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A Review paper on Inband Device to Device Communication

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Abstract: *The highly increasing demand for mobile users has lead to drastically increase of network usage. This has forced for the development of new techniques and method of wireless communication. D2D i.e. device to device communication is one of the new paradigm introduced in order to have successful and stable communication between devices present in the near vicinity. D2D has gained lot of attention due to its feature of accessing licensed and unlicensed spectrum both. It mainly is advantageous because of its key feature of offloading the base station loads. It's a direct communication between transmitting user end and receiving user end, without hopping from base station. Depending upon the use of spectrum D2D are of four types in wider sense. And mainly divided as inband and outband. Inband is most adopted techniques for D2D. In this paper we present a review of different inband device to device communication work from establishing of D2D communication in inband spectrum, to its method of enhancing use of its resources. Different techniques implemented and which are the domain which are less exploited and which can further increase use of Inband D2D.*

I. INTRODUCTION

There is a tremendous increase in number of users of wireless communication as well as major increase in data usage of individual users. This leads to a very rapid evolution in communication system. In last few decades the communication systems have changed from 1G-2G-3G, from wired system to wireless system. There is also a very wide emergence of new technical gadgets as smart phones, tablets, due to this a major increase has occurred in cellular users along with the applications of different kind of multimedia services like sharing data and communication in forms of different apps such as voice calling by use of internet, image sharing, mobile television, video calling and High Definition (HD) graphics games etc. Hence there is an increasing requirement for higher data rate transmission.

The demand of spectrum is increasing but the total network capacity remains constant i.e. fixed. So the enhanced used of all network resources becomes very important issue for all the telecom companies. So the spectrum which was initially assigned only for calling (1G) should now be utilized for all types of communication in form of video calling, chatting, data usage. The 4G technology promises more enhanced use of MAC layer in order to satisfy user demands upto some extent. But this would still cope up with extremely increasing demands. Above that aspects like congestion of spectrum, spectrum efficiency, power control and frequency utilization should also be considered. Taking under consideration the demand for high spectral efficiency, it is crucial to increase network capacity, so that one can accommodate the high bandwidth consuming applications and services with efficiency and best use of spectrum.

This has lead to development of new methods and technology like 3GPP (Third Generation Partnership Project), LTE (Long Term Evolution), UMTS (Universal Mobile Telecommunications System), EUTRA (Evolved Universal Mobile terrestrial radio access), EUTRAN (EUTRAN network) technology. There are more enhanced works going on in this field to meet user demands. More additional features and techniques are added in order to have optimum utilization of the network. In order to develop more advance methods, LTE-Advanced concept is introduced. As a part of LTE-A different methods for efficient spectrum utilization was introduced. Device to device communication was one of the techniques introduced in it.

There have been many methods other than device to device communication which are implemented to increase spectrum efficiency and may sound similar to device to device communication such as cognitive radio systems, enhanced utilization of Bluetooth, zigbee, Machine to machine communication, MANET etc. But device to device communication is different from them. In cognitive there is usage of white spaces present in the spectrum, which is not present in device to device communication. Major difference in D2D and other technologies is presence of a supervising entity in D2D. There is a managing entity (in inband Base station) which manages connection establishment process, and allows a controlled communication. This makes D2D different for other technologies. While machine to machine communications sounds very familiar to D2D, it is different as M2M mainly concentrates on exchange of communication between infrastructures and nodes. This exchange of information is possible between nodes at any distance and not only in near proximity. Device to device communication is one of those methods use to solve high data rate demand for devices present in near proximity.

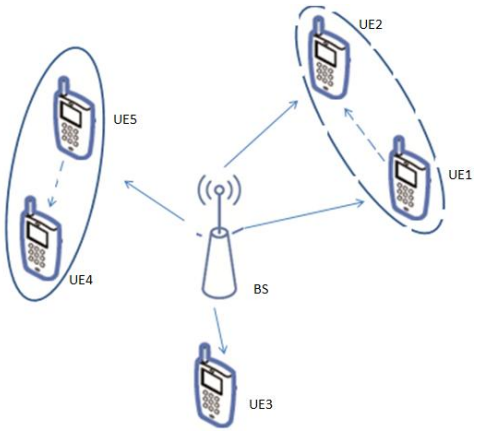

Figure1: A simple example of D2D and cellular network

In simple words, device to device communication can be defined as direct connection between two users without intermediate base station connection. In traditional form of cellular communication the connection between two users is through one or more than one base station. Any communication takes place only through base station, form transmitting end to base station and then from base station to receiving end. This is executed in form of uplink and downlink communication. But in D2D the exchange of information takes place directly without base station as intermediate junction. So D2D is considered as a non-transparent communication to the base station and network as there is no involvement of it during communication. D2D are mainly classified in two types outband and inband. If communication of D2D occurs in licensed spectrum then it is known as Inband D2D, while if D2D communication occurs in unlicensed spectrum then it is known as outband D2D communication.

Accessing licensed and unlicensed spectrum is a advantage to D2D establishment. Depending upon the network either can be selected. The working and connection establishment for both inband and outband is different due to this reason both method cannot be accessed at same time. As outband allows the D2D communication in unlicensed band, due to this the spectral use of licensed version is not affected. At the same time it offloads the spectrum. But such communication is not reliable as they cannot be accessed by base station so it is less preferred.

II. OVERVIEW OF OUTBAND D2D

The utilization of unlicensed spectrum has many advantages. It firstly does not use any of the cellular spectrums, leading to reduction of interference, and offloading of the network load. This was the major reason outband was introduced. However accessing non- licensed spectrum, some addition interface has to be considered. It can be executed using some of the existing technologies like Bluetooth, Wi-Fi, We-Max or Zigbee.

In outband D2D as it uses spectrum other than licensed, Base station will no more have any control on the D2D. Neither for connection establishment and nor during communication. This aspect has both advantage and disadvantage, the only advantage is that there will be more resources available for cellular communication. While there is disadvantage that connection will be all at its own which can autonomous without any control. It is also not advisable as communication will have no trace back aspect.

Outband D2D is further classified as controlled and autonomous. The classification is based on the nature of communication taking place between two devices. There is another technology which controls the communication in controlled communication. There is no command of the cellular technology in the connection establishment and communication. This can be achieved by use of cellular network advanced management features to control D2D communication to improve the efficiency and reliability of D2D communications. This leads to the significant improvement of throughput, power efficiency and spectrum utilization.

While in autonomous as the name suggest there is no control on D2D communication, only control that exists in such communication is in cellular range. And the D2D has uncontrolled communication. This is the major drawback of Outband the uncontrolled flow of communication in unlicensed spectrum. Autonomous outband D2D is mainly used in order to reduce the overhead which are present in the cellular networks.

Outband D2D has several advantages over Inband communication as D2D and cellular has independent communication, taking place simultaneously in the network. This avoids the major problem of interference present in any network. This allows the communication using the spectrum which is not previously allotted. This leads to zero cellular resources usage.

And in turn no resource is blocked or occupied by D2D. As no cellular resources are used, resource management becomes easy. And as devices in near proximity uses overlay the cellular resources can be used for other far connections.. But there are several disadvantages also present in selecting this form of D2D communication they are: As base station is not involved in communication in case if interference is created between two connections then its handling becomes very difficult. And there is no organised method to deal with such interference. Correct encoding and decoding protocols are required to have communication in unlicensed spectrum. This protocol should be aware to all the devices present in the D2D communication. Two separate interfaces to access licensed and unlicensed spectrum is required. This at times may lead to additional hardware and software for communication. Power control becomes major issue in order to support both cellular and D2D connection, as both these interfaces may occur at the same time. It should be taken care that wireless interfaces like LTE and Wi-Fi are required to have outband communication, or some similar interface to establish communication in unlicensed spectrum.

There are several works present in Outband D2D like use of clustering and game theory to increase system throughput using Outband D2D. New concepts are worked out for Outband which are deadline based, there are work which also covers the mobility aspects. As Outband requires more accurate evaluations and its establishment is complex, Inband has become much more popular than Outband.

III. INBAND D2D COMMUNICATION

Inverse to outband, Inband is controlled form of D2D communication. The decision of establishing D2D communication is taken by Base station. This type of D2D accesses cellular spectrum, so the problem of uncontrollable interference in unlicensed spectrum is avoid. This overall increases the QoS of the network. All the decision for D2D connection, D2D power control, resource allotment is taken by base station. Due to this reason there is full involvement of base station in during communication establishment. Above this, the communication between D2D is not through base station this saves the spectrum. So there are both advantages of supervising the process as well as keeping the base station free after the connection is established is present. This has become the major attraction to select D2D communication as Inband. The only and most important disadvantage of Inband is its interference created in the licensed spectrum. So interference management becomes main part of any Inband D2D communication system. Device to device communication inband gives the facility of reliable communication between two devices in near vicinity with higher data rate, instant communication and reduces overloading effect. At the same time it has to consider the interference management, resource allocation and energy consumption issues.

There are several advantages of Inband over Outband they are: As the communication is fully controlled, QoS management becomes simpler than outband. Inband uses licensed spectrum itself, any cellular devices can access Inband communication. Underlay provides parallel sharing of spectrum which considerably increases spectral efficiency. And Base station has record of all the connection cellular and D2D, which allows transparent allotment of resources in the network.

Depending upon the way licensed spectrum is shared between D2D and cellular communication, Inband can be divided into two parts. They are underlay-Inband and overlay-Inband communication.

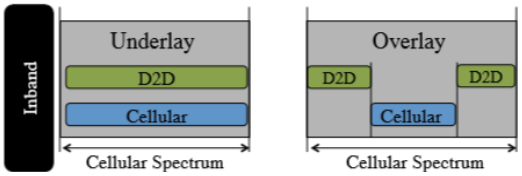

Figure2: Classification of Inband D2D

As shown in the figure in underlay-Inband D2D there is parallel sharing of the licensed spectrum by both cellular and D2D. They use same spectrum resources, leading to the concept of reusing the spectrum. While in overlay-Inband D2D they have dedicated resources for D2D and cellular, there is no parallel using concept. This leads to blocking of spectrum. When the number of D2D and cellular are fixed and are known prior then such system can be selected. But for system having fast changing condition in terms of number of user it is generally not selected.

IV. UNDERLAY INBAND D2D COMMUNICATION

Among all four types of D2D, underlay is most preferred because of its reliability, controlled communication and efficient resource use features. There are many works present in this domain. Among all the works done in D2D about 60% of work present is in underlay inband domain. It has controlled communication as the base station supervises the decision of

two devices having a D2D connection, its power allocation and resource management. It uses same resources as cellular communication; connection establishment is also managed by base station same as in cellular network, the difference is that base station is involved only till connection establishment and not after that. The communication that takes place no more follows path through base station instead it is now direct. Other aspects of communication as resource allocation and power control to reduce interference are done by base station.

In underlay communication the power required to have D2D connection is much less than regular cellular connection, this leads to a power efficient system, as the distance for communication decreases the interference created by link becomes limited. As there is no use of addition hardware or addition protocol to access the unlicensed spectrum, its establishment has low cost and it is more flexible method. In this, the devices can have easy switching from cellular to D2D and vice versa as same resources are used to access both the connections.

There are many work done in underlay D2D communication in which there are different work done in order to increase spectrum efficiency, power efficiency and QOS of the system. There are several connection establishment work present which defines algorithm to be followed for establishing connection. One of the method suggested in [2] is use of mechanisms for D2D communication session setup first and then in later part of paper the session management in LTE System Architecture Evolution. A interference limited scenario is created and simulations are performed in this environment. And the results reflect that D2D communication can increase the total throughput. In this dedicated signalling, automatic handover of network routed traffic (for D2D links) and interference coordination mechanisms are mainly used. Here the worst case for interference limited area scenario is been evaluated, assuming the results in other scenario will provide better results than that of present. In this two methods for session setup and its management is described. They are traffic dependent and signaling dependent session setup algorithms. Further here they have presented interference coordination for Uplink and downlink period in brief. In this way they have presented brief idea of establishing D2D in SAE procedures and functions for D2D session setup and mechanism to limit interference. Another method for connection establishment is suggested in [1] which majorly deals with interference cancellation technique. Depending upon this interference avoidance method resource allocation algorithm is defined in this section. Here all resources shared are of uplink cellular. The main control to allot power and other resources lies under control of base station. This allotment of resources and power is used to limit interference in the whole hybrid system of cellular and device to device communication.

Here the method to deal woth near-far interference (one of the most common interference) is considered. It deals with both cellular and D2D interference present in the system. A Common control channel (CCCH) method is present here. In this the base station supervises system and identifies the interference present in system and later broadcast information to users. RRM (Radio Resource management) method is utilized by every node to avoid interference. The major steps covered in this is first broadcasting, second listening third resource allocation.

Several works are present in order to have power control and allocation method like described in [3]. In this a power control mechanism for D2D is described. Resource sharing of uplink in D2D is done. The method of controlling maximum D2D transmission power is using power control of cellular is done. This allows underlay D2D communication even in fully loaded interference limited system and that to without reducing the system throughput of the cellular network. Orthogonal Frequency Division Multiple Access (OFDMA) infrastructure is considered. Base Station (BS) controls the transmit power and the resources that has to be used for each D2D. Above that resource allocation of resource block to each users and initialization is also handled by base station. So, there is a quick chance for the BS to reduce the interference which is created by the cellular and D2D links. Such a method is used for sharing the uplink resources in coming section. Here uplink power control method is considered. This allows reduction for dynamic signal range when more than one devices are present. Framework of cellular uplink power control used, the power control is under base station. It performs power control by reducing the transmitting power. This power control includes mathematical processes over SINR of cellular and device to device both. This power is calculated analytically considering uplink SINR of cellular network and SINR of D2D system. If it is not possible only then the first free RB is allocated. The remaining free RBs are allocated to the neighbour or the adjacent RB. Resource sharing is done as following method in this downlink and uplink resource sharing, separate (dedicated for D2D) and only cellular mode are suggested. Further using Shannon capacity formula the sum rate for each mode is calculated to obtain the most optimum mode.

Above that there are works present in order to reduce transmission power so that interference can be reduced. There are also many works present in power optimization considering a algorithms for optimization that can be solved by MINLP (Mixed integer nonlinear programming)[4][5].In [4] author has analyzed the resource sharing in a D2D communication underlaying cellular system. Cellular Base stations are expected to be capable of selecting the best scheme for cellular and D2D connections in case of resource allocation. Here they have shown that Inter-cell interference control mechanisms efficiently handle inter-cell interference based on power control and different methods of resource scheduling. Optimization problem for power and resource allocation is suggested with constraint of transmitters power, this is evaluated for intra-cell conditions, for special spectrum reuse for underlay device to device communication. For resource sharing they have considered three modes: NOS (Non-Orthogonal Sharing mode), OS (Orthogonal Sharing mode) and CM (Cellular Mode). Further they have

considered two optimization cases. In greedy sum-rate maximization, cellular and D2D communication are treated as competing services. The maximization is subject to a maximum power or energy constraint. While in [5] they have formulated a MINLP problem for improving overall system throughput. For the optimal resource allocation author has presented a three-step Scheme of first D2D using QoS awareness for admission control where priority is given to the required SINR, if requirement is satisfied only in such case resource sharing can exist between D2D and cellular. Secondly Partner reuse factor is used and Optimization for power control for the D2D is used. And lastly weighted matching method i.e the maximum weight match pair is considered to have allowed as a reuse partner for D2D is implemented.

Further there are concepts of different modes of D2D which include forced D2D, path loss D2D and opted D2D which gives overview of in which scenario D2D has to be forced or optionally selected.[7]. In this depending upon the calculated value of SINR there are four possible mode selections of different devices present in a network in near proximity. The threshold SINR required for D2D to overcome interference caused by the other users, is used to select the mode of communication. Depending upon the above factors either of the below four modes are selected, they are first cellular: Old traditional cellular mode is only present in the network, with no feature of having D2D communication. Second OPT D2D in this mode selection is done by mathematically calculating device power for all devices, in order to minimize the device powers. Third PL D2D**,** this is a path loss dependent method. Comparison of path loss of both cellular and D2D connection is done. And D2D mode is selected only when its path loss is less than that cellular. And Force D2D, in this for devices falling in the range of device to device communication, only D2D connection is established and not cellular. Depending upon system capacity value, processing gain, distance between two devices and path loss either of above mode is selected.

In [24] the author a method of sequential second price auction is presented. This method is used for resource allocation of D2D. In this the auction method is followed by inst4eqad of highest bid payment the winner has to pay second highest amount of bid. The auction of all resources is done. The devices should bid for the required resources. The bidding value will be function of overall system throughput. As a result every D2D devices bids for the resource block available in the network and this bidding leads to the increase of system throughput. From the simulation results it is observed that significant improvement in the throughput is observed. In this ways optimal resource allocation is achieved by auction method, in such a way that there is achievable throughput increment.

In [25] a heuristic algorithm based on the Hungarian algorithm is proposed by the author. Here they have considered a single cell scenario. It targets to reducing the interference in turn maximizing the number of D2D pairs. For this they have formulated the problem as a non-linear programming. The results shows that there is minor increment in the D2D pairs which are established but no major increment occurs. The optimum solution for formulated problem is achieved but the D2D pair increment still remains less than 10%.

There are several works which combines concept of M2M and D2D. The authors of [26] propose to use D2D communication in a M2M communication system. Generally there are many numbers of devices involved in M2M communication. But message size used for communication is comparatively. There is high congestion in M2M communication and many overhead are present in such communication. Taking under consideration all above point a combine network of D2D and M2M is suggested by the author. It uses the relay method to control the M2M traffic. All these decision assisted network is taken at the base station end. By applying this a considerable reduction in overall overheads is observed.

In paper [27] the author suggests a new method of virtual infrastructure. The nodes are considered virtual infrastructure. This method is mainly suggested to improve the system coverage and improve cellular spectrum use. Every node is assigned a relay node which assists the nodes the traffic requirement and then depending upon the network condition the node takes decision for link establishment and communication. Round Robin scheduling policy is used to reduce interference between two nearly placed devices. The simulation is performed by Monte Carlo simulation method, and result gives significant improvement in the throughput.

Summary: In the above section there are may works described in order to for communication link, further reduce interference and different method in order to achieve high throughput and improve overall system performance. Further field of more improvement of QoS can be explored. Further the distance varying D2D range can be explored. Works on significant and accurate D2D to cellular switching and vice versa can be further explored.

V. OVERLAY INBAND D2D COMMUNICATION

Here also the device to device communication occurs in the licensed spectrum itself. But there is no parallel sharing of the spectrum. In this there is a specified part of spectrum dedicated to D2D communication. This leads to reducing of spectrum use for the traditional cellular communication. As shown in figure 2 a part of spectrum is divided for cellular and D2D communication. This eliminates the factor flexibility of spectrum sharing. So if the cellular spectrum is overloaded and D2D spectrum is empty still the cellular communication cannot be established in D2D spectrum and vice versa. This leads to inefficient use of the licensed spectrum. The most important and major advantage of overlay is that there is no interference

present in between cellular and D2D communication. Overlay Inband D2D is mainly implemented for situational demand. The network where there is constant and high probability of device to device communication. That is scenario where the dedicated spectrum for D2D is utilized fully. And the division of the spectrum is fully justified. The major problems and limitation present in overlay is much different than that of underlay. In overlay main aspect covered is power control and allocation. To opt for correct method for utilization and switching from D2D to cellular and vice versa.

In [6] the main concentration is lead on spectrum sharing in order to increase spectrum efficiency of the network. In this the consideration to a OFDM based system for cellular user is taken. Device to device users uses the downlink signal power in order to determine their own kink path loss to the base station of the cellular system. Device to device users will then up scale the transmit power which is dependent on the path loss, in such a way that they can communicate in D2D form, i.e. directly with each other during the uplink band which in turns causes only minimal interference to the whole cellular and D2D system.

Then a traditional cellular network is considered, with circular cell of a known as radii namely R and base station is considered to be in the centre of cell. There are two users considered cellular user and D2D users. Cellular communicating is expected to be through base station and D2D through hop (single or multiple). Here D2D users are allowed to use the same frequency resources as that of the Cellular as long as that use does not cause the SINR of the cellular link to fall below the required threshold of minimum value. To attain this goal, it is assumed that D2D users are well aware of the margin of cellular users and also about the amount of interference that they can cause to the existing system. Here two scenarios one of uniform distribution of users and other clustered are considered as given below

Spectrum reuse is accomplished when both cellular and D2D user communication in same time at same frequency. To achieve this here two steps are suggested: first resource discovery: It is about knowing the potential D2D pair possible in the D2D range. Also information about availability of channel, required power for each channel must be discovered. Second neighbour and path discovery: Perfect routing is required once the potential D2D pair are discovered. This is done once the final destination end of communication is decide from the previous step. Then the bound is mathematically calculated for the transmitting power for both cellular and D2D user and has also calculated path loss between BS and D2D transmitter. Further they have proposed a Single Hop analysis for uniform and cluster distribution.

In [23], the author basically deals with the method for mode selection and node discovery. It suggests a method for network assistance to solve the problems of inefficient sevices, quality of service and power control method. It estimates a method for cellular control on D2D communication at the network level. In this base station is involved in connection establishment only, it has to be noted that base station only helps in monitoring process and not communication process unlike the traditional method. In traditional methods for connection establishment in D2D regular monitoring for other nodes is done at regular interval. This consumes a lot of energy in monitoring and listening process. But here the base station is assigned the method of monitoring at random interval. This leads to power control mechanism of the D2D devices. In turn the mutual interference created between simultaneously taking place D2D connection is reduced, as interference created while monitoring is eliminated. This technique is verified in this paper using Monte-Carlo simulation procedure.

Other work constitutes to different relay methods like incremental relay mode used in order to improve system throughput for D2D communication in cellular networks. Many multicast methods are also suggested which helps in switching between D2D to cellular and vice versa. This can also be accomplished by incremental relay mode fir transmitting end. The switching from D2D to cellular takes place when D2D link fails. There is a significant improvement in system throughput. And considerable reduction in outrage probability is observed.

Summary: There are many work present on power control and resource allocation. Several works gives acceptable throughput and resource allocation method for optimum results. Further area of variable dedicated spectrum can be explored. Dynamic allotment of spectrum algorithm can be formulated in order to achieve better system throughput.

VI. CONCLUSION

Due to increase of user the telecom operators have discovered new technologies as apart of this venture D2D was formulated to have enhanced use of spectrum for devices present in near vicinity. Firstly the requirement of D2D and its classification discussed. Then a brief overview about Outband D2D is given. Later Inband D2D is discussed in detail. And review of the work done in underlay and overlay D2D is presented here, and later summary of further topics which are still unexplored is mentioned.

VII. REFERENCES

[1] Shaoyi Xu, Haiming Wang, Tao Chen, Qing Huang, Tao Peng, 'Effective Interference Cancellation Scheme for Device-to-Device Communication Underlaying Cellular Networks', IEEE magazine 978-1-4244-3574-6/10, 2010

[2] Klaus Doppler, Mika Rinne, Carl Wijting, Cassio B. Ribeiro, and Klaus Hugl, 'Device-to-Device Communication as an Underlay to LTE-Advanced Networks' IEEE Communications Magazine , December 2009
[3] Pekka Janis, Chia-Hao Yu, Klaus Doppler, Cassio Ribeiro, Carl Wijting, Klaus Hugl, Olav Tirkkonen, Visa Koivunen, 'Device-to-Device Communication Underlaying Cellular Communications Systems.' Int. J. Communications, Network and System Sciences, 2009, 3, 169-247
[4] Chia-Hao Yu, Klaus Doppler, Cassio B. Ribeiro, and Olav Tirkkonen, 'Resource Sharing Optimization for Device-to-Device Communication Underlaying Cellular Networks.' IEEE transactions on wireless communications, vol. 10, no. 8, August 2011
[5] Daquan Feng, Lu Lu, Yi Yuan-Wu, Geoffrey Ye Li, Gang Feng, and Shaoqian Li, 'Device-to-Device Communications Underlaying Cellular Networks', IEEE transactions on communications, vol. 61, no. 8, August 2013
[6] B. Kaufman and B. Aazhang, "Cellular networks with an overlaid device to device network," in Proceedings of Asilomar Conference on Signals, Systems and Computers, 2008.
[7] Sami Hakola, Tao Chen Janne Lehtom and Timo Koskela," Device-to-Device (D2D) Communication in Cellular Network - Performance Analysis of Optimum and Practical Communication Mode Selection", in the WCNC , IEEE communication society, 2010.
[8] Anurag Kumar, D. Manjunath, Joy Kuri, WIRELESS NETWORKING, Morgan kaufmann publishers
[9] Guanding Yu, Zhaoyang Zhangt, Yan Chen, Jing Shi, and Peiliang Qiu, 'A Novel Resource Allocation Algorithm for Real-time Services in Multiuser OFDM Systems' IEEE magazine, 0-7803-9392-9/06,2006
[10] Yong Li, Zhaocheng Wang, Depeng Jin and Sheng Chen, 'Optimal Mobile Content Downloading in Device-to-Device Communication Underlaying Cellular Networks', IEEE transactions on wireless communications, vol. 13, no. 7, JULY 2014
[11] Niannian Dan, Bingbing Li, Bing Lan , JunRen, Chang 'Resource Allocation over Cooperation for cross-cell D2D Communication Underlaying LTE Network',IEEE magazine, 978-1-4799-2827-9/13,2013
[12] M. Zulhasnine, C. Huang, and A. Srinivasan, "Efficient resource allocation for device-to-device communication underlaying LTE network," in IEEE 6th International Conference on Wireless and Mobile Computing, Networking and Communications, pp. 368-375, Niagara Falls, Oct. 2010.
[13] P. Janis, V. Koivunen, C. Ribeiro, J. Korhonen, K. Doppler, and K. Hugl, "Interference-aware resource allocation for device-to-device radio underlaying cellular networks," in Proc. IEEE Vehicular Technology Conference 2009-Spring, Barcelona, Apr. 2009.
[14] K. Doppler, C.-H. Yu, C. B. Ribeiro, and P. Janis, "Mode selection for device-to-device communication underlaying an LTE-advanced network," in Proceedings of IEEE WCNC, 2010, pp. 1–6.
[15] H. Min, J. Lee, S. Park, and D. Hong, "Capacity enhancement using an interference limited area for device-to-device uplink underlaying cellular networks," IEEE Trans. Wireless Commun., vol. 10, no. 12, pp. 3995– 4000, 2011
[16] Jose Mairton B. Gabor Fodor, Tarcision F. Maciel, "Performance analysis of Network Assisted two-hop D2D communication"International conference 2014
[17] K. Huang, Y. Chen, B. Chen, X. Yang, and V. Lau, "Overlaid cellular and mobile ad hoc networks," in IEEE Int. Conf. Communication Systems (ICCS), 2008, pp. 1560-1564.
[18] K. Doppler, C. B. Ribeiro, and J. Kneckt, "Advances in D2D communications: Energy efficient service and device discovery radio," in Int. Conf. Wireless Communication, Vehicular Technology, Information Theory and Aerospace Electronic Systems Technology (Wireless VITAE), 2011, pp. 1-6.
[19] J. C. Li, M. Lei, and F. Gao, "Device-to-device (D2D) communication in MU-MIMO cellular networks," in Proceedings of IEEE GLOBECOM, 2012, pp. 3583–3587.
[20] Y. Pei and Y.-C. Liang, "Resource allocation for device-to-device communication overlaying two-way cellular networks," IEEE Transactions on Wireless Communications, vol. 12, no. 7, pp. 3611–3621, Jul. 2013.
[21] M. Jung, K. Hwang, and S. Choi, "Joint mode selection and power allocation scheme for power-efficient device-to-device (D2D) communication," in Proceedings of IEEE VTC-Spring, 2012, pp. 1–5.
[22] C.-H. Yu, K. Doppler, C. B. Ribeiro, and O. Tirkkonen, "Resource sharing optimization for device-to-device communication underlaying cellular networks," IEEE Transactions on Wireless Communications, vol. 10, no. 8, pp. 2752–2763, August 2011.
[23] G. Fodor, E. Dahlman, G. Mildh, S. Parkvall, N. Reider, G. Mikls, and Z. Turnyi, "Design aspects of network assisted device-to-device communications," IEEE Communications Magazine, vol. 50, no. 3, pp. 170–177, 2012.
[24] C. Xu, L. Song, Z. Han, Q. Zhao, X. Wang, and B. Jiao, "Interferenceaware resource allocation for device-to-device communications as an underlay using sequential second price auction," in Proceedings of IEEE ICC, 2012, pp. 445–449.
[25] T. Han, R. Yin, Y. Xu, and G. Yu, "Uplink channel reusing selection optimization for device-to-device communication underlaying cellular networks," in Proceedings of IEEE PIMRC, 2012, pp. 559–564.

[26] N. K. Pratas and P. Popovski, "Low-rate machine-type communication via wireless device-to-device (D2D) links," arXiv preprint arXiv:1305.6783, 2013

[27] K. Vanganuru, S. Ferrante, and G. Sternberg, "System capacity and coverage of a cellular network with D2D mobile relays," in MILITARY COMMUNICATIONS CONFERENCE-MILCOM, 2012

