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Throughput Enhancement for Device to Device Communication in LTE-A Networks

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ABSTRACT: *In this paper, we propose a method to improve throughput in LTE-A networks for device-to-device (D2D) communication. To acquire the potential for providing high throughput in LTE-A networks by device-to-device (D2D) communications, the power control, delay and interference parameters among D2D links should be carefully managed. Interference factor affects the signal capacity and reduces the transmission efficiency. To increase the throughput, we propose a power control technique which determines whether the D2D pair can share the same resources with a specific cellular link. QoS degradation is observed due to interference problem. We will describe how intercellular interference affect the throughput for an LTE-A network. Simulation results show that the proposed techniques can be able to throughput gain over traditional D2D communications.*

KEYWORDS: OFDMA, SC-FDMA, ACI, ISI, SINR.

1 INTRODUCTION

Device-to-Device communication allows the proximity users to communicate directly with each other without the involvement of BSs. Enhancing the network throughput, spectral efficiency, energy efficiency and reducing the network and UEs power consumption are some of the basic challenges. Basically, the interference management techniques are divided into two categories: mode selection and resource management. The mode selection based technique allows the mobile users to select an appropriate mode, i.e. the conventional cellular mode and D2D. The resource management based technique is capable of improving the network performance by properly allocating resources, such as power, time slots and radio spectrum [1]. When a pair of device to device UEs communicates using the uplink cellular resources, the device to device communication might be affected by the simultaneous transmission between a CUE and the BS. Moreover, if there are multiple concurrent D2D pairs, the accumulated interference may also influence the quality of the signal received by the BS. If device to device communication reuses the downlink resources, the transmitting DUE might cause reception failures of its nearby cellular UEs. LTE-Advanced supports femto cells network deployment, but such deployment give rise to inter cell interference by using the same frequency in neighboring cells [5]. To take the advantage of the storage capacity at smart phones, cache-enabled D2D communications have been proposed recently, which can offload the content delivery traffic and hence boost the network throughput significantly [2], [6]. Since only the users in proximity communicate to each other, the distance between a user and the undesired transmitters can be close and hence the interference in D2D networks is strong, which needs to be carefully controlled. In an early work of studying cache enabled D2D communications, the D2D users are divided into clusters. Then, the intra cluster interference among D2D links is managed by using time division multiple access, while the inter cluster interference between D2D links is simply treated as noise [8]. LTE-A is basically designed through OFDMA (Orthogonal Frequency Division Multiple Access) and SC-FDMA (Single Carrier- Frequency Division Multiple Access) techniques to achieve best rates and quality calls. Thus, it increases the capacity of the network in terms of number of simultaneous calls per cell up to 200 calls [3].

Device to device networks directly connect the UEs in an ad-hoc fashion and operate on their own without going through the infrastructure. One of the important challenge for device to device communication is to provide high data rate services. The applications like video streaming, social networking etc. leads to quick drainage of battery. To overcome this problem, solar energy harvesting techniques can be employed for throughput maximization.

In this paper, we will discuss how LTE-A network performance depends widely on SINR and throughput. For that, interference types in mobile networks will be presented in section II, Section III presents the inter cell interference in LTEAdvanced. Mathematical analysis is summarized in section IV. Simulation results are described in section V. Finally, section IV will conclude the paper.

2 SYSTEM MODEL

In D2D communication a user communicates with the other user in the same cell if they are in the *D2D proximity*. The D2D proximity is the region around a D2D transmitter that the D2D transmit signal reach the D2D receiver with the signal-to-noise ratio (SNR) above some pre-defined minimum threshold level. We consider a total of M available frequency resources that are shared between D2D and cell users. The same can be repeated M times for all M resources. It is assumed that all users and the base station have a single omni-directional antenna. Each D2D user has two options for receiving data: relay via base station (BS Relay), or direct transmission from the other device (D2D Direct) as shown in Fig 1.

Interference is a factor that affects the signal which limits its capacity and transmission efficiency. The main types of interference in mobile communication are inter-symbol interference (ISI), co-channel interference (CCI), adjacent channel interference (ACI) and inter-cell interference (ICI) [4]. In inter-symbol interference during the transmission of a signal, the electromagnetic waves undergo reflections depending on various types of environment (urban, suburban and rural).

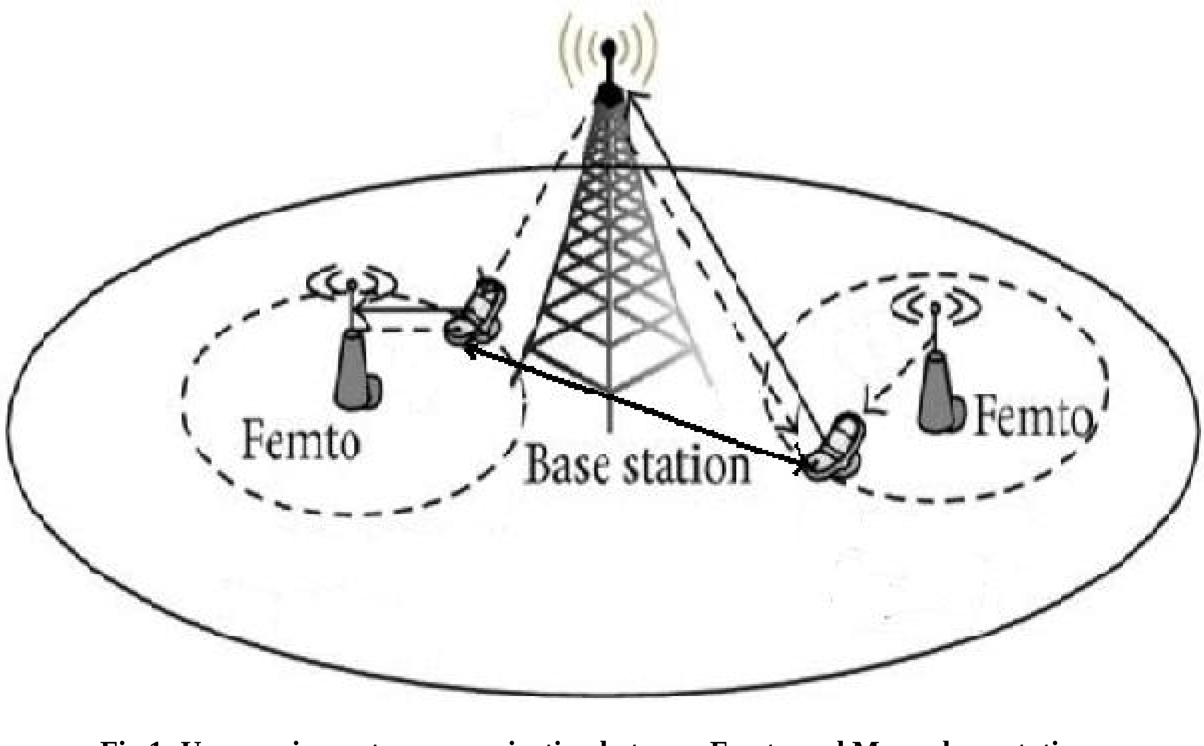

Fig 1: User equipments communication between Femto and Macro base stations.

Thus a symbol can reach the mobile user through several paths. Hence these different lengths symbol is received many times at different intervals and at the same time, the mobile receives several different symbols which is difficult to differentiate [7].

Co-channel interference problem appears when cells use the same channels and adjacent channel interference results from imperfect receiver filters which allow nearby frequencies to leak into the pass band [9].

The interference in LTE-Advanced standard appears when the downlink radio resource allocated to a cellular UE is simultaneously reused by multiple D2D communication pairs, the transmitting BS may affect a D2D UE receiver's reception, while the CUE's reception might also be influenced by the D2D UE transmitters.

The interference-management techniques are divided mainly into two categories: *mode selection* and *resource management* [6]. The *mode selection* based technique that enables the mobile users to choose an appropriate operational mode, i.e. the conventional cellular mode and D2D mode. The *resource management* based technique, is capable of optimizing the network performance by properly allocating resources to the mobile users, such as power, time slots and radio spectrum. We assume that cellular users communicate with base stations while device –to-device users communicate directly with each other. The main aim of this paper is to provide a frame work with average achievable throughput evaluation to allow for identifying a desirable set of network parameter (e.g., density and transmit power of both networks).

3 ANALYSIS OF SINR AND THROUGHPUT

A small low power cellular base station is called Femto cell. The calculate effect of femto cell on the Signal to Interference Noise Ratio (SINR) and on the throughput of a macro cell user, the simulation was conducted by increasing the number of femto cells each time and by varying the distance (*d*) between the macro cell user (m) and macro cell base station (M). The distance (*D*) between the macro and femto base stations are assumed from 10m to 100m.

The SINR of a macro cell user m is given by [1]:

$$SINR_m = (P_M G_{m,M})/(N_o \Delta_f + \sum_{M'} P_{M'} G_{m,M'} + \sum_F P_F G_{m,F}) \qquad (1)$$

Where P_M and $P_{M'}$ are respectively the transmit powers of servant macro cell M and neighboring macro cell M'. $G_{m,M}$, $G_{m,M'}$ and $G_{m,F}$ respectively correspond to the channel gains between macro cell user m and servant macro cell M, neighboring macro cell M' and neighboring femto cell F. P_F is the transmit power of neighboring femto cell F. N_o corresponds to the white noise power spectral density. Δ_f is subcarrier spacing.

The parameters considered for SINR of a macro cell user m are shown in Table 1.

Table 1. Parameters for SINR of a macro cell

PARAMETERS	VALUE
Subcarrier spacing	15 KHz
Number of Users N	15
Macro base station transmit power	46 dBm
Propagation Path Loss	0.8
Femto base station transmit power	20 dBm
Neighbour Cell Power Interference	-10.3 DBM
Capacity of Cell M	10^5 BPS

The throughput of the same macro user m thus can be approximated by [1]:

$$Throughput = W \log_2 (1+ SINR_m) \qquad (2)$$

Where W is the available bandwidth.

The signal to interference noise ratio (SINR) is considered as an important indicator for BS to D2D link quality. LTE-A network model is considered with M base stations (eNB) and each base station with N users as shown in Fig.1. Each UE is covered by one or more base stations and the nth user will connect to the mth base station to transmit the data with power level Pe.

The DUE SINR from [8] is given by

$$SINR_D^k = (P_D^k |h_D^k|^2)/(IEI^k + \sigma^2) \quad (3)$$

Where P_D^k is the power transmitted by the DUE which is calculated b using the equation P_D^k = min{Pmax ,P0 + α PL} (4)

Pmax is maximum allowed transmit power. P0 is a device specific transmission power, according to noise condition of the receiver. α is a parameter representing path loss effect, where the value of α value is set as α ={0,0.1,0.2,0.3,………0.9,1}. PL stands for the downlink path-loss estimate calculated by each user. $|h_D^k|^2$ is the channel gain between target D2D pair, IEI^k is the interference due to IEI from the CUEs. Bellman-Ford algorithmic approach is used to find throughput of the D2D pair.

The throughput of the D2D pair can be approximated by

$$Throughput = W \log_2(1+ SINR_D^k) \quad (5)$$

Algorithm1: Bellman-Ford Algorithm

Step 1: Initialize Pmax ,P0, α , PL,

Step 2: Calculate shortest path using dist[v] > dist[u] + weight of edge uv, then update dist[v]

i.e dist[v] = dist[u] + weight of edge uv

Step 3: Find P_D^k ,

Step 4: Initialize h_D^k , IEI^k and σ

Step 5: Obtain $SINR_D^k$

Step 6: Calculate throughput of the D2D pair by using Throughput = W $\log_2(1+ SINR_D^k)$

4 SIMULATION RESULTS

For efficient throughput maximization in LTE-A networks for device to device communication is measured and evaluated in this section. Results are analyzed using LabVIEW platform. The parameters considered for simulation is shown in Table 2.

Table 2. Simulation parameters

Parameter	Value
Pathloss model for D2D users	38.46 + 20 $\log_{10}(d_d)$ dB
downlink path-loss (P_L)	15.3 dB
Max allowed transmit power (*Pmax*)	200 mW
device specific transmission power (*Po*)	100 mW
System Bandwidth (*B*)	15 kHz

Obtained results show the affect of throughput depending on macro and femto cells. Simulation is performed for *d*=5m, *d*=20m and *d*=50m. The distance (*D*) between the macro and femto base stations are assumed from 10m to 100m.

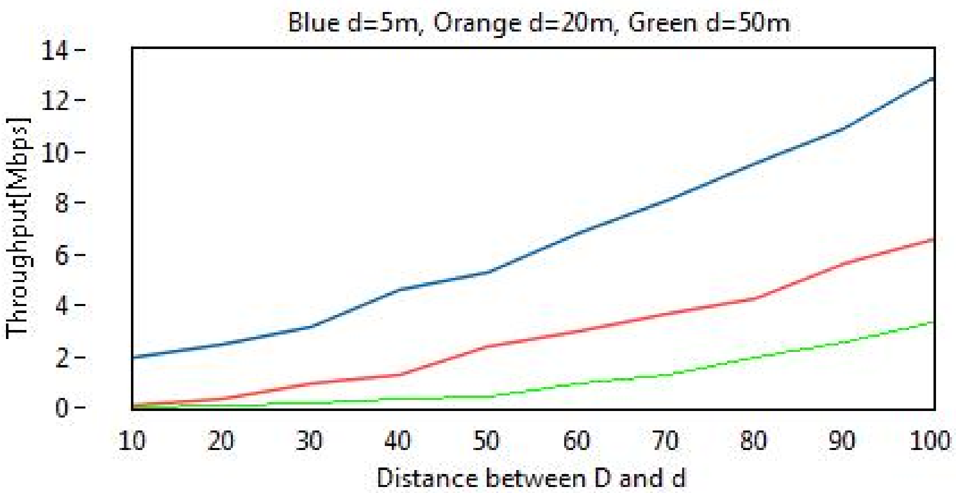

Fig 2: Macro and Femto users throughput according to *D* and d (Conventional)

It is observed that the throughput increases as number of femto cells in the served macro cell and distance between macro cell user and macro cell base station decrease and vice versa. The Macro and Femto users throughput performance for the conventional method (i.e using equation 1 for SINR calculation) is as shown in Fig 2.

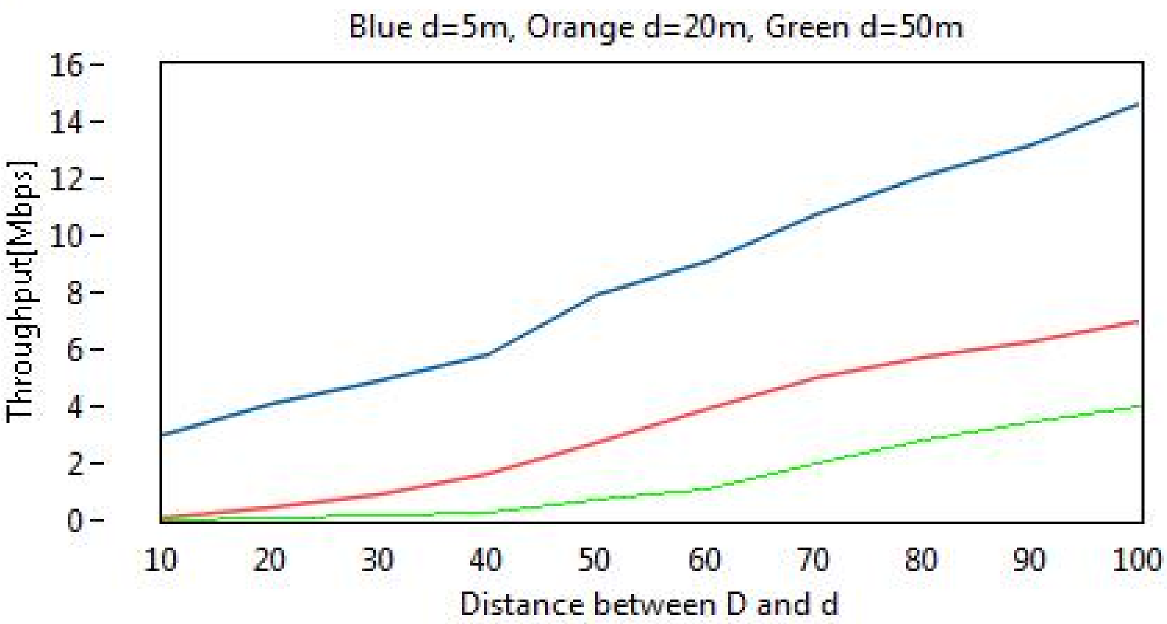

Fig 3: Macro and Femto users throughput according to *D* and d (Proposed)

The Macro and Femto users throughput performance for the proposed method (i.e using equation 3 for SINR calculation) is as shown in Fig 3. It is observed that the throughput is increased from 12.8 Mbps (conventional approach) to 14.6 Mbps (proposed approach) for d=5m. The similar changes for the other values of d are shown in the graphs.

5 CONCLUSION

This work helps us to control the power in LTE-A networks for D2D communication system. In this paper we assumed an LTE-Advanced network with user equipments covered by a Femto base station and macro base station. The LabVIEW tool is used to simulate the mathematical model developed for throughput maximization. The simulation results show that the proposed Bellman-Ford approach algorithm effectively helps to increase the throughput for device to device communication. By using solar energy harvesting techniques the power requirements can be further minimized and hence further enhancement in the throughput can be achieved.

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