Review of Ultra-Dense Networks Integration with Device To Device (D2D) Communication

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***Abstract*— The current network architecture scene can be a challenge due to the increasing number of user equipment and its diversity. Furthermore, the demand for greater data rates and lower latency by the users are increasing. Deployment of the Ultra Dense Networks (UDN) described is to support future wireless network and meet user demands in future wireless networks. Combined with other technologies such as Device to Device (D2D) communication, it will provide benefit to the wireless communication. In this paper, challenges in existing research efforts are analyzed and future avenues for research is presented. Apart from that, this paper considers the features of the D2D and UDN to collaborate later. Generally, by deployment of large small cells, factors such as the traffic offloading, idle mode capability, power consumption, and energy efficiency should be considered. Basically, from the potential challenges that have been identified, it is obvious that the integration between D2D and UDN is a key enabler for potential solution. Finally, the research gaps for research between integration of UDN and D2D can be identified with challenges and open problems that have been presented.**

***Index Terms*— Ultra Dense Network (UDN), small cells, Device to Device (D2D), traffic offloading, idle mode, power consumption.**

I. Introduction

EVER increasing requirements and demands of users of mobile networks such as on capacity, coverage, peak rate, throughput, and latency are the main drivers for the network's further enhancement. One of the most promising approaches is efficient reuse of existing frequency bands. This can be accomplished by several options, such as densification of base stations and deployment of small cells underlying the conventional cellular networks also known as Ultra-Dense network (UDN) [1], Device to Device (D2D) communication, or combinations of UDN and D2D in the communication system.

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Moreover, UE at the cell edge that is facing network coverage problem needs the relay role for connection or to enhance capacity. In that case, the availability of D2D communication in UDN environment is required to reach the target in order to achieve the quality of service in wireless communication.

UDN can be defined in terms of the cell density without the consideration of the user density. According to [2], ultra dense scenarios can be considered when the number of cells is around 103 or more per square kilometers. In addition, according to [3], [4] dense urban scenarios are considered when the active user's density is less than the number of access point. A simplified UDN scenario is as shown in Fig. 1 with huge number of small cells such as picocell and femtocell deployed to support the increasing number of UE. Furthermore, UE at cell edge that suffers with network coverage needs relay for connection as well as incorporation with other technologies such as D2D communication.

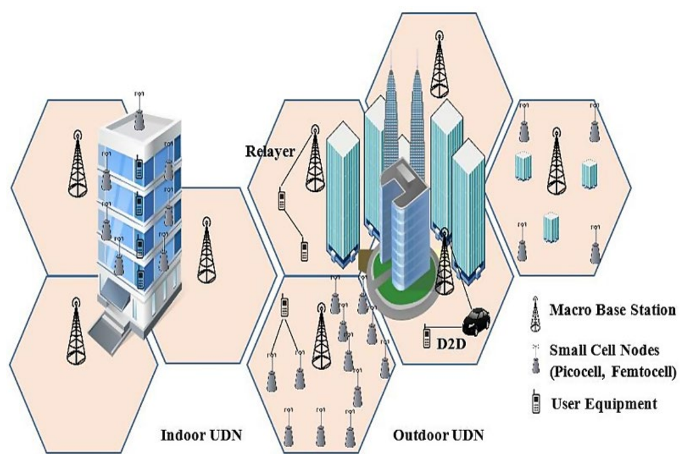

Fig. 1. An example of a UDN

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D2D can be defined as a direct communication between two user devices without travel across a Base Station (BS) [5]. Generally, D2D communication may occur on the cellular spectrum either in-band or out-band [6]. Furthermore, today's cellular networks can potentially be in range for direct communications in order to use high data rate services. In contrast, all communications must traverse the BS in conventional cellular network despite the communication being in short distance or in range for D2D wireless communication. Hence, the spectral efficiency of the network may be enhanced by using D2D communications in wireless communication scenarios. Basically, the D2D communications are not only limited to enhance spectral efficiency but to improving throughput, energy efficiency, delay, fairness, capacity, and power control [7]. The D2D for the next generation in cellular communication more extensive in many areas including multi hop relaying [8]-[10], cellular offloading [11]-[13], vehicular networks [14]-[16], public safety service [17]-[19], and proximity based services [20], [21]. In that case, the integration between D2D and UDN will provide benefit to the communication system.

Basically, the principle of the UDN can be classified into three features such as (i) the number of UE is equal or less than the sum of small cells. Nonetheless, with a large quantity of small cells, the frequency reuse can be improved and concurrently in macro cells the spectrum sharing occurs. Apart from that, the balancing network loads, congestion in networks, and network capacity can be improved with the deployment of dense small cells [22]. (ii) UDN comprises of small cell, macro cell, relay, D2D links, or dense with interconnected cross tier deployment which will increase the complexity of the networks. Due to the multi-tier deployment, frequency with different signals are transmitted across the overlapping area between macro cell and small cell. Apart from that, large frequency reuse factor occurs as the distance of small cells is close to each other. Thus, the interference coordination is a critical issue to reduce and to support resource management [22]. (iii) The last feature is flexible switching and fast access. The UE that is moving regularly switch the connection among the BS or access points in dense deployment environment. In order to provide smooth connections and accomplish better service, high quality Handover (HO) and optimal connections is vital [22].

Generally, Heterogeneous Network (HetNet) is developed from the conventional macro cell-only network known as homogeneous networks (HomNet). Hence, UDN is another evolution from HetNets. The main differences between regular HetNets and UDN are as follow: (i). BS to UE density. In regular HetNets, the UE density is larger than the BS density, while in UDN, the UE density is smaller than the BS density. As a result, and in contrast to regular HetNets where the BS are powered on most of the time, in UDN, BSs with no active UEs should be powered off to reduce unnecessary interference and save power. (ii). The propagation conditions - In regular HetNets, Non-Line of Sight (NLOS) interferers count for most cases, while in UDN, Line of Sight (LOS) interferers count for most cases. As a result, and in contrast to regular HetNets where simple single-slope path loss model is usually assumed to obtain the numerical or analytical results. In UDN, more sophisticated and practical path loss models should be considered. (iii). Diversity loss - In regular HetNets, there is a rich UE diversity, while in UDN there is a limited UE diversity. In contrast to regular HetNets where independent shadowing and multi-path fading among UEs in one cell are usually assumed to obtain the numerical or analytical results and in the UDN, such assumption is not true. Thus, new results for UDN should be derived and the numerical or analytical results for regular HetNets cannot be directly applied to UDN [23].

This paper is focused on the review of existing research efforts in D2D communication that incorporates current cellular communication system in UDN. Furthermore, D2D communication is one of the component in next generation cellular technologies in order to identify the research gaps and to find out the question that had yet to be answered. The published research in different disciplines were reviewed, taking into consideration the UDN scenarios. In this respect, this paper aims at bringing further common understanding and analyzing the potential gains in the collaboration between D2D and UDN.

Thus, this paper can be summarized and outlined as follows: Section II explains the overview for D2D classification consisting of D2D radio resource management, D2D communication scenarios, D2D selection communication mode, D2D power consumption, and advanced concepts in D2D communication. Section III presents the integration between UDN and D2D and the benefit from the collaboration. Section IV summarizes the challenges and possible solutions according to UDN small cell deployments and D2D communications. Finally, Section V draws the conclusions.

II. Device to Device (D2D)

This section describes high level overview on D2D classification. The classification of D2D comprises of several distinctive categories such as D2D radio resource management and D2D scenarios. Besides that, this section gives insight into D2D mode selection, analyzes research dealing with power consumption, and advanced concepts in D2D communication. All of the abovementioned items are then discussed later in the next section. Individual categories are described in the following subsections.

A. D2D Radio Resource Management

The communication mode identifies whether the D2D user (DUE) communicates directly without traversing BS or traversing the BS. Furthermore, it specifies whether D2D uses the conventional cellular communication or not. In this regard, Table I shows the communication modes used by D2D and frequency reuse either Uplink (UL) or Downlink (DL). It consists of three communication modes which are Cellular mode (CM), Dedicated mode (DM), and Shared mode (SM).

1) Cellular Mode (CM)

The CM corresponds to the conventional cellular communication as the DUE exchange data through the BS and no direct exchange of data between the DUE takes place. This mode is usually used if the UE distance from each other is too far. The advantage of the CM mode is that interference can be easily managed by the BS and no new features have to be implemented. On the other hand, the CM is characterized by a low spectral efficiency.

2) Dedicated Mode (DM)

The DM is a mode allowing two DUEs to transmit data directly between themselves without intermediate BS, which would relay data. Still, the BS has to dedicate radio resources for the DUE transmission and thus the cellular user (CUE) cannot exploit the full capacity of the BS. The radio resources are used with a higher efficiency than in the case of the CM, since only one transmission direction, either the DL or the UL is used for the D2D transmission. Note that in some of the literature, this allocation mode is also referred to as an orthogonal mode or an overlay mode**,** as transmission of the CUE and the DUE has assigned a non-overlapping orthogonal radio resource. The advantage of the DM is that the BS does not need to handle interference among the CUEs and the DUE.

3) Shared Mode (SM)

In the SM, the same radio resources are used both for the DUE and for the CUEs. In some of the literature this mode is referred to as a non-orthogonal or an underlay mode. Similarly to the DM, the SM can use either the DL or the UL radio resources. From the spectral efficiency perspective, this option is even more profitable for the system, since the reuse factor is higher than in the case of the CM or DM. Nevertheless, the SM also has some disadvantages because strong interference could be generated among the DUE and the CUEs. To prevent the generation of harmful interference, new techniques and procedures should be introduced to the system. Indirectly, the complexity of the whole system is increased.

TABLE I
COMMUNICATION MODES EXPLOITED D2D COMMUNICATION

Communication Mode	Direction	Frequency reused			
		Uplink Reused		Downlink Reused	
Cellular Mode (CM)	Uplink	CUE	DUE	CUE	DUE
	Downlink	CUE	DUE	CUE	DUE
Dedicated Mode (DM)	Uplink	CUE	DUE	CUE	
	Downlink	CUE		CUE	DUE
Shared Mode (SM)	Uplink	CUE + DUE		CUE	
	Downlink	CUE		CUE + DUE	

B. D2D Communication Scenarios

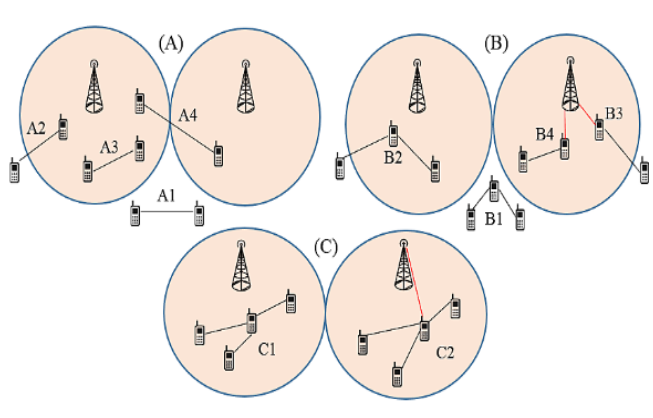

Fig. 2.D2D communication scenarios

This section illustrates possible scenarios that could be considered for D2D communication. Generally, D2D scenarios can be classified by several aspects as shown in Fig. 2 and described as follows:

1) Coverage

This aspect distinguishes whether the pair of DUE is under the coverage of a cellular network. In this context, we can categorize D2D communication as in coverage (Scenario A3), partial coverage (Scenario A2, B2), or out of coverage (Scenario A1, B1) [24],[25]. For the in coverage scenario, both DUE are within the coverage of the cellular network. While in partial coverage, one DUE is in the coverage of the cellular network whereas the second one is out of coverage. For the out of coverage, both DUE are outside the cellular communication network. Note that this scenario is considered mainly in 3GPP for public safety cases, when the network can be temporarily disabled.

2) Type of D2D Communication

This aspect expresses how many DUEs are involved in D2D communication. It consists of one to one communication or one to many communication. For one to one communication, two DUEs create one D2D communication pair with direct communication. While in one to many communication, one DUE multicasts or broadcasts data to several DUEs in a cluster. This option is also labeled as device to multi-device (Scenario C1 and C2).

3) Area of D2D Communication

This aspect distinguishes whether both communicating DUEs are served by the same cell or not. The DUEs creating a D2D pair or a cluster are attached to the same BS for the same cell (Scenario A3, B4). In contrast, for different cell (Scenario A4), the DUE belonging to the same D2D pair or cluster are attached to different BS.

4) Relaying Functionality

The DUE may have relaying functionality to retransmit data of other DUE within its proximity. This feature can be used to enhance capacity or extend coverage. In the case of capacity enhancement, the DUE attached to another DUE with relay functionality is usually in coverage of the BS (Scenario B4). On the other hand, in order to extend coverage (Scenario B3), the DUE which is out of coverage may use other DUE in order to reach the BS.

C. D2D Selection of Communication Mode

Proper mode selection plays a crucial role in D2D communication. The reason is that it determines the potentials to increase the frequency reuse factor. This section firstly describes and discusses research dealing with mode selection using various metrics, such as distance, energy efficiency, and path loss.

1) Mode Selection According to Distance

Path loss metric towards more realistic assumptions considering real distance among the DUE and the BS is presented in [26], [27], and [28]. Mode selection according to the mutual distance of DUE is taken into account in [7]. The study assumes the use of either the DM or the SM. In order to lessen the transmit power of the DUE, the authors propose an optimal D2D mode selection threshold. The optimal threshold is inversely proportional to the BS density and linearly increase with the path loss exponent based on the analytical and numerical results observed. Hence, with an increasing number of BS, the CM becomes more favorable. From the study, DM and SM are able to elevate the overall performance of the network with respect to the CM. However, the selection of mode is performed only according to the distance between the potential DUE. The inaccuracy of distance derivation is a key aspect that is not addressed in the paper [7]. A proposal which selects the mode not only according to the distance between the DUEs as in previous papers, but also according to the distance to the BS, is introduced in [27].

Potential D2D transmitters use direct communication in case the D2D quality is equal to the cellular UL. The factor with an impact on the selection is so-called bias factor T_d, which regulates the distance from the BS at which the DUE can communicate directly via D2D communication. The results show that the proposal is superior to more simple distance-based mode selection in terms of the outage probability of CUE, the intensity of admitted D2D links and the average transmit power of DUE. The transmission mode selection in [28], and [29] only considered link distance between DUE and D2D mode only for the users with shorter link distance than a threshold.

2) Mode Selection According to Path Loss

The communication through the BS (using the CM) is established if the path loss (P_L) between the DUE is above a threshold P_{Lmax}. If the path loss between both DUE is lower than the P_{Lmax}, D2D communication takes place (the SM is selected). Of course, the selection solely according to the path loss measurement is far from optimal as it does not reflect exact channel quality [30].

3) Mode Selection According to Energy Efficiency

In previous papers addressing the mode selection, the main objective is to improve capacity of the whole system. Another criterion for mode selection is energy efficiency, as assumed in [31]. The mode selection is based on a coalition game, where the DUE cooperates in order to reduce transmission cost. Cooperation means that the DUE within the same coalition uses different resources and does not interfere with each other.

In general, the DUE can select from the CM, DM, or SM. The D2D users form coalitions for individual modes (three groups of users are formed) to get the benefit of coalitions in terms of lower transmission cost. The advantage of the proposed scheme is that it can react to changing situations in the network to the situation when new D2D connections are created or terminated. Under such circumstances, existing D2D pairs can change the coalition from time to time if they can profit in terms of energy efficiency. However, mode selection according to energy efficiency should be done jointly with selection of capacity.

In contrast, the paper in [32] proposes two different cases which are aimed at maximizing the system energy efficiency and abandoning the D2D pairs with bad energy efficiency performance. For the first case, it comprises of three scenarios which are light load, medium load, and heavy load. The situation involves the cellular mode, dedicated mode, and reusing mode based on network load. The D2D pairs with bad energy efficiency performance will be abandoned and not all D2D pairs can be admitted. In the second case, a modified model is developed, where all D2D users can access the network and all the D2D pairs can be admitted.

D. D2D Power Consumption

Generally, maximization of D2D energy efficiency is achieved by minimization of overall power consumption. In this regard, we can classify the studies dealing with minimization of transmission power at the side of the UE, BS or both.

1) Minimization of Power Consumption at the UE

One of the ways to achieve low energy consumption in power control-based approaches is to exploit clusters [33]. The UE is selected to be part of the cluster if overall power consumption is decreased. In the UL direction, the energy consumption is composed of energy consumed by the cluster members transmitting to the head of the cluster, by the cluster head during reception of these transmissions, and finally again by the cluster head, which transmits data to the BS. Thus, in the DL direction, power is consumed at the side of the cluster head by reception of data from the BS by retransmission to cluster members and at the side of cluster members during reception of this transmission. Since the condition in the UL and the DL may be different, one DUE can use a different cluster for the DL and UL transmission in order to preserve the battery.

The proposed method comprises of two steps. Firstly, each DUE is connected to the BS (each cluster is formed by one DUE). In the second step, denoted as coalition formation, individual DUE subsequently forms clusters on the condition that by participating in the cluster they allow the power consumption of the UE to be reduced. The UE with the inferior energy consumption on the link to the BS will be chosen as the cluster head of each cluster. The paper proves by means of simulation that the power consumption may be significantly reduced if the method is used. However, the system does not consider the impact on the overall capacity of the network. Nevertheless, capacity and energy efficiency should be addressed jointly, especially in the case of more than one hop transmission, since the same data are sent more than once.

2) Minimization of Power Consumption at the BS

Whereas in [34], minimization of total DL transmission power and overall power consumption at the side of the BS are considered. The D2D communication is allowed only if the DUEs are close to each other and if they are far away from the BS. For this case, to accomplish the Quality of Service (QoS), the BS would have to transmit with high power. Nonetheless, when the subcarrier and bit allotment is done, the transmission mode will be selected.

3) Minimization of Power Consumption at the UE and BS

The saving of power at both the UE and the BS is assumed in [35]. The authors propose joint operation of D2D communication and green cellular networking. The idea is to form cooperative clusters of D2D users that share content. To that end, one DUE is selected as head of the cluster which communicates with BS at long range or acts as a relay for other devices. Then, the received data from the BS are multicast to other DUE within the cluster at a short distance. If the sum of the energy consumption for individual coalition members is higher compared to the energy consumption in coalition, the DUE will be included in the cluster. In addition, the cluster close to the cell boundary can be served by individual BS in such a manner that some BS can be temporarily switched off. Nevertheless, the BS can be turned off only if a small number of UEs is currently connected to the network.

E. Advanced Concepts in D2D Communication

Another concept exploiting D2D communication is based on enhancement of the UE functionality by means of relaying. In general, the relay concept can be exploited to extend coverage and to enhance capacity. In addition to this, single hop and multi hop D2D communications can be benefit to any kinds of network as well.

1) Extension of Coverage

A relay concept wherein the DUE serves as a relay and can both extend coverage and improve system capacity is described in [36]. The paper describes protocol architecture and evaluates data and signaling routing if the DUE uses the relay for connection to the BS. If the DUE is in coverage of the BS and uses the relay to enhance capacity and only data are relayed and signaling is exchanged directly between the relay and the BS. On the other hand, in the coverage extension scenario (the DUE is not under coverage of the BS), both data and signaling have to be relayed by the relay because the DUE cannot reach the BS. The assignment of the relay to the conventional UE in order to improve capacity is based on end to end throughput. Nonetheless, the relay is not used if the direct path can offer higher end to end throughput. On the other hand, in the coverage extension mode, the DUE with the highest channel quality to the BS is selected as a relay.

2) Enhancing Capacity

Generally, the source or destination is always the BS. On the other hand, a relay- assisted D2D network where two DUE can communicate via idle UE (relay) is considered in [37]. The DUE are assumed to communicate either directly or via idle UE relay by means of two hop communication in order to enhance capacity. The idle relay is used only on the assumption that the relay selection range r, which is the distance from the relay node to the midpoint between source and destination nodes is lower than R, which is the maximum value of r. The optimization of the relay selection range is also addressed, since the optimal R varies for different scenario parameters.

Another feasible way to enhance capacity by exploiting D2D communication for relay purposes is introduced in [38]. The DUE do not have any dedicated resources and have to cooperate with the CUE. The cooperation consists in the fact that the D2D pair serves as in-band relay for the CUE. Consequently, the DUE transmit their own data while simultaneously relaying data for the CUE in the DL. To that end, the DUE transmitter exploits a superposition coding scheme as it transmits linear combinations of its information and the CUE data. Such cooperation is allowed only if the CUE data rate is not degraded.

3) Single Hop and Multi Hop

The users communicate with each other using one hop or multi hop in D2D communication and can happen with or without the cellular network infrastructure. Based on to different studies, single hop communication promises reduce delay and energy consumption and improved network coverage in multi hop D2D communications. Besides, single hop and multi hop D2D communications able to improve the performance in terms of data rate [39]-[41], Quality of Service (QoS) [42]-[44], spectrum efficiency [45]-[47], network capacity [48]-[50], and balanced network load [51]-[54].

III. ULTRA DENSE NETWORK (UDN)

In order to realize the requirements and to address expected congestion of data traffic, the mixture of different technologies in 5G networks is needed for such purpose [55]. In this section, the integration between UDN and D2D communication as one of the most relevant technologies to the dense network is discussed. Moreover, this section discusses on the understanding and perceived effort of current research and the challenges that need to be identified and addressed.

A. Traffic Offloading in UDN

Basically in UDN, small cells can be categorized as fully functioning BS or macro extension access point. The fully functioning small cell BS is meant for coverage in a smaller area capable of performing all the functions of a macro cell with lower power. In contrast, a macro extension access point acts as an extension of the macro cell to enhance the signal coverage and undertake the functions of physical layer only [55]. In the current era, operators are concerned about offloading cellular data, as it is necessary to accommodate the growing demand for cellular data. Hence, technologies in offloading technique such as D2D from 3GPP is needed.

For offloading the traffic, small cells offer the efficiency and competition among the users for resources gets lesser as the cell size gets smaller. Basically, small cells vary in some features such as the cell sizes and transmission power, and provide a massive increase in spectrum efficiency. Deploying a huge number of small cells with low power results in UDN. Generally, UDN is a network with large number of access point per unit area and one of the technologies that leads to the improvement in network capacity and assists in frequency reuse and control of outages [34].

B. Idle Mode Capability in UDN

When there is no active UE within the coverage areas, one important advantage of having a large number of cells in the network is that a huge number of them could be turned off when the situation occurs [56]. Thus, interference to neighboring UE can be reduced and hence minimizes the power consumption. The network would have the key ability of adapting the distribution of active BS to the distribution of active UE, and thus the number of active cells, transmit power of the network, and interference conditions would strongly depend on the UE density and distribution [23]. D2D can be used as the green networking technique in UDN because power consumption will be increased with the deployment of small cells in great numbers [58]-[62]. This situation needs proper solution in minimizing the energy consumption.

C. UDN Power Consumption and Energy Efficiency

The massive number of small cells consume more power despite a small footprint of small cell. Thus, in dense networks, power consumption plays a key role. Furthermore, link quality and QoS conflicts with the need to increase energy efficiency. Thus, the user experience should be investigated and becomes an interesting model in UDN in order to maximize the energy efficiency. Hence, incorporating D2D in UDN with the proper technique could minimize power consumption and maximize energy efficiency at BS, UE, or both.

IV. PERFORMANCE METRICS IN UDN

In this section, the commonly used performance metrices in the modelling of UDN problems explained. These metrices are basically refer to coverage probability, rate coverage, average spectral efficiency, area spectral efficiency, network throughput, and energy efficiency.

A. SINR Distribution

The link quality is good enough to proceed to a successful connection or SINR distribution of user falls below a minimum threshold. In other words, the coverage probability, success probability, and the SINR distribution measure the quality of the link between the user and the serving BS.

B. Average Spectral Efficiency

The efficiency of the spectrum is a crucial performance metric in 5G networks due to the shortage of spectrum along with the high data rate requirements. The efficiency spectrum defined as the average number of transmitted bits per second per unit bandwidth.

C. Network Throughput

The network throughput defined as the average number of successfully transmitted bits per seconds per hertz per unit area. Basically network throughput is another metric to quantify the performance of UDN [63].

D. Energy Efficiency

Energy efficiency can be defined as the ratio of the network throughput or the area spectral efficiency to the power consumption per unit area [64].

E. Area Spectral Effciency

Area Spectral Efficiency is defined as the average achievable data rate per unit bandwidth per unit area [65]. Moreover, the Area Spectral Efficiency is an important metric to quantify the performance of UDN. Therefore, the reuse of spectrum per unit area increases as the cellular networks dense.

V. CHALLENGES AND POSSIBLE SOLUTION

In this section, the main challenges faced on the way to ultra-dense small cell deployments integration with D2D are highlighted. These challenges remain unresolved even though contribution of existing work set up the basics to overcome the challenges in UDN and D2D. This section presents the following challenges and possible solution needed to overcome them according to existing research.

A. Smart Idle Mode Capabilities

The availability of an efficient idle mode capability at the small cell BS is key to mitigate inter-cell interference and save energy. In idle mode, it is important that small cell BS minimize signaling transmissions and consume as little power as possible. In order to achieve energy efficient deployments, a small cell BS in idle mode should not consume any power. Another feasible solution would be to equip the small cell BS with a sniffing capability, as proposed in [66], such that the small cell BS is idle and switches off most of the small cell BS modules when it is not serving active UEs. When the small cell is idle, it transmits no signaling and wakes up upon the detection of uplink signaling from the UE towards the macro cell tier [67]. However, dynamic small cell idle mode control also poses new challenges such as the Ping-Pong cell re-selection. To be more specific, a suddenly powered-on BS might confuse idle UE since they need to re-select cells according to the best Reference Signal Received Power (RSRP) rule, and then go back to their previous cells when such small cell BS returns to idle mode. The Ping-Pong cell re-selection greatly consumes UEs battery life and it should be avoided.

B. Co-Existence with Wi-Fi (Unlicensed Band)

In order to gain access to more frequency resources, LTE small cells may be deployed in unlicensed bands where they are required to coexist with Wi-Fi networks. However, when LTE and Wi-Fi nodes are using the same frequency band, the Wi-Fi nodes may tend to stay in listening mode waiting for a channel access opportunity and the high power interference from the LTE network. Simulation results have shown in previous studies that when co-existing with LTE nodes, if these ones do not implement any co-existence mechanism, Wi-Fi nodes in some indoor scenarios may spend even up to 96% of the time in listening mode [68]. This significantly degrades Wi-Fi performance. New coexistence solutions have to be devised to enhance LTE and Wi-Fi coexistence and ensure that those two networks share the unlicensed bands in a fair manner.

In future wireless communication, D2D are anticipated to coexist with small cell networks that involve small BS operating in licensed cellular spectrum and operating in unlicensed spectrum in a proper manner. In the network footprint of a macro BS, a single D2D link will reuse the spectrum occupied by a conventional cellular link [69]. Basically, D2D communication can utilize either the in-band cellular spectrum or out-band spectrum. The out-band spectrum can either be an unlicensed spectrum or allocated spectrum taken from the licensed band [7]. LTE for Unlicensed Spectrum (LTE-U) must adhere to unlicensed spectrum requirements such as set transmit power limits and collision avoidance. By using the unlicensed spectrum that is available, D2D transmissions potentially keep away from cross-tier interference with CUE channels at the cost of complicating the unlicensed spectrum usage [70]. In [69], a Listen Before Talk (LBT) algorithm is described for LTE-U D2D coexistence with Wi-Fi. Moreover, when combining D2D with LTE-U, the network's wide capacity improved throughout the entire coverage area.

However, there are several challenges in order to incorporate D2D communications with LTE-U. From the performance and fairness perspective, it is apparent that a longer duration of transmission for D2D communications using unlicensed bands can improve the throughput performance of D2D communications. In contrast, when Wi-Fi network is busy, a longer duration of transmission is acute to the throughput attainment of LTE-U enabled D2D communications. Anyhow, a longer duration of transmission might affect the attainment of nearby Wi-Fi access point and users. Thus, a relevant algorithm should be proposed for choosing a proper transmission period. For the same purpose, the D2D routing algorithm with LBT is used in [71] to analyze the effect of LTE-U D2D on the Wi-Fi capacity. The three different Wi-Fi traffic volume is selected to analyze the performance. It is found that the D2D would take a longer delay when there is a high level of contention in the local unlicensed spectrum. Furthermore, D2D reduces the Wi-Fi network capacity by sharing the unlicensed spectrum but increases the overall network capacity (licensed and unlicensed).

C. *Outdoor Network Performance*

The increasing number of small cells is able to enhance the network capacity significantly and simultaneously fulfills the data traffic demand in indoor scenarios as a large data transmission occurs. However, the data traffic in outdoor scenarios should be carefully considered.

These small cell deployments are mainly in the form of home small cells, known as femtocells [72], but many operators have also already started to deploy outdoor small cell solutions to complement their macro cell coverage [73]. In [74], proposed algorithm for small cell downlink that comprise of four stages where one of them is incorporated with D2D communication. The plot shows the incorporation with D2D resulting in free channels for other UE and a higher data rate.

D. *Integration with Advanced Techniques*

Generally, a large number of small cell deployment can improve network capacity around hundred fold [75]. The main enabler is the integration with other advanced techniques such as D2D communication [76]. Nonetheless, the complexity comes from the massive coordination among the advanced techniques. The consideration such as spectral efficiency, energy efficiency, and power consumption creates new challenges.

E. *Power Consumption and Energy Efficiency*

Energy efficiency is crucial and needs to be considered in dense small cell networks. The large number of small cells will consume a massive amount of energy despite the small transmit power of each small cell. The environmental impact of this energy consumption needs to be considered in the deployment of dense networks. The small cell BS can be put into sleep or idle mode when there are no UE connected due to the random activity of UE. Nonetheless, energy efficiency and network performance need to be considered. Hence, how to determine the optimal set of BS to be turned to sleep mode is a complicated problem and should be addressed. However, a number of energy saving schemes have been investigated and can be applied to both BS and UE to improve energy efficiency. In [77], several schemes have been proposed to maintain a database to support cluster-based small cell deployment in both indoor and outdoor environment. While in [78], a distributed cluster-based energy efficient resource allocation scheme for UDN had been designed. Consider two-tier UDN which consists of a picocell tier and femtocell tier. Similar to [35], the idea is to form cooperative clusters of D2D users that share content. To that end, one D2D user is selected as a cluster head, which communicates with the BS at long range. Then, the received data from the BS are multicast to other D2D users within the cluster at a short distance. BS in the cells with low or no traffic load can be put in sleep mode in order to improve energy efficiency due to the traffic load fluctuation and as another major design goal for 5G [79], [80]. Incorporating between D2D and UDN as the main enabler to improve the energy efficiency and the power consumption as well.

F. *Propagation Model*

In the study of dense networks, consideration of three dimensional channel modelling constitutes one of the open research. In addition, the investigation of multislope path loss models in different densification contexts should be considered. The propagation characteristics in UDN suggest the use of Rician fading model which requires further detailed investigation in order to model the channel fading.

In the wireless communication problems, the propagation modelling is an important part of the investigation. The Line of Sight (LOS) transmission components being most probable as the network densification brings the access point closer to the users. The LOS transmission should be considered in order to study the dense networks with a different propagation model such as for indoor networks where the cells are deployed in buildings for each floor. Hence, three dimensional propagation modelling should be taken into account.

A significant impact on the Area Spectral Efficiency (ASE) performance of small cell networks when incorporating LOS and NLOS transmission in path loss model is studied in [81]. While in [82], the study consists of single slope and multi slope path loss model as well as encompassing both closest and strongest BS association. In order to reduce the impact of network densification, a frequency reuse mechanism is proposed in both the coverage probability and the ASE.

VI. Conclusion

As one of the leading technology in 5G mobile wireless networks, UDN faces many challenges due to the limited resources and high application requirements. In this paper, the problem and the potential solution of the existing work across a variety of areas have been explored and compared. Nevertheless, a number of potential challenges were identified based on the existing research, which needs further investigation and study.

D2D communication underlying cellular mobile networks offers several advantages such as offloading of an overloaded mobile cellular network, minimizes power consumption, and improves energy efficiency in UDN. Efficient idle mode capabilities at the small cells has been shown to be the key to save energy as a result of the large number of small BS deployment in UDN. In order to benefit from the direct communication between mobile devices, D2D paradigm introduces several critical challenges that must be addressed. These studies show the potential of D2D in terms of high performance gain in cellular networks, which is an integral part of future mobile networks. Basically, from the potential challenges that have been identified, the integration between D2D and UDN is obvious as a key enabler for the potential solution.

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