with a direct communication between random selected pairs of relay-source nodes from the poll. The paper demonstrated that using the same pairs of source-relay nodes in a CC system is better, in terms of bit error rated, to a stand-alone direct communication between a random pair from the same poll of nodes.

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