Enhancing Signal to Interference Noise Power ratio and Coverage area in Device to Device enabled 5G Cellular Networks using Mode Selection Technique

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Abstract— **Fifth Generation (5G) is the upcoming stage in the development of the entire mobile communication technology. Device-to-Device (D2D) assisted cellular networks improve the network performance in terms of throughput, capacity, coverage, high data rate. Device-to-Device (D2D) enabled cellular networks offer different modes of communication. The selection of particular mode is important to enhance the performance of system. This paper explains mode selection technique which enhances network performance in terms of Signal to Interference Noise power ratio (SINR). Our paper further explains about mode selection point, its dependency on transmit power and the method of enhancing SINR by changing the cellular radius. From the simulation results it is found that there is an improvement in SINR of the system by 2dBm compared to that of the system shown in literature.**

Keywords— **Device-to-Device, 5G, Mode selection, Signal to Interference Noise Power Ratio.**

I. INTRODUCTION

The proliferation of smart phones in the past decade has contributed to the improvement of productivity and lifestyle quality. The wide spread use of cellular devices leads to high traffic volume, strain the limited cellular bandwidth and capacity. To meet the challenges, the third generation partnership project (3GPP) long-term evolution (LTE) continues to standardize technologies with higher data rates, lower latency, and lower power consumption. Presently, LTE-Advanced (LTE-A) supports new technology components for LTE to meet various communication service requirements [1],[2].

Generally, 2nd generation (2G) to 4th generation (4G) systems are designed from a network-centric perspective. However, fifth generation (5G) cellular networks (which is expected to be launched around 2020) do not need to be network-centric and move towards device-centric systems. Device-to-Device (D2D) communication, as a technology component for LTE-A, allows direct wireless links between mobile users without routing data through a base station (BS) or the core network.

D2D communications can bring some benefits compared to the conventional infrastructure-based communication in a high data traffic and short radio spectrum. The direct benefits include improved system throughput, reduced transmission delay, increased spectrum efficiency and energy efficiency particularly for networks that support proximity-based services (e.g., social networking).

The 5G cellular networks, with D2D Communication enabled within are known as two-tier networks. The two tiers in these networks are the macro cell tier and the device tier. Conventional cellular communication is supported by the macro cell tier, while D2D communication is supported by the device tier. The classification of D2D communication is discussed in [3-5].

The D2D enabled cellular network offers different modes such as D2D silent mode, D2D reuse mode, D2D dedicated mode, Cellular mode. This paper mainly concentrates on two modes cellular and D2D dedicated mode (simply as D2D). The process of choosing between the modes is called the mode selection. Mode selection reduces interference if it is carefully done. The mode selection is done in such a manner that it should enhances signal to interference noise power ratio (SINR), throughput, capacity and coverage area of the network.

To meet the performance requirements mentioned above the mode selection is done through the following schemes i.e., distance cut-off scheme [6], link gain scheme [7], Guard zone scheme [8].

There are number of mode selection schemes as in [9-14]. The mode selection is done by considering different constraints depending on the condition of the network like channel conditions, power constraints. A simple model in which only one D2D link and one cellular link is studied in [9, 10]. Author of [9] explained mode selection in single and multiple cell scenarios with only one D2D link and cellular link whereas author of [10] explains the joint technique of power control, mode selection that optimize the sum rate of both cellular and D2D communication in a single cell.

Multiple D2D and cellular links are studied in [11, 12]. Author of [11] discusses about transmit power minimization through joint mode selection and power allocation subjecting to particular link constraints whereas [12] explains the procedure of maximizing system throughput by jointly considering mode selection, channel allocation and power control. Paper [13] tells how a mode selection is done in a single cell with D2D reuse mode and dedicated mode. [14] explain the way of mode selection between cellular mode and D2D reuse mode by considering SINR requirements of users. Moreover [9,12] explains the way of mode selection between the cellular mode, D2D dedicated mode, D2D reuse mode that reduces the interference caused between the D2D links and CUE links.

The existing works purely focus on the binary mode selection where each D2D link can operate using binary mode indicator to indicate the selection of certain mode. Further research is going on to design the D2D link that can operate on multiple modes called mixed-mode operation. Resource management is simultaneously implemented while mode selection.

Joint optimization problem of mode selection and base station selection in multi base station cellular concept has been given in [15]. Centralized graph approach is used to solve the problem. Mixed integer nonlinear programming (MINLP) which defines joint mode selection and allocation of resources is solved by heuristic algorithms [16],[17].

Mode selection based on energy efficiency in case of dedicated or shared resources is studied by authors in [18],[19] where heuristic suboptimal solution and bound and branch solutions are used. It has been proved that second solution is more complicated than that of first solution.

The papers discussed above depends on static mode selection. The paper [20] explains how mode selection is carried in dynamic environment. However paper [20] explains the dynamic mode issue it does not consider device mobility but it states the best mode according to the device position within the cell. The paper [21] discuss the mode selection concept of semi-static and dynamic mode selection and concludes that dynamic mode selection is more accurate than the semi-static mode selection.

The author of paper [22] explains the distance based mode selection technique by considering the SINR say (γ). Present paper focus on enhancing the SINR say (γ_i) i.e., ($\gamma_i > \gamma$) with the cellular radius R. The paper not only defines the best mode but also derives the theoretical expression for mode selection point.

Proposed method in this paper considers distance dependent path loss interference links and users whose positions depend on cell radius R.

The paper is presented as follows. Section II explains system model and derivation of the mode selection point. Modified case is mentioned in section III while section IV highlights simulation results. Finally section V concludes paper.

II. SYSTEM MODEL

System model is shown in Fig. 1 and Fig. 3 illustrates flow chart which explains how simulations are carried out in this paper. The system model consists of M users {say U_1, U_2, U_3 ……..U_M}, D2D pair consisting of (D2D transmitter (D2D_TX), D2D receiver (D2D_RX)), a single base station. Users can engage in cellular connection or D2D connection inside the cell. The users are distributed uniformly in the cell such that they should change their positions when the radius of the cell ‘R ‘is changed. The base station knows the location of the users by localization technique [23]. A single D2D pair is considered for every loop. The base station and D2D_RX is considered as cellular pair. Users are moving randomly with in the cell.

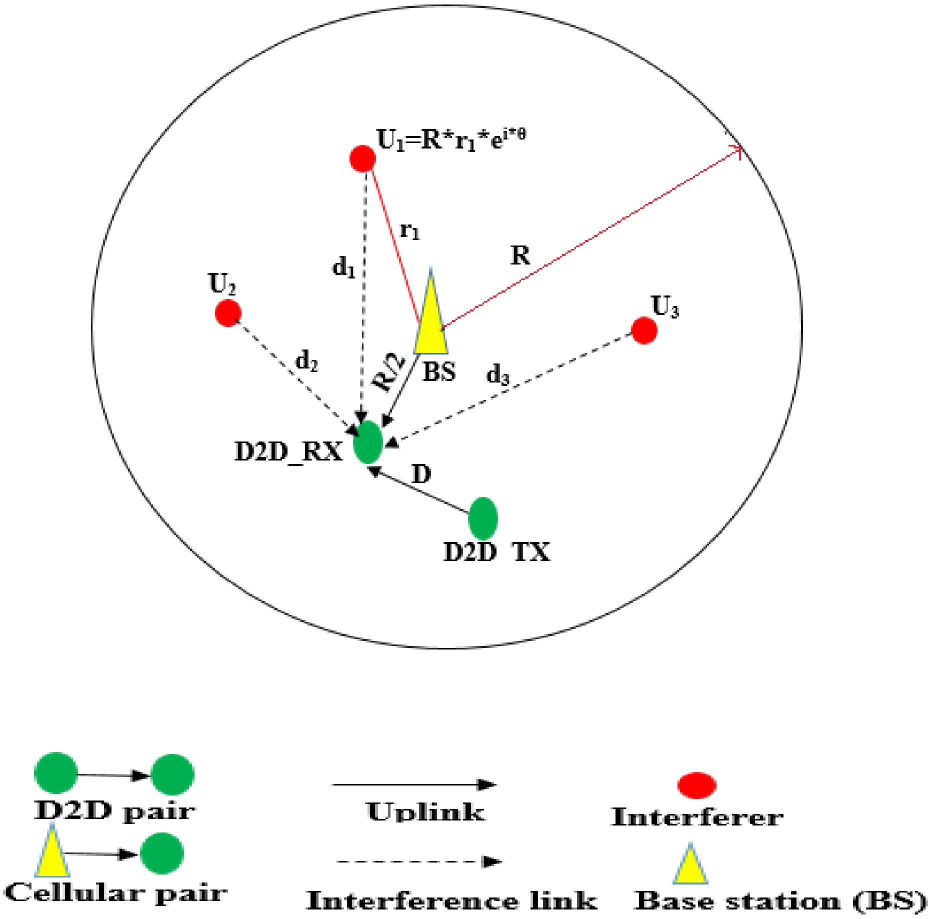

Fig. 1 System Model

Uplink communication is only studied here. Power control is not considered and take responsibility that the transmit power of users are fixed ubiquitously. The uplink transmitter and receiver in D2D pair and cellular pair are designed as OFDM transmitter and receiver. The related information regarding bandwidth, number of subcarriers (N), carrier frequency, cyclic prefix length is given in Table 1. OFDM assumes input data stream as frequency samples. The data (x) is first converted from serial stream to parallel stream depending on the number of subcarriers. Now serial to parallel converter takes serial stream of input bits and outputs N parallel streams. These parallel streams are individually converted into required digital modulation format (BPSK) say S. The modulated data (S) is converted to time domain by IFFT block after on which cyclic prefix gets added resulting in the OFDM signal.

The OFDM signal is sent to receiver via channel. The uplink channel is modelled as the Rayleigh Flat Fading channel (h) with single tap. The additive white Gaussian noise (AWGN) power of -20dB is added at the receiver device. The OFDM receiver performs the reverse operations to that in the transmitter block. The interference links are also modelled as the Rayleigh flat fading channels with distance dependent path loss d_k^{-n}. The signal received at the receiver device is given as $y=h*x + n_o$.

Where h = Impulse response of Rayleigh flat fading channel
x = Transmitted signal
n_o = Additive white Gaussian noise

Let Y_p be the power of signal (y) , I_p be the interference power, N_o be the thermal noise power at the receiver device then signal to interference noise power ratio (SINR) is given as $SINR = \frac{Y_p}{I_p+N_o}$.

If we consider path loss (L_p) between D2D_TX and D2D_RX, distance dependent path loss at interference links then receiver performance is characterized by Signal to Interference Noise Power Ratio (SINR) given by

$$SINR = \frac{P_t/L_p}{\sum_{k=1}^{M} P_I/{d_k}^n + N_o} \tag{1}$$

Where P_t =Transmit power of base station (in case of Cellular connection)
Transmit power of D2D_RX (in case of D2D connection)
P_I=Transmit power of interferer
d_k= distance between k^{th} interferer and D2D_RX (where k ranges from 1 to M)
N_o = Thermal noise present at the receiver, n= path loss exponent

$$L_p = \left(\frac{4*\pi*D*F}{C}\right)^2$$

Where D = distance between devices in D2D pair (in case of D2D connection)
distance between devices in Cellular pair (in case of Cellular connection)
C =velocity of light and F= carrier frequency in (GHz)

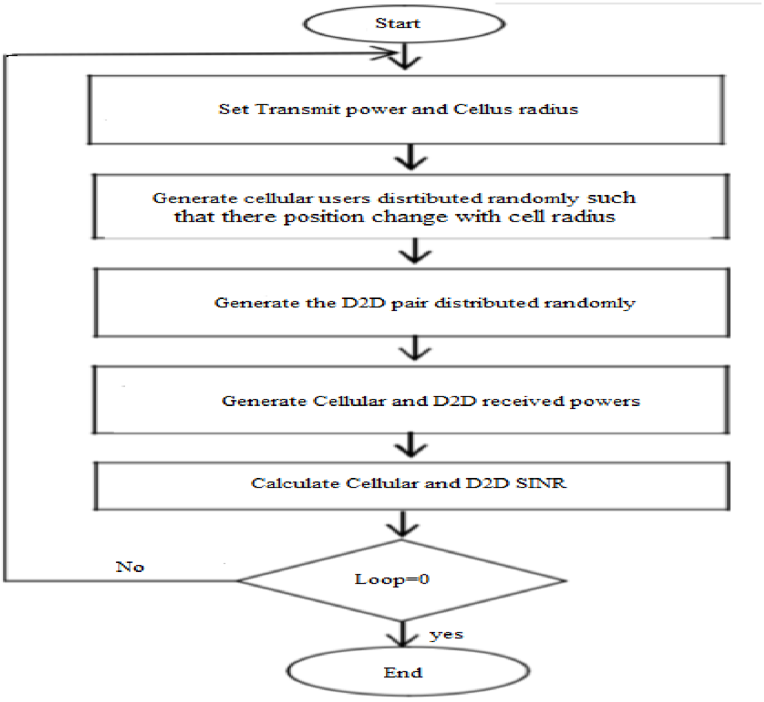

Fig. 2 Flow Chart

Relation between D2D SINR and distance between D2D pair is shown in Fig. 5. D2D SINR decreases with increase in distance between D2D pair. At some distance (say 1Km) D2D SINR and Cellular SINR are equal. The distance where both values are equal is called mode selection point. Mode selection point gives information about the switching between two connections (either Cellular or D2D), in our case information is purely in the form of distance. Switching is done based on SINR value. If SINR value in D2D mode is greater than in Cellular mode D2D mode is chosen or vice-versa. Let P_{d2d_tx}, P_{bs} (in Watts) be the transmit powers of D2D_TX and base station, $d_{D2D,}$ $d_{cellular}$ be the distance between D2D pair and Cellular pair then D2D SINR and Cellular SINR equations are as given below

$$D2D\ SINR = \frac{P_{d2d\_tx}/L_p}{\sum_{k=1}^{M} P_I/{d_k}^n + N_o} \tag{2}$$

$$Cellular\ SINR = \frac{P_{bs}/L_p}{\sum_{k=1}^{M} P_I/{d_k}^n + N_o} \tag{3}$$

Let I_p be the interference power which is given as

$$I_p = \sum_{k=1}^{M} P_I/{d_k}^n + N_o \tag{4}$$

Let us ignore the effect of thermal noise at this instant then equation (2) & equation (3) are reduced to

$$D2D\ SINR = \frac{P_{d2d_{tx}}/L_p}{I_p} \tag{5}$$

$$Cellular\ SINR = \frac{P_{bs}/L_p}{I_p} \tag{6}$$

Mode selection point is a point where the value of both D2D SINR and Cellular SINR are equal which is shown in Fig. 5. Let us simplify equation (5) and equation (6) by substituting L_p in them and after equating both of them we get

$$\frac{P_{d2d\_tx}/{d_{D2D}}^2}{I_p} = \frac{P_{bs}/{d_{Cellular}}^2}{I_p} \tag{7}$$

The mode selection point gives the information of the communication distance between the devices in the D2D pair i.e., d_{D2D}. Then the equation for the mode selection point is given as

$$d_{D2D} = d_{Cellular} * \sqrt{P_{d2d_{tx}}/P_{bs}} \tag{8}$$

III. PROPOSED METHOD

In this paper we are modelling Users as

$$U_{km} = R * r * e^{i*\theta} \tag{9}$$

Where U_{km}=position of the interferer
R= Cell radius
r = distance of interferers from the centre of the cell
θ = angle at which interferer is located

Let us consider SINR from equation (1) ignoring the effect of noise power (N_o)

$$SINR = \frac{P_t/L_p}{\sum_{k=1}^{M} P_I/{d_k}^n} \tag{10}$$

Where d_k = distance between interferer and D2D_RX
R/2= Position of D2D_RX
$d_k=(U_{km}-(R/2))$

Substituting d_k in equation (10) we get

$$SINR = \frac{P_t/L_p}{\sum_{k=1}^{M} P_I/(U_{km} - \frac{R}{2})^n} \tag{11}$$

As already mentioned in section II we are assuming transmit power of all users to be same (i.e., P_t=P_I) then further simplifying equation (11) it is reduced to

$$SINR = \frac{2^{-n}/L_p}{\sum_{k=1}^{M} R^{-n}(2 * r * e^{i*\theta} - 1)^{-n}} \tag{12}$$

If $K_m = 2 * r * e^{i*\theta}$ then

$$SINR(\gamma_R) = \frac{2^{-n}/L_p}{\sum_{k=1}^{M} R^{-n}(K_m - 1)^{-n}} \tag{13}$$

Let I_m be the interference power given as

$$I_m = \sum_{k=1}^{M} R^{-n}(K_m - 1)^{-n} \tag{14}$$

$$SINR(\gamma_R) = \frac{2^{-n}/L_p}{I_m} \tag{15}$$

Equation (20) gives SINR equation for a cellular network of radius R
Similarly the SINR equation for a cellular network of radius (R+L) is given as
Where L is an integer

$$SINR(\gamma_{R+L}) = \frac{2^{-n}/L_p}{\sum_{k=1}^{M}(R + L)^{-n}(K_m - 1)^{-n}} \tag{16}$$

Let I_i be the interference power given as

$$I_i = \sum_{k=1}^{M}(R + L)^{-n}(K_m - 1)^{-n} \tag{17}$$

$$SINR(\gamma_{R+L}) = \frac{2^{-n}/L_p}{I_i} \tag{18}$$

Comparing I_m and I_i we can say

$$I_i << I_m \tag{19}$$

From (19) we can say that

$$\gamma_{R+L} > \gamma_R \tag{20}$$

Thus our proposed method yields better SINR value than in paper [22].The simulation results obtained for a radius of 2 Km is shown in Fig. 4. The results obtained for a radius of 3Km is shown in Fig. 7 and D2D SINR for a cellular network of radius 2Km and 3Km are also compared.

The D2D SINR value is improved from 1 watt to 1.6 watts in our paper. Fig. 5 illustrates simulation and theoretical results of D2D SINR for a cell of radius 2Km. Number of users before and after increment of cell radius should be same.

IV. SIMULATIONAL RESULTS

Here an LTE-A based OFDM network simulation is carried by system level simulator (Matlab). Table I gives detailed simulation parameters. As stated before for simplification, consider one base station. A total of 2000 different scenarios with different locations for users are applied. The cellular user numbers is kept constant and they are uniformly distributed. Each time D2D pair is choosing randomly from these users. The network model of D2D enabled cellular network which is simulated in Matlab is shown in Fig. 3. The blue point represents BS location, red points represents cellular nodes (users / interferers) and the green points represent D2D pair.

The measured SINR in dBm for cell radius 2Km is indicated with respect to the distance between D2D pairs in Fig. 4. As stated previously depend on equation (1), it is notified that when proximity distance between D2D pairs become larger SINR value reduced. At the beginning, D2D connection has larger SINR than cellular connection. Next at certain point when the communication distance between D2D pair and between BS and (D2D_RX) device (here we set as 1 Km) becomes equal, SINR becomes equal too. After that SINR in case of cellular connection becomes larger than D2D connection as BS is close to D2D_RX than D2D_TX. Fig.5 explains the meaning of mode selection. When the distance between the pairs is less than x, network transmits data through D2D connection otherwise network transmits via BS (cellular mode) in order to enhance overall SINR. Optimal mode selection technique enhances SINR.

When the distance between the D2D pair and Cellular pair is same the SINR values are same only when transmit powers are fixed and the resulting mode selection point will be the receiver location i.e., (R/2). Though the distance between the D2D pair and the cellular pair is same and the transmit powers are different the mode selection point will not be the receiver location. The Fig. 6 shows example of different mode selection point obtained by changing transmit power of base station as 43dBm and D2D transmit power as 30dBm.It is clear from the Fig. 6 that D2D SINR is reduced from 30dBm to 27dBm because of low D2D_TX transmit power and cellular SINR is increased because of high base station transmit power which is also one of the reason for changing the mode selection point. The mode selection point in Fig. 6 is obtained by considering cell radius 2Km, D2D_RX at R/2 and number of users as 20.

The enhanced D2D SINR obtained for a cellular network of radius 3Km with D2D_RX at R/2 is shown in Fig. 7.

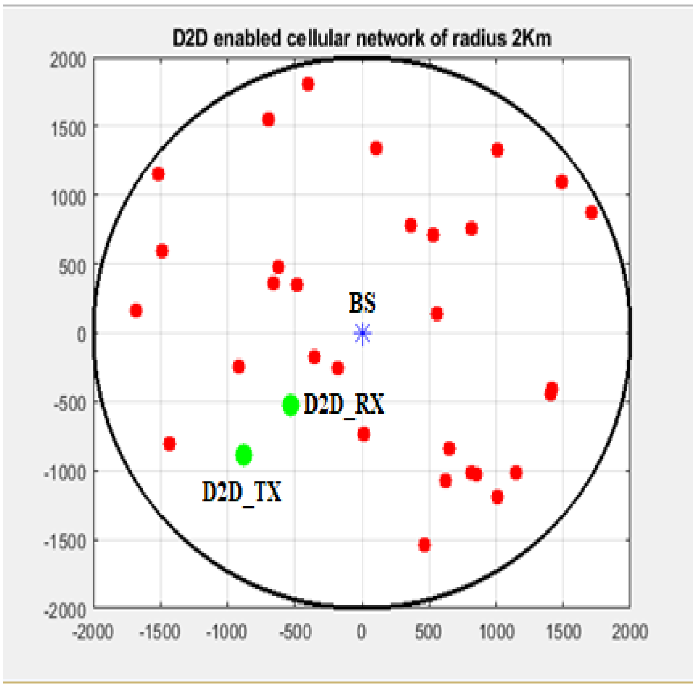

Fig. 3 Network Layout of the D2D enabled Cellular Network

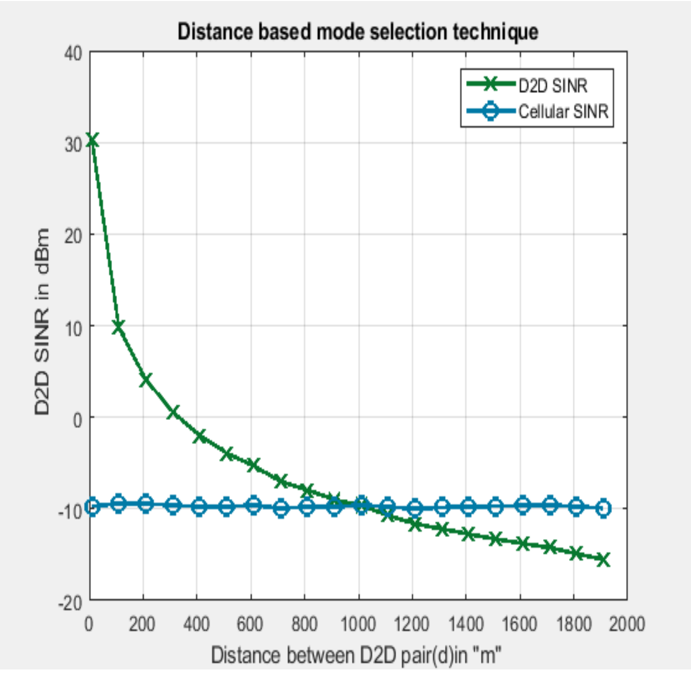

Fig. 4 Mode selection technique

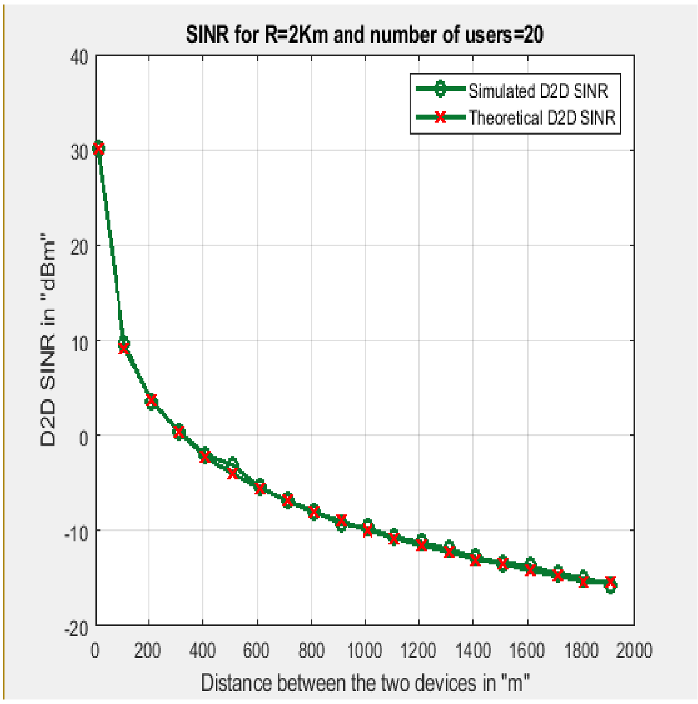

Fig. 5 Comparing simulation results with the theoretical results

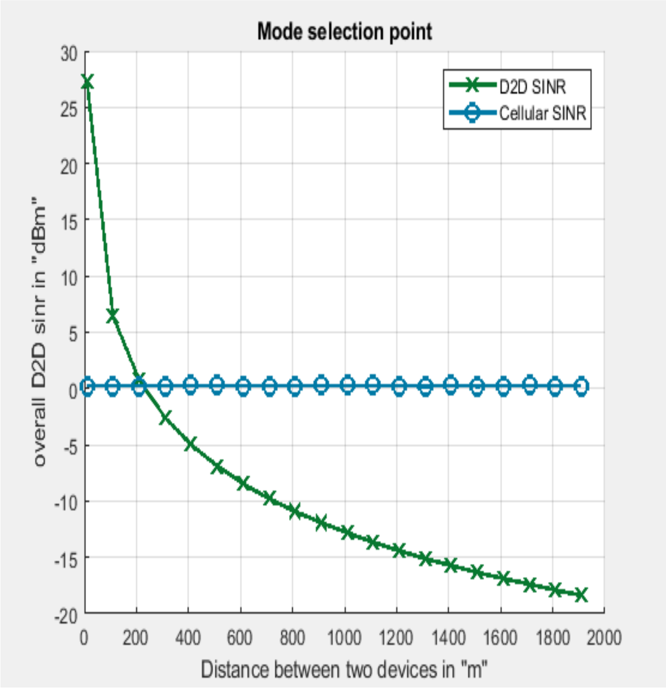

Fig. 6 Change in mode selection point

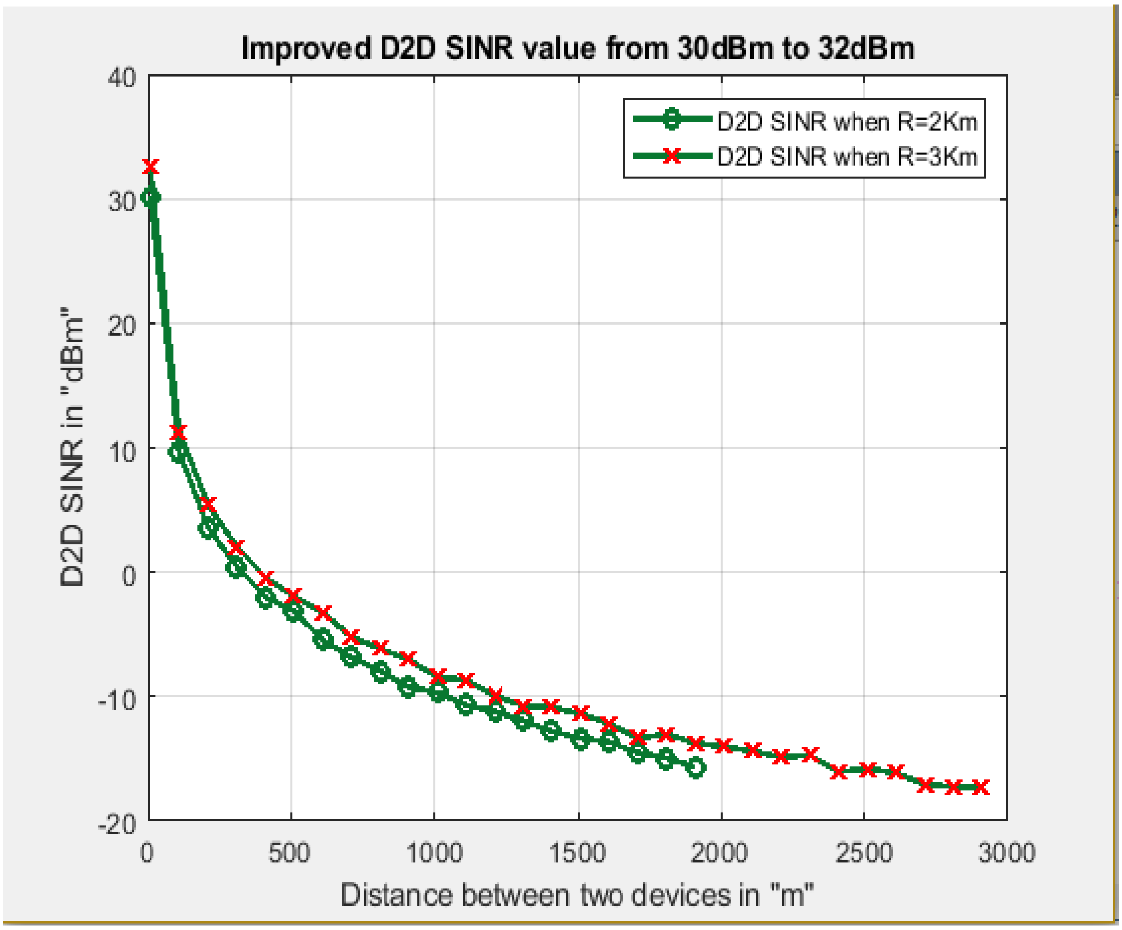

Fig. 7 Enhanced D2D SINR with a change in radius for Users=20

TABLE I
SIMULATION PARAMETERS

Parameter	Value
OFDM bandwidth	20 MHZ
Total number of data subcarriers (N)	64
Total number of used subcarriers	52
Carrier frequency (F)	2.3GHz
Cyclic prefix length	16
Transmit power	43dBm
Cell radius (R)	2-3Km
Number of users (M)	20
Thermal noise power (N_o)	-174dB/Hz
L	1Km
Loop	2000
Path loss exponent (n)	3.5
Velocity of light (C)	$3*10^8$m/s

V. CONCLUSION

The Fifth Generation (5G) in mobile communication offers a high data rate from 1 to 10 Gb/s to support reality applications. The Device-to-Device technology is the 5G standard designed to meet the above data rate requirement.

In this paper the concept of mode selection is explained between two modes Cellular and D2D and discussed about the parameters that has impact on the mode selection point. The method of obtaining enhanced D2D SINR by changing the cellular radius is studied here. The D2D SINR is improved from 30dBm to 32dBm in this paper.

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