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UPLINK RESOURCE ALLOCATION FOR DEVICE-TO-DEVICE COMMUNICATION IN LTE-A NETWORK

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Abstract

Device-to-Device (D2D) communication is one of the prominent and key technique in the next-generation wireless network. In D2D communication, resources are share between Device-to-Device users and cellular users. If the resource allocation is not shared properly then, there is an interference between device-to-device users and cellular users in the network. In D2D communication to mitigate the interference and improve the channel capacity is one of the challenging tasks. So, in this paper underlay as well as overlay scenarios in Long Term Evolution-Advanced (LTE-A) using uplink resource allocation scheme is proposed. In this analysis, orthogonal frequency resources are utilized and thereby reducing the interference in the channel, but at the cost of some throughput of cell-edge users. The proposed method makes use of the same orthogonal frequency resources and simultaneously allows the D2D users to reuse the left-over frequency from the cellular users. As a result, the throughput of the cellular users, as well as the cell-edge users, remains the same whereas the throughput of the D2D users increases significantly, thereby increasing the overall system throughput.

Keywords: Device-to-Device communication, LTE-A, Resource allocation, Resource blocks, Throughput, Uplink.

1. Introduction

Device-to-Device (D2D) communication, also known as proximity-based services (ProSe), facilitates ad-hoc networks with small coverage distance under laying the cellular communication system by sharing the same frequency resources of cellular users [1-4]. Device-to-Device (D2D) communication means direct communication between two user equipment's (UEs) without the involvement of base station (BS). Direct communication between any kinds of spectrum is called D2D communication [5-8]. Bluetooth and Wi-Fi technologies are operating in unlicensed bands would also represent D2D communication. Nowadays, there is a need for higher data rates within the available spectrum for which D2D communication is one of the key solutions.

Device-to-Device (D2D) communication technology is used to expand the cellular capacity, refining the user as well as the overall system throughput, and prolonging the battery lifespan of the UE(s) [9]. So, the benefits of D2D communication are higher spectrum efficiency, higher energy efficiency, and large capacity, creating new peer-to-peer and proximity services, public safety, etc., [9]. Device-to-Device (D2D) communication shares the sanctioned frequency bands with cellular users via the orthogonal/multiplexing method. One of the main reasons for the introduction of the D2D communication system is to enhance the throughput of the overall cellular communication system. If the resources are not shared properly between D2D UE(s) and cellular users, then the interference exists in the network, so system throughput is decreased [10, 11].

Mishra et al. [12] proposed a device-centric based resource allocation method to improve the system throughput. Noor Mohammed et al. [13] and Li et al. [14] used optimization techniques to allocate a dedicated resource between D2D users and cellular users, and it is provided that efficiency is improved. Feng et al. simulated different resource allocation methodologies and throughput comparison was analysed.

Rajkumar et al. [11] proposed distance-based resource allocation scheme to reduce the interference between D2D users and cellular users. Interference management scheme was proposed in D2D based multi-tier heterogeneous cellular network [16] and quality-of-service (QoS) of the network was improved.

Shamaei et al. [17] distributed resource allocation scheme was proposed using a matching theory approach to mitigate the interference and intensify the network performance. A resource allocation and interference reduction mechanism were examined in heterogeneous network-based D2D communication [18]. It is proved that inter and intra cell interferences are minimized and sum rate is maximized.

Inter-cell interference between CUE and D2D users is minimized by adopting a hybrid scheme of almost blank sub-frame mechanism and fraction frequency reuse method [19]. Nugraha et al. [20] proposed a D2D communication based underlay network a fixed and adaptive power control mechanisms minimize the interference.

Liu et al. [21] proposed a joint mode selection and power control mechanism in D2D based heterogeneous network to minimize the interference and provide adequate QoS to the network. A tractable interference management mechanism is proposed using a mode selection scheme to control the co-channel interference between D2D users and CUE [22].

Research Contribution

From the literature, it is examined that interference is minimized and improves the system throughput using device-centric algorithm, distributed resource allocation scheme, fractional frequency re-use method, joint mode selection and power control mechanism, adaptive power control mechanism, and distance-based resource allocation method. Best of our knowledge, the above interference reduction methods are not examined the throughput of cell edge users. The main challenge is to improve the throughput of cell edge users with existing resources of the network. So, in this paper, the effective resource allocation method is proposed to improve the throughput of the cell edge users without compromising the throughput of all other users in the network.

This paper is structured with the following sections: The system model is described in Section 2. Pre-existing resource allocation methods are discussed in Section 3. The proposed resource allocation method is explained in Section 4. Results and discussions are presented in Section 5. Finally, Section 6 concludes the paper.

2. System Model

Figure 1 shows the node deployment scenario in the uplink single-cell environment, cellular UE(s) and D2D UE(s) are randomly distributed. The star denotes the evolved NodeB (eNB), asterisks denote Cellular UE and D2D pairs are denoted by block dots. The cellular UEs are making communication through eNB and D2D UEs are directly communication with each other without the help of eNB. Cellular users are already in communication with eNB using some resource block and these resource blocks can be shred to DUE for their communication. Orthogonal channels are assigned to the cellular users and these orthogonal channels are going to be assigned to the D2D user as well. A single cell environment is considered with 210 cellular users and 21 pairs of D2D UE’s D2D UE(s) reuses uplink resources of LTE-A, which is consisting of 50 RB.

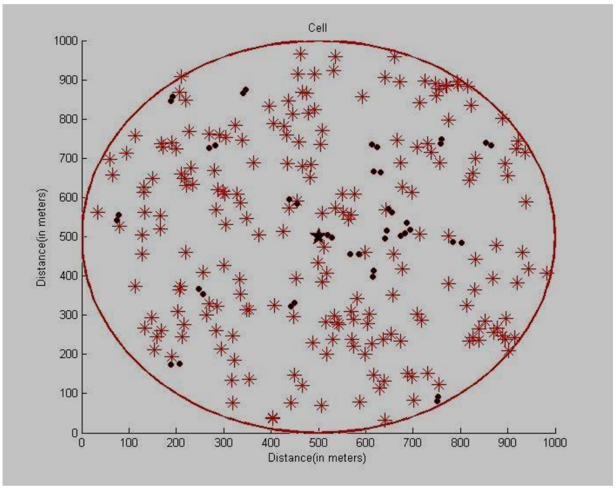

Fig. 1. Node deployment.

The Urban Macro model [15] is considered for estimating the path loss. The path loss (PL) expression as follows

$$PL = 16.9\log(l_0) + 46.8 + 20\log\left(\frac{f_c}{5}\right) \quad (1)$$

where, l_0 is the distance between D2D and UE(s) which is measured in terms of meters and f_c denotes the carrier frequency which is in GHz.

During the uplink phase, if D2D pairs share the channel with cellular UEs then there is interference at eNB. If d^{th} D2D pair is reusing the RBs of the k^{th} cellular UE, it receives interference from cellular k^{th} cellular UE and other transmitters of the D2D pair (i.e., d'^{th} D2D pair) where $d' \neq d$. D_k is defined as a set of variables denoting the indexes of D2D UE(s) sharing the channel with the k^{th} cellular UE. The channel rate of k^{th} cellular UE is computed as follows

$$\gamma_k = log_2\left(1 + \frac{p_k g_{ke}}{\sum_{(d\in D_k)} p_d g_{de} + \sigma^2}\right) \quad (2)$$

The channel rate of the D2D pair d ($d \in D_k$)

$$\gamma_d = log_2\left(1 + \frac{p_d g_{dd}}{p_k g_{kd} + \sum_{(d'\in D_{k\backslash d})} p_{d'} g_{d'd} + \sigma^2}\right) \quad (3)$$

where p_k, p_d, and p_d' are the transmission power of k^{th} cellular UE and d^{th} and d'^{th} D2D pair respectively. The g_{ke} represents gain between the k^{th} cellular UE and the base station. Similarly, g_{de} denotes the gain between the d^{th} D2D pair and the base station. The σ^2 gives the noise power at the receiver. The $\sum_{d\in Dk} p_d g_{de}$ in Eq. (2) is the received interference power at the base station from D2D pairs in D_k and $p_k g_{kd} + \sum_{d'\in Dk\backslash d} p_d' g_{d'd}$ in Eq. (3) is the interference power from k^{th} cellular UE and d'^{th} D2D pairs, where $d' \in D_k$,, $d' \neq d$.

The system sum rate for the uplink phase as follows

$$\gamma_t = \sum_{k=1}^{K} \gamma_k + \sum_{d=1}^{D} \gamma_d \quad (4)$$

3. Pre-existing Resource Allocation Method for D2D

For analysing the performance of the pre-existing techniques, the following scenarios are simulated [15]:

3.1. Case basic

Figure 2 shows that resources are shared by the only cellular network, i.e., without D2D UE's.

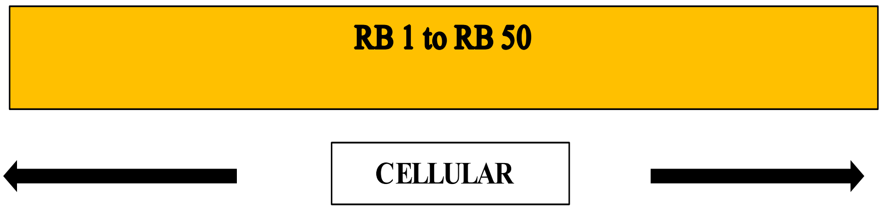

Fig. 2. Basic _Case.

3.2. Case All_RB_Reuse

Figure 3 shows that the D2D UE(s) reuses all the uplink frequency resources with the cellular network system. Due to this, a considerable amount of interference is introduced in the channel.

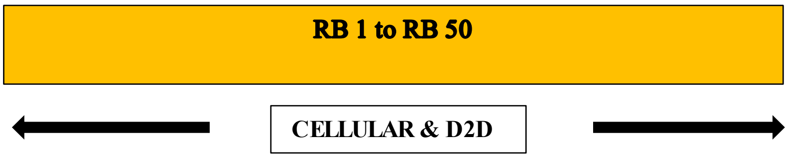

Fig. 3. All_RB_Use.

3.3. Case 10_RB_Reuse

Figure 4 shows that the D2D UE(s) reuses 10 RB(s) of the cellular network. Whereas Cellular UE(s) use all RB(s). The amount of interference here is decreased considerably.

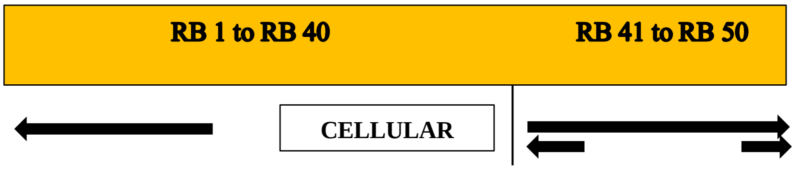

Fig. 4. 10_RB_Reuse.

3.4. Case 10_RB_Sep

Figure 5 shows that D2D UE(s) utilizes dedicated 10 RB(s) of uplink frequency resources of the cellular network. The remaining 40 RB(s) are dedicated to Cellular UE(s). It implies that the RB(s) of D2D and cellular UE(s) are orthogonal. So, the interference further reduced, and the throughput is increased correspondingly.

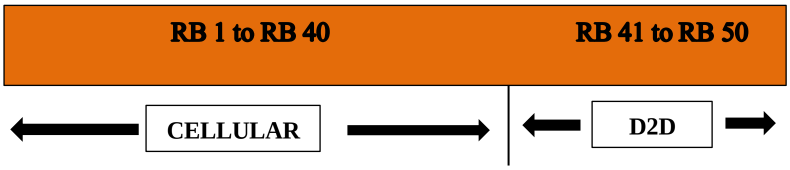

Fig. 5. 10_RB_Sep.

4. Proposed Methodology

According to the existing methodologies and algorithms, an orthogonal distribution of the frequency spectrum between the cellular UE(s) and D2D UE(s) gives the maximum throughput, not only for the cellular UE(s) and D2D UE(s) but also for the cell-edge users. This in turn has led to an augmentation in the overall system throughput thus indicating a better utilization of the licensed spectrum available for the network. However, there is still a scope to mitigate the interference experienced by the system. The proposed methodologies incorporate allocation of resource blocks to the system in such a way that it further reduces the interference and increases the throughput of D2D communication system without disturbing the throughput of cellular users and cell-edge users. Figure 6 shows the distribution of usage of the RB(s) in such a way that the cellular UE(s) use 40 RB(s), whereas the D2D UE(s) use 10 RB(s) dedicated to them. Simultaneously, the D2D UE(s) are also allowed to use the left-over channel resources from the 40 RB(s) which is given to the Cellular users.

As we have seen in the previous case, 10 resource blocks are specially allocated for D2D communication system whereas the remaining 40 resource blocks are allocated to the cellular users in the network. As a result, the D2D pairs lying within proximity of each other or assigned the same resource block, encounter some interference that affects their throughput adversely. Based on the results of Case 10_RB_Sep, we choose D2D pairs to reuse 40 RB(s) with cellular UE(s). The block diagram for the proposed Test_Case is depicted as follows:

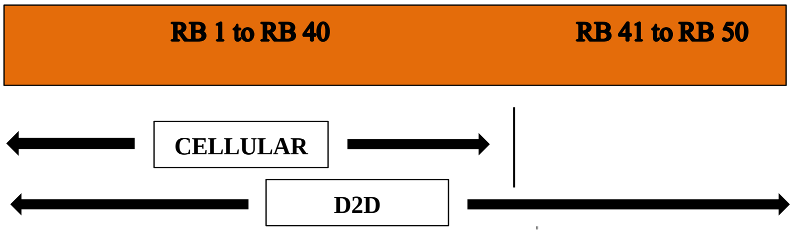

Fig. 6. Proposed Test_Case.

4.1. Proposed Test_Case_1

In this Proposed Test_Case 1, D2D pairs having minimum throughput to reuse the 40 RB's of cellular UEs. The constraint is that it utilized the RBs of Cellular UEs which are far away from each other. The rest of the D2D pairs are utilized the 10 RBs.

4.2. Proposed Test_Case_2

In this Proposed Test_Case 2, D2D pairs having maximum throughput to reuse the 40 RB's of cellular UEs. The constraint is that it utilized the RBs of Cellular UEs which are far away from each other. The rest of the D2D pairs are utilized the 10 RBs.

5. Results and Discussions

The simulation parameters are shown in Table 1. The proposed test case results were compared with the 10_RB_Sep case (i.e., best case of the pre-existing scheme). Simulation is performed in single-cell environment and UEs are randomly deployed in the cell and D2D pairs are separated by maximum range to meet the QoS. The total number of RB's is 50.

Figure 7 shows the average throughput of cellular users. The basic case is referred as first case, where the resources are utilized by only cellular users, and resources are not allocated to D2D users. So, throughput increases because there is no interference between D2D users and cellular users. The All_RB_Reuse is referred to as the second case, whereas all the resources are shared by cellular users and D2D users, so interference increases, and throughput decreases as compared to the first case. The 10_RB_Reuse is referred to as the third case. In the third case, 10 RBs are dedicated for D2D users whereas total RBs (i.e., 50 RBs) are utilized by cellular users due to orthogonality between them the interference is minimum, and throughput is increases when compared to the second case. The 10_RB_Sep is referred to as the fourth case. In the fourth case, there are dedicated 10 RB's for D2D users, and the remaining 40 RB'S are dedicated to cellular users. So, resources are shared properly then interferences were minimized, and throughput increased compared to the third case and equal to the first case.

Table 1. Simulation parameters.

	Values
Cell Radius	500 m
Range of D2D Communication	10 to 20 m
System resources	Uplink
D2D UE Transmission Power	20 dBm
System bandwidth	10 MHz
Carrier frequency	2 GHz
Number of Cellular UE(s)	210
Number of D2D pairs	21
Noise Power	-104 dB
Cellular UE Transmission Power	23 dBm

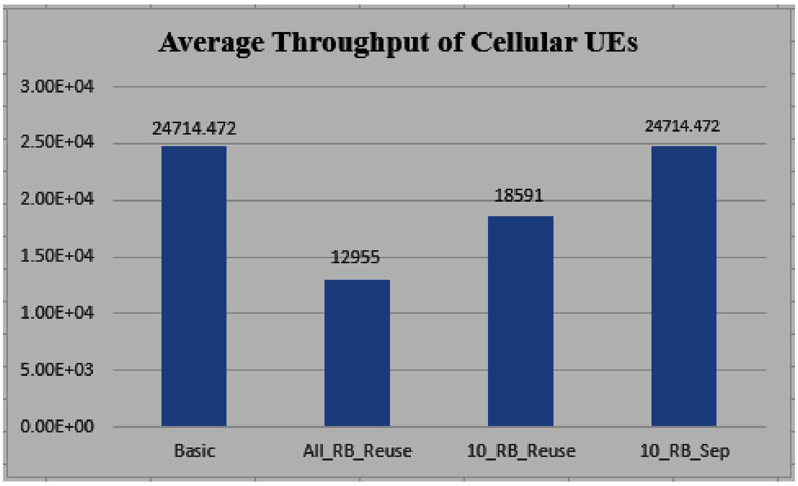

Fig. 7. Average throughput of cellular users.

Figure 8 shows the average throughput of D2D users. The first case was not considered because D2D users are not present, i.e., only cellular users. Throughput analysis has been done for the second case, third case, and fourth case. The fourth case (10_RB_Sep) case provides high throughput when compared to all the cases because of dedicated RB's between D2D users and cellular users.

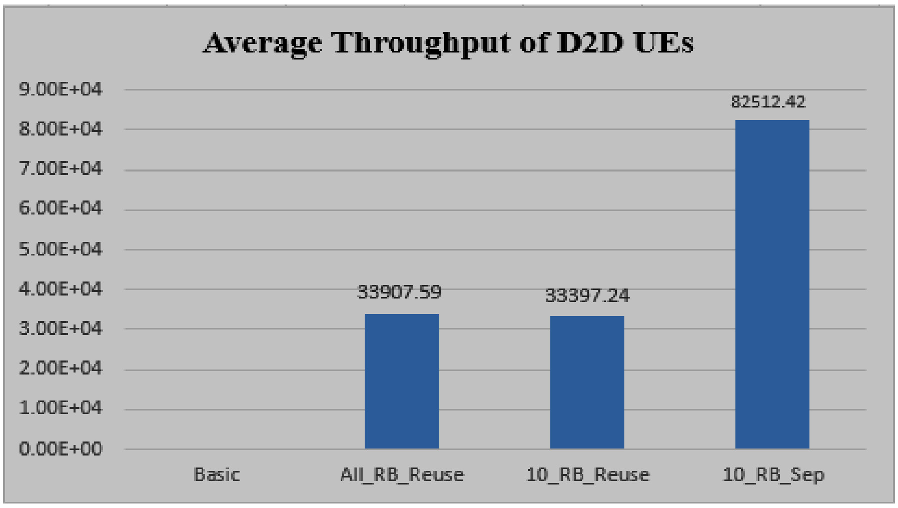

Fig. 8. Average throughput of D2D users.

Figure 9 shows the average throughput of the overall system, i.e., combination of average throughput of cellular users, average throughput of D2D users, and the average throughput of cell-edge users. The fourth case (10_RB_Sep) provides better throughput than other cases because of the proper sharing of resources. If resources are shared properly then interferences were minimized, and throughput was increased. Further, the proposed test cases are compared with the best case, i.e., fourth case (10_RB_Sep).

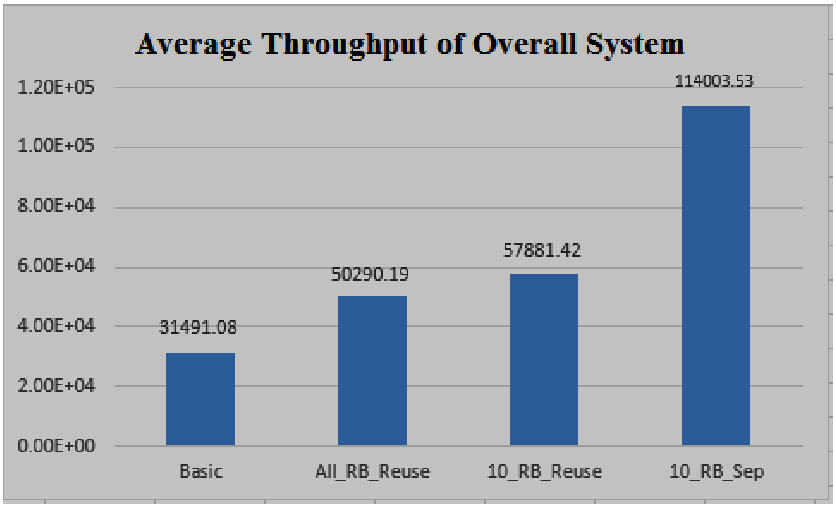

Fig. 9. Average throughput of overall system.

Figure 10 shows the average throughput of cellular users for the fourth case (10_RB_Sep), proposed Test_Case_1, and propose Test_Case_2. It shows that the fourth case (10_RB_Sep) and Test_case_1 and Test_Case_2 are same throughput. Because the resources are orthogonal to each other, so no interference between them.

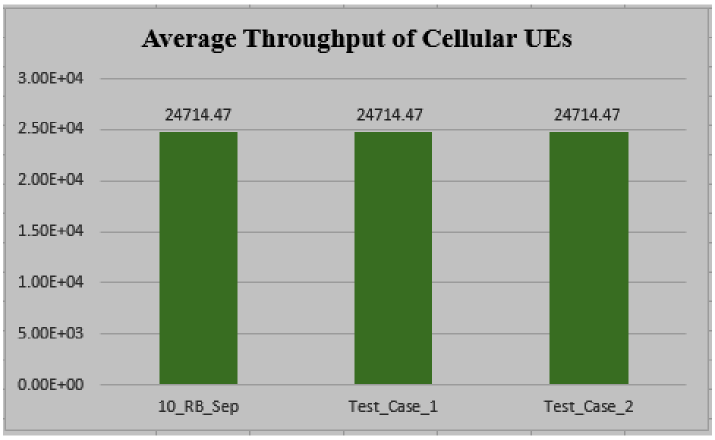

Fig. 10. Average throughput of cellular users with proposed test cases.

Figure 11 shows the average throughput of D2D users for 10_RB_Sep, Test_Case_1, and Test_Case_2. The fourth case (10_RB_Sep) is minimum throughput compared to Test_Case_1 and Test_Case_2. Because Test_Case_1 and Test_Case_2 are effectively utilized the cellular resource along with existing D2D resources. But the fourth case (10_RB_Sep) utilized only 10 RBs which are allocated to D2D users, so throughput is decreased. The Test_Case_1, minimum throughput D2D users utilized the resources of cellular users but it is not much effective, so throughput is increased by approximately 3% when compared to the fourth case (10_RB_Sep). The maximum throughput of D2D users utilized the resources effectively, i.e., more resources are allocated so throughput increased by approximately 11% when compared to Test_Case_1.

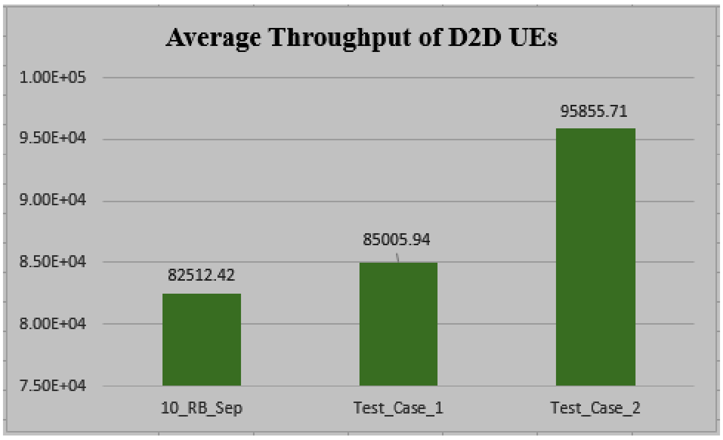

Fig. 11. Average throughput of D2D users with proposed test cases.

Figure 12 shows the average throughput of the overall system for 10_RB_Sep, Test_Case_1, and Test_Case_3. In this analysis average throughput of cellular users, the average throughput of cell-edge users, and the average throughput of D2D users are considered. In this analysis, the Test_Case_2 provides higher throughput than Test_Case_1 and the fourth case (10_RB_Sep) because of the effective utilization of resources.

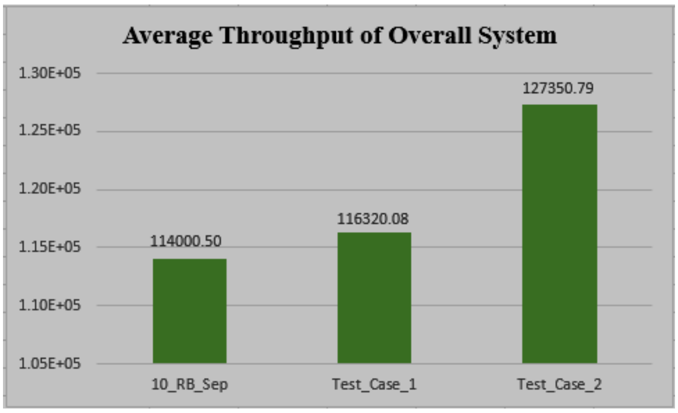

Fig. 12. Average throughput of overall system with proposed test cases.

6. Conclusion

In this paper, the channel utilization of D2D users was analysed. In the proposed method, 40 RB's are dedicated to cellular users, and the remaining 10 RB's are utilized by D2D users. To effective usage of resources, D2D users have utilized the cellular resources which are not used by them. In this Proposed Test_Case 1, D2D pairs having minimum throughput to reuse the cellular resources, but in this Test_Case_1 D2D users are not utilized the cellular resources effectively so throughput increases marginally when compared to fourth case (10_RB_Sep). In the proposed Test_Case_2, maximum throughput of D2D pairs is reuse the resources of the cellular, whereas D2D users are utilized the cellular resources effectively so the throughput increases when compared to proposed Test_Case_1. From the simulation t of proposed Test_Case_1 and proposed Test_Case_2, it is observed that if the proper utilization of resources between D2D users and cellular users then the cell edge users' throughput also increases marginally. If the throughput of the cell edge users is increasing then interferences of the system are minimized. In the future, a joint power control algorithm to be implemented in the network then system throughput further increases.

Nomenclatures

f_c	Carrier frequency, GHz
g_{de}	Gain between the dth D2D pair and the base station
g_{ke}	Gain between the kth cellular UE and the base station
l_o	Distance between D2D and UE(s), m
p_d	Transmission power of dth pair
$p_{d'}$	Transmission power of d'th D2D pair
p_k	Transmission power of kth cellular UE
PL	Path loss
Υ_k	Channel rate of kth cellular UE
Υ_t	System sum rate for uplink phase

Greek Symbols

σ^2	Noise power at the receiver

Abbreviations

BS	Base station
D2D	Device-to-Device
LTE-A	Long Term Evolution - Advanced
ProSe	Proximity-based services
RBs	Resource blocks
UE's	User equipment's

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