Using Genetic Algorithm with Frequency Hopping in Device to Device Communication (D2DC) Interference Mitigation

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Abstract—**Device-to-device communication (D2DC) is an important and challenge technique in the next generation of wireless communication that it can effectively reduce the load of base stations and simultaneously allows user equipment (UE) to proceed in direct communications. In D2DC, devices are very close among themselves and therefore the resulting interferences maybe quite serious, it becomes an important issue of how to properly select a UE owner so that when this UE owner searches for its associated communicating UEs in its service range they will suffer the least interference effect. In this paper, as UEs are distributed and clusters of UEs are formed in the D2D communication area; we propose to use K-Means to locating a UE around the cluster center as the UE Owner of the cluster. With this formation of UE clusters and UE owners they still have the chance to incur interferences among UE clusters due to they may be possibly use the same frequency band in their communications. Frequency hopping technique is then considered in this paper to further reduce the co-channel interference. In this paper it proposes to use Genetic Algorithm (GA) with frequency hopping technique to optimally select the number of frequency channels required in the system and then allocate these frequency channels to the UE clusters for their D2D communications. Simulations have been performed in a D2DC system with the proposed GA algorithm to reveal the effectiveness of the designed algorithm in the allocation of frequency channels to the clusters with minimum interference effect.**

Keywords- Device-to-device communication (D2DC); Genetic Algorithm(GA); Frequency hopping; Frequency reuse; K-Means; Interference Mitigation.

I. INTRODUCTION

Long Term Evolution – Advanced (LTE-A) is introduced in 3GPP Release10 [1] that is the next evolution of LTE to implement the requirements issued by the ITU-R of the International Telecommunication Union (ITU) [2] for IMT-Advanced (International Mobile Telecommunications-Advanced). LTE-Advanced is the next level revolving technique of LTE; Comparing with LTE, LTE-Advanced can provide higher throughput, higher peak data rate, and wide bandwidth. D2D is an important task in beyond 3G (B3G) wireless communications; it is a technique applying in cellular network that devices in the cellular network can communicate through LTE-Advanced protocol directly with each other without passing through the base station as implemented and regulated in the conventional communication protocol. D2D communication can reduce the load of base stations and efficiently utilize the spectrum resource [3].

A hybrid system consisting of cellular network and D2D communication network has been introduced in next generation wireless communication system [4] where the communications among D2D devices may suffer interferences from communications in the cellular network. Many papers [5-9] have proposed measures in the mitigation of interference and to improve the system performance; in [5] it proposed to use radio resource management (RRM) concept to mitigate the interference from the cellular network to the D2D communication while in [6-8] they proposed to use power control mechanism to reduce the interference and to improve the performance in D2D while in [9] it proposed to use radio resource allocation technique with fractional frequency reuse (FFR) scheme to avoid interference.

In this paper, we propose a solution to carrier frequency selection and allocation for D2D UE clusters; we use GA to optimize the selection of carrier frequencies under the criterion of minimizing the co-channel interferences.

This paper is organized in the following. In section II, a D2D communication system model is introduced, a link budget is then implemented to classify the UE Users into many clusters. The K-Means is applied to all clusters to locate certain Use Equipment (UE) as the center of the cluster and then GA technique is exploited to allocate carrier frequencies to these formed clusters. In section III a system with proper system parameters is formulated and simulation is performed to the formulated system to see the effectiveness of our proposed GA algorithm in the allocation of carrier frequencies to the devices clusters. A conclusion is drawn in section IV to summarize the system performance when using GA algorithm in the allocation of the carrier frequencies.

II. SYSTEM MODEL

A device to device (D2D) communication network is as shown in Fig. 1 where each device can transmit signals with each other. Many UEs in the network forms a cluster and a UE in the cluster is identified as the UE Owner that is located more or less in the center of the cluster by utilizing the K-Means measure [10-11]. The other UEs in the cluster are identified as UE Clients. It is assumed that it has at least one UE Owner and one UE client in each cluster and the UE Owner is the control unit to initiate the communication. There are possibly many clusters exist in the cellular network; every UE Owner in one cluster uses a specific frequency channel in its communication with the UE client such as in the broadcasting communication. With this frequency allocation it may introduce interference among clusters due the assignment of same frequency among clusters. How to mitigate this kind of interference among clusters will be the main task of this paper.

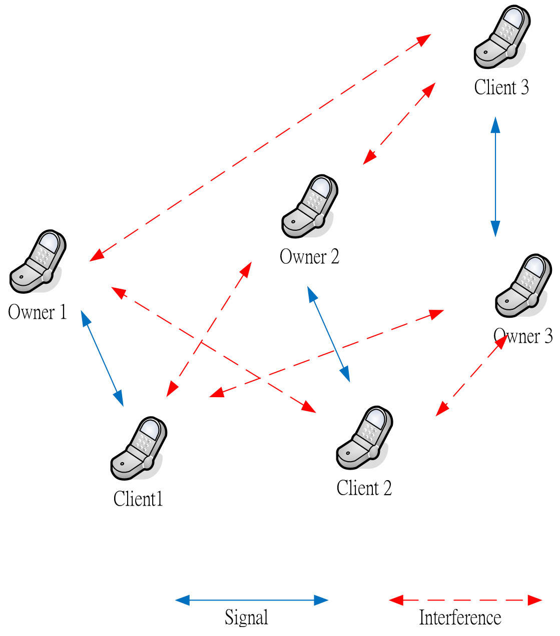

Figure 1. D2D system model

A. Link Budget

Channel fading plays an important role in the wireless communication; when signal transmits through the channel it will encounter various interferences such as the multipath effect when the signal transmits through the buildings, forests and terrains. The multipath effect will enhance or fade the transmitted signal to make it is impossible at the receiver terminal to accurately determine the transmitted signal instead of using statistical consideration. The channel model in wireless communication is derived through analysis and simulation of the channel statistical characteristics and modified through empirical measurements; many channel models have been proposed [12]. Summarily the received signal strength at the UE Owner /UE Client can be estimated from the following equation:

$$P(dBm) = P_t + G_t + G_r - PL \qquad (1)$$

where

P_t: Transmitting power of UE Owner/UE Client (dBm)

G_t: Antenna gain of UE Client /UE Owner (dBi)

G_r: Antenna gain of UE Owner/UE Client (dBi)

PL is using from 3GPP Urban Micro(UMI) D2D model [7], with the following equation:

$$PL=40\log10(R)+30\log10(f)+49 \qquad (2)$$

R: distance between device and device in kilometer

f: Carrier frequency in GHz

B. *K-Means clustering*

K-Means is proposed by J. B. MacQueenin 1967 that it separates N populations into k set of clustering on the criterion of minimizing the following equation [10]:

$$\arg\min \sum_{i=1}^{k} \sum_{x_j \in S_i} \| x_j - \mu_i \|^2 \qquad (3)$$

where (x_1, x_2, …, x_N) are the given observations (samples) and μ_i is the average location (or the "center") of the cluster S_i.

In this paper, it implements this methodology to separate the UEs in the cellular network into UE clusters and in every cluster to select one UE around the center of the cluster as the UE Owner of the cluster. The process of K-Means in the clustering of UEs has the flow diagram as shown in Fig. 2.[11].

Step 0: Randomly generate N populations (UEs) and decide the number of clusters, k, will be generated.

Step 1: Random generation of k initial cluster centers: In the initialization, randomly selecting k elements from the N populations as the centers of k clusters.

Step 2: Initial clusters generation: Select one element from the N populations and evaluate the distances of this element to each cluster center as determined in Step 1. Find the cluster center which has the minimum distance from this element and then this element will be assigned as a member of the cluster. Do the same step to all remaining elements in the N populations and then each element has been assigned to a cluster. Initial clustering of UEs has been formulated.

Step 3: Update and generate new cluster center for each cluster. From the clusters as formulated in Step 2 re-calculate each cluster center from its constituent elements. Replace the initial random cluster centers, as determined in Step 1, by these updated cluster centers and these updated cluster centers will be new cluster centers. The relation between the initial cluster center and the new updated cluster center for the i_{th} cluster satisfies the following relation, where $m_i^{(t)}$ and $m_{i^*}^{(t)}$ are the old and updated cluster centers for ith cluster at time t respectively:

$$S_i^{(t)} = \{x_j : \| x_j - m_i^{(t)} \| \le \| x_j - m_{i^*}^{(t)} \| \quad for \ all \quad i^* = 1,....,k\} \qquad (4)$$

Step 4: Update the cluster members. For each cluster element re-calculate its distances from each new cluster centers and reassign this element to a new cluster if it has the minimum distance from this new cluster center among all cluster centers.

Step 5: Repeat the Steps 3 and 4 until the cluster members in each cluster are not changed.

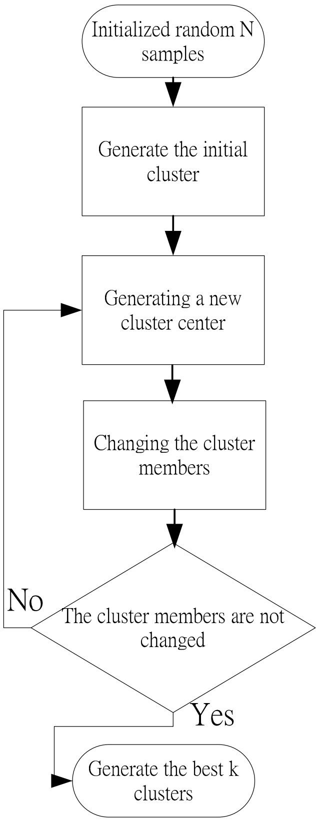

Figure 2. Flow Chart of Clusters Determination Using K-Means Measure

C. *Genetic Algorithm(GA)*

In [13], it implements Genetic Algorithm(GA) to allocate frequency channels for base stations in Multicast-Broadcast Single Frequency Network (MBSFN).

In the limited number of available frequency channels and possible frequency reuse patterns in the cellular network it becomes a challenge task of how to allocate frequency channels to UE clusters to minimize the interferences among UE clusters. In this paper we propose to use GA algorithm with possible frequency hopping technique to generate the possible frequency allocations to the UE clusters so that the interference among UE clusters will be minimized.

In GA algorithm it generates a large number of chromosomes and then through mutation and crossover processes to select the best chromosome to meet certain objective functions. We use the same methodology as in GA to adaptively find the best frequency channel for each UE cluster. The GA methodology can be summarized in the following steps as shown in Fig. 3.

Step1: Initialization

When a cellular network is deployed it needs to allocate frequency bands to each cluster in certain criterion. Basically it has given two parameters, n and p, where n is the number of clusters and p is the number of frequency bands, and it has the following allocation:

$$c(m)=\left\{ k\ ;\ \begin{matrix} 0 \leqslant m \leqslant n-1 \\ 1 \leqslant k \leqslant p \end{matrix} \right\} \qquad (5)$$

where

n : number of cluster, $1 \leqslant n$

p : number of frequency band, $1 \leqslant p$

The chromosome size is determined from the number of clusters; if it has n clusters in the system then the chromosome has size from c(0) to c(n-1). The gene size in each chromosome is determined from the number of channels, p, and it generates genes from 1 to p. For example if the number of available frequency channels is 3 then it will generate randomly the genes of 1, 2 and 3.

Step2: Evaluation and selection

We generate an n by n matrix to formulate the interferences among clusters. In the entry (i, j) of the matrix for cluster i, the entry will be 1 if cluster i is interfered by cluster j while the entry is 0 if it is not interfered by cluster j. In this paper two clusters are considered interfered each other if they are located side by side. For example in Fig. 5cluster 1 is considered interfered by clusters 2 and 3 while cluster 2 is interceded by clusters 1, 3, and 4. Then the interference matrix for the configuration of Fig. 5 has the form as shown in equation (6).

$$\mathrm{Matrix} = \begin{bmatrix} 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 \\ 1 & 1 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 \end{bmatrix} \qquad (6)$$

We can then evaluate the fitness function from the interference matrix to get the best chromosome. If the fitness is identified as a frequency band whether it interferes with its near frequency band it assigns a value 1 if it interferes with its near frequency otherwise it has fitness 0. In the case with parameter p set for 3, we have the fitness function as shown in Table I. We have the genes [1 3 2 1 1] for chromosome1 that has the corresponding fitness value [1 1 1 0 0], while it has genes [1 3 2 1 3] and fitness vale [1 1 1 1 1] for chromosome 2. It is from this table it concludes chromosome 2 is better than chromosome 1.

TABLE I. CHROMOSOME AND ITS ASSOCIATED FITNESS VALUE

Chrom1	1	3	2	1	1
Fitness value	1	1	1	0	0
Chrom2	1	3	2	1	3
Fitness value	1	1	1	1	1

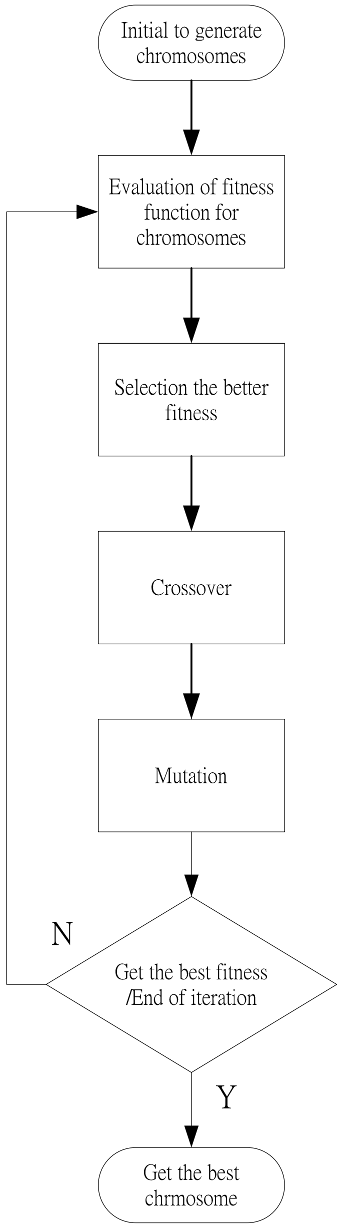

Figure 3. Flow Diagram of GA Algorithm

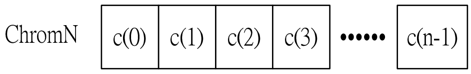

Figure 4. Chromosome type

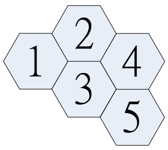

Figure 5. DeploymentCellular Network

Step3: Mutation

The mutation is a random process that it chooses a gene from a chromosome, and mutates it to other chromosome; it then generates a new chromosome. As shown in Fig. 6, the original chromosome as Chrom1 has been mutated to the other chromosome shown as Chrom1'.

Step4: Crossover

The crossover is a random process to choose a gene from a chromosome, and it crossovers with the corresponding gene in other chromosome, and generates a new chromosome, for the example as shown in Fig.7,the original chromosomes as Chrom1 and Chrom2 have been crossover to other chromosomes as Chrom1' and Chrom2'.

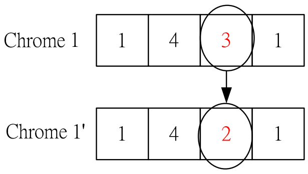

Figure 6. Chromosome mutation

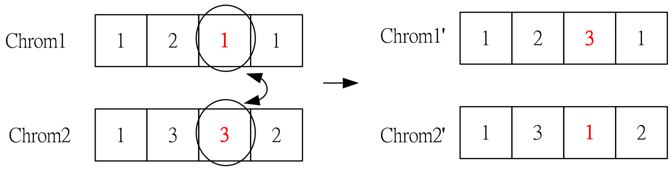

Figure 7. Chromosome crossove

D. Frequency Hopping

As shown in Fig. 8 is a cellular network with a three frequency reuse clusters structure that are identified with three letters A, B, and C. In this paper frequency hopping technique is applied into the network so that the frequency allocation to the clusters can be varied in a predefined pattern. Usually it has two categories of frequency hopping, namely, full hopping or partial hopping. In full hopping frequencies in all clusters are varied when they are hopping while for partial hopping certain clusters frequencies may not be varied as illustrated in Table II. In the table the current frequency allocations are assumed as 1, 2, 3 then with full hopping or partial hopping its new frequency allocation will be possible as shown in the table.

TABLE II. FULL HOPPING AND PARTIAL HOPING

Frequency Type	A	B	C
Current	1	2	3
Full	2	3	1
Full	3	1	2
Partial	1	3	2
Partial	3	2	1
Partial	2	1	3

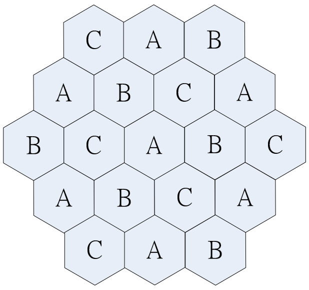

Figure 8. A cellular network with three frequency reuse pattern

III. SIMULATION RESULT

A D2D communication system with system parameters as assigned in Table III has been simulated to study its resulting interference mitigation performance when GA algorithm with frequency hopping is applied to the system. The link budget and the path loss as exposed in Section 2.1 have been used in the calculation of receiver signal strength between any two communication UEs (one UE Owner and one UE Client). The network has the resulting UEs clusters as shown in Fig. 9 from implementing the K-Means process and it determines that UE_4, UE_{14} and UE_{15} are the cluster centers.

In the above simulation it uses K-Means to "optimally" separate UEs into clusters with best UE owner identified in each cluster but it still cannot resolve the interference problem as it reveals from the resulting clusters that UE_4 and UE_{14} are overlapped to certain extent; and consequently when it has more clusters in the network its resulting interferences may become serious; it needs to resort to other measures such as frequency reuse to solve the overlapping problem.

TABLE III. SYSTEM PARAMETERS

Distribution of UE	**Randomly uniform distributed**
Number of UE	30
Number of cluster	3
UE P_t	300mW
UE G_t	0
UE G_r	0
Carrier frequency (Hz)	2G
Cluster algorithm	K-Means

In the D2D communication system as simulated, it is not appropriate to allocate fixed frequency reuse patterns to the cells as UEs distributions in the network are dynamically varied; it can exploit GA algorithm to allocate frequency channels to the clusters so as to achieve minimum interference effect among clusters at any instant. The system performances are evaluated when GA algorithm is exploited to allocate the frequency reuse patterns to the cells when the number of frequency available for assignment is varied from 3 to 6.

In the simulation only the first layer of co-channel interference clusters, i.e. 6 clusters, for each cluster are considered in the interference calculation. In Table IV it lists the relevant parameters for implementing GA algorithm.

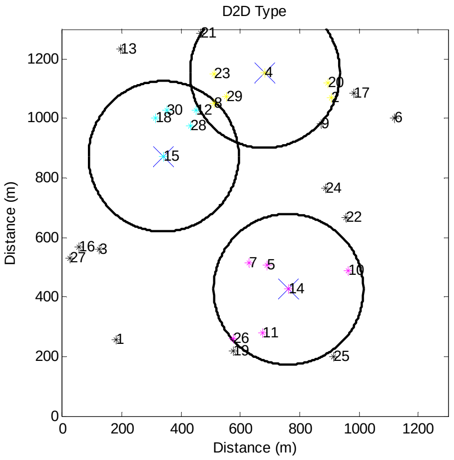

Figure 9. Resulting D2D clusters from K-Means process

TABLE IV. PARAMETERS FOR GA ALGORITHM

Number of clusters	37
Number of chromosomes	1000
Number of frequency channel	3-6
Number of iteration	10000

TABLE V. NUMBER OF POSSIBLE FREQUENCY ALLOCATIONS WHEN USING FREQUENCY HOPPING

First Layer Interference Clusters Considered	
Channel	***Solution***
6	968
5	176
4	20
3	6

Furthermore in the implementation of frequency reuse, the constituents of every cluster may be changed since the UEs are moving they are not fixed at certain locations; for this situation it can be solved by exploiting frequency hopping technique. In the frequency hopping when the available frequency channels are varying from 3 to 6; they have the results as shown in Table V. It shows in Table V the possible combinations of frequency allocations for clusters in the D2D network simulated when frequency hopping is implemented with available frequency channels varying from 3 to 6 and the maximum number of chromosomes (UEs) is limited to 1000.

IV. CONCLUSION

In D2D communication, the positions of the UEs in every cluster are varying with time while the positions of the base stations are fixed therefore if it only applies frequency reuse algorithm in D2D communication it will not effectively mitigate the interference effect. In this paper we presented in D2D communication that under frequency reuse consideration a frequency hopping technique to effectively reduce the interferences. When more frequencies are available we can get more frequency reuse sets for the clusters in the system frequency allocation. When the available frequency resources are limited we presented in this paper to implement GA algorithm to search for the best frequency allocation and consequently to attain the best communication in D2D communication.

ACKNOWLEDGMENT

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