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Device Discovery in D2D Communication: A Survey

OMAR HAYAT[1,2], RAZALI NGAH[2], SITI ZAITON MOHD HASHIM[3], MUHAMMAD HASHIM DAHRI[2], REZA FIRSANDAYA MALIK[4], AND YUSNITA RAHAYU[5]

[1]Department of Engineering, National University of Modern Languages (NUML), Islamabad 44000, Pakistan
[2]Wireless Communication Centre (WCC), Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Johor Bahru 81310, Malaysia
[3]Big Data Centre, Faculty of Computing, Universiti Teknologi Malaysia, Johor Bahru 81310, Malaysia
[4]Faculty of Computer Science, Universitas Sriwijaya, Palembang 30128, Indonesia
[5]Department of Electrical Engineering, Faculty of Engineering, Universitas Riau, Pekanbaru 28293, Indonesia

Corresponding author: Omar Hayat (ohayat@numl.edu.pk)

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ABSTRACT Device to Device (D2D) communication was first considered in out-band to manage energy issues in the wireless sensor networks. The primary target was to secure information about system topology for successive communication. Now the D2D communication has been legitimated in in-band by the 3rd Generation Partnership Project (3GPP). To initiate D2D communication, Device Discovery (DD) is a primary task and every D2D application benefits from DD as an end to end link maintenance and data relay when the direct path is obstructed. The DD is facing new difficulties because of the mobility of the devices over static systems, and the mobility makes it more challenging for D2D communication. For in-band D2D, DD in a single cell and multi-cell, and dense area is not legitimated properly, causing latency, inaccuracy, and energy consumption. Among extensive studies on limiting energy consumption and latency, DD is one of the essential parts concentrating on access and communication. In this paper, a comprehensive survey on DD challenges, for example single cell/multi-cell and dense area DD, energy consumption during discovery, discovery delay, and discovery security, etc., has been presented to accomplish an effective paradigm of D2D networks. In order to undertake the device (user) needs, an architecture has been projected, which promises to overwhelm the various implementation challenges of DD. The paper mainly focuses on DD taxonomy and classification with an emphasis on discovery procedures and algorithms, a summary of advances and issues, and ways for potential enhancements. For ensuring a secure DD and D2D, auspicious research directions have been proposed, based on taxonomy.

INDEX TERMS D2D communication, device discovery (DD), energy efficiency, discovery latency, in-band and out-band.

I. INTRODUCTION

Device to Device (D2D) communication has been adopted in the out-band, however, it was not explored in the in-band for the initial three cellular eras. A D2D was presented in the fourth era after Long Term Evolution (LTE) Release 12 in late 2012 [1]. In the early research on D2D communication [2], authors proposed multi-hop cellular system to enhance throughput by utilizing devices as relays, and afterward in [3], a D2D has been proposed by enabling peer to peer (P2P) communication of mobile devices to reduce interference. Though D2D communication has numerous improvements, there remain difficulties to implement this innovation effectively, because the devices are heterogeneous in nature and with different configurations. Furthermore, the device power level is chosen grounded on the up-link power to minimize the interference of the cellular devices. Specifically, D2D communication will need effective Device Discovery (DD) procedures for proximity services, resource allocation for DD, and DD security. Due to the rapid growth of miniaturized wireless devices, DD has gained special attention worldwide for D2D. For instance, devices such as smartphones, Personal Digital Assistants (PDAs), and

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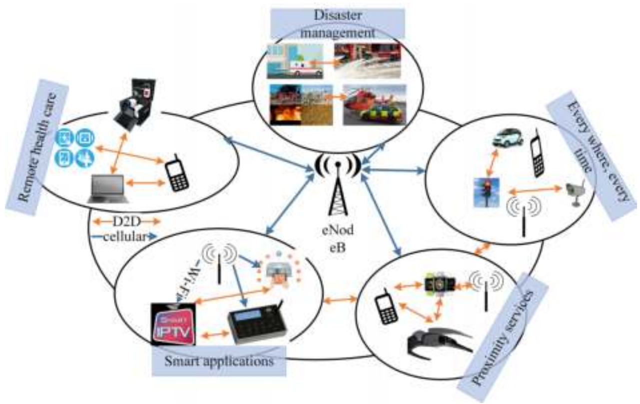

FIGURE 1. Device discovery applications scenarios.

sensors have attracted attraction due to proximity services [4] as explained in Fig. 1.

Traditional uses of DD incorporate observation of natural surroundings, ecological monitoring, and ocean observation. Furthermore, recently developing applications, for example, climber logging, object chasing, and social networking, are entering our day by day life. The most recent applications of DD in D2D are proximity services, health care services, ubiquitous services, and emergency services which are not delay tolerated. In addition, a Mobile Ad-Hoc Network (MANETs) is comprised of devices that are independently self-organizing, while the greater part of the present wireless communication relies upon costly center systems and talker systems. Such a vast level of opportunity and self-arranging capabilities make them particularly appropriate for environments and circumstances in which pre-characterized network foundation goes beyond assistance or does not occur at all. A distinctive application would be hazardous situations where communication between search team, rescuer, and restorative staff needs to be established in spite of the devastation of system infrastructure. Additionally, their applications in moving devices (vehicles) have led to the advancement of VANETs (Vehicular Ad-Hoc Networks) [5], where moving vehicles speak with one another to upgrade road protection and conveyance productivity. Conversely, local and social networks have limited power devices with processing, transmission capabilities and data collection [6]. They are especially appealing to those concentrations that require to the collection and evaluation of environmental data, for example, humidity and temperature in an expansive territory.

Motivated by the requirement for connectivity continuation and context awareness [7], [8], discovery among proximal devices (associate DD) serves as an essential for both categories of systems (in-band and out-band). After the initial DD, devices can communicate only with each other. A trivial answer for the issue is to hold radio on every time with the end goal that neighbor devices can discover each other individually without further ado. However, the essence remains in the power shortage; devices are battery-fueled and current battery limits cannot bear the cost of on radio over for a system lifetime. It is realized that inert listening overwhelms the network power spending plan. As a trade-off, devices need to turn the radio on/off occasionally and during on state, devices consume more energy. Regardless of the inference of energy consumption, this prompts the vulnerability in discovery latency. Typically, discovery latency and energy consumption are two key measurements by which the power efficiency of neighbor DD is assessed. It is attractive to have low energy consumption and discovery latency at the same time; however, they are dependent on each other and this is a trade-off that makes energy effective neighbor DD challenging.

In this survey paper, DD algorithms, protocols, and associated parameters (energy consumption, discovery latency, accuracy) are surveyed, and based on the fundamental design they can be generally grouped by five basic standards: deterministic or probabilistic, synchronous or asynchronous, in-band or out-band, energy triggered or time/angle of arrival and single/multi-cell or dense areas. While explaining these standards, several representative algorithms are presented, for example, the Birthday [9], Disco, Searchlight [10], Quorum and more algorithm detail is explained in Fig. 2. The classification of discovery algorithms is stochastic/probabilistic, bio-inspired, hierarchical and context-aware. Most of the researchers proposed stochastic/probabilistic algorithms for DD due to latency. Despite various fundamental standards, it is demonstrated that they can be combined into a generic context under coherent duty cycles. A subjective examination is made among the algorithms including different criteria. Finally, we revealed insight into future research directions towards effective associated DD. The research direction is, therefore, to learn about device mobility pattern and exploit the knowledge to improve the discovery process efficiency. It is believed that the knowledge addition for DD procedures and algorithms can bring in further benefits and optimization, not only DD but also communication in IoTs scenarios for next-generation networks.

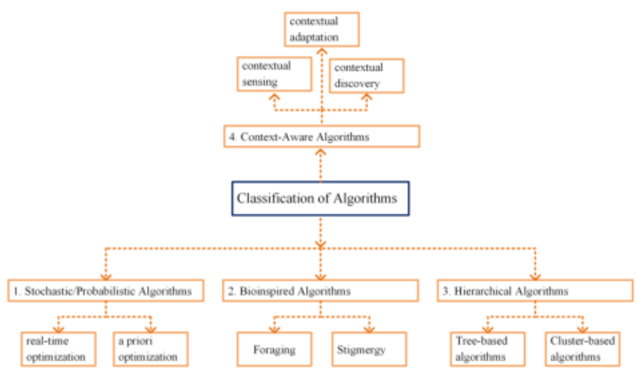

FIGURE 2. Algorithms classifications.

The rest of the paper is organized as follows: Section II explains the motivations and contributions of the research with used terminologies and assumptions for device discovery procedures and algorithms. Section III discusses

TABLE 1. Evaluation of existing surveys with this survey.

References	Objectives	In-band	Out-band	Energy efficiency	Discovery latency	Mobility	Is applicable for 5G?	year
[11]	Wireless Position Estimation	✗	✓	✗	✓	✗	✗	2008
[12]	Energy-Efficient DD in Ad Hoc and WSNs	✗	✓	✓	✗	✓	✗	2015
[13]	Neighbor Discovery in IoTs	✗	✓	✓	✓	✗	✗	2015
[14]	Position-based forwarding for VANETs systems	✗	✓	✗	✓	✓	✗	2016
[15]	Cooperative localization for 5G	✓	✗	✗	✓	✓	✓	2017
This survey	The device discovery in D2D communication	✓	✓	✓	✓	✓	✓	

the device discovery architecture for 5G technology, and the device discovery challenge is well-defined in Section IV with device discovery categories and recent advances in device discovery methodologies. The open issue of device discovery research is elaborated in Section V with performance metrics and future research directions. The paper concludes in Section VI.

II. MOTIVATIONS AND CONTRIBUTIONS

There has been a plenty of work on out-band D2D communication, but research on in-band D2D communication is comparatively in early stages. To initiate D2D communication, DD is a primary task and very few researchers have workd on DD for in-band D2D communication. The motivation behind DD is the practical applications in cellular system, especially in VANETs and more applications are explained in Fig. 3. Consequently, this comprehensive survey discussed the requirements and challenges of DD in all aspects. Before this, very few surveys have been done on DD in out-band, while only a survey is performed in in-band DD as explained in Table 1. In [11] authors offered a survey on wireless position estimation, but they did not consider the in-band, energy analysis and device mobility for DD. In [12], authors suggested a survey on energy efficient DD in Ad-Hoc and WSNs, but they did not reflect discovery latency, in-band, and this research is not for the next-generation network. A survey on neighbor discovery in IoTs is explained in [13], but the authors did not contemplate in-band and device mobility. In [14] a survey on position-based routing for VANETs systems is studied, but the authors did not include energy efficiency and integration for 5G systems. A survey on cooperative localization for 5G is proposed in [15], but energy efficiency is not considered in this survey. The algorithms for moving devices need to be applied in D2D scenarios where device accessibility is not considered. It depends on the human mobility pattern based positioning algorithms for dynamic and static objects [16], [17] as explained in Fig. 4. The objective of mobility aware algorithms is to exploit and understand the mobility pattern for further optimization. Therefore, the estimation

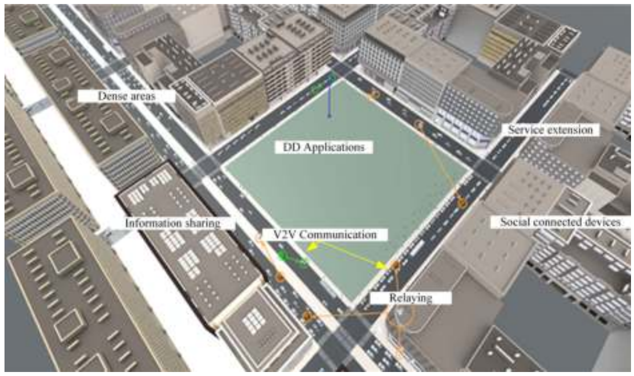

FIGURE 3. Practical applications of DD in VANETs and dense areas.

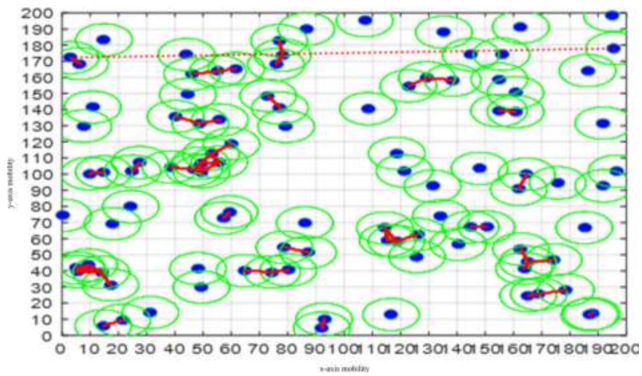

FIGURE 4. Device mobility pattern in 200 × 200 m^2.

that exploits mobility pattern knowledge is the favored choice in light of the high mobility nature in D2D scenarios.

The contributions of this survey and comparison with the past surveys on DD are explained in Table 1. To make an effective comparison with past surveys, this work done is categorized in DD in terms of significant research difficulties, including DD in in-band and out-band, energy efficiency and discovery latency, device mobility, and it is a state of the art work done on DD for future generation network. The principal objective of this research is to give the readers a contemporary and ultra-modern survey article for what has been completed, proposed solutions, algorithms, and protocols on DD to date and to classify the problems that require further attention. More particularly, the real commitments of this survey can be abridged as:

- A classification and analysis of associated DD.
- To present existing DD research in D2D communication which will be helpful for interested readers in this field.
- To explain the DD essentials and exploration results accomplished so far on DD in D2D, including in-band and out-band, deterministic and probabilistic, synchronous and asynchronous, single cell and multi-cell, dense areas and energy efficiency.
- A qualitative comparison of outcomes for in-band and out-band.
- A quantitative assessment of energy efficiency, single/multi cell and dense areas.
- Future research directions.

A. TERMINOLOGIES

In the context of energy conservation, a device turns off its radio after transmitting the discovery signal and wait for the response. Therefore, this state of a device is called an idle state. Conversely, a device is active when its radio on and it may transmit or receive to neighbor devices. Two devices are characterized to be neighbors if they communicate discovery signal in out-band and in-band D2D, which means that they are inside the transmission range of one another when both signal are strong. However, in in-band, center system informs the neighbor devices for the D2D link. That is why in-band DD is full of spatial characteristics [18], [19]. The process in which devices switch between idle and active (time allotment between these two states), is known as duty cycle. Formally, a duty cycle is the portion of time, where a device is devoted to active status. Naturally, a bigger duty cycle results in more prominent energy consumption in the radio module. Conversely, as a duty cycle time expands to some degree, it increases the probability to discover any undiscovered devices. An energy consumption prototype for idle and active devices sending discovery signal to the center system is explained in Fig. 5. When an active device goes to sleep, it takes zero transmission time interval (0TTI) with zero energy consumption. Along with when devices mutually prompt each other, it takes 1TTI with 22mW/TTI.

A DD delay is another term that is often examined together with duty cycle. This term defines how long a device has to wait up until it discovers a neighbor or to be discovered by the neighbor. In different technologies, devices consume a different amount of energy at different phases. Three technologies for device's radio features comparison is made in Table 2. In DD context, it depends on search and scan energy, range, an idle state, and energy transfer. A cellular band (in-band) consumes much less energy than out-band. For more detail, DD has two segments: initial discovery and final discovery. Initial discovery starts when two proximal devices come into proximity to each other. These devices are then finalized

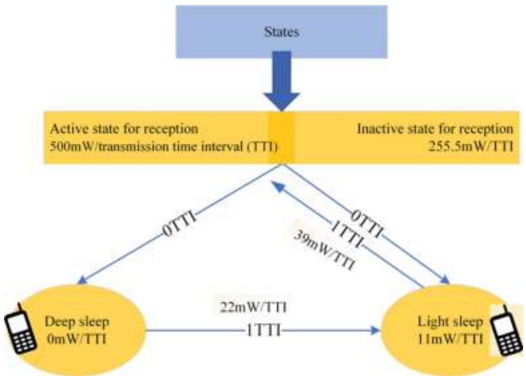

FIGURE 5. Energy consumption prototype for idle devices sending discovery signal to the center system [20].

TABLE 2. Devices radios features [13].

Network	Energy transfer j/MB	Idle energy (mW)	Scan Energy (mW)	Throughput (Mbps)	Range (m)
Bluetooth	0.1	10	120	0.7	10
Wi-Fi	5	770	1290	11-54	100
Cellular	100	0	0	0.5-1	500

when both are recognized by each other using beacon signal or any other technique [21]. Note that it is more difficult to accomplish a quick initial discovery because a device has no clue about its neighbor. Also, synchronicity is a considerable feature for neighbor discovery. As indicated by the need for time synchronization, DD procedures are sorted into synchronous and asynchronous.

B. ASSUMPTIONS FOR DD PROCEDURES AND ALGORITHMS

The assumptions will facilitate to understand the presented problems before DD procedures and algorithms' investigation in detail. These presumptions are required to simplify conventions, ignoring some features that have a negligible impact in DD or are hard to address by DD procedures and algorithms.

1) COMMUNICATION LINKS

Most of the studies on DD expect bidirectional communication links with the same transmission range. Such symmetry simplifies DD procedure and algorithm design. Note that this may not hold in pragmatic applications; a device A could accept device B as its neighbor, though B is uninformed of A's presence because of the concise communication range of A. To overcome this assumption, possible conditions can be incorporated such as device power, signal characteristics, and obstacle blockage.

2) DISCOVERY SIGNAL DECODING

A discovery signal decoding failure typically occurs due to corruption. It can also occur during the time when interference is ignored. The justification behind this presumption is

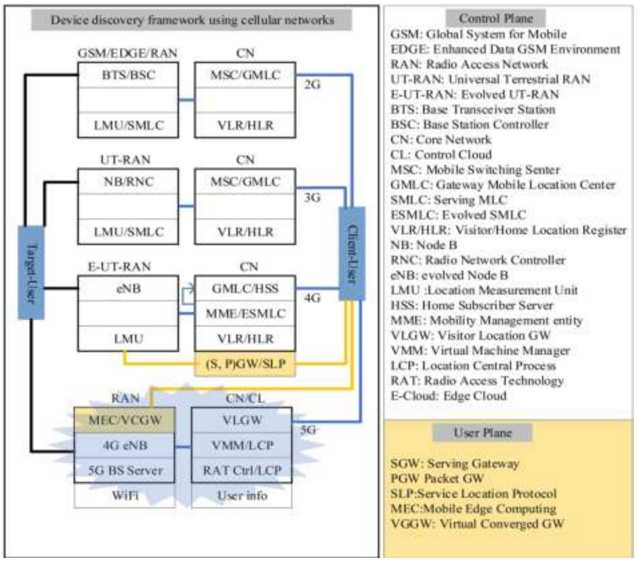

FIGURE 6. Device discovery architecture and technology used in 5G.

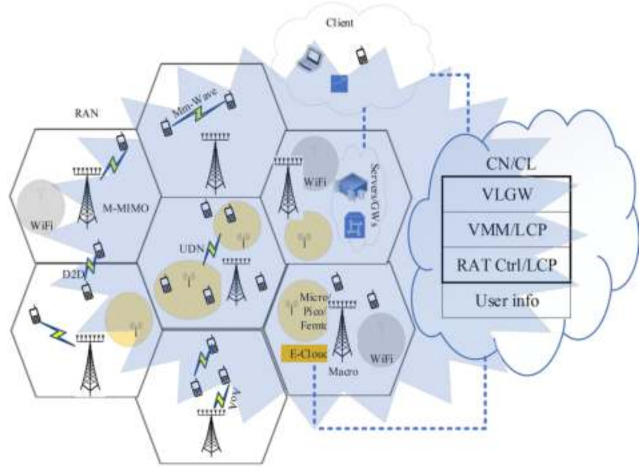

FIGURE 7. 5G intuitive device discovery architecture.

that a successful DD procedure as a progressing procedure can ensure the possible discovery of neighboring devices, taking more additional time than anticipated if decoding failure is considered. Also, managing decoding failure is the activity of Medium Access Control (MAC) for collision avoidance. Theoretical DD algorithms can coordinate with MAC protocols in certifiable applications.

3) CLOCK OFFSET

It is expected that thee is no warm-up delay from inactive to active state and no clock offset. It is supposed that device state switching is deprived of consuming any time. In addition, the device's clock runs at the same time, however, such deviation is additionally disregarded for simplification [22].

III. DEVICE DISCOVERY ARCHITECTURE FOR 5G TECHNOLOGY

In typical DD architecture in the cellular systems, there are three basic system components, which are client user, target user (both are devices) and server (base station) as explained in Fig. 6. In the evolution from 2G to 5G, different elements are incorporated according to the user's demand. There are two main planes, a control plane and a user plane. A Location Measurement Unit (LMU) is defined in 3G, and because of its proximity, services are started. Actually, this unit causes motivation for D2D communication and DD. A 5G system comprises cloud in which all the technologies are integrated which helps for DD and tracking. An intuitive device discovery architecture for the next-generation network is detailed in Fig. 7. The major element of the cloud is Core Network (CN) in which Visitor Location Gateway (VLGW), and Location Central Process (LCP) are used for DD. These units report to the Edge Cloud (E-Cloud) for local DD in in-band and global DD for out-band. A server gathers different area related data and estimates the objective area [23]. A client user is an object that transmits a discovery request to the system in order to obtain the area data of the target user. A complete discovery architecture mostly comprises two planes: control plane and user plane (Note: all the elements are explained in Fig. 6). There is no user plane in 2G to 3G. The control plane is used to discover the position of devices. User plane is defined in 4G onward to activate the proximity services. The 5G system will not be an essentially incremental evolution of the 4G system. Hence, with the end goal meeting the necessity of higher discovery performance, a general discovery architecture coordinating emerging communication innovations is needed, particularly in view of past architecture.

A planned DD is discussed for 5G systems considering emerging technologies in 5G systems. As shown in Fig. 7, the device discovery architecture comprises three sections: A Radio Access Network (RAN), Edge(E)-Cloud, and Control Cloud (CL) or Core Network (CN). The differences between discovery architecture of 5G with respect to 2G-4G systems is given as follows: RAN is consisted of multiple Radio Access Technology (RAT) and could be picked adaptively by the environment, for example, RSS, discovery quality, and device capabilities. E-Cloud and CL consist of Network Function Virtualization (NFV) and Software Defined Network (SDN) which cause deep programmability, network virtualization, and flexibility. The discovery can be carried out in either control plane or user plane determined by the necessities of discovery quality. By distinguishing the control plane and user plane, real-time device discovery could be completed in the RAN to minimize communication delays. The discovery in the planes could accompany each other well to improve discovery performance.

In the evolution of the cellular systems, numerous technologies have been incorporated, for example, Timing Advance (TA) in 2G, the Idle Period for the Down-Link (IPDL) in 3G and Positioning Reference Signal (PRS) in 4G [23]. 5G is considered to incorporate several integrating

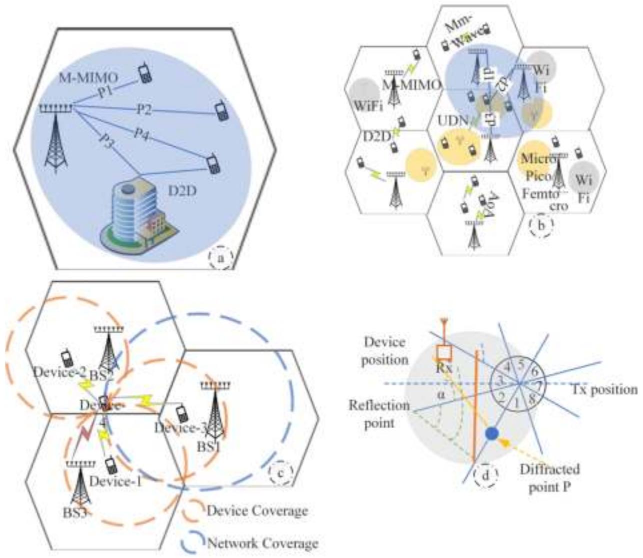

FIGURE 8. Device discovery based on anticipated technologies in 5G systems.

technologies with no limitations related to communication and potentially helpful for discovery. Three most pertinent technologies, Massive MIMO (M-MIMO), millimeter (mm)-waves and Ultra-Dense Network (UDN), help for device discovery in D2D communication as presented in Fig. 8. These technologies participate in strengthening DD and D2D communication as well. In Fig. 8 a) Massive MIMO could conduct LOS and NLOS credentials and the device discovery is estimated based on Line of Sight (LOS) and Direction of Arrivals (DOAs). Furthermore, the precision of DOA measurements could be enhanced with M-MIMO. b) In an ultra-dense network, the small cells distribution is modeled by Poisson Point Process. Therefore, the probability density function of the distances between the device and its three nearest base stations are d1, d2, and d3. Using the distances, the device's discovery can be estimated via triangulation approaches [22]. c) Through D2D communication device-1 and device-2, the devices play their roles as pseudo base station and offer additional position related data for the discovery of the device-4 [24]. d) A mm-wave base station or device transmits a discovery signal and received by the target device via multi-path. There may be LOS, reflection and refraction paths, and based on this device discovery is made.

IV. THE DEVICE DISCOVERY: A CHALLENGE

An essential design prerequisite for D2D systems is DD which empowers devices to discover potential contenders in the proximity and set up a direct link with them. Basically, DD has two location-based types; local and global DD. In in-band D2D communication, local DD exist with self and remote DD as is explained in Fig. 9. To achieve this errand, devices communicate discovery signals among themselves to accumulate information, for example, device area, distance, device identity, channel state and so on. This

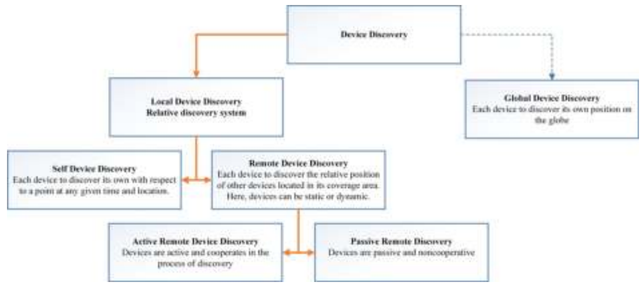

FIGURE 9. Types of DD.

information is utilized by the devices to assess the likelihood of clustering into the pair with one another. If the discovery stage and communication stage occur at the same time, it is termed a-posteriori discovery, though, in a-prior discovery, the DD is the prerequisite for D2D communication. A DD in D2D communication usually is categorized into two groups: centralized and distributed discovery.

A. DEVICE DISCOVERY CATEGORIES

A DD procedure is categorized into two main types, which are centralized and distributed DD. All the remaining techniques are function based on these categories [25].

In the Centralized DD, devices discover one another with the assistance of the centralized entity, normally a base station or access point. The device illuminates the base station regarding its objective to communicate with adjacent devices. The base station starts the signal exchange between two devices to acquire fundamental information, for example, channel conditions, power and interference control policy dependent on the system pre-requisites. The participation of a base station during the DD process can be finished or partial dependent on the pre-designed suite of protocols. If the base station is totally included, the devices are not permitted to start DD with one another. Each discovery signal among devices is facilitated by the base station. For this situation, the devices just tune in to the discovery signals transmitted by the base station and transmit discovery signal to it with the end goal to start the DD process. If the base station is partially included, the devices transmit discovery signal to one another for DD without getting prior authorization from the base station. Nevertheless, the devices include the base station to exchange the Signal to Interference Noise Ratio (SINR) quantity and path gain of every device. This assists the base station to decide the plausibility of communication among devices. At last, the base station asks for both devices to begin the correspondence.

The distributed DD method permits the devices to discover one another without the inclusion of the base station. The devices communicate the control signals intermittently to discover the neighboring devices. However, interference, synchronization issues, and power of discovery signal often emerge in the distributed mode. Therefore, In-band DD is efficient in every aspect of D2D design. Based on centralized

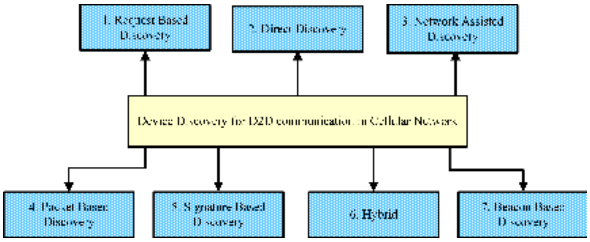

FIGURE 10. **Possible DD scenarios in D2D communication for in-band and out-band.**

and distributed category, many more schemes of DD have been proposed for in-band and out-band as shown in Fig. 10. The network-based DD, direct discovery and beacon-based discovery are for in-band and remaining are for out-band.

B. RECENT ADVANCES IN DD METHODOLOGIES

A beaconing DD method was introduced in [43], [44], where devices transmit discovery signal in parallel spaces utilizing Orthogonal Frequency Division Multiple Access (OFDMA). The devices search for beacon signals to find different devices in proximity during the initial DD stage. In this arrangement, spaces are chosen dependent on the foundation of least interference. A DD procedure is proposed in [45], where neighboring devices identify potential D2D accomplices by catching sounding reference signal codes amid up-link transmissions. In LTE, every device is booked on the sounding reference signal channel routinely to allow the base station to gather data for up-link channel scheduling. The devices can distinguish other devices which have a high-sounding reference signal like their neighbors.

Energy-efficient DD for public safety scenario in D2D networks is proposed in [46], where major constraints overlay interference and simultaneous user access of resources considered. The outcome is the maximum number of discovering devices with energy efficiency. The results in [46] present that the suggested D2D-DM method increases the number of discovered devices compared with static and random back-off patterns. D2D neighborhood DD by a device is suggested in [47] where static devices discovery is discussed in out of network and time of discovery is investigated. A mathematical model is developed in [47] for moving D2D devices and results are verified by Monte-Carlo simulation. In [48], the authors recommended privacy-preserving DD and authentication method for D2D in 5G heterogeneous network. Along with security threats are incorporated for next-generation networks and an integrated privacy protection DD and authentication scheme is proposed for heterogeneous D2D devices using identity-based and ECDH [48] methods. Performance results achieve privacy protection with ideal efficiency. A full duplex empowered time efficient DD is proposed in [49] for public safety using IB-FD. A framework for IB-FD structure focus on public safety devices is suggested to minimize DD delay and increase spectral efficiency. The suggested framework has the ability of transmission mode switching from half duplex to full duplex. To verify the results system level simulation is performed and results are compared with standard random access technique. The results indicate that with public safety priority method around 37% DD time as compared with random access technique [49].

DD and localization supported by UAVs in prevalent public safety systems are suggested in [50]. In this article direct discovery is performed using proximity services and in the absence of core network like in disaster situation discovery signal is transmitted over UAV to device link. Simulation results are considered based on MUSIC algorithm and achieve maximum accuracy. Moreover, performance results are calculated by the throughput and packet error rate [50]. A social aware using deep learning DD mechanism is proposed in [51], where the social aware relationship is applied. The proposed method decreases the malicious DD and increases the efficiency of DD. Simulation results explain that BS obtain trusted candidate device among devices based on social information. DD algorithms performance analysis is made for D2D communication are made in [52], in which some metrics are defined and metrics are accuracy and RMSE. Simulation results explain that it minimizes discovery error and maximize accuracy. It also minimizes the algorithm complexity. In [53], priority based full duplex DD for public safety D2D system is suggested. Results explain that inband full duplex performs well compared with half duplex on the same radio resources and results are compared with random mode. It saves discovery time around 37 %.

The adaptive approaches have been proposed by the same researcher in [54] and [55] to discover the devices. In [54], the searching rate of DD is varied dependent on the information acquired from the social realm. The social realm information is comprised of network and centrality of a specific device. In [55], devices stay unconscious until contact probability with the device is low and wake up to search for neighboring devices when the probability of DD is high. A contact probability depends on the social relationship history of the device as well as explained in Table 4. The device relationship depends on contact and contribution history, and social similarity index. In contact history, contact interval, frequency, and duration are very important for effective DD.

An artificial intelligence significance in cellular network for intelligent 5G systems is discussed in [56], where importance of artificial intelligence techniques are highlighted. Every imperative characteristic of D2D in cellular networks, including device mobility management, radio resource management among cellular uses and D2D users, service provisioning management among D2D users, DD, and many more require artificial intelligence. However, challenged with ever-increasingly complex configuration problems and developing new service necessities, it is still inadequate for 5G cellular systems if its deficits complete artificial intelligence functionalities. Many algorithms have been implemented as explained in [56] for 5G systems for different parameters configuration and distinctive artificial

TABLE 3. Summary of the research work.

Synchronous/Asynchronous device discovery techniques	rendezvous protocol [26]
	Directional antennas [27]
	Directional antennas [4]
	Context-Aware Discovery [8], [28]
Dense device discovery techniques	Glowworm swarm-based DD [29]
	SDL algorithm [18]
	Firefly algorithm [30], [31]
Quick device discovery techniques	Application of Common and Group Channels [32]
	Signature-based discovery [33]
	Service advertisement [34]
	Mobile inference engine [26]
	COAST [35]
Energy efficient discovery techniques	Proximity and dynamic region assessment [36]
	Social Application based discovery [37], [38]
	The iterative matching algorithm in 3-D [39], [37]
	Bayesian non-parametric forming [35]
	Social Overlapping Neighbor discovery [40]
	Performance analysis of network-assisted DD [41]
	Adaptive wake-up scheduling [42]

TABLE 4. Social relationship discovery.

Relationship	Description
Contact history	Contact interval
	Contact frequency
	Contact duration
Social similarity	Devices in contact book
Contribution history	Reciprocity index

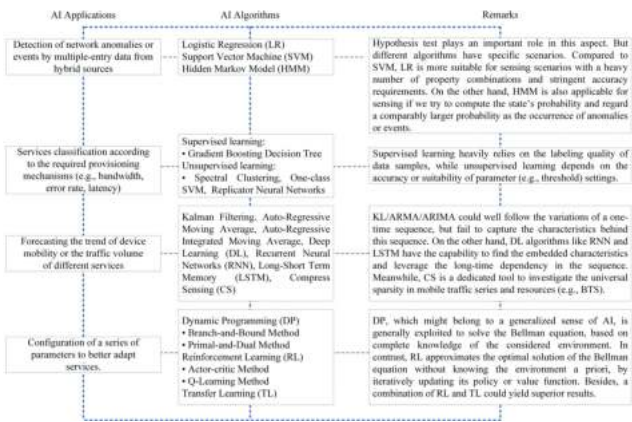

FIGURE 11. Distinctive artificial intelligent algorithms with application and definations.

intelligent algorithms to improve cellular networks in terms of candidates technologies (D2D, M-MIMO) are presented in Fig.11. The configurable parameters in 4G devices has enlarged to 1500 from 500 in 2G devices and 1000 in 3G devices. If this learning continues, a standard 5G device is likely to have 2000 or more parameters. Moreover, in 4G, D2D only supports proximity and public safety services, but network assisted D2D between vehicles and devices arises to a certainty, and the V2V, V2X services are becoming a hot topic for better services in automobiles.

A power control technique for effective D2D communication is proposed in [57]. A sensing based radio resource

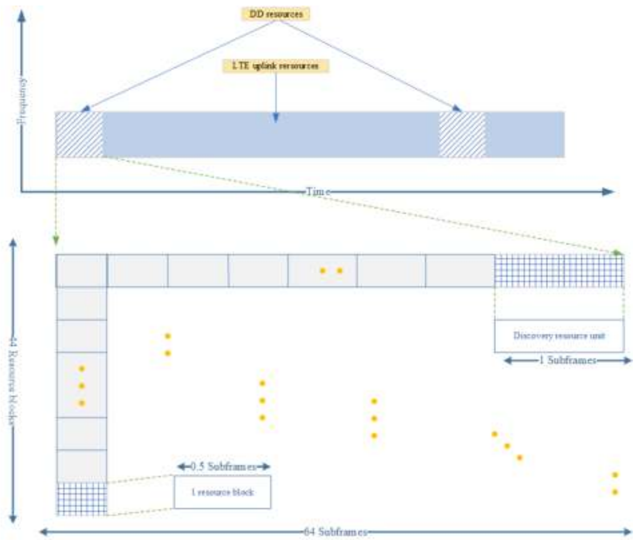

FIGURE 12. DD resources in LTE.

selection scheme for DD is proposed and equated with random selection in [58] for LTE application. A case of LTE resource allocation, delineating discovery resource unit and period for DD is given in Fig. 12. It has been demonstrated that for sensing-based selection, performance degrades when sensing outcomes are obsolete or when device's mobility is fast. Nonetheless, the sensing-based scheme usually out performs than random based scheme in the distributed system. From the LTE up-link resources discovery resource unit is appended. Each resource unit has one sub-frame and each resource unit has two resource blocks. For effective DD, resource scheduling is needed to avoid collision and interference.

A novel DD method based on wireless channel's correlation is proposed in [36]. The base station makes an uneven estimate of the location of the devices by relating these channel factors with the referenced up-link estimates. Discovery

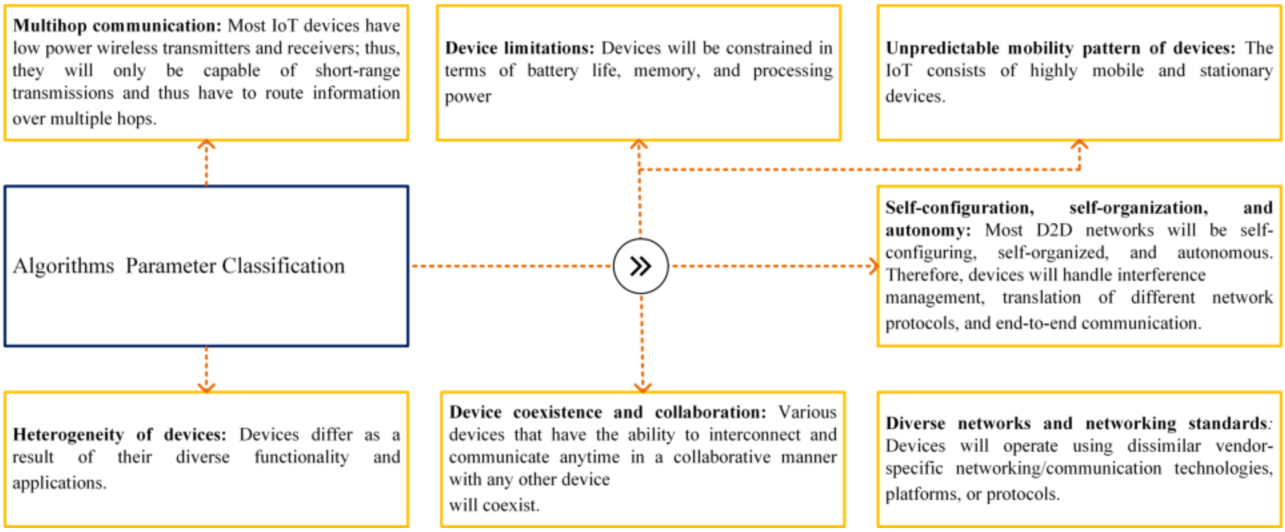

FIGURE 13. DD algorithm parameters classification.

signals are planned to be transmitted dependent on the quality of delay and azimuth spread of the adjacent devices. The authors uncovered that energy consumption can be reduced by up to 70% in comparison to ordinary strategy Flash LinQ [59] when utilizing their proposed plan. To guarantee fast DD, the authors in [60] projected a quick pairing methodology by utilizing inverse popularity matching order strategy rather than the traditionally utilized Kuhn-Munkres algorithm in [61]. A signature based DD technique was suggested in [33]. This paper gives a proficient method to limit the collisions during the discovery stage while utilizing the least physical resources. Autonomous DD technique dependent on Flash LinQ was offered in [59]. The noteworthy power consumption of devices is a genuine worry during the DD phase. Besides, a continual searching issue turns out to be more basic. Hence, the researchers in [62]–[65] gave energy efficient DD schemes while enhancing the performance of the system.

Tic-Toc DD rendezvous protocol is proposed in [66] for devices to send and receive discovery signal. This protocol gives better average discovery latency compared to the current protocols. An ignorant proximal discovery protocol is explained in [67]. It is uncovered that the ignorant proximal discovery protocol ensured discovery with insignificant discovery delay in the heterogeneous and asynchronous environment. In a analogous research on asynchronous DD, the authors of [41] compared and discussed four conceivable arrangements with relieving the loss of sub-carriers orthogonality in OFDM networks. These answers incorporate ECP (extended cyclic prefix), advanced ECP and dynamic receiver timing and positioning, and semi-static timing and positioning with different timing hypotheses. A structural design for asynchronous topography discovery is proposed in [68]. In this research, a topology manager is utilized to produce an optimal scanning succession. The outcomes yielded a 30% to 70% enhancement in discovery ratio in chaotic deployments. In [69] the researchers use Q- Learning procedures to expand the functionalities of asynchronous proximal discovery protocols while limiting energy utilization and discovery latency. In conclusion, an efficient DD algorithm depends on the following parameters explained in Fig. 13. Therefore, it is needed to propose robust algorithm for DD. This robust algorithm should incorporate heterogeneity of devices, diverse network standards, devices configurations and limitations, as well as the parameters as presented in Fig. 13.

DD technology by means of received signal strength is suggested in [70], where relative discovery algorithms are instigated in WSN testbed using outdoor and indoor background. The results from [70] prove 1m discovery error for TOA and 2m for RSS. A cooperative localization for WSN is proposed in [71], where a statistical model is established based on RSS, AOA, and TOA. The proposed model is applicable for UWB framework as well. In [72], the authors proposed ad-hoc and cooperative discovery system for hybrid cellular and ad-hoc networks. The results demonstrate that the proposed scheme gives more accuracy compared with conventional procedures in a cellular system [73]. An efficient service DD algorithm using counting Bloom filter is recommended in [74]. The authors claim in [74] that this is a novel approach for dense area devices based on computed service feature. In [75], the authors proposed neighbor DD for wireless systems through compressed sensing. The compressed neighbor DD systems are much more effective than conventional random DD, where devices must retransmit with random delays to be effectively discovered. A directional cell discovery is proposed in [76] for mm-wave cellular networks, where results disclose two main findings: i. digital beamforming outperforms analog beamforming ii. omnidirectional transmission outperforms random directional.

In [77], the authors proposed an asynchronous probabilistic DD algorithm for mobile WSNs. In this article, an asynchronous probabilistic technique is applied, and energy consumption analysis is made by latency and discovery ratio. The simulation results express that the proposed algorithm performs better than SearchLight and Birthday [9]. An energy-efficient DD in opportunistic networks is proposed in [78], named eDiscovery, and applicable for opportunistic communication using smart devices. The results validate that eDiscovery saves 44% energy and 21% discovery ratio compared to continuous inquiry duration and period methods and results are verified through many simulations using the ns-2 simulator. Cooperative DD for multi-interface is suggested in [79] for self-organizing networks, where based on the jump and stay procedure, a rendezvous algorithm is proposed. The results approve that the anticipated rendezvous algorithm accomplishes higher performance compared to conventional approaches.

The authors in [80] proposed a neighbor DD for ad-hoc networks cooperatively using full-duplex and compressed sensing. Mathematical and simulation analysis is made and compared with prevailing schemes and the proposed scheme reduces 96% signaling overhead and increases decoding accuracy by 25%. Time and energy-efficient contention resolving DD are proposed in [81] for 3GPP LTE-A systems. System-level simulations are performed, and the schemeperforms remarkably well in D2D system. Results are compared with random access method and give twofold discovery range and improved discovery ratio. DD and configuration structure for IoTs is proposed in [82], where the automatic control loop is applied. The simulation results, prove that the proposed scheme minimizes interference between devices. Radio access based DD in LTE is proposed in [83], where authors provide dedicated spectrum allotment to discover devices. Optimal performance is achieved in terms of discovery transmission and slots and results are compared with different radio access approaches. A BTS assisted neighbor DD for D2D systems is proposed in [84], where optimization uncertainty is solved by scheduling. Greedy based scheduling is applied on probabilistic discovery and results are assessed by performance methods.

DD approach using spreading technique is proposed in [85] for public safety. Orthogonal codes are used for spreading technique and the codes are drawn from orthogonal matrix known as Hadamard matrix. The results are verified by the probability of false alarm and misdetection. The same authors in [86] proposed a cooperative DD using spreading technique for public safety. The results are verified by the probability of false alarm and misdetection again. A novel DD scheme for cellular systems is suggested in [87], where discovery signaling algorithm is applied for discovery message exchange between device and network. A novel stochastic geometry is applied to investigate system performance in terms of discovery success ratio and minimum mandatory time slots for the DD scheme, and results are verified by the simulation. A machine aided DD based on coupon collector pattern is proposed in [88]. The authors developed a generative model using coupon collection, where unknown devices can be discovered. This DD process is factorized by the innovation and quality of discovery and verified by the simulation. Anticipated neighbor DD time with preceding information is discussed in [89], where developing, confines and optimization are elaborated for DD. The simulation results are analyzed among prior information versus no prior information and the effect of uncertainty are also evaluated.

In [90], the authors suggested neighbor aware DD for out of network devices. This is novel in terms of out of network DD framework and results are analyzed for enhanced discovery probability. In [91], the authors proposed DD using Trellis Tone Modulation with message passing demodulation. The proposed scheme gives 1.5 times more discovery ratio compared with FDMA based DD. Roommates behavior-based indoor DD approach for LTE D2D is proposed in [92]. Results from [92] prove that it saves24% energy per device and improves SINR compared with other methods. In addition, the proposed scheme provides high indoor accuracy, is robust against noisy data and needs no device interactions. In [93], the authors provided a survey for in-band DD and D2D communication. In this survey, DD requirements are discussed such as energy, dense area discovery, and discovery in underlay D2D. Along with these issues, fast DD in single and multi-cell also will be needed. DD signal is designed in [94] for D2D communication, in which the reference signal is multiplexed utilizing Zadoff–Chu (ZC) sequence detection and transmission. The results validate that the proposed design is robust against collision and delivers fast and accurate DD for the dense area. Moreover, results are validated by random and smart random search. Performance analysis for DD algorithms is performed in [52], where complexity and estimation error are evaluated. The metrics and measures are characterized in terms of success ratio, residual energy, RMSE, and accuracy. Also, two studies Cosine and Hamming, are specified and compared with reference RMSE for assessment.

From the previous discussions and literature survey, the possible solutions that have been proposed are shown Fig 14. In conclusion, there is need to propose a DD with minimum DD delay and maximum energy efficiency. Possible proposed schemes for DD with parameters are shown in Table 5. These parameters are probabilistic, deterministic, synchronous, asynchronous, in-band, out-band, multi-cell, dense area, and many more.

C. MINIMIZATION OF DD DELAY AND MAXIMIZATION OF ENERGY EFFICIENCY

There is limited literature on minimization of DD delay in D2D communication. In [95], the proposed strategy out-flanks traditional DD techniques even when the congestion occurs in the network. In particular, starting neighbor device transmits discovery signal while answering partner device replies a reacting outline. Both transmitting and answering frames are transmitted utilizing a typical

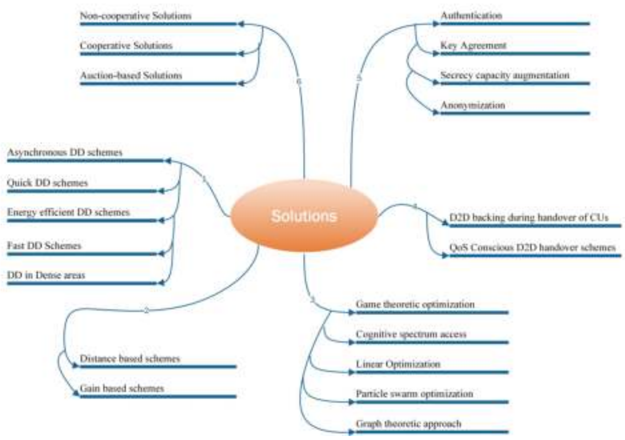

FIGURE 14. **Possible solutions by the existing DD schemes.**

channel and in agreement with a super frame configuration. The outcome is a quick (minimum delay) DD even in extensive congested systems. A DD scenario is modeled in [96], in which dual radio devices are used and the standard service discovery time and is determined by counting the interruption periods. The model also considers diverse channel and mobility circumstances of devices. An open platform for smart devices is suggested in [97], which incorporates remote sensing by the on-request employment of extra services. This additionally gives the important platform services to help run-time adjustment, checking, and information investigation. Along with DD delay, some researcher have suggested energy efficient DD techniques. An energy efficient DD technique is investigated in [98], which performs D2D discovery strategies only when there is a high probability to discover different devices. The outcomes demonstrate that substantial energy saving can be acquired utilizing their proposed discovery component. In another work in [12], a plan that offloads the discovery procedure from devices as well as to the LTE core system has been explained. The authors additionally investigated the energy utilization profiles of different discovery components.

An energy efficient DD in D2D cellular systems for public safety consequences is proposed in [46], where maximum DD problem is investigated in overlay D2D under devices simultaneous resource accessing. An iterative algorithm is applied for DD maximization, which affords the competence to switch the DD mode from half duplex to full duplex when SINR is below a pre-stated threshold. Performance of half duplex and full duplex mode devices is assessed using open loop power control and it is disclosed that open loop power control does well compared to half duplex. For example, at 50% of CDF with$P = -100\,dBm$, the full duplex mode devices are transmitting with 78% less power compared to half duplex devices. A user association for interference lessening and load balancing in public safety is proposed in [99]. The authors focus on the topics for user association in heterogeneous networks to reduce the interference and afford load balancing for devices. The questions arise here, that if the devices or small cells are moving, then the DD is the big challenge in terms of precision, energy efficiency and fast DD.

An interference mitigation technique by up-link power control is proposed in [100] for femto cells using user (device) priority. This scheme does well for QoS based power control in heterogeneous networks and system throughput, and power allocation optimization for femto cells. An interference aware radio resource allocation structure for underlay D2D communications is proposed in [101]. An effective radio resource and power allocation is necessary for D2D users and cellular users to avoid the co-channel interference. The authors in [101] suggested resource allocation for D2D groups, which maximizes the throughput using interference alignment, adaptive antenna arrangements, and groping method for D2D. A system level simulation is performed and compared the results by random sharing scheme, which improves by 23.8%.

A 3-D (Dimensional) iterative coordinating algorithm is proposed in [37] to enhance the sum rate of D2D pairs while ensuring the QoS prerequisites of both cellular and D2D interfaces instantaneously. In cellular systems, the devices contain multi-dimensional social qualities and different interests. This is why they may have similitude with more than one network. These multi-dimensional social qualities of the devices impact their social affiliation which drives them to frame covering communities. In this specific circumstance, [40] proposed a plan to actively estimate the job of covering community devices in different communities. The plan progressively alters the beacon identification rates as indicated by the association condition of other intra and inter-community devices to enhance the system power efficiency and proximal discovery rates. It was demonstrated that these covering community devices can act as a bond to enhance information sharing during the DD process. Table 3 presents an overview of the research works discussed above, along with some other noteworthy examinations on DD. The surveyed literature can be grouped into four basic parameters; Synchronous/Asynchronous DD, dense area DD, quick DD, and energy efficient DD. Hence, many techniques and algorithms are proposed against each type. However, very few authors have worked on combined parameters.

D. MISCELLANEOUS

A DD procedure for multi-hop LTE cellular system is proposed in [2], where each discovery resource is divided into a 1/8th time of one physical resource. Timing in advance technique is used to minimize the delay and cyclic prefix. The DD reception and transmission time is $20\,ms$ with$20\,ms$ gap and it is helpful for interference minimization between discovery signals. In addition, a copy of discovery signal is repeated every $35\,ms$ and receiver device take $14\,ms$ to recognize it, which causes a delay in DD procedure. Another DD signal design formula for OFDMA systems is suggested in [3], where the discovery signal is placed on top of the data up-link channel. The value of DD signal is simply depending on sub-carriers and causes inaccuracy due to poor discovery signal quality. The value of one DD signal is 0.0019% of every sub-frame. If the total devices pairs in one sector are 12, the regular signaling overhead will be $12 * 2 * 0.0019$ and causes congestion and energy consumption.

VANET supported DD considering the contention and E2E delay is recommended in [5]. In contention delay, VANET supported DD depends on roadside units' separation and their coverage. It concluded that large separation causes delay,but is also dependent upon the traffic volume (Vehicle/Hour/Lane). A traffic volume of 200 creates 10 ms delay and when increased to 700, creates 90 ms delay. In the total delay known as E2E delay is the combination of contention delay and processing delay is also included in delay analysis. Traditionally, 30 ms is the processing delay at eNB and roadside units. So, 2s to 3s E2E delay, which presents efficient DD, is projected in [5]. Both delays are quite large for high-speed traffic. A wireless peer DD is proposed in [6], where green DD procedure is formulated with devices' spatial density. A DD performance prerequisite and transmission probability are assessed by area transmit power. For $100k/m^2$ devices, spatial density with maximum power 23 dBm provides 60% area transmit power. This procedure consumes more power for next-generation standards. A survey is made in [13] on a neighbor DD in IoTs scenarios using the opportunistic network. Two main DD methods are discussed: probabilistic based like Birthday and deterministic based like Quorum-based. In Birthday protocols, a certain number of devices are picked randomly, and their birthdays grows as the number of people (users) increases, with 23 people with probability 50% and 57 people with99% probability. In Quorum-based protocols, time slots are overlapped at least twice every $n2$ slots used between two devices. For $n2$ slots, 5×5 grid is overlapped.

Energy efficient DD in 3GPP LTE-A networks is proposed in [20] for social cloud applications. An application mismatch error ($\delta(0, 1)$) is defined. At $\delta = 0$, it saves up to 70% energy and relies upon the direct DD period, with gain drop up to 25% while utilizing a shorter periodicity of 2s. At $\delta >= 1$, it saves 50% energy and reduces 20% signaling overhead compared to cloud-based methods. Bio-Inspired proximity DD for D2D communications is suggested in [31] with synchronization and D2D simulator constructed. Outdoor propagation model for NLOS (dB) is used with the values $P = 43.5 + 25log10(d)$ for $d < 60m$ and $P = 40.0 + 40log10(d)$ otherwise. The performance is evaluated at 1000 trails and converges, but it has slow DD rate. An energy-efficient based proximal DD survey is made in [21] for Ad Hoc and WSNs. In this survey, two duty cycles are taken for DD procedure: symmetric and asymmetric. Average latency is calculated among different protocols and concluded that under symmetric, Birthday protocol is 20% quicker than Disco and 13% quicker than U-Connect and under asymmetric, Disco outclassed the others by about 40%.

Proximity DD for D2D over the cellular network is proposed in [33], where signature-based DD is suggested for traditional cellular network. The false detection is kept 0.01 below per discovery period for the signature-based DD signal. It is observed that packet-based DD is 20 dB poorer in sensitivity, which causes a 20 dB weakness in range. A novel D2D peer DD scheme using spatial correlation of channel is proposed in [36], where power consumption analysis are made in which proposed method saves power consumption by 70% compared to method proposed in [59] when probability of detection is 0.5. At probability of detection 0.9 accuracy is quite high and power consumption reduces significantly. A social-aware DD for underlaying cellular D2D communication is proposed in [54], where DD signal delivery ratio and energy consumption are analyzed. The DD delivery ratio increases with energy. At energy 0.4 the DD delivery ratio reaches 48% to 50%. The peer DD ratio for simple energy is 35% to 38%. For shared network method, peer DD ratio improves from 31% to 58% associated to simple energy method. A DD signal delivery ratio improved 33% by [59].

A network science method for DD in mobile D2D is projected in [55] where human mobility is considered along with DD signal delivery ratio and delay and energy consumption. The proposed method [55], keeps balance between energy consumption and delivery ratio fluctuation. Energy factor range is defined from 0.3 to 0.7 and if energy factor is 0.7, it saves 30% power and offers 5% of delivery ratio. A joint DD in synchronous networks is suggested in [63], where a synchronous network with N devices randomly deployed on a finite level and all devices want to discover each other. A joint iterative decoding method does well, and it may gain by 100% over single user decoding method and by 20% over the SIC. Energy-efficient DD in 3GPP LTE-A networks is proposed in [98], where system level simulations for DD is conducted for assessing the energy efficiency of the DD mechanism. 50 devices with 10 m coverage area and having $\frac{1}{2}$ probability for active and $\frac{1}{2}$ probability for sleep mode are uniformly distributed with different states, such as state duration and transition probabilities. All the devices in coverage area have transmit and receive power to be around 0.4 w of battery power.

Network assisted DD for D2D communications is proposed in [102], where delay and signaling overhead is assessed. When all the devices transmit, signaling overhead occurs. The proposed algorithm in [102] is 25% better than the existing algorithms. A DD in LTE-A system for proximity based services is proposed in [103], where a closed form formula is derived using stochastic geometry. A preamble sequence with 0.5 ms length and round-trip distance 100 m with 0.6 μs delay is transmitted for DD. This causes delay and interference. An efficient DD procedure for 5G enabled D2D networks is proposed in [104], where collision and access probability are discussed. As the multiple D2D devices that instantaneously demand access has < 10, the collision probability will be below 0.1. The access demand is increased, causing inaccuracy and delay. A network assisted D2D direct DD for underlay is suggested in [105], where BTS energy consumption assessment is made

Messages	Proposed scheme size (bits)	Standards size (bits)
Proximity request	3832	3608
Map request	3072	2848
Map response	2704	2344
Proximity inquiry	3032	3032
Location request	2624	2624
Location response	2584	2584
Proximity req ack	2312	2312
Location rep req	2624	2624
Location report	2336	2336
ProSe location upd	2776	2776
Proximity Alert	3416	3248
Decision message	2440	0
Total	**79304**	**30336**

FIGURE 15. Cloudlet computing discovery message sizes [106].

between orthogonal and underlay discovery, and energy efficiency comparison is made as well. At 600 payloads, a BTS consumes 55 mW for orthogonal and 84mW for underlay. For energy efficiency comparison, at 600 payloads, orthogonal gives 17.5j/B energy efficiency and underlay gives 15.5j/B energy efficiency. Hence underlay is better than orthogonal, but still energy comparison is an open research issue at device level.

An analytical analysis for service discovery is made in [106] for LTE-A D2D using a cloudlet computing and discovery message sizes are calculated as explained in Fig.15. A Novel D2D DD scheme using random back off is proposed in [107] for LTE-A networks. The random back off method obtains 61.4% DD compared to [108] with DD probability 13.6%. It is 6.4% better than [108]. A new energy efficient DD procedure for self-organization D2D networks is proposed in [109], where power based fuzzy discovery data is achieved. The results analysis shows that distance error has 2% performance loss logically for 20% estimation distance error.

Enhancing D2D direct DD based on forecasted device density patterns is suggested in [110], where an adaptive D2D DD algorithm is formulated. The algorithm is developed based on device density prediction and historic network traces. The proposed algorithm is compared with existing algorithms for 3GPP standards. Only two parameter network balance and DD time are taken for algorithm analysis and improves performance by 60%. Adaptive and cooperative coding for network based on MAC protocol for D2D is proposed in [111], where network coding is used for both analytical and simulation. The results present that the recommended protocol has benefits in terms of QoS without energy consumption. The proposed method achieves 73% improvement for signal error rate in [0, 0.5]. The gain of the proposed method is higher for high data rates, accomplishing a 71% increase for signal error rate of equal 0.3. It is important for this survey to discuss open research issues in DD as explained in the below section.

V. OPEN RESEARCH ISSUES IN DD

In fact, DD is a trade-off of energy efficiency and discovery latency in multi-cell and dense area. Due to moderate development in battery innovations, energy remains a bottleneck to constrain wide uses of D2D communication. In addition, DD depends on procedures and algorithms such as probabilistic deterministic, synchronous, asynchronous and many more. While there is not yet a substantially large number of older DD approaches, they have not been completely designed to achieve the properties of these new difficult situations. Therefore, in the next section, we will exhibit some of the difficulties for DD as open research issues as well as required solutions.

1. *Initial DD signal*: To discover different neighbor devices, an initial discovery signal is communicated by the device. However, this signal can be effectively obtained by proximal devices. The information conveyed by initial discovery signals can likewise influence different devices due to inappropriate scheduling. In this specific circumstance, design parameters, for example, radio resources for the composition of initial signal assume the critical job.

2. *The frequency of initial DD signal:* The implementation of D2D devices are affected by the number of discovery signals. Even when the discovery signals have a pre-determined strategy and structure, the continuous broadcasting of discovery signal by devices can cause noteworthy interference for other devices in the system. Conversely, if the quantity of discovery signals is low, at that point the data with respect to neighboring devices can be decayed. To address this issue, appropriate scheduling plans in the system can limit the frequency of discovery signals. Another arrangement can be as the social connection between communities to accelerate the DD utilizing the least number of discovery signals.

3. *Synchronization:* In D2D communication, usual devices in the system are synchronous with the base station or center system. This infers that the scheduling and time frame is indicated by the base station. In any case, it turns into a challenge during DD when the second device stays outside the coverage of the base station with which the primary device is associated. For the situation of asynchronous discovery, the devices need to constantly look for a different device in the vicinity [4].

4. *Multi-cell DD:* In the cellular network with device mobility, if devices belong to different cells, then DD becomes a big challenge because the question is who and how radio resources will be provided and who will be benefited. One multi-cell DD scheme is proposed in [112] and is explained in Fig. 16. In this method along with the base

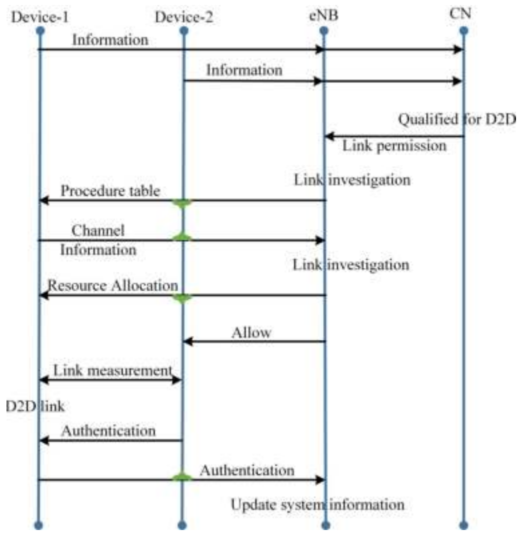

FIGURE 16. Multi-cell device discovery.

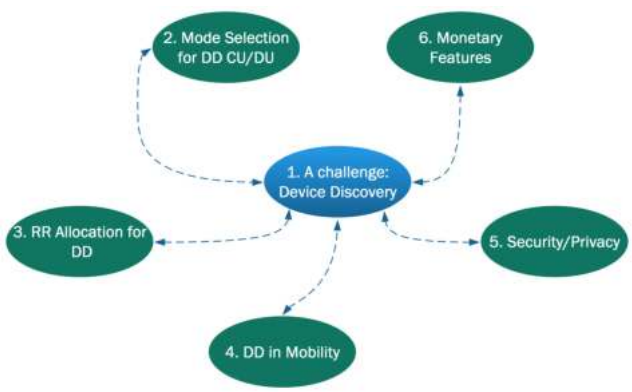

FIGURE 17. Challenges for DD procedure and algorithm.

station, the core network is also involved. So, it is needed to propose discovery signal scheduling, which is critical.

5. In *self-explanatory Fig. 17* more DD challenges are explained and prerequisite effective solution in terms of DD delay and energy efficiency.

i. DD for fast moving devices

ii. Radio resources (RR) allocation for DD

iii. DD management when devices switch from cellular users (CU) to D2D users (DU) and vice versa

iv. DD privacy for cellular users

v. Monetary benefits distribution.

A. PERFORMANCE METRICS

Among the extensive literature survey on DD, there are two important performance indicators for DD in a single cell and multi-cell and in dense areas; energy efficiency and discovery latency. Energy efficiency depends highly on the discovery latency. A discovery latency has statistical properties and may change in the different application context. Very few researchers have worked on discovery latency. However, in some applications, initial discovery latency is the only concern and some applications are affected by final discovery latency. Regardless, it is attractive to have a high energy efficiency and a low discovery latency. However, it is not hard to perceive a trade-off between energy efficiency and discovery latency. A higher energy efficiency usually prompts a lower discovery latency. Therefore, how to adjust these two parameters turns into the key problem to accomplish. To shorten the discussion, a composite metric named the power-latency product is proposed in [113] with the result of average energy consumption on worst discovery latency. Generally, its performance is good when either factor remains constant and after need to be optimized. Another important parameter is the discovery accuracy [17] to assess the performance of discovery procedure and algorithm. It speaks the difference of true value and estimated value of discovery. Precision is another parameter to calculate the re-producibility of progressive discovery measures. This value can be utilized to evaluate the robustness of the discovery algorithm as it uncovers the variety of discovery appraised over several iterations. To calculate the precision, the median discovery of random devices must first be calculated initially. After that Euclidean error of each estimated device is computed using median position.

B. FUTURE RESEARCH DIRECTIONS

Future DD algorithms should be capable of gain information and to determine the accessibility of devices in order to foresee future meetings of devices by relying on appropriate information. Such appropriate information should help the devices in optimization of both energy and discovery latency by decreasing power utilization when devices are learned from ambiguity. A quick discovery is required when two devices are in range and want mutual communication. New frameworks for DD should be formulated by including optimization in the prediction and learning algorithms. Both new features are capable of depicting characteristic properties of mobility and new information sources. These features are equipped to give better clarification on the imagined patterns of experiences. By gaining superior learning about the environment and by merging approaches, it will be conceivable to gain a superior comprehension of the context surrounding devices. Therefore, accomplishing better accuracy in prediction need further optimization for D2D scenarios. Although several approaches to proximal DD have been proposed, many issues still stay open for future work and explained as;

I. Social learning. Customary DD algorithms, including the ones discussed in this survey, focus on DD scheduling among the devices. It is contended here that this probably won't be proficient enough for mutual DD. In fact, devices can include their scheduling data to discovery signal such that their neighbors can take in the wake-up patterns, prompting a fast discovery in future or more energy conservation in co-prime structure. A device can educate its neighbors of the determination of prime number(s). Neighbors are trained about social learning, such as social similarity, contact and contribution history as detailed in Table 4. After the initial

TABLE 5. Possible proposed schemes for DD with parameters.

References	Description	Probabilistic	Deterministic	Time/angle of arrival	Energy triggered	Asynchronous	Synchronous	In-band	Out-band	Single/cell multi-cell	Dense areas	Year
[9]	Birthday Protocols for DD	✔			✔	✔			✔			
[114]	DD technologies by means of signal strength.	✔		✔		✔			✔		✔	
[70]	Relative discovery in WSN		✔	✔		✔			✔			2003
[97]	Neighbor DD using smart antennas		✔		✔		✔			✔		
[115]	Least Squares Algorithms for mobile location	✔		✔		✔		✔	✔		✔	2004
[116]	Adaptive AR model for NLOS	✔		✔		✔		✔	✔			
[117]	Mobile positioning with fundamental limitations using wireless networks		✔		✔		✔		✔			2005
[71]	Cooperative localization in WSN	✔			✔	✔			✔		✔	
[118]	Network-based location with developing challenges	✔		✔			✔	✔	✔	✔		
[27]	Neighbor DD in wireless networks using directional antennas		✔	✔		✔		✔		✔		
[73]	Analysis of Wireless Geo-location for NLOS		✔	✔	✔		✔		✔		✔	2006
[119]	A simple algorithm for neighbor discovery in wireless networks	✔			✔		✔		✔			
[32]	UWB based positioning using hybrid TOA/AOA		✔	✔		✔			✔			
[26]	Asynchronous DD and Rendezvous		✔			✔			✔			2008
[34]	Cross-layer service discovery using Bloom Filters	✔			✔							
[72]	ACPS: cooperative positioning	✔	✔		✔				✔	✔	✔	
[11]	Wireless position estimation survey	✔	✔	✔	✔	✔			✔			
[120]	Access points location using differential evolution	✔			✔		✔				✔	
[74]	Efficient service discovery algorithm using counting Bloom Filter		✔		✔	✔			✔		✔	2009
[121]	Link discovery		✔			✔			✔			
[122]	Service discovery in opportunistic networks		✔			✔			✔		✔	2010
[10]	Searchlight: Asynchronous discovery protocol		✔		✔		✔		✔			2011
[63]	Joint discovery wireless networks	✔			✔		✔			✔		
[123]	ALOHA-Like discovery in WSN	✔			✔						✔	
[59]	Autonomous DD		✔					✔	✔	✔		2012
[124]	Pre-Handshaking discovery protocols in full duplex WSN	✔					✔		✔			
[31]	Bio-inspired discovery and Synchronization		✔				✔	✔	✔		✔	2013
[125]	Physical layer design DD	✔					✔	✔		✔		
[102]	Network-assisted DD	✔	✔		✔			✔		✔	✔	
[126]	Efficient Algorithms for discovery in wireless networks	✔				✔					✔	
[75]	DD for wireless networks using compressed sensing	✔			✔		✔		✔		✔	
[3]	Signal design for DD in OFDMA cellular networks			✔	✔		✔	✔		✔		
[96]	Service discovery protocols in cellular networks: Reactive against Proactive	✔	✔		✔		✔	✔	✔		✔	2014
[127]	Collision detection DD	✔			✔	✔			✔			
[108]	A discovery scheme for synchronous distributed networks	✔			✔		✔		✔		✔	
[128]	Network-assisted DD in LTE systems	✔			✔		✔	✔		✔		
[129]	Advancing DD by using provisional discovery resource		✔	✔		✔		✔	✔		✔	
[98]	Energy-efficient DD for proximity assistance in 3GPP				✔			✔		✔	✔	
[21]	Energy-efficient DD in Ad-Hoc and WSN: A survey		✔		✔	✔	✔		✔			
[45]	Enabling D2D using DD in LTE Networks		✔	✔			✔	✔		✔		
[2]	DD for multi-hop cellular networks	✔		✔		✔		✔	✔		✔	
[33]	Proximity discovery over a cellular network		✔		✔		✔	✔		✔		
[130]	Congestion in DD for proximity-based services		✔				✔					2015
[76]	Cell discovery in mm-wave cellular networks	✔		✔		✔		✔	✔	✔		
[131]	Directional DD in dual-band networks		✔		✔	✔		✔	✔			
[28]	Context-aware cell discovery		✔		✔		✔	✔	✔			
[77]	Asynchronous probabilistic discovery algorithm in WSN	✔				✔			✔			
[103]	DD for proximity service in LTE	✔			✔		✔	✔		✔		
[12]	Service discovery in social networks: Survey	✔	✔	✔		✔	✔				✔	
[78]	Energy efficiency of DD in opportunistic networks	✔			✔		✔	✔	✔		✔	
[132]	Power control and collision determination schemes for DD		✔	✔			✔					
[79]	Cooperative DD self-organizing networks	✔	✔			✔	✔				✔	
[6]	Green random access for DD	✔			✔	✔			✔	✔		
[104]	Efficient DD and access procedure for a 5G network		✔		✔		✔	✔	✔		✔	
[13]	DD for opportunistic IoT network: A survey	✔	✔	✔		✔	✔	✔	✔	✔	✔	

TABLE 5. ***(Continued.)*** **Possible proposed schemes for DD with parameters.**

References	Description	Probabilistic	Deterministic	Time/angle of arrival	Energy triggered	Asynchronous	Synchronous	In-band	Out-band	Single/cell multi-cell	Dense areas	Year
[105]	Network-assisted direct DD with underlay communication				✔			✔		✔		
[133]	Enabling DD transmissions in LTE with fractional frequency reuse				✔			✔		✔	✔	
[134]	DD Algorithm in Ad-Hoc networks		✔		✔	✔			✔			2015
[80]	DD in Full-duplex using compressed sensing Ad-Hoc Network	✔		✔		✔			✔		✔	
[135]	Social-aware DD in underlaying cellular networks	✔			✔		✔	✔		✔		
[82]	DD and configuration for IoTs	✔			✔		✔		✔		✔	
[40]	Social community-aware DD		✔		✔	✔			✔		✔	
[65]	The Sleepy Bird based energy efficient DD	✔			✔				✔			
[8]	Cell discovery with context-aware in 5G Networks	✔		✔			✔	✔	✔		✔	
[106]	An Analytical study on service discovery	✔	✔		✔	✔	✔			✔	✔	
[132]	Power and collision control DD		✔	✔	✔			✔	✔			
[81]	Users' priority-based DD scheme for Pro-Se in LTE-A	✔			✔		✔	✔		✔		2016
[36]	Channel correlation base DD scheme	✔		✔			✔		✔		✔	
[136]	Performance evaluation DD for LTE		✔		✔		✔	✔		✔		
[137]	Fast discovery with full duplex technology	✔			✔	✔		✔			✔	
[138]	Can full duplex cut the discovery period?		✔		✔			✔		✔		
[139]	Proximity services based direct discovery		✔		✔	✔			✔		✔	
[83]	DD in LTE: A radio access viewpoint	✔			✔		✔	✔		✔		
[41]	Performance analysis DD in random spatial networks	✔	✔	✔		✔	✔	✔	✔			
[55]	Network science approach DD	✔	✔		✔	✔	✔	✔	✔		✔	
[37]	Joint Peer Discovery	✔			✔		✔		✔		✔	
[140]	Proximity discovery in LTE for mobile health communities	✔			✔		✔	✔		✔		
[84]	Base Station Assisted DD		✔	✔			✔	✔		✔		
[5]	VANET assisted DD: Delay Analysis	✔				✔			✔		✔	
[44]	Cooperative DD in in-Band cellular networks			✔		✔	✔	✔		✔	✔	
[86]	Cooperative DD using spreading Technique	✔	✔			✔	✔		✔		✔	
[85]	DD using spreading Technique		✔		✔		✔	✔	✔		✔	
[95]	Channel access for enabling quick discovery	✔		✔	✔		✔	✔		✔		2017
[42]	Adaptive transmission algorithm for direct discovery		✔		✔		✔		✔		✔	
[87]	DD scheme for underlay cellular networks	✔			✔		✔	✔		✔		
[88]	A Coupon-Collector model for discovery	✔			✔						✔	
[107]	DD scheme based on the random back off	✔		✔			✔	✔		✔		
[38]	Peer discovery using social and service attributes		✔		✔		✔		✔		✔	
[89]	On expected DD time modeling with bounds and optimization	✔			✔		✔		✔			
[29]	Glowworm Swarm based DD in cellular networks	✔			✔			✔		✔		
[18]	DD using sphere decoder like algorithm		✔		✔		✔	✔		✔	✔	
[90]	Neighborhood-aware DD	✔		✔			✔		✔		✔	
[91]	Multiple-Access technique for DD	✔			✔		✔		✔		✔	2018
[92]	ROOMMATEs: Indoor DD approach for LTE		✔		✔	✔		✔		✔		
[112]	Cooperative DD for in-band cellular networks	✔		✔		✔	✔	✔		✔		
[109]	DD procedure in self-organization network	✔					✔		✔		✔	

DD, they can alter their own scheduling for future DD in view of application necessities. A major challenge of accepting this thought is how to guarantee discovery proficiently as the scheduling is balanced, and different from one they communicated with previously. For instance, if a device only includes active discovery resource unit for fast discovery, its discovery latency would be high in the dense areas. In recent work [109], the number of transmissions is enhanced as active slots. Further enhancement and analysis are left open.

II. Cooperative DD. Besides social learning from the discovery signal, another probability to help neighbor discovery is to use cooperation among devices. A cooperative DD [44], [112] is defined as a DD that is performed based on the base station and device knowledge cooperatively as presented in Fig. 18. It reduces the signaling overhead and energy consumption [44]. In addition to direct DD among neighbors, indirect DD is also considered in this survey, in which two devices discover each other by means of a third device. The concept behind this is that two devices with the identical neighbor(s) are neighbors with a high chance. Their mutual neighbors may act as cooperator to expedite the indirect discovery. However, as neighborhood connection is

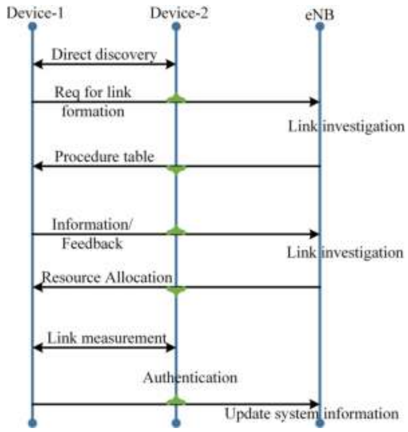

FIGURE 18. **Cooperative DD.**

not transitive, such indirect discovery may not be legitimate. The similarity of two devices using the power ratio between devices is assessed in [109] for common neighbors. However, as neighborhood connection is not transitive, such indirect discovery may not be legitimated. Further examination of indirect discovery and other cooperative ways are required.

III. Multi-hop DD. We hold a supposition of single-hop neighbors in this survey. However, it is conceivable to characterize and utilize multi-hop neighbors, where two devices are not inside the coverage range of one another directly. Therefore, at least one regular one-hop neighbor is needed. Such one-hop neighbors promise to benefit on several customary network services, such as localization, routing network, and connectivity. So far, there has been no research work that concentrates on multi-hop neighbor discovery. The challenges that must be addressed multi-hop include reliance on DD, communication and load balance. We anticipate that novel research work will fill this breach.

IV. Dense area discovery. Most of the existing DD algorithms focus on two devices discovery and apply this mechanism on the entire system. However, in numerous applications, for example, living space observing, rescue and asset tracking, the discovery of a group devices attract greater interest. Because of its flock nature, prevailing algorithms may not be productive. Cooperation among flock devices may be received as an important mechanism.

V. Moving device discovery. In comparison with the functions of WSNs, uses of mobile computing are further identified with daily life and turned out to be widely known in recent years. With the rapid growth of smart devices, for example, tablets and mobile phones, fast moving DD in single cell and multi-cell is critical. A typical example is the human mobility patterns statistics. In an e-Discovery in [140], the authors proposed an efficient DD protocol as the initial step to bootstrapping cooperative communication for cellular smartphones. It is anticipated that lot of research work will be conducted in this direction.

VI. In self-explanatory Fig. 19 more open issues on DD are elaborated. All the issues are based on self-explanatory

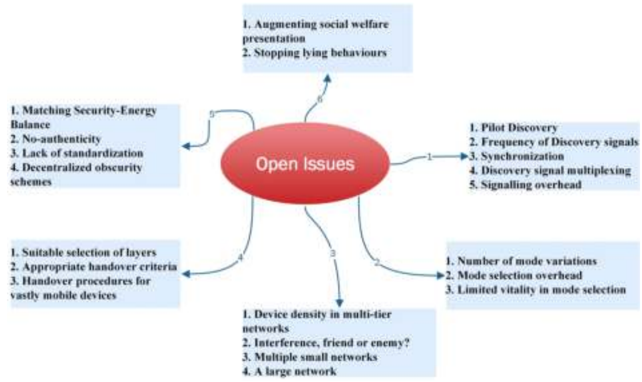

FIGURE 19. **Open issues for DD procedure and algorithm.**

Fig. 14 and self-explanatory Fig. 17. All these issues require solution and should be taken into consideration.

VI. CONCLUSION

In this paper, DD for D2D communication has been broadly outlined. The scenarios and taxonomy classify DD protocols, and highlight the distinctions between algorithms. The algorithms for moving devices is also discussed for D2D scenarios where devices accessibility is not considered. The objective of mobility aware algorithms is to exploit and understand the mobility pattern for further optimization. Therefore, the estimation that exploits mobility pattern knowledge is the favored choice in light of the high mobility nature in D2D scenarios. In this survey, ideas are gathered predominantly in the literature on neighbor DD in both out-band and in-band networks. In general, neighbor DD procedures and algorithms can be generally characterized depending on their basic standards: probabilistic, deterministic synchronous, asynchronous single cell, multi-cell and dense areas. Several algorithms and protocols are compared for in-band and out-band under these principles and discovery latency, energy efficiency, mobility are assessed. The quantitative analysis are made among different DD algorithms and procedures to enhance the scope of survey article. Additionally, several future directions are pointed out in this field. As a basic procedure in both energy management and communication, neighbor DD will remain significant in the research group and further research will extend the understanding of DD mechanism in in-band D2D communication. In conclusion, knowledge via neighbor DD impacts not only such algorithms but also routing techniques. If such information is exploited and connected to routing, it could help in formulating new autonomic and clever algorithms. Finally, in D2D scenarios where information is shared across heterogeneous systems, rust management has turned into another challenge. This challenge should be addressed to protect security and privacy of information and of devices within information fusion process.

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OMAR HAYAT received the B.Sc. degree in electronic engineering from the Islamia University of Bahawalpur (IUB), Bahawalpur, Pakistan, in 2007, the M.S. degree in electronic engineering from Islamic University Islamabad (IIU), Islamabad, Pakistan, in 2011, and the Ph.D. degree in electrical engineering from the Wireless Communication Centre (WCC), Faculty of Electrical Engineering, Universiti Teknologi Malaysia, under the supervision of the Dr. R. B. Ngah. He is currently an Assistant Professor with the Department of Engineering, National University of Modern Languages (NUML), Islamabad. His research interests include access technologies, next-generation networks, and emerging technologies of the 5G wireless communication networks.

RAZALI NGAH received the Ph.D. degree from the University of Northumbria, U.K., in 2005. Since 1989, he has been with the Faculty of Electrical Engineering, Universiti Teknologi Malaysia (UTM), where he is currently an Associate Professor. He is also the Deputy Director of the Wireless Communication Centre, UTM. His research interests include antennas and propagation for communications, device-to-device communication, radio over fiber, and photonic networks.

SITI ZAITON MOHD HASHIM received the B.Sc. degree in computer science from the University of Hartford, USA, the M.Sc. degree in computing from the University of Bradford, U.K., and the Ph.D. degree in soft computing from The University of Sheffield, U.K. She is currently an Associate Professor with the Universiti Teknologi Malaysia (UTM), Johor Bahru, where she is also the Head of the Department of Software Engineering, Faculty of Computing. She is also a member of the UTM Big Data Centre of Excellence (UTM-BDC), UTM. She has authored or coauthored more than 150 publications, 80 proceedings, 57 journals, and 800 citations, with 13 H-index. She has supervised/cosupervised more than 20 master's and Ph.D. students. Her research interests include soft computing and applications, machine learning, and intelligent systems.

MUHAMMAD HASHIM DAHRI received the B.E. degree in telecommunications from the Mehran University of Engineering and Technology (MUET), Pakistan, in 2010, the master's degree in electrical engineering from Universiti Tun Hussein Onn Malaysia (UTHM), in 2014, and the Ph.D. degree from the Wireless Communication Centre (WCC), Univerisiti Teknologi Malaysia (UTM), in 2019. He is currently a Postdoctoral Research Fellow with UTHM. He has authored more than 30 research articles in various indexed journals and conference proceedings. His research interests include reflect array antennas, planar printed antennas, and 5G communication for antenna design.

REZA FIRSANDAYA MALIK received the S.T. (Bachelor of Engineering) degree from the Institut Sains dan Teknologi Nasional (ISTN), South Jakarta, in 2000, the M.T. (Master of Technique) degree from the Institut Teknologi Bandung, in 2003, and the Ph.D. degree from Universiti Teknologi Malaysia (UTM), in 2011, where he investigated the Routing Optimization Scheme in wireless mesh networks using particle swarm optimization. He is also appointed as a member of the Communication Networks and Information Security (COMNETS) Research Laboratory, Faculty of Computer Science, Universitas Sriwijaya. His current research interests include pervasive computing and artificial intelligence.

YUSNITA RAHAYU received the B.Eng. degree from the National Institute of Science and Technology (ISTN), South Jakarta, in 1999, and the M.Eng. and Ph.D. degrees from Universiti Teknologi Malaysia (UTM), in 2004 and 2009, respectively. She has experience of more than 14 years in academic and research position at various international and national universities. Since 2005, she has been with Universitas Riau (UR), where she is currently an Assistant Professor and a Researcher with the Faculty of Engineering. She has conducted various research projects from national and international grants. She has published more than 30 articles in national and international conference, five book chapters, and 15 international journals. Her research interests include radio transceiver design, antenna design, sensor networks, device-to-device communication, controlling and monitoring systems, the IoT, and wireless communication systems. She is also active as a Reviewer and Technical Program Committee Member for various journals and conferences. She is a member of the IEEE Antenna and Propagation Society Region 10.