Facilitate Device to Device Communication Using Cellular Networks: Challenges and Performance Aspects

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Abstract— Cellular networks facilitate the most important aspect of human life, communication. There is a serious need to cater to the tremendous growth of traffic on these networks; Device-to-Device (D2D) communication using cellular network attempts to provide answers to the above problem. D2D communication ensures high spectral efficiency by directly connecting devices without hopping through the base station. There is a herculean growth in some cellular applications like distribution of content, data download, control function, and switching function with cellular networks in D2D communication. Cellular networks share resources using uplinks and downlinks. This paper looks at how D2D communication takes place using these sharing methods and consequently will analyze the associated performance issues. This paper assesses the allocation problem to maximize network with spectral efficiency, power efficiency, performance with quality-of-service (QoS) among both the D2D users and cellular users (CUs). The paper also discusses interference management, multihop D2D communications, and D2D interchanges in heterogeneous systems with an effective performance evaluation.

Index Terms— D2D communications, Quality of service (QoS), Cellular users (CU), and multihop.

1 Introduction

In order to meet the current needs of telecom users, mobile administrators are continuously trying to come up with new technology. The current technology, while meeting the demands for the time being, will not be able to keep up the pace with the rising number of mobile users. One of the innovative ideas that promise to deal with efficiency problems is Device-to-Device communication.

Basic idea behind D2D communication- The communication rather than passing through the Base Station (BS) as shown in Fig. 1, takes place in a direct fashion among the devices.D2D may either use cellular uplink or downlink for the communication. [1].

Problem- While traditional cellular users are usually distant and cannot have direct communication; this architecture usually benefits the BS where the data rate is low and in turn conserve cellular spectrum. But due to the sudden shift of most of user activities on cell phone, the data rate has substantially increased. The activities like sharing, gaming and so on which takes place potentially in close proximity can be achieved through D2D communication.

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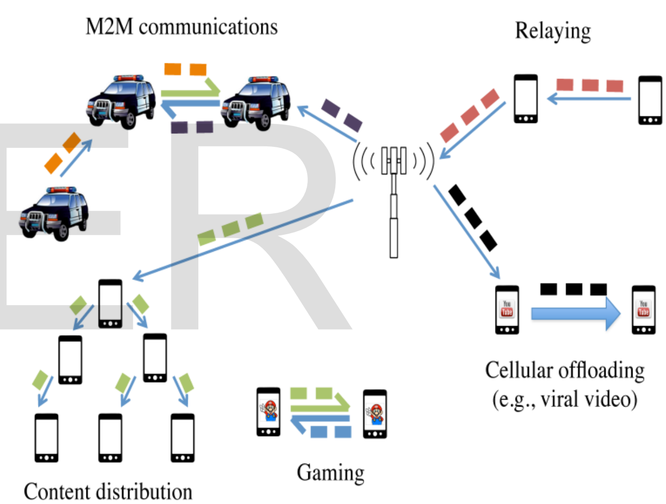

Fig 1. Delegate utilizaton instances of D2D correspondences in cellular network [1]

Advantages – Improving spectral efficiency is one aspect of D2D communication. By controlling the interference level, the radio spectrum can be accessed very quickly. It also improves the overall energy efficiency, throughput and helps in achieving various gains, including proximity, pairing and hop gain.

History – The paper “Multihop cellular: A new architecture for wireless communications” [2] first discussed D2D communication. The papers – “Cellular Networks with an Overlaid Device to Device Network and Interference avoidance mechanisms in the hybrid cellular and device-to-device systems” [3] then targeted the improvement of the spectral efficiency of the cellular network. Qualcomm’s FlashLinQ first attempted to come up with D2D communication under laying cellular networks [4].

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When D2D communication takes place along with the cellular communication, as shown in Fig. 2. – underlay in band, several issues are encountered –D2D communication interference must not reduce the quality of the traditional cellular users. Some researchers suggest that a fraction of the cellular resources be solely allocated to D2D communication – overlay inband [5]. Other researchers also suggest adopting outband so as not to waste any of the cellular resources. In this method, the radio interference is managed by the BS.

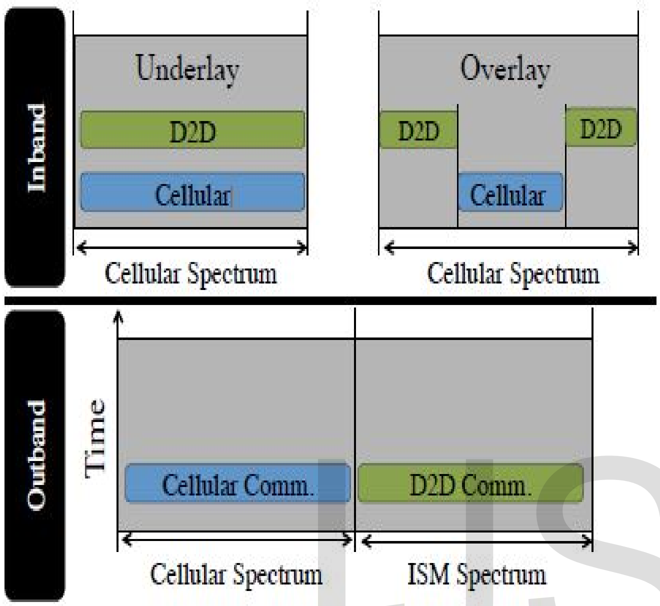

Fig2. Types of inband and outband in cellular Networks[1]

2 SETTING UP D2D SESSION

The first step for any device to establish a connection with anotherdevice is discovering a peer device. A user can manage the mode of their own device by keeping it in the open or the restricted mode. In the open mode, a UE, as long as it is in the proximity of the other device, can be detected. This leads to a very simple device discovery mechanism. In the restricted mode, a device cannot be detected by any other device unless it is grantedthe permission to do so. This helps to maintain the privacy of the user [6].

With respect to the network, UE discovery can either be a tight or a light BS control [7]. In the tight BS control approach, the user who wants to initiate the service first transmits its discovery data and specifies the intended target that will receive that data. In the light BS control, the BS does not broadcast the resources and the discovery data in a continuous fashion, but rather in a periodic fashion. The interested users can then connect via the discovery data they receive.

The next step is setting up the D2D session. After the discovery phase, in order to maintain and control the connection, the D2D users need to establish D2D sessions. This can be done by two methods as discussed in [10], IP-based detection and dedicated D2D signaling.

3 RELATED WORK

A general idea embodies a cell arrangement in which client gadgets can correspond with one another, either by means of method for routine cell mode or through method for direct D2D correspondence [2]. At the end of the day, a D2D characteristic is coordinated into the cell system operation so that the radio assets of the cell system are utilized for both correspondence modes and are controlled by the BSs or other system components.

Since D2D correspondence is another drifting subject in cell systems, there is no review accessible on the theme. Be that as it may, from a design viewpoint, D2D correspondences may appear to be like Mobile Ad-hoc NET works (MANET) and Cognitive Radio Networks (CRN). Albeit there is no standard for D2D correspondences, in cell system are required to be administered/controlled by a focal element (e.g., developed Node B (eNB)). D2D clients may act self-ruling just when the cell framework is inaccessible [3]. The contribution of the cell organized in the control plane is the key contrast in the middle of D2D, and MANET and CRN. The accessibility of an administering/overseeing focal element in D2D interchanges determines numerous existing difficulties of those such as white space identification, crash shirking, and synchronization [8].

In addition, D2D correspondence is essentially utilized for individual bounce correspondences; hence, it doesn't acquire the multihop directing issue of MANET [9]. A broad study on range sensing calculations for cognitive radio applications also directing conventions for MANET can be found in also [10], individually. Multi device-to-Multi device (M2M) correspondence [11] is an alternate construction modeling that may advance from D2D-like plans. M2M is the information correspondence between machines that does not essentially require human association. Despite the fact that M2M, similarly to D2D, concentrates on information trade between (various) hubs in the middle of hubs and base, it doesn't have any prerequisites on the separations between the hubs [12]. In this way, M2M is application-situated and innovation free while D2D goes for vicinity integration administrations and it is technology dependent.

In 3GPP LTE particulars, UEs are dispensed with a particular number of subcarriers for a foreordained time span, which are alluded to as physical asset pieces (PRBs) [12]. Every PRB is equivalent estimated and characterized as comprising of 180kHz in the recurrence space with 12 sequential subcarriers (subcarrier dispersing of 15 kHz) and one space (0.5 msec) in the time span. A PRB is the littlest component of asset assignment by the eNB. At the point when a D2D combine needs to impart under laying a cell system, how to apportion cell assets to the D2D transmission is discriminating following the obstruction to other essential CUEs which ought to be kept beneath a certain level while the D2D correspondence likewise needs to be satisfied with quality [13]. Asset designation ought to be mutually considered with mode determination, that is, whether the system can permit some channel assets to the D2D match, and assuming this is the case, whether some committed PRBs or some imparted PRBs the D2D pair will acquire [14]; on the off chance that it is an imparted case, which cell UEs' asset squares ought to be imparted to this D2D pair; in the event that it is a committed case[15], what number of PRBs ought to be allowed for this D2D correspondence. Then again, rather than unified asset distribution, in which the eNBs take full obligation in controlling/dispensing the assets of D2D interchanges, asset distribution might likewise move ahead in an appropriate way. On the off chance that D2D correspondence is great between two UEs, the UEs need to sense the system environment, get to the cell assets without creating unsafe impedance to the CUEs, and illuminate the eNBs of D2D asset occupations[16].

The D2D is situated as pair to boost the quantity of allowed D2D correspondence matches in a framework in the interim maintaining a strategic distance from the solid obstruction from D2D correspondence to the cell correspondence [2]. In a genuine situation the quantity of the D2D correspondence pair is alter and irregular. The creators consider how helpful accomplice determination can be advanced in an irregular client situating environment [17]. Deterministic outflows are determined for theideal number of helpful accomplices as a capacity of the channel qualities.

4 CHALLENGES

D2D communication over WiFi and Bluetooth can be managed easily, as the connection activation and handling can be manually done by the users; moreover, the users are not much concerned about the privacy and security of the data[18]. Also, these individual D2D pairs do not acquire much density which further curbs unnecessary interference.

In a controlled environment, D2D communication using cellular networks provide much better services; however, it also brings with it many challenges. The cellular capacity can be increased tremendously by reusing the spectrum resources and by facilitating the distance between the UEs in connection[19]. Hence, by offloading much of the traffic from the central BS, we can take advantage of high data rate which is localized. As D2D communication takes place in close proximity, the CU power consumption can be reduced and hence, the battery is better conserved with D2D communication.

Major Challenge – In order to establish and maintain connections, these D2D communication devices need to constantly discover each other[20]. This leads to high interference and thus building a huge D2D area which is a challenging aspect[21].

Other challenges include managing the power consumed by the communicating devices, discovering devices, device data synchronization, and security of the transmitted data. Also, the data transfer or the session should be seamless.

Therefore, a standard D2D model that provides a standard protocol, a device lookup method, applications, design and security aspects are required[22].

As discussed, based on how the cellular spectrum is used, a decision can be made regarding how D2D communication takes place.

The inband D2D suggests that the cellular spectrum can be used for both, the cellular as well as the D2D communication.

The inband underlay in which both modes of communication share the same radio resources, that is, reuses the spectrum resources and hence enhances the spectrum's efficiency.

On the other hand, although the inband overlayuses the cellular spectrum, it is given defined cellular resources. This helps to facilitate direct connection betweenthe transmitter and the receiver.

Advantage- there is a high control over the cellular spectrum.

Disadvantage- as D2D and cellular users share the same spectrum, it is susceptible to high interference.

Solution - the inference can be lessened at the expense of increasing the computational overhead of the D2D users as well as the BS. The disadvantage can be mitigated to some extent by using good resource allocation schemes.

The outband D2D suggests that D2D communication takes place in an unlicensed spectrum as opposed to the licensed cellular spectrum. This can be achieved by using certain wireless technologies such asBluetooth that works on the unlicensed spectrum. Hence, this mode requires an additional interface for communication. Thus, in order to give the control of this new interface to the cellular network or to leave it up to the D2D users is debatable[23].

Advantage - the interference level drops substantially.

Disadvantage - the interference in an unlicensed spectrum is not fully controllable which can threaten QoS.

The manner in which the network discovers a device in the "Setting up D2D Session" is discussed in this section. Though the tight BS control enables a brisk and a good user discovery, it also produces a high signal overhead at the BS. Though the light BS control does not burden the BS, it lacks the efficiency provided by its counterpart, tight BS control. In this scheme, the UE devices need to wait for the discovery data from the peer UE devices in order to transfer their own resources.

5 PERFORMANCE ANALYSIS

The system level simulations depicted further determine the optimum and practical capacities of the system in a D2D communication. A comparison of the results is carried out with respect to the cellular communication [8].

A. Simulation Model, User Distribution and Simulation Parameters[8]

Each network has a BS and a sector.Simulation parameter per device is theprobability for devices communicating locally.Devices without any local communicating peer are distributed uniformly over the system area. According to the device index, the two consecutive devices that are locally communicatingform a pair.One of devicesfrom the pair is distributed uniformly over the system area whereas the other device of the pair is distributed uniformly upon a disk(centered by the first device) and the radius of the disk isgiven as another simulation parameter. Thus the radius is the maximum distance between devices communicating locally.

All the simulation parameters are depicted in Table I.

B. Simulations (Numerical Analysis)[8]

System capacities are analyzed against system outage:

Cases:

CELLULAR All devices are in cellular mode that is, there is no availability of D2D communication mode.

OPT D2D Mode selection vector for all devices is searched in order to minimize the first norm of the device powers combined

Parameter	**Value**
Cellular layout	Isolated cell, 1-sector
System area	User devices are distribut-

	ed withina range of 500 m from the BS
Path loss model for cellular link	128.1 + 37.6log10(d[km])[14]
Path loss model for D2D link	148 + 40log10(d[km]) [14]
Shadow fading standard deviation	10 dB for cellular mode links and12 dB for D2D mode links [14]
Noise spectral density	-174 dBm/Hz
System bandwidth	5 MHz
Noise figure	5 dB at BS / 9 dB at device
Minimum coupling loss	70 dB BS-Device / 40 dB Device-Device
Antenna gains and patterns (transmitter and receiver)	BS: 14 dBi Device: Omnidirectional 0 dBi
BS: 14 dBi Device: Omnidirectional	BS: 14 dBi Device: Omnidirectional
Processing gain	Cellular 30 / D2D 15
Probability of local communication per device	0.2, 0.4
Maximum distance between locally communicating devices	5, 50 [m]

Table 1. Simulation parameters

over two time slots (18) and to fulfill eigenvalue criteria.

PL D2D D2D mode is selected if path loss between communicating devices is less than minimum of path losses between each device and BS.

FORCE D2D D2D mode is selected always for locally communicating devices.

In Fig. 3 the system capacity can be obtained in terms of the number of users in the system for the following parameters:

Outage probability: 5 %

Maximum distance between locally communicating devices: 50 meters

Local communication probability: either 0.2 or 0.4.

Inference: when the maximum D2D distance is quite large,the potential improvement available from D2D capability in the system is not much. The available performance improvement increases as a function of increasing local communication probability. Likewise,it can be inferred that using path loss based or forcing all locally communicating devices into D2D communication mode will not yield much results in this case. The situation worsens as local communication probabilityincreases. This happens as these methods do not consider the interference situation[8].

Fig.4 depicts the impact of decreasing the maximum distance between locally communicating devices where the maximum distance is 5 meters. It can be judged that even PL D2D and Force D2D give good results, almost reaching the achievable upper bound. In addition to gains with OPT D2D method, as the local communication probability increases, gains with two other mode selection methods also increase[8].

Inference-a mode selection algorithm should be such that it could first check if the path loss or link gain between locally communicating devices were below a certain threshold. The algorithm could then further use PL D2D to decide the used communication mode for the D2D pair in question. Also, in a system where devices share the same radio resource, the PL D2D algorithm could be based on interference awareness in which interference measurements from devices could be used for mode selection especially in the case of the large maximum distance between communicating devices[8].

System outage - probability that eigenvalue criteria of the interference matrix [13] cannot be fulfilled.

To study capacity in a cellular network we are mainly interested in to find the capacity when the system outage is around 5%. We simulate the system realization via means of multiple independent drops and by averaging over the drops we can derive the probability for the eigenvalue criteria with certain parameter settings. The obtained probability is considered as the system outage [8].

Fig. 3. System capacity at 5th percentile of the system outage for different mode selection algorithms compared to pure cellular communication mode system. [8]

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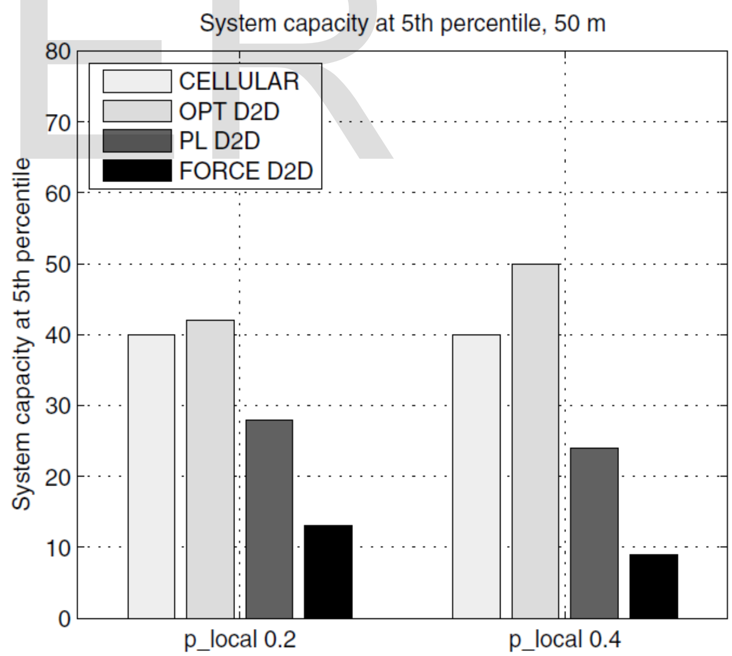

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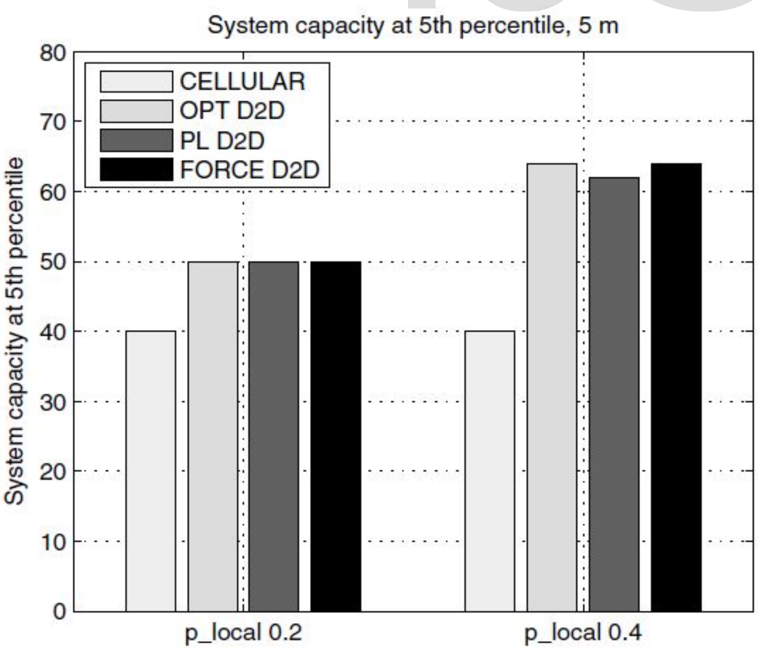
Fig. 4. System capacity at 5th percentile of the system outage fordifferent mode selection algorithms compared to pure cellular communicationmode system.[8]

6 RESULT

A system equation was derived, which can be used to analyze and evaluate a system where both the modes of communication exist. In order to prevent D2D technology's hindrance to the pure cellular network, communication mode algorithms should be devised keeping all the parameters in mind. According to the performance analysis results, the major affecting factors for the performance gains from the D2D are maximum distance between communicating devices, the local communication probability and the mode selection algorithm [8].



7 FUTURE SCOPE

As an extension to D2D communication in the cellular network, multi-device-to-multi-device (MD2MD) communication is advanced for effectual multimedia matter to be allotted, this can not only beat the drawbacks of D2D communication (if any). Mostly, with the MD2MD communication we can distribute the data with higher efficiency and more security.

8 CONCLUSION

In this article, a technology that has the potential to revolutionize cellular communication was discussed. Various facets of D2D communication were discussed in this article. Some the topics addressed includes communication spectrum of D2D transmission, setting up of a D2D connection, some of the related works in this technology etcetera. The paper mainly focusses on the challenges that are faced in the D2D communication and also describes a way to evaluate the performance of this technology. An extension of D2D, multi-device-to-multi-device upholds a great significance for future research as it covers a larger area and provides more stability than the D2D communication. D2D communication in a cellular network can be enhanced by tackling the challenges discussed in the paper.

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