Secrecy-Enabled Power Allocation Scheme for 5G Networks

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Abstract— The Device to Device (D2D) communication is adopted as one of the promising technologies in the 5G networks to tackle the higher demanding data rate. The D2D communication reuses the cellular user's (CUs) spectrum to communicate with proximity users to provide spectral efficiency. However, the spectral efficiency of the cell may decrease when the resources (bandwidth allocation and power allocation) of the channels cannot be optimally allocated. In this study, we have proposed secrecy enabled power allocation scheme for 5G networks. The proposed scheme is based on a social group optimization (SGO) algorithm to enhance the secrecy rate of the considered networks. For this, we have considered a system where CUs and D2D users are located in a coverage area of eNodeB (eNB) where an eavesdropper (ED) is present to wiretap both the CUs and D2D users' channels. The objective of the proposed scheme is how to allocate the optimal transmit power to the CUs and D2D users with the intention of enhancing the secrecy rate. To determine the solution, we have formulated an optimization problem with the constraint of minimum QoS guaranteed further we have proposed an SGO based solution. Additionally, we have conducted a simulation to examine the performance of our proposed scheme. The simulation results portray that our proposed scheme outperforms other related schemes mentioned in the literature.

Keywords—5G Networks, D2D communications, Secrecy rate, Power allocation, Social group optimization (SGO).

Introduction

D2D communication is considered as a promising technology to tackle the aggressive demand data rates in the 5G networks. The D2D communication is proposed by the Third-Generation Partnership Project (3GPPP) release -12 [1]. The basic concept of D2D communication is that the proximity users are directly communicates to each other i.e., bypassing the eNB in cellular frequency bands [2]. Which provides better spectral utilization, low latency, higher data rates, etc. D2D communication uses the cellular frequency either in an orthogonal manner or a nonorthogonal manner.

In an orthogonal frequency allocation, the D2D users have the dedicated frequency for communication to avoid cochannel interferences. This type of frequency allocation is adopted where efficient spectral utilization is not desirable. Where in non-orthogonal frequency allocation the D2D users reuse the cellular frequency to communicate with other D2D users. The reuse of the cellular frequency by D2D users creates the cochannel interference to the CUs. This leads to the degradation of the whole cellular system. Although the efficient allocation of the cellular frequency can enhance the spectral efficiency as well as data rate of the users.

Many research articles are available to efficiently allocating cellular resources to enhance spectral efficiency and data rate [3-5]. In [3], the authors proposed a power allocation scheme for D2D underlay CUs. They have considered one CUs and one D2D user in a cell and proposed an optimization-based power allocation scheme to enhance the data rate of the networks. In [4] authors proposed a BAT optimization-based power allocation scheme to enhance the data rate of the CUs and D2D users. In [5] the authors proposed a PSO-based power allocation scheme for 5G networks. The intention of the proposed scheme is to allocate the transmit power optimally with the guarantee of minimum QoS required.

Interference management is a very crucial issue in the 5G networks which has to be managed efficiently. In recent years many researchers have proposed schemes where the interference generated by the D2D users is utilized to secure the communication from eavesdroppers. [6] the authors proposed a Tabu Search Algorithm (TSA) based resource allocation scheme to enhance the secrecy rate of the CUs and D2D users. In [7] the authors proposed a Stackelberg game model-based channel allocation scheme to enhance the secrecy rate of the CUs and data rate of the D2D users. Both [6-7] the proposed scheme is designed to enhance the secrecy rate of the users by efficient allocation of the available channels. Although they have fixed the transmit power for both the CUs and D2D users. The fixed transmit power can degrade the secrecy rate of the network especially when the D2D pair distance is fluctuating frequently. When the D2D pair distance is far with fixed transmit power can degrade the secrecy rate of the user. The shortcomings of the above-mentioned literature motivate us to propose an optimal power allocation scheme for 5G networks. In this study, we have proposed an SGO based power allocation scheme for a 5G network which is capable to enhance the secrecy rate of the networks.

The rest of the paper is organized as: in section -2 we have present the system model of our proposed scheme. Problem formulation and the proposed power allocation scheme is present in Section-3 and section-4 sequentially. The results and discussion is presented in section -5. Finally, we conclude this study in section-6.

System Model

In this section, we have described the system model of our proposed scheme. Here we have considered a single-cell scenario where eNodeB (eNB) is deployed in the center of a macro cell. The CUs are uniformly distributed in the coverage of the eNB and the D2D users are underplayed in the cellular communication. We have examined the uplink scenario for the CUs and D2D users. Furthermore, a virulent eavesdropper (ED) is assumed to wiretap the CUs and the D2D users' channels in the coverage of the eNB.

The mathematical formulation of the system model is expressed as:

The M number of CUs are presented in the cell and denoted as a set of CUs = {CU1, CU2, CU3, ...CUm} and the N number of D2D users are presented in the cell and denoted as a set of D2Ds = {D2D1, D2D2, D2D3, ...D2Dn}. Here every D2D users have a pair of one transmitter D2Dt and one receiver D2Dr within a predefined distance. The set of D2Dt is denoted as D2Dt = {D2Dt1, D2Dt2, ...D2Dtn} and D2Dr = {D2Dr1, D2Dr2, ...D2Drn}. The RBk number of channels or resource blocks are available for the communication and denoted as RBk = {RBk1. RBk2.........RBkm}.

In this study, we have examined the transmit power optimization of the CUs and D2D users so the resource allocation is assumed to be fixed. Where one resource of CUs is reused by multiple D2D users and all the CUs have their orthogonal resources. For simplicity, we have allocated the sequential resource allocation where the resources of CUs are allocated to the D2D users on a first come first serve basis. To display the users (CUs & D2D users) association in a resource block we define two binary variables RB_m^k and RB_n^k as an assignment indicated. Where the RB_m^k (RB_n^k) = 1 indicates that the CUs m and D2D n are associated with the rbk resource block otherwise the RB_m^k (RB_n^k) = 0.

Consider a scenario where Ith CUs and Jth D2D users are associated with the uplink RBk resource block. For this the signal to noise plus interference ratio (SINR) of Ith CUs and the jth D2D user is calculated as :

$$SINR_{m,k}^{cu} = \frac{RB_m^k P_{cui} G_{CUi-eNB}^k}{\sigma^2 + RB_n^k P_{D2Dj} G_{D2Dtj-eNB}^k} \tag{1}$$

$$SINR_{n,k}^{D2D} = \frac{RB_n^k P_{D2Dj} G_{D2Dt-D2Dr}^k}{\sigma^2 + RB_m^k P_{cui} G_{cui-D2Dr}^k} \tag{2}$$

Where the P_{cui} , P_{D2Dj} denotes the transmit power of the CUs and D2D users sequencelly. The channel gain of CUs to eNB and the D2Dt to eNB is denoted as $G_{CUi-eNB}^k$ and $G_{D2Dtj-eNB}^k$ where the σ^2 represents the noise power. In Eq. (2) the $G_{D2Dt-D2Dr}^k$ and $G_{cui-D2Dr}^k$ represents the channel between the D2D transmitter-recovers and channel gain between the ith CUs and the jth D2D recovers. The data rate (DR) is calculated by the Shannon’s capacity formula [8] as:

$$DR_{m,k}^{cu} = log_2(1 + SINR_{m,k}^{cu}) \tag{3}$$

$$DR_{n,k}^{D2D} = log_2(1 + SINR_{n,k}^{D2D}) \tag{4}$$

Sequentially the SINR from the ith CUs and jth D2D users to the ED is calculated as:

$$SINR_{m,k}^{cu-ED} = \frac{RB_m^k P_{cui} G_{CUi-ED}^k}{\sigma^2 + RB_n^k P_{D2Dj} G_{D2Dtj-ED}^k} \quad (5)$$

$$SINR_{n,k}^{D2D-ED} = \frac{RB_n^k P_{D2Dj} G_{D2Dt-ED}^k}{\sigma^2 + RB_m^k P_{cui} G_{cui-ED}^k} \quad (6)$$

Where the G_{CUi-ED}^k and $G_{D2Dt-ED}^k$ denoted the channel gain between the ith CUs to ED and the channel gain between the D2D transmitter to the ED. Sequentially the data rate is calculated as:

$$DR_{m,k}^{cu-ED} = log_2(1 + SINR_{m,k}^{cu-ED}) \quad (7)$$

$$DR_{n,k}^{D2D-ED} = log_2(1 + SINR_{n,k}^{D2D-ED}) \quad (8)$$

The secrecy capacity of a wiretap channel can be calculated as the difference between the legitimate channel data rate and the illegitimate channel data rate [9]. Here the illegitimate channel is treated as the EDs channel which has the capability to wiretap the legitimate channel. The secrecy capacity of the CUs and the D2D user is calculated as:

$$SC_k^{cu} = \left[log_2\left(1 + SINR_{m,k}^{cu}\right) - log_2(1 + SINR_{m,k}^{cu-ED})\right]^+ \quad (9)$$

$$SC_k^{D2D} = \left[log_2(1 + SINR_{n,k}^{D2D}) - log_2(1 + SINR_{n,k}^{D2D-ED})\right]^+ \quad (10)$$

The $[.]^+ = \max(.,0)$. In this study, we have considered a system where a virulent ED has the intention to wiretap the classified data of the CUs and the D2D users. Although the presence of D2D users operates as a friendly jammer. Eq (9) and (10) clearly indicate that the secrecy capacity of CUs and D2D users can be enhanced by decreasing the data rate of the EDs link. The aim of this study is to enhance the secrecy capacity of the CUs and the D2D users which can be achieved by optimal allocation of the transmit power of CUs and the D2D users with the aim of decreasing the data rate of an ED.

Problem Formulation

The main objective of this study is to enhance the secrecy capacity of the CUs and D2D users by allocating the optimal transmit power. Here the constraints are the minimum quality of service (QoS) requirement is guaranteed. The mathematical formulation of the proposed scheme is presented as:

$$\underset{RB_m^k, RB_n^k}{max} \left[\sum_{m=1}^{CUs} \sum_{k=1}^{RB_k} SC_k^{cu} + \sum_{n=1}^{D2D} \sum_{k=1}^{RB_k} SC_k^{D2D}\right] \quad (11)$$

s.t.

$$P_{cu} \geq P_{cu}^{max} \quad (C1)$$

$$P_{D2D} \geq P_{D2D}^{max} \quad (C2)$$

$$DR_{m,k}^{cu} \geq DR_{m,k}^{cu(QoS)} \quad (C3)$$

$$DR_{n,k}^{D2D} \geq DR_{n,k}^{D2D(QoS)} \quad (C4)$$

$$RB_m^k = 1 \quad \text{(C5)}$$

$$RB_n^k \geq 1 \quad \text{(C6)}$$

$$RB_m^k,\ RB_n^k \ \in (0,1)\ \forall\ m\ \in CUs, \forall\ n\ \in D2D \quad \text{(C7)}$$

The function present in Eq. (11) is a maximization function of the secrecy capacity where the constraint (C1) and (C2) make sure that the transmit power of both the CUs and D2D users are always less than the maximum transmit power. The constraint (C3) and (C4) are responsible for the minimum QoS is guaranteed. The constraint (C5), (C6), and (C7) are responsible for one CUs can share only one resource blocks and the D2D users can shares more than one resource blocks where the $RB_m^k,\ RB_n^k$ are the binary variables.

Secrecy enabled power allocation scheme

In this section, we have demonstrated our proposed SGO based power allocation scheme for 5G networks. The SGO algorithm is proposed by satapathy and naik in 2016 [10]. The basic principle of SGO optimization is that the solution is driven by learning from other candidate solutions. Every element brings intelligence from others to solve an issue like a human being. The elite solution is driven by the best elements among all candidate solutions which is called the fitness value. Where the SGO scheme is divided into two phases first is the improving phase and the second is the acquiring phase. In the first phase, the proficiency of every element in the group is increased by the elite element of the group. The elite element of a group is one that has the highest knowledge. Furthermore, in the second phase, the elite element is calculated by the collective cooperation among all the other elements in the group.

We have modelled our power allocation problem as a maximization problem of the SGO algorithm. According to the SGO there are two phases i.e., improving phase and acquiring phase which is modelled as:

Improving phase: In the improving phase, the knowledge level of every individual user is increased by acquiring the knowledge from the best user i.e., maximum secrecy capacity achieved by the users with respected allocated power values. Let the number of the CUs and the D2D users are M and N sequentially as denoted in the system model section. The best user is calculated among all the users by

$$CU_{new} = c * CU + r(CU_{best} - CU) \quad (12)$$

$$D2D_{new} = c * D2D + r(D2D_{best} - D2D) \quad (13)$$

Where CU_{new} and $D2D_{new}$ denotes the new solutions and c is a introspection parameter and r denotes the random number between o and 1. By the use of Eq. (12) and (13) every user can update int knowledge in terms of optimal transmit power. After that, the second phase comes into the picture which is acquiring phase.

Acquiring phase: In this phase, every user enhances their knowledge by interacting with other users as well as interacting with the best user in the group. The updating with the help of other users and with the help of the best user can be done by the following equations:

$$other\ users_{cu} = CU - CU_{others} \tag{14}$$

$$other\ users_{D2D} = D2D - D2D_{others} \tag{15}$$

Here the CU_{others} and $D2D_{others}$ denotes the CUs and D2D users other than the best users and itself. So, the updating of the acquiring phase is calculated as:

$$CU_{new} = CU + r_1(CU - CU_{others}) + r_2(CU_{best} - CU) \tag{16}$$

$$D2D_{new} = D2D + r_1(D2D - D2D_{others}) + r_2(D2D_{best} - D2D) \tag{17}$$

After completion of both the two phases a decision is made by the proposed scheme is that whether the new solution is acceptable or not by the greedy selection express by the equation given below.

$$CU_{new} > CU_{old} \tag{18}$$

$$D2D_{new} > D2D_{old} \tag{19}$$

The step-by-step procedure of the proposed SGO based power allocation scheme is described in Algorithm 1.

Algorithm 1: *Secrecy enabled power allocation scheme for 5G Networks.*

$\boldsymbol{initialization}$: $Population\ size\ N,'\ C',maximum\ iteration,$

$uperbound\ P_u\ and\ lowerbound\ P_l;$

$\boldsymbol{Step\ 1}$: $Random\ population\ size\ is\ generated$

$based\ on\ the\ initialization\ phase;$

$\boldsymbol{Step\ 2}$: $Calculate\ the\ first\ fitness\ value;$

$\boldsymbol{for\ i = 1\ to\ N}$

Improving phase: Calculate the best users by Eq. (12) and, (13);

Acquiring phase: Update the best users by Eq. (16) and, (17);

Greedy selection: Select the new solution by Eq. (18) and (19);

End for loop

Step 3: *Repeat the step 1 and 2 until termination criterion meet;*

Simulation result and discussions

In this section, we evaluate our proposed secrecy-enabled power allocation scheme and present the result. We have simulated our proposed scheme in the MATLAB programming platform. As described in the system model section we have considered a single-cell scenario where CUs, D2D pairs, and ED are uniformly distributed in the coverage area of eNB. We have done a Monte Carlo simulation to obtain our results. We have compared and analyzed our proposed power allocation scheme with the random-based and graph-based schemes in the presented system model. We have analyzed our proposed scheme with variations of many parameters like D2D distance, number of D2D users, and the minimum QoS guaranteed.

Figure -2 displays the performance of the overall secrecy rate vs the varying D2D pair distance. The figure clearly indicates that the overall secrecy rate decreased with respect to increasing the D2D pair distance in each cycle. The prominent reason is that when the D2D pairs are in the optimal range they contribute to enhancing the secrecy rate otherwise they can degrade the overall secrecy rate. Although the proposed scheme outperforms other related schemes.

Figure 3 displays the performance of the overall secrecy rate vs the number of D2D pairs. In this simulation, we have fixed the CUs to 50 all the CUs have their dedicated resource blocks then we increase the D2D users in every cycle. The figure indicates that as the number of D2D pair increase the overall secrecy rate is also increased. The reason behind that is increasing the D2D pairs also increases the interference towards the ED which is beneficial to enhance the overall secrecy rate of the cell. **Figure1**

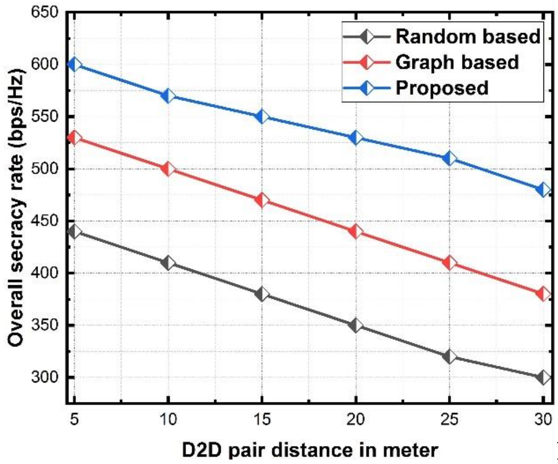

Figure1

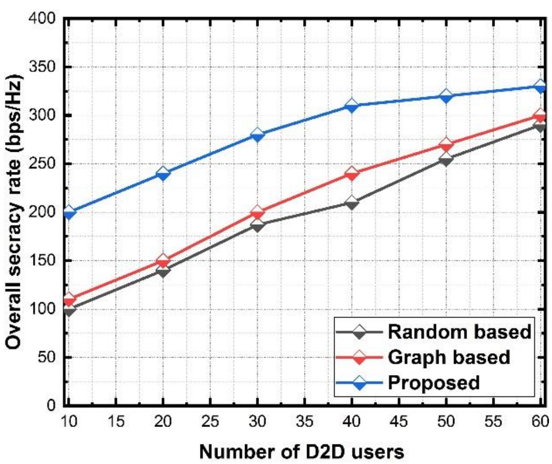

Figure 2

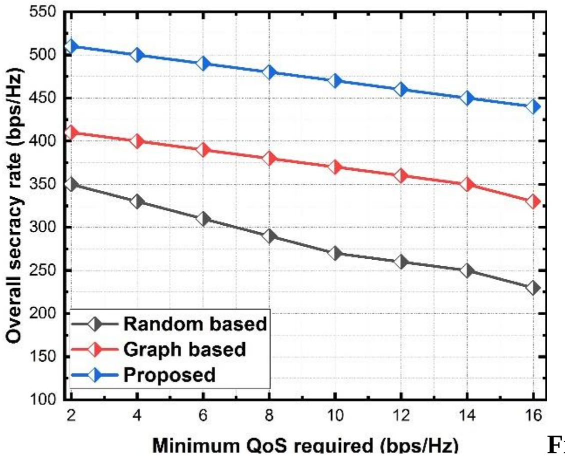

Figure 3

Conclusion

In this study, we have proposed a secrecy-enabled power allocation scheme for 5G networks. The proposed scheme is based on the social group optimization (SGO) algorithm to enhance the overall secrecy rate of the cell. For this, we have formulated an optimization problem which is solved by the SGO scheme. Moreover, we have compared and analyzed our proposed scheme with random-based and graph-based schemes with the outcome of our proposed scheme enhance the secrecy rate by approx. 30%.

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