International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 5
May 2017

Review on Device-to-Device Communication

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ABSTRACT - *The sudden outburst of wireless mobile devices has given rise to limitations such as energy consumption, spectrum crisis, etc. which cannot be fulfilled using 4G. With ever-increasing demand for higher spectral efficiency, higher data rate we have reached the heights where there is a need for invention that is beyond 4G i.e. 5G. We have observed that there is no direct communication between devices in the licensed bandwidth in a conventional cellular system where the devices communicate with one another through the base station. Hence the rising demand for capacity requirement and higher data rate forced people to think in an unconventional way. Device to Device Communication is an evolving technology in 5G which avails many vantages for the Long Term Evolution (LTE) advanced networks. In this review paper a two tier cellular network has been envisioned. D2D classification, its architecture in LTE advanced network, the protocols used to implement it, and the various challenges faced by it have been discussed in this paper.*

Keywords:D2D Communication, Inband D2D, Outband D2D, interference management and routing algorithms.

INTRODUCTION

To fulfil the requirements of the users we need to have an approach towards a well-planned reuse of presently available frequency bands [1]. This can be obtained by various alternate ways such as densifying the base stations and making use of small cells underlying the conventional cellular networks, deploying spectrum sharing and cognitive radio [2], or D2D communication. In D2D Communication the devices communicate with one another independently without the need for a control centre. The devices work together to collect, share and pass on the information in multi-hop manner. Finally, judgement of the gathered information is based on the smartness of the devices [3]. Device relaying helps the devices in a network to act as transmission relays and contribute to a large wireless mesh network. D2D communication functionality makes it possible which permits two closely placed devices to communicate with one another in the licensed cellular bandwidth without the involvement of a base station [4]. This technology has been proposed to increase the optimality of resource utilization and spectral efficiency. It enables direct data flow between devices [5]. This D2D functionality if availed would lower the communication cost among devices. D2D Communication also plays an important role in traffic offloading and natural disaster management. Some D2D communication functionality is exhibited by Bluetooth and Wi-Fi which work in unlicensed band where the interference is not under control. Moreover, they do not provide security and quality of service (QoS) guarantee [4].

1. D2D CATEGORIZATION BASED ON OPERATOR CONTROL

A two-tier 5G cellular network has been envisioned in this paper namely, the macro-cell tier and the device tier. The macro-cell tier constitutes base station-to-device communications as in a conventional cellular system whereas device tier constitutes only D2D communications. In the device tier communication realization, the operator has various levels of control. D2D communication can be categorized on the basis of degree of involvement of cellular operator [4].

1.1 Device relaying with operator controlled link establishment (DR-OC)

Communication of a device located at the edge of a cell with a base station can be accomplished by relaying the information contained in it through other devices. In this way the device is able to acquire a higher quality of service and greater battery life. The operator communicates with the relaying devices for partial or full control link establishment [4].

International Journal of Engineering Technology Science and Research
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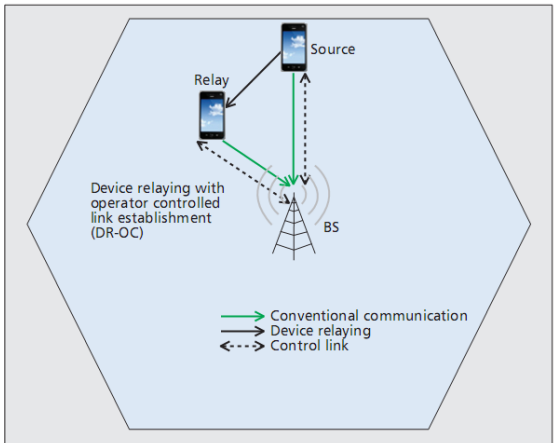

Fig 1: Device relaying communication with operator controlled link establishment (DR-OC) [4].

1.2 Direct D2D communication with operator controlled link establishment (DC-OC)

In DC-OC the source device communicates and transfers and receives information from the destination device without the requirement for a BS, but the operator assists them for link establishment [4].

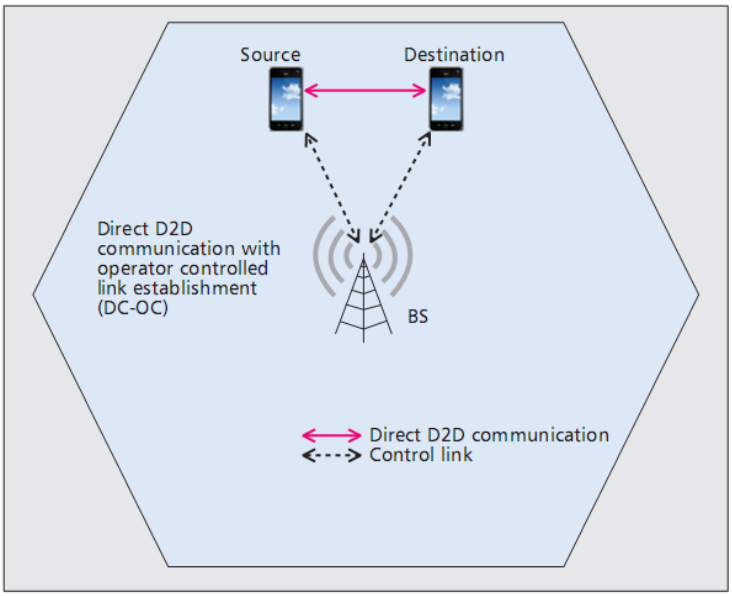

Fig 2: Direct D2D communication with operator controlled link establishment (DC-OC) [4].

1.3 Device relaying with device controlled link establishment (DR-DC)

The source device and destination device coordinate among themselves and communicate with each other with the help ofrelays between them. There is no involvement of operator in the process of link establishment [4].

2.4 Direct D2D communication with device controlled link establishment (DC-DC)

There is direct communication between the source device and destination device have direct communication without the need for operator control [4].

In DC-OC and DR-OC the base station is involved in allocating resources and setting up of call therefore, the base station eliminates the issue concerning interference with the help of centralized methods. In DR-DC and DC-DC, resource allocation between the devices is not performed under the supervision of any central entity due to which the devices unavoidably influences the macro-cell users. To make sure that the influence is

International Journal of Engineering Technology Science and Research
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ISSN 2394 – 3386
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minimal the designing of a two-tier network must be done using intelligent interference management techniques and schemes exhibiting appropriate resource allocation [4].

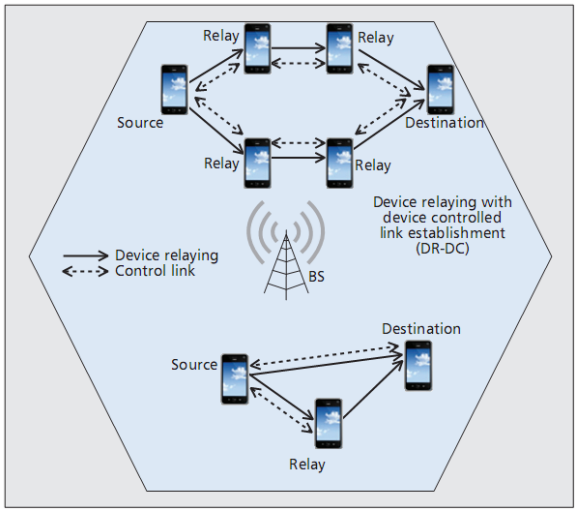

Fig 3: Device relaying communication with device controlled link establishment (DR-DC) [4].

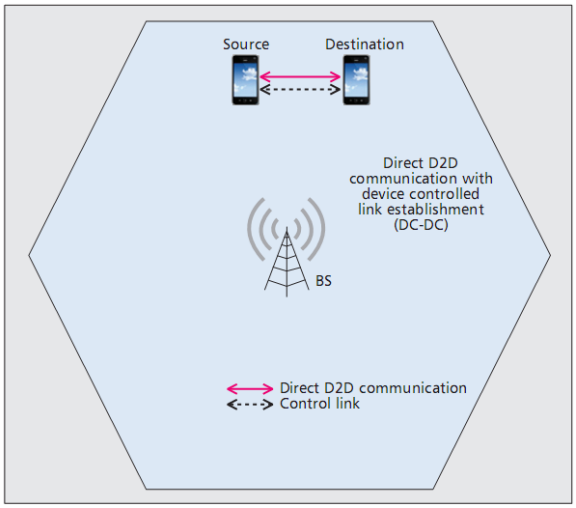

Fig 4: Direct D2D communication with device controlled link establishment (DC-DC) [4].

2. D2D CLASSIFICATION

D2D communication is known for its non- transparency to cellular network and it can take place on the cellular spectrum or unlicensed spectrum. Besides increasing spectral efficiency, D2D communication also improves delay, throughput, fairness and energy efficiency [6]. D2D communication is classified as shown in figure 5.

2.1 Inband D2D: In Inband D2D the cellular spectrum is used for both the links i.e., cellular links as well as D2D links. The reason behind choosing this type of communication is high control over licensed (cellular) spectrum [6]. It has been observed by few researchers that the interference in the unlicensed spectrum is such high that it is almost uncontrollable [7,8] which poses limitation for QoS delivery. Inband D2D communication is further classified into two categories namely, underlay D2D and overlay D2D as shown in figure 6.

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2.1.1 Underlay D2D: In underlay D2D communication, D2D links and cellular links share the same radio resources [6]. But this type of communication poses a threat of interference between cellular and D2D communication [9]. To mitigate the effect of interference overlay inband D2D has been proposed.

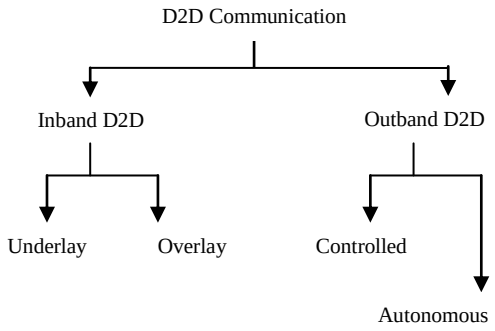

Fig 5: D2D Communication Classification [6].

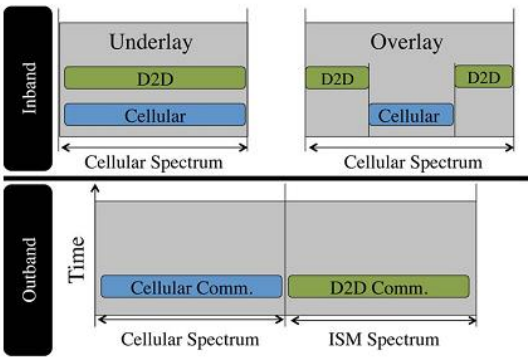

Fig 6: Representation of underlay inband, overlay inband and outband D2D [6].

2.1.2Overlay D2D: In overlay D2D communication, D2D links are provided with dedicated cellular resources [6].

2.2Outband D2D: Here, the unlicensed spectrum is utilized by D2D links. It is used largely as it helps in mitigating the interference between cellular and D2D links. As the unlicensed spectrum requires an additional interface it chooses other wireless technologies such as Bluetooth, WiFi etc [6]. The cellular devices having two wireless interfaces (e.g., LTE and WiFi) can avail outband D2D, and thus cellular and D2D communications can take place at the same time [6].The outband D2D is further classified as controlled D2D and autonomous D2D communication.

2.2.1 Controlled D2D: The cellular network is given the control of the additional interface [10]. This improves the reliability and efficiency of D2D communication [6].

2.2.2Autonomous D2D: Some researchers propose the cellular communications to be controlled whereas leave the D2D communications to the users. It reduces the overhead of cellular networks [11].

The spectral efficiency of cellular networks can be improved in Inband D2D by the reuse of spectrum resources which is offered by underlay inband D2D communication or by the allocation of dedicated cellular resources to D2D links which is offered by overlay inband D2D communication. But Inband D2D communication also has certain demerits such as interference management between the D2D and cellular links which can be mitigated by proper resource allocation thus increasing the complexity [6].Researchers are

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IJETSR
www.ijetsr.com
ISSN 2394 – 3386
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exploring the advantages of outband D2D and considering it as a more feasible option to inband D2D. As the mobile market is flooding with smartpnones greater number of these devices are furnished with more than a single wireless interface which makes it easier to effectively implement outband D2D.

3. D2D COMMUNICATION ARCHITECTURE

The D2D architecture comprises of Evolved Packet Core (EPC) and Evolved Universal Terrestrial Access Network (E-UTRAN). The assistance of D2D is validated by two functional entities present on the network side namely, Proximity Based Service (ProSe) Function and ProSe Application Server and one entity on the user side i.e. ProSe Application [13].

Table 1: Benefits and limitations of inband D2D communication [12]

Benefits of Inband D2D	Limitations of Inband D2D
1) Exploitation of spatial diversity increases Spectral efficiency of cellular spectrum in underlay D2D. 2) As eNBs are used for controlling management of QoS becomes easy. 3) Any mobile equipment can use Inband D2D.	1) Controlling the interference level is challenging. 2) Cellular and D2D transmissions cannot take place simultaneously. 3)Power control and resource allocation is complex.

Table 2: Benefits and limitations of outband D2D communication[12]

Benefits of Outband D2D	Limitations of Outband D2D
1) Allocation of resources is easier. 2) Cellular and D2D transmissions can take place simultaneously. 3) No interference between cellular and D2D links. 4) Devotion of cellular resources to D2D links is not required.	1) Encoding and decoding of packets is necessary. 2) Requires atleast two wireless interfaces. 3) Efficient pwer control is required.

ProSe Function is performed as a logical function which avails three different sub-functions [13] as follows:

(i) Direct Provisioning Functionincludes parameters for D2D communication and D2D discovery. The parameters are associated with authorization policy.

(ii) Direct Discovery Name Management Function identifies a D2D application and its assistance in the network for D2D discovery purposes is accomplished.

(iii) EPC-level Discovery ProSe Function performs network associated functionalities such as subscriber information management, authorization and charging.

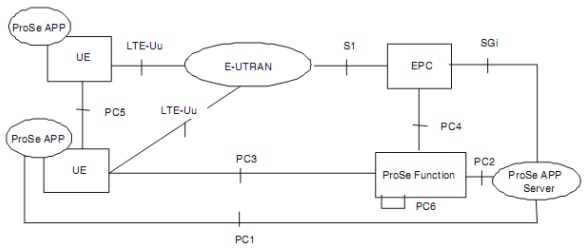

Fig7: D2D enhanced LTE architecture [13]

ProSe Application Server makes available ProSe Applications and helps in mapping users to the individual functions. Along with this it also accumulates information concerning all the available functions.

PC1 interface acts as the reference point between the ProSe App Server and the ProSe application in the UE. It defines application level signalling requirements [13].

PC2 interface acts as the reference point between the ProSe Function and the ProSe App Server. It defines the intercommunication between ProSe functionality and ProSe Application Server [13].

PC3 interface acts as the reference point between the ProSe Function and UE. It defines the intercommunication between ProSe Function and UE [13].

PC4 interface acts as the reference point between the ProSe Function and EPC. It defines the intercommunication between the ProSe Function and EPC [13].

PC5 interface acts as the reference point between UE to UE that is used for controlling and user plane for communication and discovery, for one-to-one communication and relay [13].

4. APPROACHES FOR D2D COMMUNICATION

As D2D communication in cellular network is growing and becoming a centre of attraction and interest it is important to find out ways of achieving intelligent D2D communication in the Internet of Things. Here, two important approaches which can be utilized to obtain D2D communication have been discussed. The approaches are analysed on the basis of participation of a network infrastructure [14].

4.1 Network-Infrastructure-Dependent D2D Communication

Figure 8 shows how this kind of architecture can be obtained. It can be achieved in the licensed or in the unlicensed spectrum.

4.1.1 D2D Communication in the Licensed Spectrum: Here, reuse of licensed spectrum is increased which in turn increases the cellular network capacity. The foremost step towards achieving D2D communication is link discovery. The devices make use of link discovery to search for other devices in its close proximity. Link discovery is performed by notifying devices about other devices within its communicating range and allotting frequency and time for sending beacons [3]. Since the location of the device is known to the network lesser time is consumed for link discovery and hence it is energy efficient [14]. This approach facilitates secure authentication as the device is preregistered with the primary network.

4.1.2 D2D Communication in the Unlicensed Spectrum: Licensed spectrum is a limited resource therefore some communications occurring via unlicensed spectrum can be off-loaded to unlicensed bands if the licensed band has no resource available in it. Link discovery is performed as in licensed spectrum. A secure D2D communication is set up by a trusted network entity anywhere, anytime thus permitting more number of devices to be connected in various locations [3].

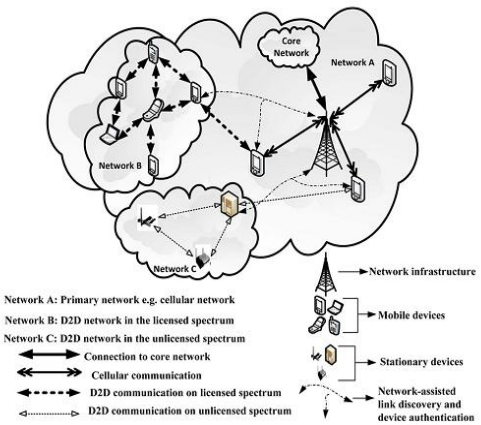

Fig 8: Network-infrastructure-dependent D2D communication using a licensed or an unlicensed frequency spectrum [3].

International Journal of Engineering Technology Science and Research
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www.ijetsr.com
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4.2 Network-Infrastructure-Independent D2D Communication

Figure 9 shows how this kind of architecture can be obtained. It can be achieved in the licensed or in the unlicensed spectrum.

4.2.1 D2D Communication in the Licensed Spectrum: FlashLinQ aims to deliver direct D2D communication over the licensed spectrum without the intervention of a network infrastructure [15]. Paging is used for link establishment and thus reliable communication occurs. The devices perform link discovery on their own and thus communication takes place between authorized devices as the devices have the knowledge of one another's presence. Hence security of information is maintained between the stationary devices or mobile within the Internet of Things [3].

4.2.2 D2D Communication in the Unlicensed Spectrum: As long as the devices are ready to communicate this approach facilitates a self-organizing D2D communication set up without any network infrastructure. The reason for its less popularity is that it needs manual intervention of the user for pairing a device with another device [3].

Table 3: Capabilities of D2D communication approaches in different situations [3]

D2D Commu -nication / Scenario	Network Dependent		Network-independent	
	Licensed Spectrum	Unlicensed Spectrum	Licensed Spectrum	Unlicensed Spectrum
Type of Device	mobile	mobile/ stationary	mobile/ stationary	mobile/ stationary
Network subscription	requiredmay	be required	not required	not required
Link Discovery	network infrastructu -re assisted	network infrastructu -re assisted	done manually by devices	done manually by devices
Security	guaranteed	not guaranteed	guaranteed	not guaranteed
Interference	controlled	uncontro -lled	controlled	uncontrolled
Energy usage	low	moderate	moderate	high

5. ALGORITHMS FOR INTELLIGENT D2D COMMUNICATION

The routing algorithms used are as follows:

5.1 Hierarchical Algorithms: These may be cluster based or tree based. In tree based algorithms the devices share the same destination which creates a traffic pattern of many to one. In cluster based algorithms the devices are classified into groups in a hierarchical manner. Devices in different level of hierarchy have different roles to be performed [16].

5.2 Stochastic Algorithms: Routing probabilities are formulated that optimize a given set of network resources such as Signal to noise ratio, energy consumption etc. The network resources are chosen on the basis of conditions prevailing within a network [3].

5.3 Context Aware Algorithms: Appropriate information is achieved about the circumstances near the device within a network using these algorithms. These algorithms then search for an optimal route to pass on the data based on obtained information [17]. This algorithm is capable of sensing information surrounding the devices. It is able to make changes in a service on the basis of present context. It is capable of benefiting from related resources [3].

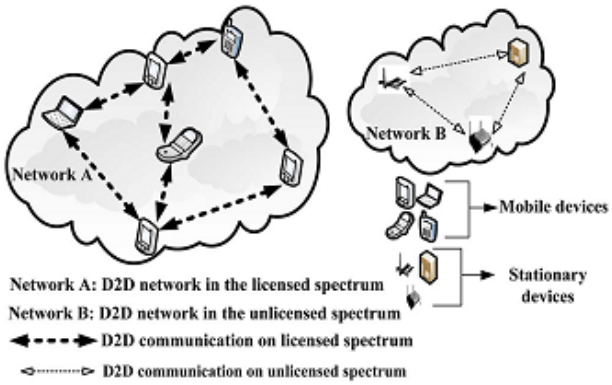

Fig.9. Network-independent D2D communication using a licensed or an unlicensed frequency spectrum [3].

5.4 Bio-inspired Algorithms: It addresses the limitations faced by large scale networks which is indicated by a dynamic and self-organizing nature, no intervention of centralized control, heterogeneous architecture etc. We observe biological systems are based on simple generic rules which produce collaborative still effective patterns for task allocation and resource management without the intervention of any controlling body [18].

Approaches to bio-inspired networking are as follows:

5.4.1 Swarm-Intelligence and Social insects: Swarm intelligence based algorithms are examples of bio-inspired algorithms. The best scrutinized branch of swarm intelligence based algorithms is Ant Colony Optimization (ACO) [19]. ACO works on the following principle [3]:

(i) Foraging: It is the process that the ants use for the discovery of the shortest path that leads their way to a food source from their nest.

(ii) Stigmergy: It is the process that the ants use for modification of the path that they have discovered and respond to these modifications by generating a kind of global collaboration among themselves.

Some pheromone is laid on the ground by a moving ant thus tracing the path by a trail of pheromone. When a randomly moving ant comes in contact with the laid trail recognizes and chooses to go behind it thus strengthening the trail with its ownpheromone. This results in the emergence of autocatalytic behaviour i.e. the attractiveness of a path for being followed increases as the number of ants in that particular path increases [19].

5.4.2 Firefly Synchronization: Lately, a novel model for clock synchronization has been put forward which finds its base from the firefly synchronization. It works on the principle of synchronization of oscillators that are mutually coupled having arbitrary frequencies. The fireflies are able to change their natural frequency making an effort to match stimuli of another frequency. The flash of each firefly is treated as a stimulus and each firefly tries to synchronize its frequency with the other fireflies [18].

5.4.3Artificial Immune System: It works on the principle of mammalian immune system [20]. It identifies the transformations in the environment or divergence from the usual behaviour of the system in complicated domain. These algorithms utilize the characteristics of immune system such as memory and self-learning.

AIScomprises of three parts which need to be worked on while computing the immune engineering processes namely, system component representation, genetic selection and affinity measures [18].

5.4.4Epidemic Spreading: It is used to interpret the information distribution, outspread of viruses in the mobile devices or internet in the wireless ad-hoc networks. This model depends on the total no of nodes present in the network. A diffusion algorithm is used to transmit and receive information among the nodes. The nodes are categorized into two groups namely, susceptible nodes and infective nodes. The susceptible nodes are then converted to infective nodes using diffusion algorithm [18].

Hence, we can conclude from the above mentioned algorithms that each one has its own significance and none can be neglected. But for intelligent D2D communication in the IoT, the most acceptable ones are stochastic, context-aware and bio-inspired algorithms [3].

6. CHALLENGES FACED

(i) Interference Management: Interference management plays a vital role in D2D communication. It becomes crucial and complexity increases when it comes to communication and computational load. Hence, this issue must not be neglected in future work [1].

(ii)Optimized Route Discovery and Management: The devices and network within which the device rests has certain constraints, hence to discover the optimized path for end-to-end D2D communication becomes difficult. For this purpose, intelligent protocols are required. Uncertainty in the device movement leads to breakage of the routes already established. It may happen that a device is available for relaying, but at the same time it may not have sufficient power to support the process of routing [3].

(iii) Device Cooperation in the IoT: In the IoT the D2D communication is of multi-hop nature. This arouses the need for proper cooperation between the devices. Optimal route selection gets affected in the process of achieving Cooperation. Therefore, a mechanism that may efficiently overcome this limitation is required [3].

(iv) Security: Security plays a key role in D2D communication because the information is transferred using other devices which pose a threat of the information remaining no more confidential [4].

(v) Communication Resource Optimization: The network resources that are available must be utilized to the maximum. The resources can be distinguished as global as well as local resources. For network dependent D2D communication there must not be any idle frequencies present as it will hamper expected D2D communication to take place and hence, new techniques are required for allocating and sharing frequency blocks whereas, for network independent D2D communication, the device switch to the available idle frequencies when it identifies the primary user of that frequency block resulting in interruption. Swapping between the frequencies exhausts the battery. Also when the same idle frequency block is detected by two different devices, they inform one another as to which frequency block they wish to use. This in turn leads to signaling overhead [3].

(vi) Device Discovery: Before setting up of the direct path for communication the devices must be aware of the devices must be able to recognize the existence of its neighboring devices and know their identity, obtain information of the services being offered and fulfill the vicinity conditions. All these tasks are very challenging. Exchange of beacon signals is carried out between the devices that wish to communicate in D2D mode as well as between the devices and Evolved Node B (eNB) for the purpose of control. This exchange of beacon signals is referred to as Peer Discovery [21].Two chief techniques used for device discovery are *Priori* and *Prosteri* [22]. In *Priori* a device transmits the beacon signal periodically before the communication. In *Prosteri*the eNBstarts the process of discovery during the actual communication between the devices.

(vii) Selection of Mode*:* Mode selection for maintaining the optimality is another difficult task. The metrics based on which modes are selected are channel quality, distance between D2D and cellular user, path loss, energy efficiency. SINR and channel quality are the popular metrics as signaling overhead is minimum and implementation is easy [21].

(viii) Mobility Management*:* The maximum allowable distance between a D2D pair must be decided on the basis of required QoS and interference constraints. The continuation of services must be maintained while a

device moves within the network during an ongoing communication which results in handover. Thus efficient handover services are needed [21].

7. INTERFERENCE MITIGATION TECHNIQUES

The sharing and reuse of radio resources by the cellular and D2D links give rise to undesirable interference which is also known as cross-tier interference. The uplink spectrum is subjected to less interference than downlink spectrum. The D2D pairs contribute to mutual interference. When there is sharing of same resource blocks by the D2D pairs in uplink as well as downlink, mutual interference comes into picture which is also known as co-tier interference [24]. Therefore, interference mitigation becomes a prime objective.

7.1Power Control: The transmitted power from a D2D transmitter must be adjusted such that it is less than a pre-decided threshold while it meets the SINR target of cellular communication. The interference faced by the cellular receivers can be eliminated with the help of eNBs setting up limitations on the transmitted power. This increases the spectral efficiency as there can be simultaneous reuse of same resources by D2D links [21].

7.2 Radio Resource Allocation Technique: Here, different radio resouce allocaton algorithms are utilized that help in the assignment of radio resources to The available D2D pairs in an efficient manner. As proposed in either uplink or downlink spectrum band for reuse of D2D link is selected on the basis of power received which is calculated by an eNB. If the received power is above the pre-decided threshold then downlink is selected else uplink is selected for reuse of D2D link. This results in reduction of signal overhead and improvement in cellular gain [23].

Another novel technique is a location-based scheme which eliminates the mutual interference between D2D and cellular links using the same up link resources. The concept behind it is usage of approachable and reusable regions. This scheme results in the reduction of outage probability of both the cellular as well as D2D links and thereby improves the reliability of the D2D communication [24].

7.3 Spectrum Splitting: It is the easiest method of mitigating interference in D2D communication. Time division multiplexing can be used to part the D2D and cellular links in the hybrid cellular network with D2D communication. But this technique results in the wastage of the spectrum available for D2D communication.

7.4 Multiple-Input-Multiple-Output (MIMO):MIMO schemes include interference cancellation technique and beamforming which helps in eliminating interference to a great extent and also provides prior knowledge of the channel state information. Beamforming helps in the generation of beam patterns of directional antenna. The generated beam is guided to the desired receiver and cancels out the unwanted interference directed towards the other users. This results in increment in SINR of the desired user and prevents the transmitted power to be wasted. Beamforming leads to increase in the capacity and spectrum reuse factor [21].

Hence, we can conclude from the above techniques that power control techniques though easy to implement does not offer performance gain as desired. The radio resource allocation techniques do not allow the D2D pairs to use frequencies that fail to comply with the constraints on QoS of the users of cellular network which causes some of the radio resources to remain unutilized. Among all other techniques MIMO is the most promising one [21].

8. CONCLUSION

In this paper we have provided a substantial review on the available written works on D2D communication. Here a 5G two-tier cellular network has been envisioned. A detailed description on the categorization of D2D based on the control level, its classification as well as its architecture has been scrutinized. Comparison of inband D2D and outband D2D has been done finally we concluded outband D2D to be the viable alternative. Thus D2D is a novel model that is being planned to be implemented in the next generation of wireless mobile networks. Also, we have discussed the limitations that are hampering its use and some techniques to overcome these limitations.

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