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Device to Device Communication under Shadowing Effects in Wireless Networks

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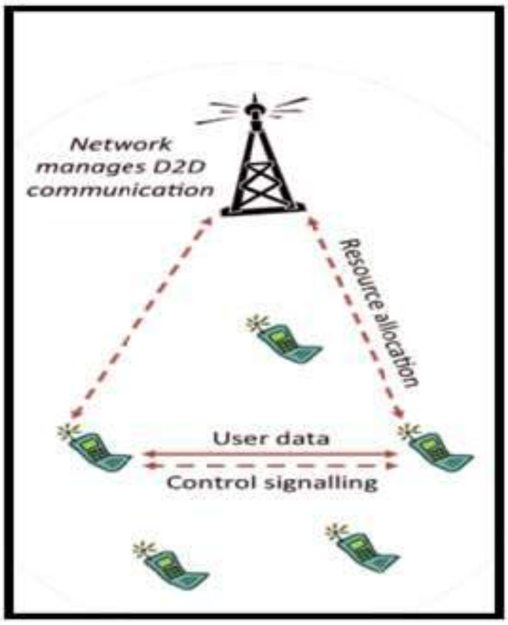
Abstract: With increasing needs in cellular network technology, such as high bandwidth requirements for multimedia applications, ever increasing number of users and a limited amount of bandwidth available to cellular network operators, device to device (D2D) communication in cellular networks has emerged as an extremely important area of research. The conventional architecture of cellular networks starts loading or in other terms overburdening the network as the number of users keep adding to the network over a period of time. In this paper we have investigated different parameters viz. outage probability and optimum distance based on which one can switch from D2D mode to cellular mode and vice versa for maintaining satisfactory Quality of Service (QoS). Also a technique for improvement of improvement of BER performance of such systems under frequency selective channels has been proposed.

Keywords: Device to Device Communication (D2D) communication, Outage Probability, Optimum Distance, Quality of Service (QoS), User Equipment (UE), Signal to Noise and Interference Ratio (SINR), Bit Error Rate (BER).

Introduction: Satisfying the basic demands of cellular users, such as voice calls and text messages, is not sufficient anymore. The cellular network operators face many problems in dealing with emerging mobile applications developed for the new generation of cellular devices, such as smart phones and tablets. These new cellular devices allow users to use services with high quality of service (QoS) requirements such as video/audio streaming, online gaming, video calls and social networking. The rapid growth of Smartphone has been so fast that the operator fails to cop up the existing infrastructure to deal with these new technologies. Although the third and fourth generations of cellular technologies (e.g., UMTS and LTE) are designed to accommodate high speed data services, the operators are still struggling with the increased bandwidth demands of cellular users. These challenges need of new communication prototype that revolutionizing the existing cellular architecture. D2D communication represents a promising technology since it allows for direct and low power communication among devices thus contributing to reduce interference and system load and improving its overall performance.

D2D communications is one of such prototype that has been introduced to harness these increasing bandwidth requirements. D2D communication in cellular networks is capable of direct communication between two cellular devices located in vicinity of each other. One of the main functions of cellular base station (BS) in conventional cellular networks is to relay traffic between cellular users. In D2D communication, the data bypasses the BS and it is instead sent using a direct communication link between the users. By-passing the BS allows D2D communications to significantly increase the spectral efficiency of the dense cellular network.



D2D Communication

Fig.1 Model for D2D Communication

The direct communication mode requires half of the resource as compared to cellular communication mode thus offering double spectral efficiency per connection typically. Also if devices in direct communication mode are closer to each other than transmission power could be lower than in cellular mode which can be then turned into battery savings at the device and reduced interference levels in the system. Further, reduced interference levels in system lead to higher system capacity and spectrum efficiency. Furthermore, D2D communications can improve the throughput, power efficiency and cell coverage. D2D users can either reuse the cellular network resources in the licensed spectrum (i.e., in band D2D) or use the resources from the unlicensed spectrum (i.e., out band D2D).

Classification of D2D Communication:

In-band D2d Communication

In-band D2D can be further classified as underlay and overlay. In overlay D2D communication, a portion of cellular resource is solely dedicated for D2D communication. Underlay D2D communication allows each D2D pair to reuse the same resource which are simultaneously being used by another cellular user. Overlay D2D improves both spectral and power efficiency because communication is done through single transmission instead of one uplink and downlink transmission. Underlay D2D has higher spectral efficiency than Overlay D2D due to reusing cellular resources. Underlay D2D improves energy efficiency as well as spectrum efficiency of cellular network.

1.3.1 Out-band D2d Communication

In out-band D2D communication, communication occurs under unlicensed spectrum. The main aim of out-band D2D communication is to eliminate the interference issues between D2D and cellular links. Transmission distance and data transfer rate is extremely lower than In-band D2D communication.

Mode Selection

It is the process of finding whether to operate UE in Cellular Mode or D2D Mode. It depends on the proximity of devices, inter-cell and intra-cell interference conditions, channel condition and instantaneous load condition on the network. Mode selections are basically of three types:

Reuse Mode Selection:

This mode is also known as Non-orthogonal sharing mode, in this mode D2D Communication will share the same resources with existing CUEs and hence may cause interference.

Dedicate Mode Selection:

This mode is also known as orthogonal sharing mode, in this mode cellular network has abundant channel Resource, so that the DUEs can use dedicated resources that are orthogonal to CUEs.

Cellular Mode Selection:

In this mode two UEs will communicate as traditional CUEs, that is, communicate with each other through the eNB.

Power Control

Power control is an important RRM function. In D2D communication, CUEs are act as primary users and its Quality of Service (QoS) requirements are delivered with priority. In such network power control, at first control the transmission power of DUEs, such that the interference from DUEs to CUEs can be reduced. Distributed power control algorithm allocates power in mixed cellular and D2D scenario so that overall throughput is maximized with minimum overall power consumption [15]. With proper power control, the interference between cellular and D2D can be coordinated for better overall performance [11].

Resource Allocation

In 3GPP-LTE specification UEs are assigned with a specific number of subcarriers for a predetermined amount of time duration, which are referred as Physical Resource Blocks (PRBs). PRB have a frequency range of 180 kHz and also 12 consecutive subcarriers. PRB is the smallest element of Resource Allocation by the eNB.

Resource Allocation should be jointly considered with mode selection i.e. whether the PRB or shared PRB pair will obtain, if it is a shared case, which cellular UEs resource Network can allow some channel resources to D2D pair, if so, whether some dedicated block should be shared with this D2D pair, if it is a dedicated case how many PRBs should be permitted for this D2D communication.

Advantages of D2d Communication

Data rates: Devices may be remote from cellular infrastructure and may therefore not be able to support high data rate transmission that may require.

Reliable communication: D2D can be used to communicate locally between devices to provide high reliability communication especially if LTE is failed for any reason.

Instant communication: As D2D communication does not rely on network infrastructure the devices could be used for instant communications between a set numbers of devices in the same way that walkie- talkie are used.

Interference reduction: As base station is bypassed in D2D communication, so fewer links are required in communication process and this has an impact on the amount of data being transmitted in the given spectrum allocation. This reduces the overall level of interference.

Power saving: As in D2D communication, communication occurs between the devices of closer proximity, thus overall transmission power requirement is very low.

Spectrum reuse: D2D enables tighter reuse of spectrum by confining radio transmissions to the point to point connection between two devices.

Security: D2D can take the advantage of key generation and distribution mechanisms available in LTE to achieve higher security.

Disadvantages of D2d Communication

D2D devices cause interference to the cellular users which affect the performance of the network devices.

D2D communications define new QoS requirements that must be addressed.

Parameters deciding switching between D2D and Cellular Modes.

1) **Optimum Distance:** The distance at which we can switch from cellular mode to D2D mode maintaining satisfactory (QoS).

The minimum distance at which such a switching can take place termed as r_d can be expressed as:

$$r_d = d_0 . 10^{\left[\frac{P_{td} - P_{rmin} + 20\log_{10}\left(\frac{\lambda}{4\pi d_0}\right)}{10\eta}\right]} \times \exp(k)$$

where

$$\exp(k) = exp\left[\frac{\xi erf^{-1}(1-2P_d)}{\alpha}\right]$$

here P_d stands for power received at a distance 'd' and d_0 stands for a constant reference distance.

Outage Probability: It's an indication of the Quality of Service (QoS) and helps in deciding the mode of operation. The outage probability of the system can analyzed with respect to UE density, distance and SINR

The Outage probability as a function of the above parameters can be given by:

$$q(\lambda) = \exp\left\{-\frac{2\pi^2}{\eta \sin\left(\frac{2\pi}{\eta}\right)} R_k^2 V_k^{2/\eta} \lambda\right\}$$

where the successful transmission probability can be given by:

$$P(SIR_k \geq V_k) = \exp\{-K_k \sum_{j\epsilon\phi} \gamma_{kj} \lambda_j\}$$

where, $K_k = C_k R_k^2 V_k^{2/\eta}$

here R_k stands for distance

V_k stands for SINR and

λ stands for UE density

Thus the analysis of optimum distance and outage probability helps in deciding the optimum mode of operation.

Improvement in BER performance of communication under frequency selective wireless channels:

Devices working in D2D or Cellular mode encounter the random nature of wireless channels. Since wireless channels exhibit frequency selectivity, therefore it leads to a degraded BER performance for frequencies encountering high fades. Therefore suppressing such frequencies improves the BER performance of the system.

The BER analysis of such a system is given below:

Let the random data signal be x(t) which is expressed as

$$x(t) = \sqrt{\frac{2E_s}{T}}[I(t)cos(2\pi f_c t) - Q(t)sin(2\pi f_c t)]$$

Where $I(t) = \sum a_n^x v(t - nT) \rightarrow$ In phase amplitude

$Q(t) = \sum a_n^Q v(t - nT) \rightarrow$ Quadrature amplitude.

The BER for such a random signal can be given by:

$$P_e = Q\left[\sqrt{\frac{1}{4}\frac{E_d}{\left(\frac{N_0}{2}\right)}}\right]$$

Where E_d denotes symbol energy, N_0 the value of noise psd and Q stands for the Q function.

The BER or P_e can be modified for different modulation signals.

Suppressing frequencies which exhibit a low SNR can be suppressed to improve the P_e

Results:

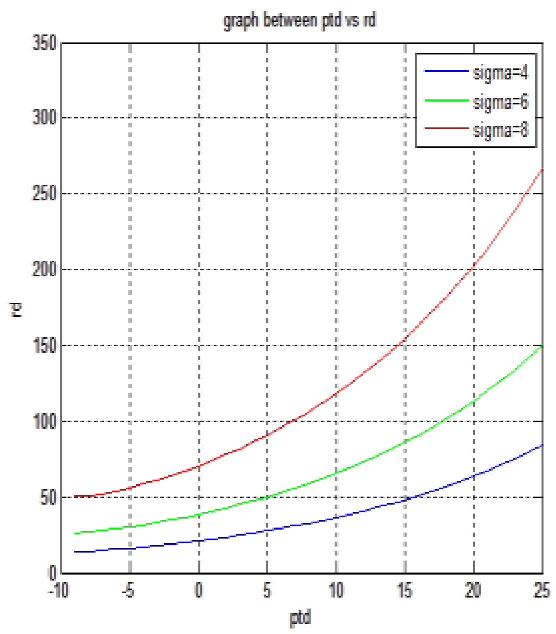


Fig. 2 Graph for optimum distance

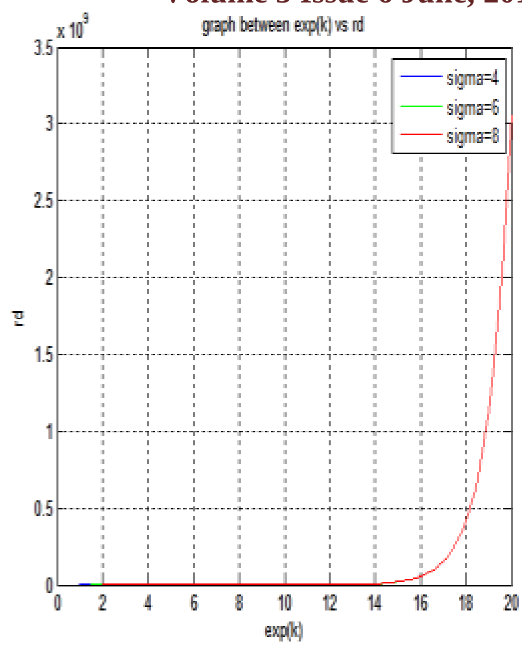


Fig.4 Graph between exponential constant and optimum distance under varying shadowing effects.

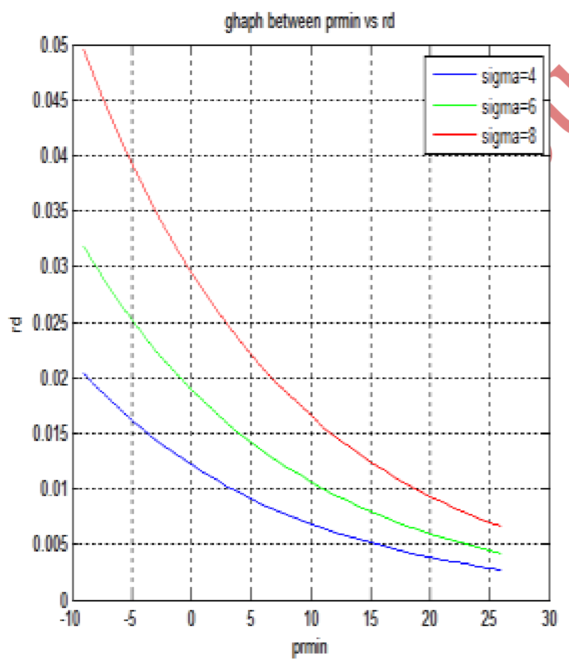


Fig.3 Graph between prmin and rd under varying shadowing effects.

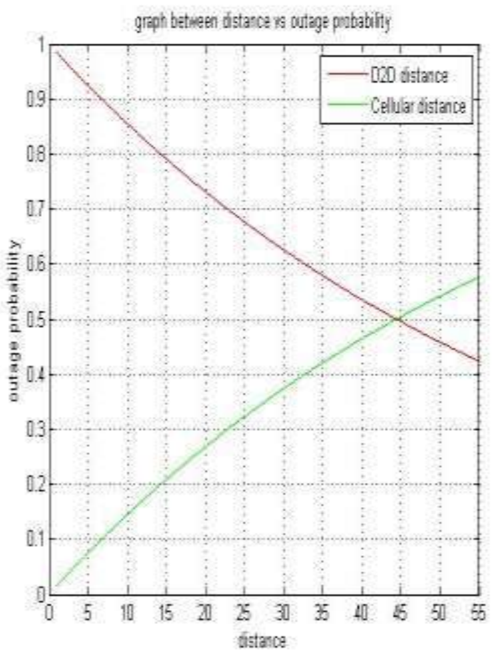


Fig.5 Graph between outage probability and distance.

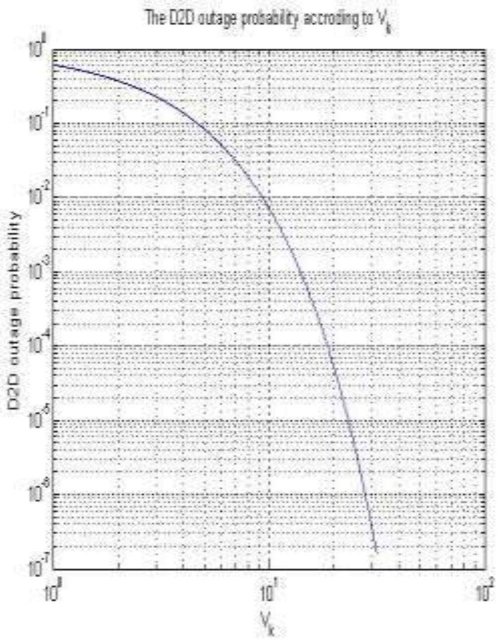


Fig.6 Graph between outage probability and SINR.

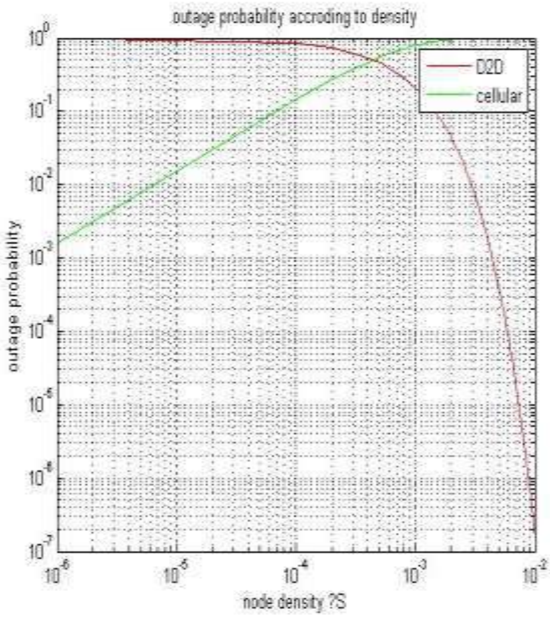


Fig.8 Graph between outage probability and node density.

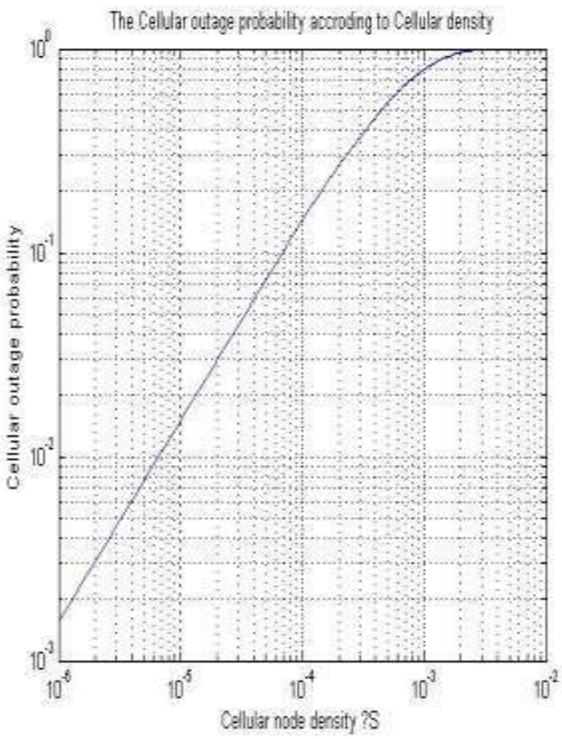


Fig.7 Graph between outage probability and cellular density.

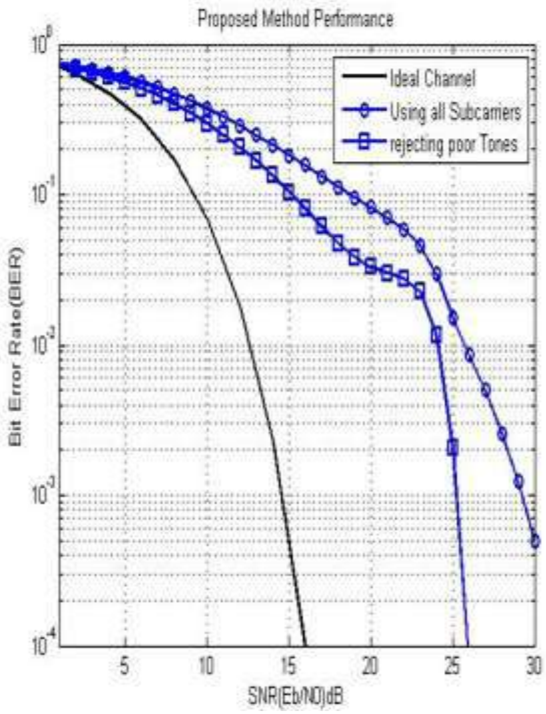


Fig.9 Graph between BER and SNR.

S.No	BER	Ideal Channel	Using all carriers(tones)	Proposed System
1.	10^{-1}	9 dB	19 dB	15 dB
2.	10^{-2}	12.5 dB	26 dB	24 dB
3.	10^{-3}	14 dB	28 dB	25 dB

Table1. BER improvement for proposed mechanism.

Conclusion:

In this work, we have analysed the optimum distance for D2D communication in terms of transmitted power, minimum received power and exponential constant k. In transmitted power case, the optimum distance increases as transmitted power increases. In minimum received power case, the optimum distance decreases as minimum received power increases. As we know that outage means fading in the signal. So to overcome this problem, we analysed outage probability in respect of SNR. We observed that as the strength of signal increases than the outage probability reduces. So there would be less chances of signal degradation at the receiver side which would result in increasing the reliability of communication. The analysis of the outage probability with respect to distance between devices, device density in the network and Signal to Noise and Interference Ratio (SINR) gives a clear picture about switching from cellular to D2D mode and vice versa. Finally the tone suppression mechanism allows BER improvement of the system. This technique is particularly useful for limited power systems such as mobile devices in cellular networks.

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