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A Survey of Device to Device and Cooperative Communication for the Future Cellular Networks

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Abstract
Device to Device and Cooperative communication are the two new emerging technologies in the new era of communication technology which differ from the existing cellular technology. In review article we have enlisted different technologies which play a very important role in third Generation Partnership Project (3GPP). In this paper we have studied the various techniques of resource allocation, Mode selection for underlay communications in terms of device to device and cooperative communication techniques in terms of Long Term Evolution and Long Term Evolution-Advanced platform. A new technique LTE-Advanced Pro has also been introduced by 3GPP. Various simulators including Vienna LTE-Advanced have also been discussed. Better utilization of the spectrum is also depicts which is done on the basis of analysis if proper resource allocation whether it is power, frequency or time and mode selection is done in the programmed manner which would result in the reduction of interference and it will also lead to the secure system.

Keywords Cooperative communication · Stochastic geometry · 3GPP · LTE-A · Exabyte

1 Introduction

The communication named device to device communication (D2D) refers to a kind of new emerging technology with the short range through which devices can communicate directly to each other. Two kinds of communicating techniques are available which are already working in Industrial, Scientific and Medical (ISM) band namely Bluetooth and Wi-Fi direct. D2D communication doesn't require any infrastructure such as base stations and access points, therefore operators are thinking to design new business models for D2D communication without purchasing extra spectrum as it provides commercial, emergency and proximity services [1]. In traditional wireless cellular system, devices are not allowed to communicate directly with each other as all communication access through base stations [2]. With the evolution of 4G and 5G the traffic growth of almost 30 times has been predicted, therefore by 2019, more than 10 Exabyte's of traffic growth per month will be circulating across cellular network. Dynamic cooperative transmission policy provides switching system as user can switch between different D2D nodes and regular cellular communication as desired [3]. Wireless communications had been evolved in the early 90's, which introduced digital cellular technology. The approach to achieve high speed data networks the deployment of 3G has been done in 1997 by ITU [3, 4]. The development of the standards, the third generation project partnership (3GPP) had started working in LTE systems in release 8 publications/specifications. Release-8 includes High Speed Downlink Packet Access (HSDPA) and High Speed Packet Access (HSPA) with the involvement of OFDMA as air interface. 3G femtocells and different characteristics were specified such as Down Link Peak Rate (DPR), Uplink Peak Rate (UPR), Downlink Spatial Layer, Modes, Bandwidth (BW) and Maximum transmit Power [3–5]. LTE was included for the reduction in cost per bit, flexibility to use new and existing bands, open air interfaces, low power consumption, congestion control and enhanced coverage. Therefore, the current LTE devices are able to achieve peak data rates of 150 to 300 Mbps [4, 5], which has given birth to the utilization

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of Internet of Things (IOT). As the work had already been started by 3GPP for LTE-A in release-9 and 4G is defined as radio interface technology. The two spectrum approaches in D2D communication takes place is the spectrum underlay in which reuse technique can be utilized by the cellular transmitters and overlay technique involves where the portion of spectrum is unutilized and can be used for increasing the transmission capacity and throughput [5]. The major considerations were on the basis of ITU requirements for 4G and 3GPP operators are as given below:

- Continual improvement to the LTE radio technology and Architecture.
- Scenarios and performance requirements for introducing heterogeneity with legacy Radio Access Technology (RAT's).
- An LTE terminal should be able to work in the LTE-A Network and vice versa.

Figure 1 is illustrating the basic device to device communications for different applications. To ensure that LTE-A can geographically accommodates the available spectrum for channel allocation above 20 MHz Therefore, for LTE-A, the requirements for peak data rate by ITU is 1Gbps and can be achieved with 4×4 MIMO and transmission BW's near to 70 MHz. Thus, the work of LTE-A is focussed on real challenges of raising average and cell performance [4, 5]. With the evolution of 3G, 4G and beyond 4G technologies (B4G), this rapid evolution is the eternal process with 5G technology and which is expected to start by 2020. Actually, the 3GPP technology has already started working on this and this had been defined in the various releases and enhanced D2D proximity service is released by 3GPP in release 13. This new technique will enhance the radio capabilities and enable new applications which will be far- far differ from the traditional smart phones, tablets and other devices. So, the commercial era is focussing on reliability in terms of more network coverage, performance characteristics which need to match all these requirements [3, 5].

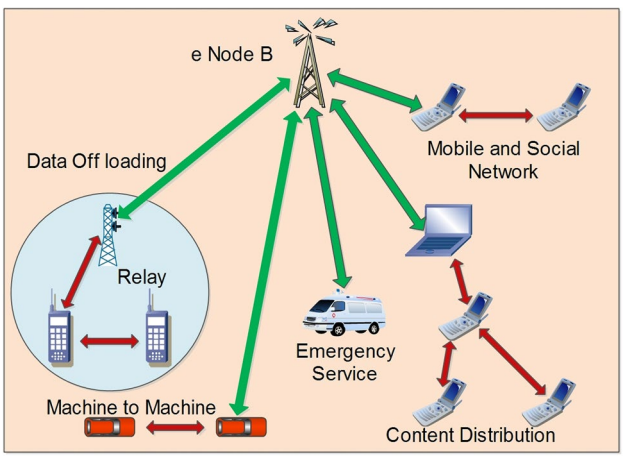

Fig. 1 Illustration of device to device communication for different applications

With the rapid changing technology from the period of 1G to 4G, it can be characterized by the shift in channel access method. Therefore, the hierarchy involves the growth from Frequency Division Multiple Access (FDMA) to Time Division Multiple Access (TDMA) and then switching to Code Division Multiple Access (CDMA) and finally to Orthogonal Frequency Division Multiple Access (OFDMA) with the improvement in different coding schemes and modulation techniques. Therefore, it includes variety of protocols, different kind of frequency bands and network types [6]. The D2D communication technique has become a hot research topic recently due to its benefit of offloading data traffic at the base station in cellular networks. D2D communication supports peer to peer, cooperative and Multihop communication that operates in an underlay networks [7].

The worldwide researcher from industry and academia are influenced by this technology and extensively explores the potentials and challenges of D2D communication in different areas which signifies that by 2020 it will be a mature technology and Support 5G technologies. In this paper we provide a comprehensive survey of available D2D and Cooperative Communication related papers. Also, we have provided information on 3GPP and METIS project activities which helps the researchers to understand the emergence of D2D and CC technology. The question for pricing mechanism has been raised and emphasized that pricing models are to be designed. Auction theory is considered to model the price mechanism. Another approach is the game theory is used for allocating resource allocation schemes in the interference limited environment which works in an intelligent manner. In terms of applications, D2D will play an eminent role in mobile cloud computing and facilitate the access to share resources that are close to each other [2].

In [8], Modelling of radio interface technique Long Term Evolution-A (LTE-A) has been done through Network Simulator-2 (NS-2) by deploying Stream Control Transmission Protocol (SCTP). Performance parameters such as throughput, congestion window and packet drops by simulating TCP–Reno, TCP–Vegas, TCP–Tahoe and SCTP Protocols. Results show that SCTP protocol outperforms than other variants of TCP. Authors of [9], studied the literature on D2D communication. Under lay In band study involves the parameters such as spectrum efficiency and Power efficiency whereas in Overlay In band doesn't involve any specific parameter. As a result D2D communication is not a transparent communication system. Autonomous and controllable network are managed by out band D2D. Although mm waves could be easily disturbed without line of sight, rather mm wave are capable to give several Gbps transmission rate

with highly directional antenna array. A coalition formation game to maximize the system sum rate in statistical average sense is proposed with the characteristic of cellular and mm wave communication. Game conversion proposed to a Nash-stable equilibrium reaches the near optimal solutions with fast converges rate [10]. Joint mode selection problem is considered through trans-receiver design problem in underlay D2D MIMO network of multi users. D2D and cellular transmissions are equally prioritized and each pair can switch between D2D and cellular mode freely. A low-complexity algorithm is designed to compute a stationary solution of the maximization problem of sum rate. With a simple closed-form update, an efficient distributed algorithm is devised in each step [11]. Device to device communication can play an important role in expanding network and routing the data between transmitter and receiver pairs has been suggested. A feasibility study is conducted to show the effect of device to device communication in increasing the rate of machine type communication devices and network coverage. A geometry based framework is shown to analyse the probability and average data rate of a M2M network to study the system performance [12]. Different cases if the conditions of channel of the direct links among D2D are not strong are investigated to support direct communication. Author considered capacity achieving lattice codes along with compute-and-forward protocol at the relay. It is also investigated that the achievable sum rate when devices communicate using the direct links. When the D2D users are closer to the relay, relay aided communication achieves better performance compared to direct communication [13]. Remainder of the survey has been organised in the following manner. Section II provides the state of art D2D communication in underlay and overlay networks for resource allocation and its management, mode selection strategies and interference management. Section III provides review on Cooperative Communication and role of 3GPP and METIS Project has been given in Section IV, Section V focuses on various performance metrics used in D2D, CC and different simulators available for D2D communication. In Section VI some open research issues are highlighted and finally concluded in Sect. 7.

2 The State of Art D2D Communication in Underlay/Overlay networks

In this section the review of the device to device (D2D) underlay and overlay communication has been presented. This section is further divided into three parts namely Resource Management Techniques, Mode selection Techniques and finally Interference Management Techniques. The major focus of the above mentioned techniques will be in the underlay techniques. So, here we present the review of the available literature on device to device by referring several IEEE special issues, IEEE Communication Magazine etc.

The device to device communication is broadly classified into two categories namely In band and Out band as shown in Fig. 2. In the In band technique Underlay device to device communication devices are only allowed to work under cellular users with the expectation to improve spectrum efficiency and thereby increasing system performance. Overlay communication works only in the vacant spectrum therefore approach is inefficient.

2.1 D2D Underlay/Overlay Communication

With the boom of smart phones and other digital consumption media's devices there is a great demand for higher data rates and network capacity. Therefore, a two tier next generation cellular systems (5G) is considered which is known as Macro cell and Device tiers. D2D communication is involved in device tiers, but the devices are able to communicate in both the scenarios i.e. with the macro cell and through device tiers. In congested areas or cell edges they are able to create an Ad hoc network. Different types of communication techniques are considered namely:

1) Relaying with operator controlled can attenuate problem of interference.
2) Direct D2D with operator controlled—Link Establishment can be cooperative and non-cooperative and this is a very challenging situation and requires supervision.
3) Device Relaying with device controlled Link Establishment and DC–DC provides access authentication, connection control, and resource allocation in terms of control and data plane by determining the link establishment.

In [14], authors suggests that for group communications, resource allocation can be designed by implementing algorithm which selects the particular devices and decides how

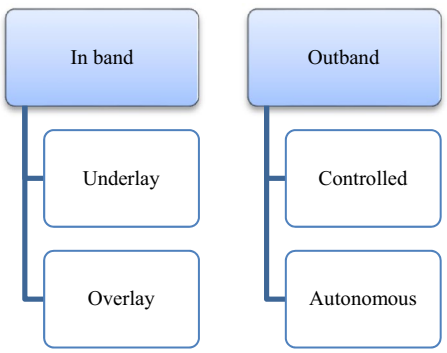

Fig. 2 Classification of bands

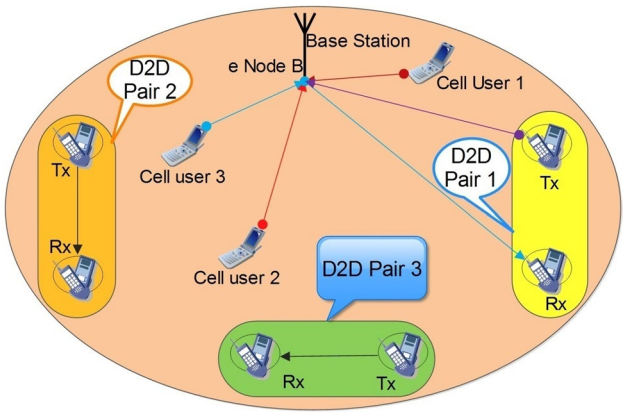

Fig. 3 Illustration of underlay D2D communications

many groups are needed for necessary and how much power is required for that group by implementing power allocation scheme. Different scenarios for frequency reuse and congestion will occur when D2D user will reuse the downlink frequency. One prime aspect they have taken that how to mitigate interference using mode selection techniques, resource allocation and power control. Another aspect considered that the lifetime of D2D networks can be extended by cooperative communication by reducing the power consumption by using resource allocation techniques.

In [15] Lei Lei et al. Studied for the D2D communications in LTE-A for the OC network. The business models for D2D communications are explored for peer to peer and for relay cases. Using peer to peer includes advantages of local data service, content sharing M2M and multicasting services. This under research D2D communication is facing the toughest problem with compared with the currently available D2D services as they are free. The relay cases involve Gateways and Cooperative systems. The technical design consideration involves the usage of unlicensed and licensed band. The unlicensed band provides uncontrolled interference as two techniques like Bluetooth and Wi-Fi are being used by the users and they operate in 2.4 unlicensed band. Licensed band can mitigate interference. Different modes i.e. D2D controlled Mode, fully controlled D2D Mode and loosely controlled D2D mode is also discussed. The D2D control here refers to access authentication, connection control, allocation of resource and lawful interception. In loosely controlled D2D mode, D2D communication use unlicensed band and operator can charge for the communication for the month for providing services and operators reserves the right to disable the facility as shown in Fig. 3. In [16], *liang zhou* presented that in 2020 mobile data will increase by 40% and D2D communication can be utilized to offload the heavy burden from traditional cellular networks. This work is related with multimedia communications. They have addressed the problem regarding transmission of heavy data

Table 1 LTE-advanced parameters comparison

Item	Release-12	Rel-13 (under work)
Downlink peak rate	1 Mbps	1 Mbps
Uplink peak rate	1 Mbps	1 Mbps
Downlink spatial layers	1	1
Duplex mode	Half duplex	Half duplex
UE receive bandwidth	20 MHz	1.4
Maximum UE transmit power	23 dbm	− 20 dbm

Table 2 Unlicensed spectrum utilization

Country	Unlicensed band range
US	5.15–5.35 GHz (UN II-1, UN II-2A), 5.47–5.725 GHz (UN II-2C), 5.725–5.85 GHz (UN II-3)
Europe	5.725–5.85 GHz
Japan	5.47–5.725 GHz
China	5.15–5.35 GHz (Indoor), 5.725–5.85 GHz (outdoor)
India	5.15–5.35 GHz and 5.725–5.875 (For low power equipment's for cellular systems, indoor applications)

Table 3 Summary of underlay techniques

Reference paper	Parameter evaluated
8	Congestion window, packet drop
9,10	Spectrum efficiency, power efficiency
15	Average throughput
16	Outage probability, signal to interference plus noise ratio (SINR)
20	Throughput, delay

via D2D. The technique includes several such as efficient video coding and proposed coding techniques such as hybrid video coding scheme and protection of data from errors. Further, they have described how to update and recommendation of different contents, how to schedule the data by employing transmission subset and cooperation transmission technique can also be adopted. Extensive simulations have been done to validate the theoretical aspects in two different scenarios such as in static and dynamic environments for the video coding, content update and claimed that this scheme is robust and outperforms (Table 1).

In [17], Sunghyun Choi described that D2D is different from machine to machine (m2m) and adapted as link layer technology. In this Flash LinQ sensors/LTE direct communication technique is elaborated, by defining different peer to peer discovery techniques such as broadcasting as evolved node b (enb) broadcasting beacon assignments, client server token case, registration and ip address analysis case. Peer to

Table 4 Summary of resource allocation techniques

S. no	Objective/parameter	Tool used	Platform	Evaluation	Conclusion
1	Resource scheduling in hetnets [28]	Dynamic programming model	LTE	Numerical	Low cost alternative to microcells in supporting traffic with little energy consumption
2	Location information based D2D resource allocation [29]	Position estimation methods	LTE	Monte Carlo simulations	Positioning errors has nonlinear effects on throughput of D2D users
3	Time division scheduling resource allocation [30]	Random TD algorithm		C-language	Claimed that the proposed TDS algorithm played a vital role for the increase in system throughput and D2D user satisfaction ratio
4	Spectrum sharing [31]	Resource and Power allocation algorithm, Proportional fairness algorithm		Numerical	Aims to maximize the weighted sum rate of D2D and cellular links with the implementation of orthogonal spectrum sharing algorithm
5	Energy efficient resource allocation [33]	Distributed coalition formulation algorithm		Numerical	Developed an analytical model for energy efficiency and claimed that the proposed algorithm provides stability and improvement
6	SC- FDMA based resource allocation and Power control scheme [34]	FFR Schemes	LTE-A	Numerical, C-based system level simulations	Improves overall cell capacity
7	Resource allocation scheme in terms of power and channel allocation for D2D communications in heterogeneous networks [35].	Stackelberg game frame work		Computer Simulations	Interference management and fairness is considered and claimed that the implemented algorithm is able to achieve increased transmit rate
8	Power and Channel allocation [36]	Greedy channel allocation algorithm		Numerical simulations on MATLAB 7.9.0	Algorithm is proposed to solve the non convex power allocation problem in order to achieve higher gain in system throughput
9	Resource allocation problem in network assisted D2D communication [37].	Message passing approach	LTE-A network	MATLAB	Claimed that system performance has been increased and provides better data rate with small increase in e2e delay
10	Allocation of multi-operator D2D communication [38].	Strategic non cooperative spectrum game		Numerical simulations	Operators may achieve significant performance gains
11	Novel resource allocation for both joint resource and power control [39].	Column Generation Algorithm, heuristic algorithm	LTE-A	MATLAB simulations	With the aim to maximize the spectrum utilization and addressed two issues i.e. interference and QoS for D2D links
12	Technique for resource allocation in D2D communication [40].	Optimized resource allocation method	LTE-A uplink system	System Level Simulation	Improved the performance of cell edge users by increasing the system gains while throughput of the system decreases a little and limits the interference
13	Resource allocation in multicell cellular system [41]	Cooperation Mechanism, Robin round scheduling algorithm	LTE network	System level simulation	Claimed that proposed scheme can improve the performance of cell edge users and cell capacity will increase

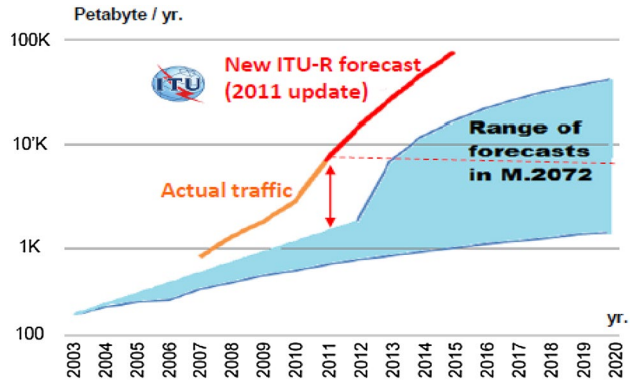

Fig. 4 Traffic growth difference [18]

peer discovery process involves the discovery of the devices up to miles and it is capable to handle numerous devices at a time and most of all privacy is maintained. In [18], Tata consultancy Services (TCS) Research networks lab, Bangalore, India, has raised certain challenges as per the Fig. 4 about the massive growth of traffic and corresponding the traffic, wide range of application and their requirements are also discussed. According to them the current statistics about 7,36,654 BTS are available in India and if release of more spectrum and more installation of BTS is done it will give more hike to capital expenditure (CAPEX) and operating expenditure (OPEX) and also shared that still theoretical limits have been achieved but not practical, as yet to deploy LTE Rel-8 technology.

In [19], that how to control interference in D2D communications. Strategies to select specific Mode, Allocation of resources, Power control method are highlighted. D2D communications with multi antenna Transmission procedures, multi hop D2D with network coding and D2D communications in heterogeneous networks are also discussed. Performance parameters like average throughput with distance control and no distance control are evaluated for uplink and downlink and results reveal that with distance control that throughput loss can be alleviated. The Network model is simulated by considering Poisson point process model thereby utilizing non- orthogonal sharing Mode. Cheng Huain and Chen Liu, [20], proposed a system model for a single cell scenario. Three DF-D2D and N cellular users are considered to manage the downlink interference using beamforming technique. Downlink DF-D2D interference can be managed by the BS. They have also analysed outage probability of DF-D2D communication for under laying cellular networks with D2D.

Gabor Fodor et al. [21], proposed the design aspects of network assisted D2D communications with different scenarios. They have assumed OFDM as transmission scheme and 3GPP LTE system for D2D design. Cellular underlay different techniques such as Mode selection, Power control and different modulation and coding rates can play an active role for networks. For networks supported Mode, the design goals are considered for D2D are peer discovery, faster pairing and performance parameters are considered such as energy consumption. Design issues for mode selection include that at which specific time, specific channel quality are considered and emphasis that mode selection measurements should be kept minimum by utilizing efficient algorithms to select the link between D2D and cellular links. Another design technique includes power control and scheduling i.e. Retransmission involves on the decision of time scale interaction and funds of distribution between network and D2D. Fangi Chen and Zhongpeng wang, [22], reviewed the techniques such as session setup, optimization of resource which guarantees the improvement in resource utilization efficiency by proper allocation. For mode selection, multiplexing mode in defined and also discussed that it will introduce inter cell interference between users. Channel allocation is also discussed and stated that it can be modelled as a programming problem. In [23], Arash Asadi et al. discussed modelling of D2D communications with LTE and Wi-Fi has been done by going beyond traditional mode optimization and mode selection schemes then by formulating a problem for joint per user mode selection, scheduling of resource, activation for connection user for Wi-Fi and LTE resources. The model has been considered for one user at a single time for D2D pairing but within the specific distance and for resource scheduling, frequency division duplexing (FDD) scheme has been utilized. In [24], Dimitrios Karvounas et al. Provides an approach based on experiments for the smart management of D2D. The evaluation of D2D scenarios based on the selection of best path is done and nodes were configured to work either as terminals or Access Points (AP's). Another scenario has been considered for the capacity expansion of the infrastructure with the aim to provide non congested links through offloading the traffic to these AP's by establishing D2D links. These scenarios' will work for CC-CRS i.e. Control channels cognitive Radio systems. The first scenario will identify the methods for further connectivity by scanning for alternative AP's is the area. It further gives a solution in order to solve the coverage and capacity expansion process by deploying path discovery techniques and path discovery processes which emphasizes for the best paths with higher signal quality. After the best path selection, decision is further provided to the nodes that results in the D2D construction and these D2D connections are implemented through 802.11 s for wireless mesh network. For evaluation purpose, they have implemented test bed experiment and for the service provision they have used SFTP Protocol. Performance Indicators such as throughput and delay are measured by considering three applications:

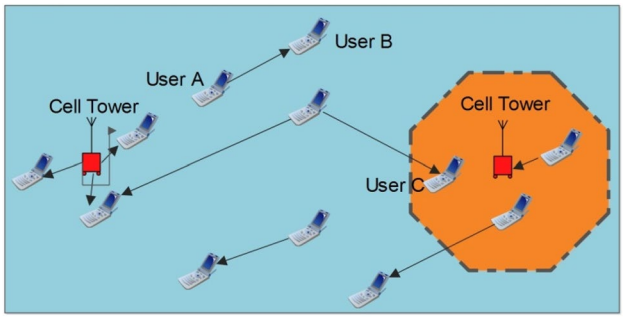

Fig. 5 Traffic offloading in cellular networks [70]

- Max of round trip time of ICMP.
- Performance of Secure File Transfer Protocol (SFTP) application w.r.t. No. Of hops.
- Streaming of video with RTS (Real time streaming protocol).

To check the feasibility of D2D communication as an underlay cellular network Klaus Doppler et al. [25], presented the mechanism for the coordination, control and to limit interference. Evaluation has been done by the system level simulator with scenario scalability of 100 m x100m which shows indoor environment, halls etc. The cellular network is operating in spitted 100 MHz band with the traffic of video and large files. Performance Indicator throughput may increase up to 65% as compared to the traditional cellular network but with the condition that if the users are close and located in the same room. Throughput decreases drastically if users are not located in the same room. Ran Zhang et al. [26], presented the latest long term evolution-unlicensed (LTE-U) technology which is helpful to meet the demands of increasing traffic for mobile communications. The various challenges for the design of LTE-U are that what would be the transmission Power and dynamic frequency selection. Therefore it is considered for the small area. Finally, the techniques such as in cellular Wi-Fi internetworking and hetnets which use licensed bands and unlicensed are compared and concluded that higher throughput can be achieved for the small cell users. The different unlicensed bands which are used in different countries are as shown in Table 2 [26, 27]:

The summary of the underlay/overlay networks is provided in the tabular form in Table 3:

Summary: In an underlay networks most of the research for D2D has taken place under the cellular networks. A cellular network provides the cooperation to offload the data when they work in the extreme conditions thereby employing different strategies. As a result performance is going to increase. So in this we have provided the extensive overview of the underlay network as overlay communication don't have much impact on communication systems.

2.2 Resource Allocation Techniques for D2D

In [28], Francesco Malandrino et al. presented the allocation of resources by deploying the heterogeneous networks, which includes discovery of the devices and scheduling process. Two tier het net based on LTE Macro cells along with micro cells have been deployed in the urban environment which is controlled by the base station. Computation for the amount of data δ which is to be potentially transferred is done by considering Interference and Signal Interference Plus Noise Ratio (SINR). The actually data being transmitted χ is decided by the resource block (RB). The limitation is that these are impractical in small scenarios and therefore increases complexity. They have also revealed that the dynamic programming is not scalable and proposed for the low complexity algorithm named as A Dynamic Programming (ADP) to ensure scalability. Kuruvatti et al. in [29], proposed that under laying cellular networks are utilized in order to enhance the better utilization or resources and to obtain Quality of service (QOS). Firstly two resource allocation schemes are employed in the network model based on distance which is used to control interference during uplink. Secondly it is virtually sectoring RA which is based on the angle of arrival (AOA) measurements. The direction of research paper is continued for location based D2D allocation schemes. So, in the case of inaccurate location or position information, reduction of interference in also considered here. To mitigate the interference in resource allocation problem for D2D Biwei chen et al. [30], considered a single scenario network model. It utilizes Orthogonal Frequency Division Multiple Access (OFDM) to support both cellular and D2D communication. Time Division Scheduling based RA is implemented. The problem which is to be solved that how to assign group of D2D pairs for each time slot and how to allocate resource blocks to D2D from cellular users. Load balancing technique is the solution thus giving the advantage of increasing throughput and interference will be avoided. For D2D users, downlink spectrum is utilised and the methodology of numerical analysis has been preferred. The response of throughput differs in location and load balancing. Therefore the residual resource blocks are deployed to increase throughput. In [31] Hoang et al. Studied a joint sub carrier and Power allocation problems and therefore iterative resource algorithm has been proposed. The system network model with downlink is employed. The objective is to maximize the weighted sum rate for both D2D and cellular links under proportional fairness scheme. Here the weight parameter $\alpha > 0$ which specifies the priority in capacity sharing between cellular and D2D links. Power allocation and resource allocation algorithm have been implemented. Abeda and Mustafa [32], gives the demonstration on Relay enhanced Technique based on

LTE-A radio interface technique. The objective is to provide more coverage that contributes to the system for the enhancement of its capacity by enabling enters services and also for the user equipment which remained isolated. The relaying topology for the LTE-A has been simulated with the bandwidth of 1 Gbps by deploying wired link. The further research continues to control the congestion in case of mobility feature. Latency will be different in case of control plane and data plane. Type-I and Type-II relay are discussed according to the 3rd Generation Partnership Project (3GPP) LTE-A standards. In [33], Wu et al. focussed on underlay D2D cellular network. A single cell scenario with the multiuser is considered with the uplink resource. Proposal of mathematical game model as a coalition for the energy efficiency in uplink resource sharing has been given. Solutions for the uplink resource allocation, power management and mode selection with Non Transferrable Utility (NTU) are provided. The distributed Multimedia applications are considered for resource sharing. The distributed coalition formation algorithm has no general rules but it has three major components namely Pareto order, Merge and Split rule and lastly able to access the stability of the partition.

In [34], Shah et al. worked on the system model for the resource allocation scheme by employing TTD configuration which supports both uplink and downlink with the advantage of reusing uplink resource. It is able to handle the interference as compared to downlink. A combined approach has been considered using LTE-A Technique on the basis of single carrier-frequency division multiple access (SC-FDMA) for resource allocation and Power control scheme by taking into account the interference as the major factor for cellular user equipment's (CUE's) and D2D user equipment. The parameter throughput has been calculated through Jain's fairness index [34] and it is calculated as:

$$J\left(x_1, x_2, \ldots x_n\right) = \left(\sum_{1}^{n} 1x_i\right)^2 \Big/ nn \sum_{i}^{n} = 1x_i^2$$

where x_i The throughput of the ith UE and n is is the total no of UE's. J ranges from 0 to 1. Higher the value of J higher will be the fairness. For power, Cellular User Equipment (CUE) are allowed to use only fixed transmit Power as it provides equal opportunity to both CUE's and DUE's for the maintenance of SINR level. He et al. [35], has modelled the system with uplink D2D in the dense environment. For the problem of RA Stackelberg game technique has been implemented in heterogeneous networks as a non-cooperative game. The scenario considered is that CUE's are not sharing their resources with D2D UE's. The consequence is the form of interference. After implementation of game in terms of two levels Frame work, Macro and Femto UE will work as a leaders and D2D will work as a followers. The leader will charge fee for the service provided by it. Using Stackelberg game, concentration is on control of power and scheduling of D2D user equipment (UE) during transmission by considering that Femto cell UE is fixed. By utilizing the same channel resource and pricing for reusing channel resource and transmit power of D2D transmitters are adjusted to maximize the utility of base station and D2D pairs. Cheng et al. [36], D2D enabled cellular networks are employed through sum rate maximization in which power and channel allocation is considered. They have proposed that extension can be done for the multicell systems with fractional frequency reuse (FFR) as the problem is intractable non convex. It involves mix integer programming with binary variables. Implementation of greedy channel allocation algorithm is done for the reduction of complexity of channel allocation for computation. In this two cellular users are not allowed to share the channel as one channel is allocated to each cellular user in a greedy manner and D2D while other can use non allocated channels. Referred as relayed D2D communication network model with multiple relays Hasan and Hossain [37], presented Radio Allocation Network approach to achieve better data rate. The objective is to maximize end to end rate by providing essential data rate requirements. The solution of the problem is message passing (MP) approach in which node is used a relay. The MP approach involves passing of messages through graphic model and nodes are considered as factor nodes and variable nodes therefore the message flows from factor to variable and vice versa. Distribution solution is also provided for resource allocation problem (RAP) and power is coupled under this control. The simulation result shows that impact of relaying on delay increases as end to end is increased but is acceptable for D2D. The evaluations have been done through simulations for distance margin, end to end delay. Cho et al. [38], presented simulative system model comprises of BS's and cellular users. Distribution is according to the Poisson Point Process (PPP) model. Two types of D2D users are associated with this model *i.e.* Intra and inter operated users. The densities of transmitters in multiple network operators (MNO's) are equally considered. FDD mode is preferred where TDD mode is challenging. Multi operator here means direct communication between those devices but their mobile operators are different, but they are supported in the relevant scenarios. Phunchongharn et al. [39], proposed heuristic algorithm to solve the pricing problem by utilizing greedy algorithm. Challenges such as distributed resource allocation to solve the problem of spectrum efficiency are discussed. The column generation is able to solve the problem of interference constraints of cellular links, SINR constraints of SINR and power constraints of D2D. Utilization of the maximum spectrum allocation is done but with a

condition that D2D link will first find the channels which are having minimum interference and accordingly weights are assigned. Parameters like transmission length and power consumption has been evaluated. Proposed scheme shows the advantage of that transmission length decreases with small increase in consumption of power in the dense scenario of D2D. Different strategies are discussed which are adopted for under laying cellular networks such as selection Mode:

- Silent mode.
- Reuse.
- Dedicated.
- Cellular mode.

Feng et al. [40], proposed network model for under laying LTE-A for the resource allocation which is divided into different cases with the distribution of RB's. Scheduling algorithm along with proportional fairness with the different scenarios firstly implemented with the resource allocation in the uplink network without D2D, secondly, reuses all uplink frequency resource, thirdly, D2D uses 10 resource blocks and last case is considered in cellular communication that 36 RB's is used. Results reveal that if the frequency reuse is utilized, throughput will raise which results in interference in cellular systems. Results also show that 10 RB's performs better and achieves equilibrium.

Dan et al. [41], proposed the hybrid network model employed under the cellular network control. It is able to select the best resource. The cooperation mechanism has been presented by implementing Robin Round scheduling algorithm in the system simulation. Threshold value of interference for D2D has been maintained and if this value increases it will generate interference. Average throughput has been evaluated for D2D and cellular hybrid networks. The result is depicting that it is higher in RA rather than traditional cellular networks.

Summary: The surveyed literature of the resource allocation techniques for the D2D communication in terms of spectrum, power allocation, time division scheduling, and location based information scheduling, energy efficient techniques for the homogeneous and heterogeneous networks. The cells that authors have considered are single and multi cells. The different proposals which have been introduced which signifies the improved performance for the different platforms i.e. LTE and LTE-A. The summary of resource allocation techniques is shown in Tables 4 and 5.

2.3 Mode Selection Techniques for D2D

Liu et al. [42], proposed the network model which uses single cell with and without relay node for one cellular and D2D pair. Apart from the spectrum or resource allocation, this study is focussed on the mode selection for D2D communications under LTE-A networks. User's Model which is known as D2D Model and described that D2D communication can happen directly over one hop. Cosine theorem has been used to calculate distance between D2D receiver and cellular user without relay nodes. All the relays are located at the uniform angle of 120°. D2D can also communicate or operate in multiple modes and it will happen for uplink/downlink transmission for underlay mode in cell edge. The disadvantage is that D2D can't reuse spectrum. Further they have discussed that with the selection of the channel modes whether it is overlay or underlay QOS can be achieved. Network model with single cell is proposed by Yu et al. [43], which comprises of M cellular users. It is connected to ENB by guaranteeing to maximize the throughput and SINR with the implementation of joint mode, channel assignment and power control techniques. Low complexity algorithm has been used and solved mathematically. The scenario has been divided in three categories such as heavy, medium and high load with reuse; reuse and dedicated, dedicated and cellular mode, respectively. Numerical simulations are analysed to verify low complexity algorithms to obtain hop gain. Future work will be focussed on the development of distributed algorithm for different channels.

Ghazanfari et al. [44], proposed novel algorithm with the scenario of single network with two D2D pairs for resource allocation, joint power loading and beamforming. Network model of single cell with K single antenna D2D pairs is deployed. The objective is to minimize sum transmission power of the system. The assumption of TDD scheme different scenarios have been taken such as interference limited and noise limited. They have applied change of variable and successive convex approximation technique in addition with Lagrangian relaxation to achieve stability. They also have designed an algorithm to simplify the complicated joint beam forming, power loading and mode selection. Wang et al. [45], investigated the D2D under laying MIMO cellular network for antenna which provides the maximum gain. Authors have provided numerical results for the commutative distribution function (CDF) of SINR at the receivers. Numerical results shown the efficiency of transmitted power of high SINR for macro and small cell. This is another method for the selection of the best mode so that ergodic achievable rate most remains high. Further, they have revealed that in high SNR, The ergodic capacity will be degraded. Maghsudi et al. [46], used a levy bandit approach for transmission mode selection for network assisted D2D communication. The network model implementation is based on the OFDMA cellular network but it is corrupted with AWGN with unit variance. Two transmission modes are considered namely cellular or indirect and direct D2D transmission mode. Pure mathematical solution is provided to solve the transmission mode selection. Mathematical

Table 5 Summary of mode selection techniques

S. no	Objective/parameter	Tool used	Platform	Evaluation	Conclusion
1	Selection of D2D pair with and without relay [42]	Single cell with overlay and underlay mode	LTE-A	Numerical verification	With the introduction of relay node can increase chance and area of D2D pair
2	To maximize the overall system throughput while maintaining SINR [43]	Branch and bound method Joint mode selection and resource allocation algorithm, heuristic algorithm for light and medium load		Numerical simulations	Overall system guarantees throughput with SINR of cellular and D2D links
3	To minimize the sum transmit power of the system [44]	Successive approximation algorithm, power allocation with Lagrangian multiplier		Numerical simulations	Algorithm efficiently handles power loading and resource allocation for underlay D2D communications
4	Investigation on Antenna selection scheme with the largest channel gain [45]	Ergodic achievable rate analysis theorem	LTE-A	Numerical simulations	Shown the impact of transmit power ratio on the high SNR
5	Selection of transmission mode [46]	A Levy–Bandit approach		Numerical simulations	Users are provided with numerical data and problem of mode selection is solved
6	For the improvement of energy efficiency of cellular networks [47]	Cellular mode D2D mode	LTE system	Numerical simulations	Strongly affected by the network parameters
7	To Minimize the power consumption and to satisfy user requirements [48]	Polynomial time heuristic algorithm/Joint Algorithm		Numerical simulations	Claimed that the proposed algorithm can achieve over 57% power savings
8	Investigation of strategy of transmission mode switching [49]	Traditional cellular mode Direct D2D mode Two way DF-relayed D2D mode		Numerical simulations	Remarkable enhance in Ergodic achievable sum rate under various interference levels
9	Social aware content downloading mode [50]	Mode selection algorithm		Numerical simulations	Algorithm is immune to individual rationality, improper behaviour and other losses
10	Device selection method for CCD (cooperative content distribution) [51]	TVB calculation technique		MATLAB simulations	Intelligent use of multiple networks allows savings of energy and increases the system performance

modelling has been done for cellular transmission and in this model stochastic payoff is a compound Poisson process, whose values can be higher or lower than the cellular mode. Further solutions include is to calculate the statistical characteristics by fitting the experimental data into a compound Poisson process for the estimation of arrival rate and the distribution of jump sizes. Penda et al. [47], focussed on the reduction in energy consumption so as to lead the greener system operation by selecting the best mode which reduces the consumption of energy and improves the proximity services. For this they have considered two modes i.e. cellular mode and D2D mode and applied Shannon's capacity formula for In band D2D communication. They have applied TDD system in a cellular mode in which transmission frame length is considered which effects the reduction of energy in the total network and secondly device energy will be minimized by applying suitable controls. With the aim to minimize the power consumption of D2D links for the uplink Gao et al. [48], proposed a single cell based OFDMA network. The proposed joint algorithm has a goal in terms of mode selection which potentially gives low power channel assignment. The algorithm provides a linear search and uses a technique of subroutine for the assessment of channel power and keeps on upgrading the most power efficient link. Authors also presented a joint practical algorithm which deals with interference, channel allocation and power alignment constraints. Results for different scenarios show that the proposed algorithm outperforms and 80% of power can be saved as compared to the cellular algorithms. All D2D and random provides an average of 57% and 78% power savings.

Ni et al. [49], has modelled the network with the single and multicell scenario. The transmission mode switching is used with the strategy to achieve the objective for the selection of the best transmission mode. By considering three modes i.e. traditional cellular communication (MODE 1), direct D2D communication (MODE 2) and two ways DF relayed D2D communication Mode (MODE 3). Mathematical Modelling has been done for the above three modes and considered interference is the another important factor which effects the communication process, whether it may a single cell or multi cell. The transmission mode employs two strategies namely by developing the relation between the interference and threshold factor. The relationships are as follows:

1. $\sum I_c < G^m$

2. $\sum I_c \geq G^m$

where I_c is the Interference in cellular Network users and G^m is the threshold value. Cai et al. [50], evaluated a frame work for physical domain transmission model property and social networking domain modes characteristics as the performance metrics in terms of downloading for the mode selection. Three modes have been considered for content downloading namely:

- MD2D: Multiple Potential Provider.
- D2D: Single Potential Provider.
- B2D: Gains contents from Base stations.

The proposed algorithm achieved 18.9% to 24% performance gain and average gain is 49.6 for $N_d = 10$ and 53% for N = 15 and finally 63.85% for N = 20 which seems to be major advantage for the system. All the analysis has been done numerically by considering the scenario where the users with multi radio capacity are randomly distributed.

With the proposal to select the best for the intelligent selection of best delivery devices Barua et al. [51], proposed the network model. Users are randomly distributed and clustered so that they can distribute the content cooperatively to the other devices by taking quality into the account. The secondary link utilizes power for the selection of best node in the scenarios of with and without overlapping coverage. The simulated results are compared when the link is used for the delivery of content to normal users and best users with the problem of network congestion. The secondary network interface is Wi-Fi and provides savings of no. of carriers which are to be utilized for energy performance. For validation they have used MATLAB simulation techniques.

Summary: The surveyed literature for the mode selection techniques aims to describe the different concepts of modes. The modes have been classified in terms of relay, antenna selection scheme, different modes of transmission and its switching which aims to achieve the upgraded output parameters such as SINR, transmit power, energy efficiency and others also. The summary of mode selection techniques is shown in Table 6.

3 Cooperative Communications

Cooperative communication provides some merits such as increasing link reliability in wireless networks and also improving coverage. Cooperative relay technique introduced the conventional device to device communications. Cao et al. [52], has utilized the underlay, overlay and simple D2D mode. The problem of joint mode selection and channel/power allocation has been solved. Authors have claimed that for the first time that cooperative D2D communication framework has been proposed for the improvement in D2D and cellular links by implementing OFDMA technique. Results reveal that outage ratio gives the sluggish response and achieving satisfactory D2D links. To validate it, simulations also have been done for the thereby

Table 6 Analytical techniques

Reference paper	Analytical technique
[2]	Game Theory, Auction Theory
[19]	Poisson Point Process (PPP)
[28]	Approximate Dynamic Programming (ADP)
[30]	Time Division Scheduling (TDS) Resource Allocation Problem
[31]	Resource and Power Allocation Algorithm
[33]	Coalition Formation Game
[34]	Proportionally Fair Resource Allocation
[35]	Stackelberg Game
[36]	Greedy Channel Allocation Algorithm
[37]	Message Passing Approach
[38]	Non Cooperative Spectrum Sharing Game
[39]	Column Generation Method
[43, 74]	Heuristic Algorithm
[44]	Lagrangian Algorithm
[46]	Levy Bandit Approach
[48]	Joint Algorithm
[49]	Transmission Mode Switching
[50]	Social Aware Content Downloading Mode Selection Algorithm
[52]	Hungarian Algorithm
[54]	Poisson-Voronoi Tessellation
[56]	Interference Avoidance Mechanisms
[58]	Successive Interference Cancellation (SIC)
[59]	Clustering Algorithm
[60]	ACNC- MAC Protocol
[61]	SYNERGY Game Theoretical Approach
[62]	Precoding Schemes
[64]	Incentive Resource Allocation Scheme
[65]	Integrated Mechanism for Cooperation
[66]	Alternative Direction Method of Multipliers (ADMM)
[72]	Amplify and Forward Scheme (AF)
[75]	Cooperative Diversity Protocols
[76]	Relay Assignment Protocol
[78]	Optimal Relay Algorithm

showing the same response in reduction in the outage ratio of cellular links while achieving satisfactory throughput of D2D links. Shin et al. [53], proposed a cooperative protocol in terms of cross network for D2D and cellular users. Mitigation of interference is undertaken with the help of D2D links by sharing channels. The evaluation methodology of 3GPP is employed in the linear cell layout scheme. As a result D2D communication assisted interference alignment performs better as compared to Block diagonalization (BD) and Zero force (ZF) beam forming techniques thereby achieving much higher data rate. In [54], Tanbourgi et al. has deployed the scenarios in intercell and intra cell D2D with null or limited interference coordination. The downlink system has implemented for cooperative users with uniform resource of time and frequency. Multiple antennas, same resources are used for pre and post transmission. It may help in balancing the interference, respectively. Stochastic geometry is used for modelling such kinds of networks in terms of scenarios where irregular deployments are taken into account. Simulated results demonstrates by giving advantage that cooperative interference cancellation (CIC) increases average throughput gain by 4% with pass loss exponent $\alpha = 3$. Thus it concludes that interference becomes more separable. Uniformly distributed Network model of cellular users with single D2D link is implemented by Shalmashi and Slimane [55], with the assumption that D2D will work in half duplex mode. The objective is to minimize the assigned power, achievable sum rate under capacity achieving coding as the performance metric. Cooperative

communication uses DF scheme during D2D transmission and TDMA scheme. The frame structure is divided into two equally time slots. The scenario is taken as the crowded environment. Numerically and simulative investigations have been done through Monte Carlo simulations and superposition coding is done in the downlink. Results show that 60% cooperation for the links are achieved in case of low density but 98% cooperation is achieved in high density also. Peng et al. [56], implements hybrid cellular and D2D network model of underlay to avoid blind interference problem. Interference Tracing mechanism is the first solution which has been proposed in which cellular mode can be decoded in other mode. The second solution to the problem of interference from D2D to cellular is BS assisted D2D RRM scheme under tolerable interference broadcasting for the calculation of estimated interference. A criterion for the intelligent resource allocation has been considered to avoid interference from Cellular User Equipment (CUE's). The performance of the hybrid system is by system simulation by radio resource management (RRM) hybrid automatic repeat request (HARQ) mechanism, resource allocation and power control. Ali [57], heterogeneous network is considered for the interference management. They have given the overview in terms of TDM based enhanced ICIC (intercell interference cancellation) techniques which has been introduced in 3GPP release 10. They have discussed:

- ABS (Almost blank for sub powers) based enhanced intercell interference cancellation (eIcIc).
- RP-ABS (reduced power-ABS) intercell interference cancellation.
- FeIcIc (farther enhanced) IcIc.
    - Transmitter based FeIcIc.
    - Receiver based FeIcIc.
- FDM based IcIc: In this key feature of CA is discussed.

Finally, coordinated multipoint (COMP) techniques are discussed in this survey. Ma et al. [58], proposed the network model which is focussed on the uplink transmission with the assumption of the homogeneous Poisson point (PPP). The base stations are distributed uniformly in the Voronoi cell which leads to the coupling of the cellular user location and base station. SIC technique has been employed at the D2D and cellular receivers as it has infinite capabilities. Network performance with and without SIC is evaluated with stochastic models which leads to calculate interference. Results reveal that SIC can provide 50% improvement with network. The results are based on the numerical analysis.

Network model of cooperative D2D Multihop scenario is deployed by Carpio et al. in [59]. The model works with the condition that all RN's will work in the half duplex mode with the aim to maximize the gain. The relay nodes must cost low. Here a macro base station that controls the signalling process and also decode and forward information with the help of relay nodes on the basis of clusters formed. Measurement of mean data rate for single; two and three cooperation hop transmission is done which is based on certain assumptions. To maximize the end to end data rate cluster construction algorithms has been implemented for two and three hop cooperative communication in the distributed manner. Datsika et al. [60], describes that cooperative gain can further be increased by implementing the network coding technique. A network model with D2D cellular network is considered for analysis. An adaptive cooperative network coding based MAC (ACNC-MAC) protocol is implemented with cooperative relay techniques and shows that it is energy efficient. Simulation results demonstrated that improvement in throughput is increased up to 71% for low and 75% for saturated data scenario and gain reaches to 71%. All these evaluations have been done for the out band D2D communications in different scenarios and evaluation work is done on the event driven C++ simulator. For security a game theoretical approach named SYNERGY is utilized by Sun et al. in [61] for the generation of cooperation key. The model of multihop D2D scenario has the assumption that every node has same power and range. Generation of secret key for the transmission of data between adjacent mobile nodes in D2D cooperative communication is done. The behaviour of the nodes is rational and selfish therefore every node is not trustable. Rational node will operate in peer to peer mode and can generate key on collaboration based Physical Layer. The methodology SYNERGY is that mobile node will act as a relay and also able to improve key generation rate. Parameters like security, computational and communication overhead is simulated in MATLAB with the aim to confirm efficiency and efficacy. Tang et al. [62], discussed different precoding schemes in the distributed system on the basis of MIMO for D2D cooperative communications and cellular downlink. They have also discussed the management of interference in D2D underlay network for the system model which utilizes TDD cellular network with the downlink resources for transmission. They have illustrated SLNR Maximization pre-coding for different scenarios to analyse the throughput w.r.t. distance by selecting the optimal D2D pre-coder. All the simulations have been performed statistically on the Monte Carlo simulator with the help of LTE compatible MIMO codebooks which is integrated with existing 3GPP standards. Mustafa et al. [63], worked for the future networks and for this they have proposed a separate framework for the same. They have proposed control and data planes separation architecture with the objective to provide ubiquitous coverage and spectral efficiency in homogeneous networks. Although the proposed frame work is not

at its maturity level and the little literature exists as claimed by the authors but they have provided the survey and given their point of view in terms of SARC. Capacity and energy enhancements can be achieved by separating the control and data planes as the system is flexible.

Network model with D2D relay is presented by Sun et al. in [64], which uses cooperative relay (CR) and Non cooperative relay (NC) relay users. The technique has employed amplify and forward (AF) cooperative protocol with TDMA. Model is focussing on uplink but can be utilized by downlink also. Allocation of resource scheme includes time and power to encourage relay data for the saving of energy or to increase the energy efficiency. They have proposed a practical scheme which is divided into three sections namely:

- Relay selection to maximize the SNR.
- Two user case set up to decompose the resource allocation problem for cooperative and non-cooperative models.
- Two dimensional search solution to achieve higher throughput with time and power resource.

Model of an isolated cell is studied by Xiang et al. [65], with the assumption that intercell interference is negligible. The aim is to improve QoS on the cell edge. A joint mechanism for the cooperative mode selection for the single cell under the hybrid network of IMT-advanced and D2D communication for power and resource partition is proposed. Optimization of cooperation between the D2D and cellular terminals is done to check whether best performance can be achieved or not. Comparison is done for the cooperative and non-cooperative mechanism. Modes with spectrum sharing such as orthogonal sharing mode for dynamic spectrum sharing and non-orthogonal sharing modes are undertaken for the optimization of power to improve the sum rate. Results reveal that cooperative mode mechanism outperforms better than the non-cooperative one. Liu et al. [66], proposed the framework for the optimization of the traffic workloads and routing has been formulated mathematically. The D2D cooperative frame work is based on video transmission duration. The two constraints are energy budget for video transmission and another is flow conservation for video streams. Routes and traffic workloads are to be scheduled so as to save the energy consumption of the battery. Energy resource can best be utilized using cooperative video transmission. Solution is provided distributed routing and load balancing with the help of a tool named as Alternative direction method of multipliers (ADMM). The statistic performance has been evaluated with the help of Monte Carlo experiments. Results for TDMA improved with a factor of 157% and claimed that performance is increased by three times.

The role of manipulating cooperative game theory is discussed by Yang et al. in [67]. It is quite important as it implements different strategies. The cooperative communication involves different topologies such as one to one, one to many and vice versa. Cooperation system involves relay system to enhance the performance of the network. The various characteristics of the CC is AF and DF. The computational parameter is SNR. Game theory has three major members namely players, strategy and utility/payoff with the assumptions that players are to be rational and selfish. Each player works with different strategy and known as dominant strategy. Nash Equilibrium (NE) technique is used to create interaction with the players. The pricing based mechanism involves the tokens or virtual currency to sell the resources such as power, bandwidth, and time at a specific price which depends upon demand and supply. Bidding is also done. Certain challenges involve the selection of the utility function, computation and efficiency of the NE. The most important is that what would be the designing mechanism for auction. Truthfulness, rationality and budget are still open challenges. A theoretical method has been discussed for cooperative communication networks by Janzamin et al. [68], for power allocation. The power allocation technique is used for bidirectional CC networks. The advantage of this scheme is that it is applicable to the wireless LAN's in which the destination is common and no virtual payment is involved. The research question of consumption of node's power is involved. Therefore Stackelberg game is the only solution. The system model implemented AF protocol for the cooperation which includes a common destination. Optimization is done by sending data in a non-cooperative mode.

Zhang et al. [69] has utilized game theory for the selfish cooperative communication networks in regard to resource allocation. The symmetric cooperative communication model has been solved with the two objectives in terms of efficiency and fairness. Each node uses Multilevel Quadrature Modulation (MQAM) with the specific/required energy to transmit information bits. The implementation has been done through Pareto optimal payoff allocation and can be obtained by solving Nash Bargaining Solution (NBS) of the cooperative game. Results demonstrate that NBS resource is fair and will give better performance independently. Li and Guo [70], discussed that LTE-A will exceed the requirements of 4G if it is integrated with the upcoming technologies such as carrier aggregation, traffic offloading and multiple antennas utilization as shown in Fig. 5. They have mainly focussed on the traffic offloading concept by implementing the pico cells, femto cells and device to device communication with the condition that they should be cost efficient.

A survey has been done in D2D communication based on LTE-A by Liu et al. in [71]. They have discussed that In band D2D technique for the centralized and distributed interference control. The author has discussed very briefly Radio resource management and mode selection techniques.

Different simulators are also highlighted along with D2D applications and services. Techniques for implementing D2D communication are discussed which includes its prototypes, experimental techniques in terms of Flash LinQ, data spotting and relay by smart phones. Zhao et al. [72], has employed AF technique for optimal power allocation versus selection with the hope to improve the performance of the relay networks. The system is modelled for orthogonal channels which can be time or frequency distributed with the technique AP (All Participate) AF. Results show that OPA-CSI scheme has improved throughput by about 2 dB but with small gain. Another objective is for the S- AF (Selection) AF. Results for outage probabilities are simulated for three schemes namely S-AF, AP-AF and direct transmission. Cooperative diversity has been achieved with S-AF for outage probability which is about 4 dB over AP-AF.

In [73], Ribeiro et al. modelled the system for the calculation of symbol error probability (SEP) for the Cooperative Diversity (CD) strategy. To compute SNR values BPSK modulation, Rayleigh Fading parameters are implemented for the SEP. For multi-hop cooperation up to 10 the average SEP's performs reasonably excellent and minimizing error probability. With the approach to consume less energy for the cooperative multi-hop broadcast problem in wireless networks Maric et al. [74] has implemented reliability schedule. Heuristic algorithm is implemented for good scheduling and Linear Program (LP) is implemented to find optimum power levels. Comparison is done with the broadcast incremented algorithm (BIP). Results depicts that heuristic algorithm is very close to the optimum values. Savings of 1.7 dB can be seen in average power of accumulative broadcast. Further distributed algorithm is based on reliable node I and hence node transmits energy and reliability will be judged by the acknowledgements.

Different efficient protocols and outage behaviour has been evaluated in cooperative communication networks by Laneman et al. in [75]. The system model cooperative diversity protocols are utilized for fixed, selection and incremented relaying. The performance of the protocols has been characterized by the outage behaviour.

The authors of [76] have proposed a new scheme which is a relay assignment scheme for the CC networks. It has three major components namely (a). Optimal relay assignment algorithm (b). Payment mechanism for the source nodes (c). Payment mechanism for the relay nodes. HERA means goddess of marriage. Challenges for CC network include selfish and cheated behaviour of the nodes which ultimately affects the system performance. The static model is considered in the network. Objective of the relay assignment problem (RAP) is to maximize the system capacity by sharing common relay nodes among the number of source nodes. But it is quite challenging task to fulfil. Therefore polynomial time optimal algorithm has been designed. For selfish users mechanism has been designed for the capacity maximization but selfish users have their own preferences for relay selection. Therefore, strategic game model for the selection of relay has been mathematically modelled. Results reveal that degradation increases proportionally w.r.t. nodes in cheating.

In [77], selection cooperation is implemented as compared to the distributed space time block coded (DSTBC) in the centralized and the non-centralized network. Outage probability is evaluated for the two schemes namely simple selection combining and for the DSTBC. Results show that selection cooperation has the superior performance than another one. In [78], Sharma et al. has solved the problem of assigning nodes by using optimal relay algorithm (ORA) by utilizing linear marking mechanism. The preferred mode is ad hoc in which multiple number of nodes acts as a source and destination. The algorithm has implemented polynomial time complexity technique which is able to achieve the required achievable rate under direct transmissions.

In [79], modelling of relaying system is implemented for power allocation. Power allocation is optimized through SNR, outage probability. Results have shown the significant improvement in SNR and outage probability. In [80], CC ad hoc networks, MANETs model with clustered architecture is considered and controlled by different AP's. Each cluster is secured with the gateway. The objective is to show how AP selects the CC nodes thereby improving network connectivity by implementing matching algorithms. Another model in which nodes rely on the synchronized data. To support cooperation, network layer plays a vital role as it has to provide network solution.

Summary: Apart from the D2D communication, cooperative communication has the major role for the utilization of spectrum whether it may be in the combination of resource allocation and mode selection. Maximum papers have used the platform of LTE but still a lot of work has to be done on the platform of LTE-A. Proposed framework for the cooperative communications shows that interference has been reduced, high data rate, average throughput and network throughput has been achieved

4 Roles of 3GPP and METIS Project

In [81], the acronym of METIS is Mobile and wireless Communication Enablers for the Twenty–Twenty Information Society. The goal of this project is to improve mobile data per unit area, higher user data rate during connected devices, low latency and higher battery life and road safety applications. In this challenging task of METIS for 5G consolidated five tasks have been designed out of which one is Device to Device Communication (D2D). The essential topics for the 5G METIS project are:

- Direct Device to Device communications (D2D).
- Massive Machine Communications (MMC).
- Moving Networks (MN).
- Ultra-Dense Networks (UDN).
- Ultra-Reliable Communications (URC).

Various organisations such as Industrial partners, Academic Partners as well as Telecom Network operators are commonly working under this project. The impact D2D communications in 5G communications is that if this technique is employed the capacity of the system can be increased twice if same bandwidth is used. Latency will also be reduced. But this project is facing certain challenges to convert into its practical shape because this model is benefitted for the individual users and it will not be easily accepted by the network operators. Obviously they will decide the payment mechanism for this also. In [82], release of nomor research specifies the 3GPP

provide the crucial services in the network. RAN was the part of test bed installation and deployed in the real world. The network assisted D2D trial comprises of firewall which is located inside the Unified Gateway entity (UGW) and logically composed of Serving Gateway (SGW) and Packet Data Network Gateway. For proper working in terms of practical D2D it requires server. The server must be able to access certain core network functions, locality information. Connectivity part is considered which is further divided into two components namely signalling and executive components. The platforms are Android, Linux based are open but for closed platforms like windows and iOs the solutions are not possible. The metrics are difficult to measure as there is much variability in the wireless environments. Signalling in the system effects energy efficiency and user' experience. Using measurement methodology signalling performance, network availability and reliability is measured. The scenario of offloading can be considered when network queues are overfilled *i.e.* 99% load. So attention is needed if QoS is required in case of 91% to 99% load in case of cell loading. Yasukawa et al. [83] discussed the various applications of D2D communications which are under 3GPP release 12. The major example is the public safety LTE. The authors discussed that after the 9/11 attacks in USA the US department of commerce presented these kinds cases to the 3GPP. So the decision was made to build a network that provides safety to the nation. It can be in terms of natural disaster, terrorist attacks etc.

The releases 10, 11 and 12 are called LTE-Advanced [84]. The Rel-12 is based on the Rel-10 and Rel-11. Some of the features of Rel-12 are as under:

- Enhances support to Machine to Machine (M2M) communications.
- Evaluation of Small cell enhancements for interference mitigation, radio based synchronization for the improvement in spectrum efficiency.
- Focussed on power efficient, public safety Proximity services (Prose).
- Interoperability Features (SON's).
- Handover performance improvement in HetNets.

Local Internet Protocol Access (LIPA) and Selected Internet Protocol Traffic Offload (SIPTO). This feature enables the traffic to be offloaded through Public Gateway (P-GW) to the private network.

A German based company named Nomor Research is working on the Future communication systems [85]. It is known for its system level Simulation services in RRM and SON. Pauli [86] states that One of the feature known as "enhanced Interference Mitigation and Adaption" (eIMTA) was highlighted in Rel-12. It is for the dynamic Adaption of TDD pattern. The advantage of this technique is that it can be used in uplink as well as downlink as per the need of the capacity. It is one of the key features of the 5G Technology.

4.1 LTE-Advanced Pro: The New Upcoming Technology

3GPP [87] is working on the new technology named LTE-Advanced Pro which involves LTE and LTE-Advanced technology series. The advancements will be covered in Rel-13. It includes various features like D2D and Prose with small cell connectivity and architecture, indoor positioning and the major work includes increase in bandwidth and the reduction in Latency. It will enhance user's experience. LTE-Advanced Pro will provide > 3 Gbps. Some of the features which were stated in the previous releases will be matured in the Rel-13.

Summary: In this the matter has been undertaken that what is going on in industry and academia. The industries namely Novel Mobile Radio and Radio Electronics are contributing a lot for developing commercial applications. Further we have highlighted the standards which are developed by 3GPP and the vital role played by the 3GPP for developing such public safety applications. A new standard named as LTE-Advanced Pro which is under research is also highlighted.

5 Performance Metrics and Simulators

Numbers of performance characteristics are evaluated in the various techniques such as in Underlay, Radio Resource Management and in Mode selection techniques. The basic information of the evaluated parameters is as below:

5.1 Evaluated Parameters

Average throughput: It is basically a hop count which is used to send the data from one link to another link. Sequence of hop should be maintained while transferring the data from one to another link. Average throughput can be calculated by taking the sum of each logical link. It is also related with the rate of Transmission [88].
Outage probability: It is also one of the performances metric in wireless communication systems. When the minimum desired service is probably not achieved in terms of Signal to Interference plus Noise Ratio (SINR). Obviously it should be as low as possible [89].
Power consumption: Power consumption is another performance metric for the increase in cost. Power consumption increases when there is limited bandwidth, multiple access techniques to be utilized such as CDMA, TDMA and so on. Different issues such as noise, reliability and security also increases the power consumption of the devices and degrades the performance [90].
Ergodic capacity: Another parameter for the design of communication system. It is used in fading systems. The achievable transmission rate must remain constant and it should remain maximum which indicates its good performance [91].
Communication overhead: Communication overhead is also the performance indicator but it has negative influence on the communication system as it reduces the efficiency of the protocol. The data bits are very difficult to replace with the overhead bits and therefore it is not a cost effective system [92].
Latency: Latency is the parameter which degrades the performance of the network. So for reliable communication or to guarantee the proper connectivity it should be as low as possible [93]. So proper scheduling is required to avoid latency. When the packet is not received by the client when sent by the server in time then it is termed as latency [94].
Signal to interference plus noise ratio (SINR): The signal to Interference and noise ratio is based on the channel realizations and interferers. It is calculated at the each receiving antenna of the base station. They are used in modulation for the reduction in error [94].
Energy consumption: Reduction in energy consumption in mobile networks is such a great issue. It can be reduced at a point where there is no or negligible transmissions. As a result it will reduce the cost of the operator [94].
Transmission length: To maximize the spectrum utilization the transmission length should be kept minimized. The D2D links are in the terms of time slots. The other objective to keep the time slots minimum so as to avoid harmful interference and to maintain QoS [95].
Delay: Quality of Service (QoS) depends upon the radio interface technique implementation. Delay increases as the size of the virtual object increases. In other words the resources are not reserved for each other. So delay is not a fair QoS parameter [94]. Usually it is the time taken by the packet to go from one point to another point in the similar network [96].
End to end rate: It is basically the time spent for each packet to be delivered at the network's node. It is measured in milliseconds (ms) [97].

5.2 Simulators

Numerous simulators are available for the evaluation of the parameters. This topic is related to the wide areas of analytical and experimental parameters. The calculation of performance metrics is based on the different network scenarios and simulation parameters. However there are different simulators are available namely NS-3, which is based on python but D2D tool box, is not available. Another simulator is OPNET which is also not compatible. Some of the mathematical simulations are performed on C++, Monte Carlo and MATLAB simulator. The latest simulators which are known as system and link level simulator. These simulators are designed on the basis of LTE-A for uplink as well as for the downlink. The particular name of the simulator is Vienna LTE-A system level simulator [98]. Faculty of Institute of telecommunications have designed these simulators. These simulators are compatible with the MATLAB. Some of the features include [99]:

- Performance Metrics for user equipment includes such as average throughput which can be peak, mean and edge.
- BER, Frame error ratio (FER) and SINR.
- Simulation parameters which need to be configured include frequency, bandwidth and different transmission modes.
- Network layout and various macroscopic path loss parameters to be configured.
- Scheduler settings include Robin Round, Proportional Fairness (PF) and Fractional Frequency Reuse (FFR).

This simulator is available for Academic research freely, whether it is for the uplink or it may be a downlink. The structure of the simulator comprises of [98]:

- Link Measurement Model.
- Link Performance Model.
- Interference Structure.
- Mobility Management.
- Resource Allocation Strategy.
- Power Allocation Strategy.
- Traffic Management.

- Network Layout.
- Micro and Macro Scale Fading.
- Precoding Techniques.
- Coordinated Multi Point (COMP) Module.

The above parameters are basically related to the link measurement and link performance model. The performance model comprises of throughput, error rates and error distribution.

The Analytical techniques which are implemented in the literature are summarised as follows:

6 Open Research Issues

Here we are raising certain issues which require attention and need to be solved for the development of further applications. As the D2D communication systems involve both underlay and overlay systems, but the major part of the cellular communication systems are concerned with the underlay module. The issues which need to be addressed are as under [100–102]:

Resource management: In D2D resource management techniques certain issues which needs attention. It is desired that if these issues are addressed the performance of the network will increase in exponential terms. Some of the issues are as under [103]:

- Location based D2D resource allocation improvement is still required with minimum deviations.
- A new technique is required which minimizes the handover among the base stations and also to develop congestion control techniques.
- Fractional frequency reuse (FFR) with resource allocation under SC-FDMA can be further extended by utilizing the reuse of uplink and downlink radio resources. Also this can be considered under Multicells by employing link selection techniques.
- High peak to average power ratio (PAPR) needs to be resolved.
- Relay aided D2D communication is worth investigating. Spectrum sharing with more than two MNO's needs attention for future aspects.

Mode selection: Mode selection plays a vital role as it deploys a strategy to select the intelligent system to enhance the performance of the network but has certain issues. These are as under [104, 105]:

- As the number of users are increasing therefore the multicells becomes the requirement for the mode selection and also for sharing the resources.
- Distributed algorithms are needed where a scenario uses D2D pair utilizes the same channel reuse.

Cooperative communications: With the utilization of short and low power transmissions by employing Pico and Femto cells, the potential of the CC can be increased [106–108]. The certain which needs to be addressed are as under:

- Efficient Synchronization between the interfering cells is required. Also for 3- hop communications there are chances that efficiency can still be improved.
- Need to study the impact of cellular links on D2D communication and to design the analytical model for the non-saturation case.
- The different approaches need to be integrated with the existing 3GPP cellular standards. Also new radio interface technique which has drawn attention i.e. LTE-Advanced Pro needs attention for the improvement in applications.

The different parameters which include energy efficiency, MM wave spectrum, carrier aggregation (CA), intracellular management in ultra-dense networks and mobility management needs to be addressed for further research in 5G networks. Also there is a great need of mobility system which needs to be deployed in the real scenario.

7 Conclusions

In this paper we have presented a comprehensive overview based on the results of the D2D and cooperative communications. The latest radio interfacing technologies which has attracted both industry and academia has also been touched. Certain standards like LTE-Advanced Pro is under the development stage. We have reviewed the resource management techniques, Mode selection techniques mainly for underlay. Then we reviewed the concepts of cooperative communication and areas under research. Most of the papers concluded the results on the basis of Numerical Simulations. Further we have focussed on the METIS Project, Novel Mobile Radio industrial research interests which are trying to improve their commercial capability in terms of 5G networks. New simulators have also been highlighted particularly for the LTE-A networks environment. So based on the above surveyed literature we have discussed some research issues which needs to be addressed.

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