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Signaling Overhead Reduction Techniques in Device-to-Device Communications: Paradigm for 5G and Beyond

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ABSTRACT Device-to-Device (D2D) communications have recently attracted researchers, attention because of their numerous applications in industry verticals. It enables communications among devices without or with the partial involvement of a central system. To initiate a D2D communications device discovery and radio resource allocation is a critical task when devices have high mobility. Maintaining the quality-of-service and continuous connectivity requires a signaling burden. An efficient mobility management procedure is necessary to discover the neighboring devices in D2D communications systems. The Discovery of a massive number of devices requires an effective radio resource management procedure that causes signaling overhead. In 5G and beyond communication system, two mobility management methods exist; device discovery and beaconing. Since device density and traffic increases exponentially with high mobility, hence device discovery and beaconing increase the signaling overhead and energy consumption in power-limited devices. Thus, signaling overhead research needs much attention in 5G and beyond systems to meet the service requirements like accuracy, latency, and battery life. Therefore, the challenges and the techniques related to signaling overhead in D2D communications are presented.

INDEX TERMS 5G, D2D communications, device discovery, signaling overhead, latency.

I. INTRODUCTION

Device-to-Device (D2D) communications are becoming a prominent choice for telecom operators with the speedy growth of wireless devices and personal communication technology. Device discovery is a leading task [1]–[3] in D2D communications, where devices broadcast beacons to discover neighbor users. Radio resources are allocated among the devices to initiate D2D communications and device discovery [4]. However, the device signaling signals raised by an enormous number of devices cause serious signaling overhead of wireless mobile networks. It influences the outage execution of the network. Therefore, it is necessary to evaluate, analyze, and assess the impact of signaling overhead on D2D communications in heterogeneous cellular systems. The heterogeneous cellular systems for next-generation consist of macro and micro base stations and an in-band D2D communications system. In in-band D2D communications, devices communicate with the involvement of a central system [5]. The overlaid framework, for example, distributed antennas systems, picocells, femtocells, and in-band D2D communications, have recently developed as an adaptable and cost-effective method for dealing with the detonating and irregular data traffic requests, which are relied upon to upsurge uncertainly.

The management of in-band D2D communications due to heterogeneous cellular systems is significantly more challenging than the conventional one-tier cellular systems. In an in-band system, various types of base stations have diverse spatial densities, cell sizes, transmit power, and backhaul

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abilities. In this article, centralized control of in-band D2D communications includes a potentially massive amount of signaling overhead in terms of device discovery signaling, resource allocation, etc., which are the key challenges. Decentralized inter-device coordination is another way of organizing heterogeneous networks for coordinated multi-point transmission, handoffs, and cooperative scheduling. Generally, inter-device coordination empowers neighboring devices to improve the gains [1], [6], which results in enhancements to signal-to-interference and noise ratio (SINR), outage rate, and spectral efficiency. The model of constrained overhead data rate, which is a combination of the overhead signal inter-arrival time and the overhead signal size, is recently considered for overhead signaling [5]. We presented the D2D signaling for the session continuity in Figure 1. Before initiating D2D communications, several signaling steps are presented in [7]. These signals are evaluated among D2D and from device to base stations. As the number of devices increases, signaling overhead occurs and results in extreme inefficiency.

In [8], the authors' calculated outage probability and analyzed the theoretical framework for conventional cellular and D2D using direct path routing in multi-hop D2D communications. Numerical results expressed that the proposed D2D communications scheme achieves around a 5% outage probability as compared to the conventional scheme with a 25% outage probability. In [9], the authors proposed an energy-efficient radio resource sharing scheme for D2D communications in Long-term evolution (LTE), and they highlighted two main challenges: quality-of-service (QoS) and energy efficiency. For mm-wave communications, energy-efficient D2D multicast scheduling was proposed in [10], where the path forecasting algorithm determines D2D paths and synchronization for link pairing. Simulation results were evaluated and compared with the state-of-the-art schemes to prove the efficiency.

In the literature, the authors discussed numerous cooperation strategies that can achieve high cooperative gains. However, the improvement in gain is compensated by the intrinsic cost of signalling overhead sharing. The overhead involved in channel state information (CSI) and device (end-user) scheduling is shared at an inadequate rate and also have the quantization error and delay [11]. Apprehensions on signalling overhead lead to non-trivial breaches between theoretical and real gains. For example, in D2D downlink cooperative processing, which perfectly presents a multi-fold throughput enhancement. However, industrial and academic simulation demonstrate that physical throughput gain is frustrating under 20%, and the significant constraining element is dividing CSI and other signalling overhead among devices [12]. Mathematically, to calculate the achievable gain of signalling overhead, the following parameters are involved, overhead signal inter-arrival time, the overhead signal size, and the overhead delay.

Before moving further, we highlight some key challenges as:

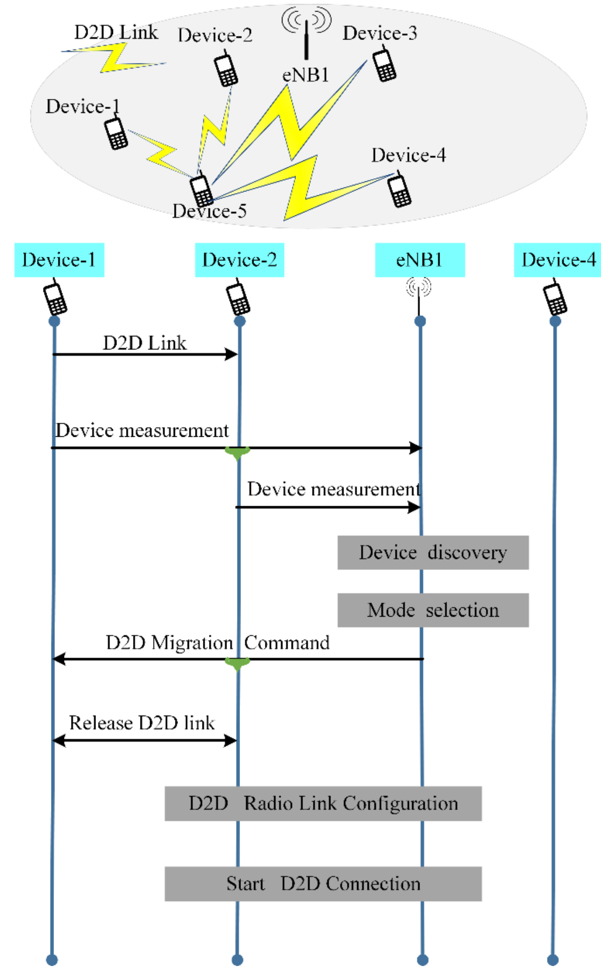

FIGURE 1. D2D signaling for the session continuity.

i. How D2D communications are performed?
ii. To initiate D2D communications, it is necessary to know the device discovery initialization process?
iii. How does the discovery area update to a device in the network?
iv. How does the discovery area list allocate to a device in the network?
v. How many cells should be in the discovery area?
vi. How signaling overhead occurs and causes inefficiency?
vii. How signaling overhead cause delay?
viii. How mobility management is burdened on signaling overhead and what are current solutions to minimize stage signaling overhead and overall signaling overhead by considering static devices and high mobility devices?

The concern in the above questions is the signaling overhead. Primarily, all Long-Term Evolution (LTE) operators consider the above questions when designing a network to get the optimal standards of network parameters. Now, LTE networks implement a dynamic discovery management system where each device has its discovery area list, which contains

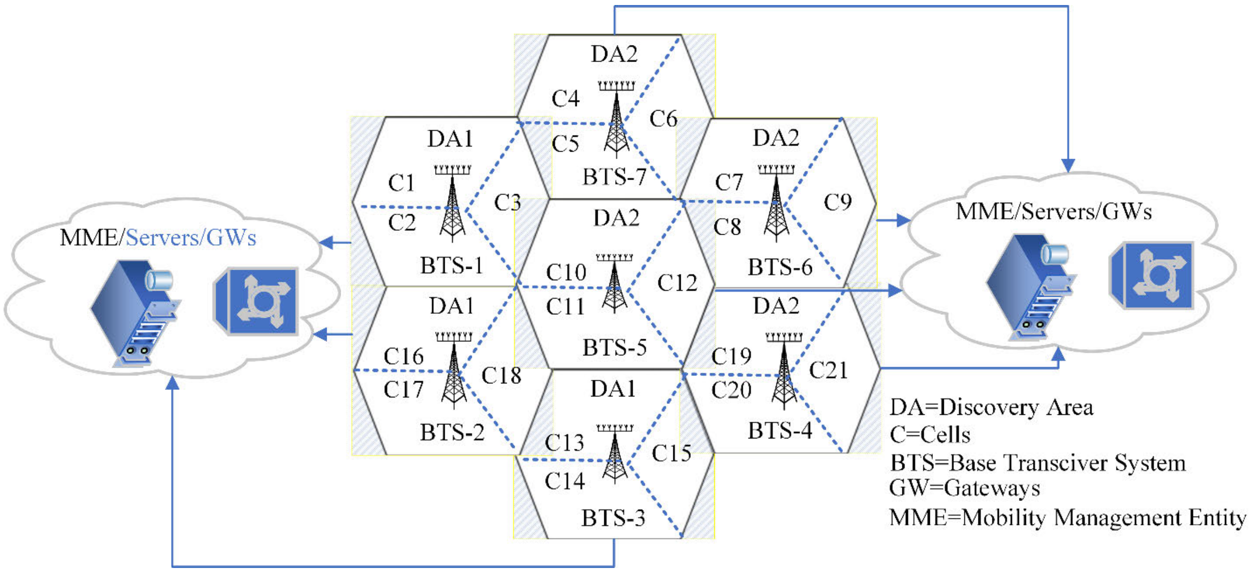

FIGURE 2. **Discovery area updating procedure in cellular systems.**

more than 16 discovery areas as explained in **Figure 2** [14], [22]. The number of cells in one discovery area depends on network topology. A gateway (GW) routes the wireless traffic and acts as the anchor for mobile devices for handovers and interfacing. A base transceiver system (BTS) provides a radio interface between devices and networks to enable communication. Typically, one discovery area comprises 1 to 100 cells [23]. In the dynamic device discovery, a specific discovery area list is allocated to the device, that comprised of many discovery areas in proximity to the device's current location [24]. This idea lessens the number of discovery requests that a device transmits when it travels inside the coverage zone. When the device crosses the edge of its formerly allocated discovery area list, it transmits a discovery area update request to update the network regarding its discovery update and obtains a discovery area list. The signaling process applies to the discovery area list to sign the conforming device. Hence, a massive number of cells in a discovery area create more signaling, which results in burdening the network. Conversely, smaller discovery areas enhance the discovery area update and cause more power consumption in the devices [25]. Excessive discovery area update requests can diminish the signaling key performance index (KPI), i.e., the success rate, as several devices cannot reply to the signaling information while answering the discovery area update procedures. Many researchers have provided the solution by network planning and are developing algorithms based on some trade-offs. In this article, we present a brief survey on the problems of signaling overhead and summarize the existing solutions. We also discuss the perceptions to evaluate current solutions and their responsibility in 5G and beyond networks.

A. MOTIVATION

The motivation of this research is to highlight the D2D communication signaling challenges in dense areas such as stadiums and shopping malls. Along with, if the devices are fast-moving, then the device tracking is a big challenge in terms of signaling. Device discovery is the initial step to initiate the D2D communications, which has signaling overhead that includes discovery area update, discovery area list allocation, and the number of cells in the discovery area. The signaling process applies to the discovery area list with a massive number of cells in a discovery area would create more signaling that burden the network. The existence of signaling overhead causes inefficiency, delay, and ineffective mobility management of the devices in D2D communications. These issues motivate us to write a survey, to sum up, the sources cause signaling overhead. We summarized the comparison of the existing surveys with this article in **Table 1**.

B. CONTRIBUTION

The main contributions of the paper are summarized here.

To the best of the authors' knowledge, this survey has discussed and addressed the following issues:

1. We analytically examine signaling overhead issues in a D2D communication system and assess them with a viewpoint of the next-generation networks. It proves that as compared with the existing LTE system, D2D has a long device battery time. Therefore, in this article, we explore the current signaling overhead solutions for various D2D use cases. We presented the consequences of the existing signaling overhead procedures and summarized the challenges for both the device and network performance.

2. This survey uniquely highlights the problem of energy consumption in devices during the signaling process. It will help to address the battery limitation issues in the power-limited devices.

The remainder of this article is organized as follows. Section II describes the existing research on signaling overhead. In Section III, overhead reduction parameters are

TABLE 1. Comparison with the existing survey papers.

References	Description
[12]	Fundamentals of signaling overhead in a heterogeneous network are explained but lack discussion related to D2D networks.
[13]	Social-aware D2D communications schemes with different features such as community, relations, and trust are studied to improve the D2D technical problems, but the authors did not contemplate signaling related issues.
[14]	The authors presented the signaling overhead reduction schemes for LTE mobile devices. Based on the discovery area list, signaling data and signaling overhead reduction is calculated by ignoring the 5G services.
[15]	The authors presented an idle state signaling of mobile devices in cellular networks under the 4G architecture. They did analytical analysis for signaling overhead measurement by ignoring D2D scenarios in a dense area.
[16]	A discovery signal is designed for neighbor devices by using a reference signal. The proposed model is robust against collision and performs accurate and fast discovery in a dense area, but as the number of devices increases the signaling overhead occurs.
[17]	Performance of signaling overhead in beyond 3G networks for security mechanism is proposed. Security mechanisms lead to more signaling overhead and this affects the system performance.
[18]	The authors summarized a detailed survey on mobile devices in D2D communications along with the challenges, practices, and principles. The authors investigate D2D in terms of mobility but did not consider the signaling impact on D2D and device discovery.
[19]	In this paper signaling management approach for IoTs based on the measurement is suggested. Two scenarios are considered in D2D vehicular and smart metering for signaling overhead analysis and concluded that signaling overhead harms signaling traffic.
[20]	The authors presented a study on signaling overhead in LTE for mobility management and presented only radio resource management solutions. They ignored the effect in a highly dense environment.
[21]	In this paper, the authors summarize a review on security and privacy issues in D2D communications. They highlighted the challenges and requirements to maintain security and privacy in D2D communications.
This survey	We presented the key issues related to signaling overhead in D2D communication by targeting device discovery and mobility management. This paper highlights the signaling overhead reduction techniques in D2D communications for beyond 5G systems to achieve low latency. The motivation and contribution sections emphasize the paper contents, which will help the researchers.

elaborated by group-based device discovery and frequency correlation. Classification of signaling overhead is mentioned in Section IV along with end-to-end (E2E) latency and cooperative device discovery. In Section V-VII signaling overhead related material is explained with scheduling request, channel gain measurement, and radio resource overhead. Future work is presented in Section VIII. Finally, we concluded the paper in Section IX.

II. EXISTING RESEARCH ON SIGNALING OVERHEAD

Based on typical use cases in D2D communications as shown in **Figure 3**, there are four D2D envisioned technologies, direct D2D, multi cells D2D, D2D local area network (LAN), and single and multi-hop D2D. In direct D2D, two devices communicate directly without consuming in-band radio resources. More than two devices make a D2D LAN for communication under the supervision of BTS. In the single-hop and multi-hop D2D, devices communicate directly or via a relay. In multi cells D2D, two devices communicate if the devices are in a different cell. The cases that involved the signaling-overhead challenges are; discovery position update, combined mobility management, and software-defined networking (SDN)-based mobility management techniques. In this section, we briefly discuss these cases.

A. DISCOVERY POSITION UPDATE

There are two possible combinations for the discovery position update: global, static, local, and dynamic.

■ **Global and static:** All the devices in that area belong to the same discovery and signaling area list. This scheme has high complexity because of excessive discovery signaling [26]. This method does not consider individual device behavior and hence has no way to lessen the changing effect when devices change over cells. This scenario generates irregular signaling when a massive number of devices enter the discovery area that requires a frequent update in the discovery list [27].

■ **Local and dynamic:** In these methods, the discovery area is not permanent beforehand, and this method does not

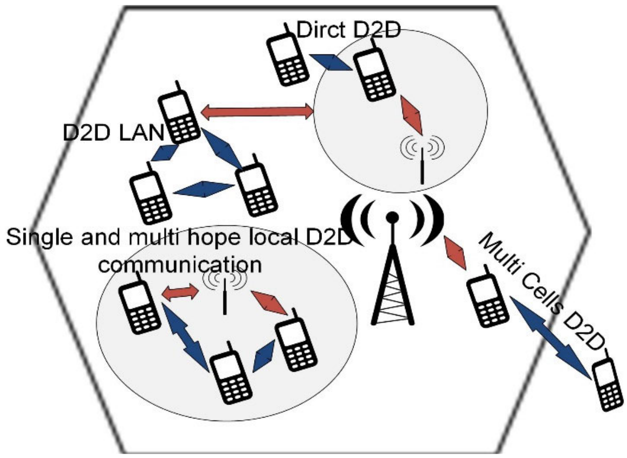

FIGURE 3. Typical use case in D2D communications. procedure in cellular systems.

care about an individual moving device pattern. LTE accepts dynamic discovery area updates where the assigned tracking area list is near the device's current location [15]. All the devices having the same discovery area list is allocated a specific tracking area list based on the position in the network [28]. The dynamic arrangements can alleviate the problems of global and static schemes [29].

B. SIGNALING SOLUTION SCHEMES

In literature, five schemes are presented to reduce the signaling overhead. These schemes are blanket signaling, first short-distance signaling, sequential signaling, profile-based signaling, and pipelining signaling.

■ **Blanket signaling:** In blanket signaling, there is simultaneous broadcasting of signaling information to all the discovery areas in a device's discovery area list. Instead of the popularity of this method, the bandwidth consumption is ineffective; blanket signaling requires large bandwidth because several cells are in contact with each other at once. They may reduce the signaling KPI achievement rate on account of high traffic [28].

■ **First short distance signaling:** This scheme starts by transmitting signaling information to the last serving cell where the device has triggered the discovery area update signal and then attempts to connect with the neighbor cells based on the first short-distance signaling. This system is hard to apply to the adjacent cells and is difficult to determine dynamically, as, in the LTE, the system does not have information about the past serving cells [26].

■ **Sequential signaling:** This system starts by transmitting signaling to the group of cells where a specific device has a high probability of discovery in the expected discovery area. These signaling areas are sequentially paged and ordered into descendant form by their probabilities. Though this system decreases the network mobbing compared with blanket signaling, it has a high operation cost, that requires more storage for signaling information of the devices, and also results in enhanced signaling delay [30].

■ **Profile-based signaling:** Profile-based signaling plan is imagined improving the bandwidth usage, signaling achievement rate KPI, considering the probability of discovering a specific device and device mobility pattern. This plan bolsters the device movement and enriches the signaling process. Thus, the profile-based signaling plan makes a 9% more progress rate than the blanket signaling plan and 3% additional than the sequential signaling. Improving both paging achievement rate and bandwidth utilization is imperative for the networks to help the massive expansion in device intensity. Also, the profile based signaling plan operates well when uncertain movements of devices are performed. Though, device mobility patterns entail being apprehended for the objective of the discovery approximation, which in turn rises the calculation overhead as well [26].

■ **Pipelining signaling:** Pipeline signaling scheme works with no preceding information about the probability of the existence of a device in a certain signaling area. Instead, several fixed sizes signaling areas are signed for all devices in a channel allocation manner. According to [30], pipelining signaling works better than blanket signaling and sequential signaling using different metrics. A signaling overhead delay is minimized because several devices can be signaled in a parallel manner in the signaling area. Results show that the pipelining signaling and sequential signaling schemes have similar behavior in their signaling cost, which in turn reduces the signaling delay. Besides, the pipelining signaling system can cope with more signaling demands than the sequential system.

C. COMBINED MOBILITY MANAGEMENT AND SIGNALING

In 5G and beyond systems, mobility management for D2D discovery and signaling management is a big challenge. To overcome these challenges, we highlighted some solutions:

■ **Optimization approach:** These approaches contemplate signaling overhead and discovery area update. Therefore, it is a multi-object optimization challenge to obtain the trade-off between the signaling cost and discovery area update. Authors in [31] expressed this as an integer programming challenge to present a suite of best solutions. Results proved that the system signaling cost of the suggested discovery scheme is reduced to 49% from 56% as compared with the optimal standard discovery. Similarly, the individual signaling cost is also reduced to 67% from 73% [32].

■ **Information based approach:** Some schemes depend on theoretic-based information frameworks to exchange information between the sequence of signaling expenses and calculation overhead. These schemes have been discussed in [33]–[35] as well. In [33], the authors proposed a Bayesian and entropy-coding based discovery area update. In these plans, mobility patterns of devices are assembled online to perform profile based signaling and better the discovery area update overhead. To start with, it decreases the signaling overhead and has a smaller amount of storage and computational cost. Another, it limits signaling overhead however wants more prominent stockpiling and computational overhead than the initial. Subsequently, these approaches have a few compromises among signaling and computational expenses. Results show that entropy-coding based, and Bayesian-based signaling area updates decrease signaling overhead around 60 to 80 for existing discovery area update in LTE. In [34], the authors anticipated temporal and spatial quantization for device discovery methods to handle the commutation between discovery area update and signaling overhead with no prior information about device mobility patterns [36]. The authors revealed that the discovery area update price decreased because of increasing signaling price but keeps low storage and computational overhead [33]. The anticipated schemes can lessen 3 to 4 updates/day discovery area update. In [35], the authors applied Shannon's entropy for forecasting an individual device mobility decoration by the adaptive algorithm, and it helps for device discovery movement to decrease the signaling cost. Though, this kind of system is susceptible to large computational costs because of maintaining a register for all device mobility patterns. Therefore, the provided solutions did not consider the signaling latency, and these solutions still have a large storage overhead.

■ **Mobility based approach:** Mobility models help to estimate the device movement pattern, giving data about device location variations in such a way that the signaling overhead and discovery area update can be compacted, which are examined in the [37], [38]. In [37], the authors proposed a device mobility pattern for discovery area update and signaling processes based on the device mobility record. During tracking area update, a device derives the anticipated device mobility pattern from its device mobility history and lists this data into the database in the system. In this case, the device does not require to trigger discovery area update while mobility in its listed device mobility pattern. In [38] unlike the solution in [37], the authors offered a framework to envisage a device's mobility by examining the device's contextual data without considering the device mobility record. The main purpose behind the mentioned methods is to lessen the signaling cost by allocating the finest discovery area list that is reliable with the device's movement. Signaling overhead related existing surveys are summarized in **Table 2**.

D. SDN-BASED MOBILITY MANAGEMENT TECHNIQUES

Numerous SDN-based mobility management techniques exist in the literature, such as the hybrid approach for Network Function Virtualization (NFV), SDN-based solutions, and open flow-based SDN.

■ **Hybrid approach for NFV:** In [48], the authors studied the impacts of integrating SDN in LTE and recommended a hybrid method to employ SDN/NFV technology. The choice of evaluation is an optimization problem. The authors explained that SDN disintegration decreases the delay but expands the overall load. However, in NFV there is no expansion in network load but increases the traffic delay because of no additional control layer [48].

■ **SDN-based solutions:** Nowadays, Small cells are an integral part of communication systems, which in turn increases the signaling overhead for the network backhaul and small cells. To tackle this issue, the authors in [48] presented a framework consist of SDN solutions to improve the backhaul communication services in small cells. Here SDN gets mobility information from the device to support devices while moving in the small cells. Simulation results proved that a signaling overhead is reduced around 50% as compared to conventional schemes [49].

■ **Open flow-based SDN:**There exist two solutions for device mobility management; dedicated and centralized [1], [16]. The centralized solutions have performance drawbacks, such as soft scalability, suboptimal routing, and a prospective one-point of collapse. Therefore, the authors in [50] proposed an open flow-based SDN that can be useful in the virtual LTE networks. They reduced the downlink packet delays by feed-forwarding the data. As a result, this helps to provide the permanency of sessions continuously in case of inter-gateway handover, which demonstrates a substantial decrease in typical handover latency [50].

III. MOVING DEVICE DISCOVERY IN D2D SYSTEMS

LTE system operators are facing challenges related to mobile communication coverage as well as giving high QoS to every device [5], [18], [51]. LTE systems must know the specific location of a device to deliver benefit to a massive number of devices. Location technologies based on four envisioned technologies in 5G networks are shown in **Figure 4**. These envisioned technologies are (a) Massive multiple-input multiple-output (M-MIMO), (b) Ultra-Dense Network (UDN), (c) D2D networks, (d) mm-wave characteristics system. To perform device discovery in M-MIMO, they used the directions of arrival (DoAs) to achieve enhanced discovery precision. However, to enable device discovery in UDN, they adopted triangulation methods that result in more accuracy and fast device discovery. Through D2D discovery, some devices cooperate as pseudo-BTS and recommend supplementary associated information for accuracy. In the mm-wave system, they estimated the targeted users via a multipath, reflection, and diffraction. We can adopt these technologies for D2D discovery, but they have a large signaling overhead. The distribution of D2D signaling measures in LTE is shown in **Figure 5.** These events are divided into six categories: session setup, paging, discovery, and tracking, inter radio access procedure, connection, and disconnection and mobility status [52]. To handle this, LTE systems need to monitor all devices, and on account of the high mobility devices, it is hard to monitor the device's exact location over the system coverage zone. In this manner, the services being conveyed to a particular device encounter delays at the same time as the system looks for the expected serving cell.

TABLE 2. Existing related surveys in signaling overhead reduction.

References	Summary
[17]	Overhead performance analysis beyond 3G systems
[19]	Signaling management approaches for cellular IoT
[20]	Study on signaling overhead for mobility management in LTE-Advanced networks
[39]	Signaling overhead reduction for the microcells and femtocells networks
[40]	The exploitation of the tracking area list for enhancing signaling overhead in LTE systems
[41]	A low latency communication technique for M-MIMO systems with minimal control signaling overhead
[42]	Performance study on the overhead of the internet signaling transport Protocol
[43]	Study of dynamic OFDMA for in-band signaling
[44]	A comparison involving the CSI overhead in MIMO networks vs cellular
[45]	Signaling focused on DoS on LTE networks
[46]	Signaling overhead handover
[47]	Study on diminishing signaling congestion in LTE location

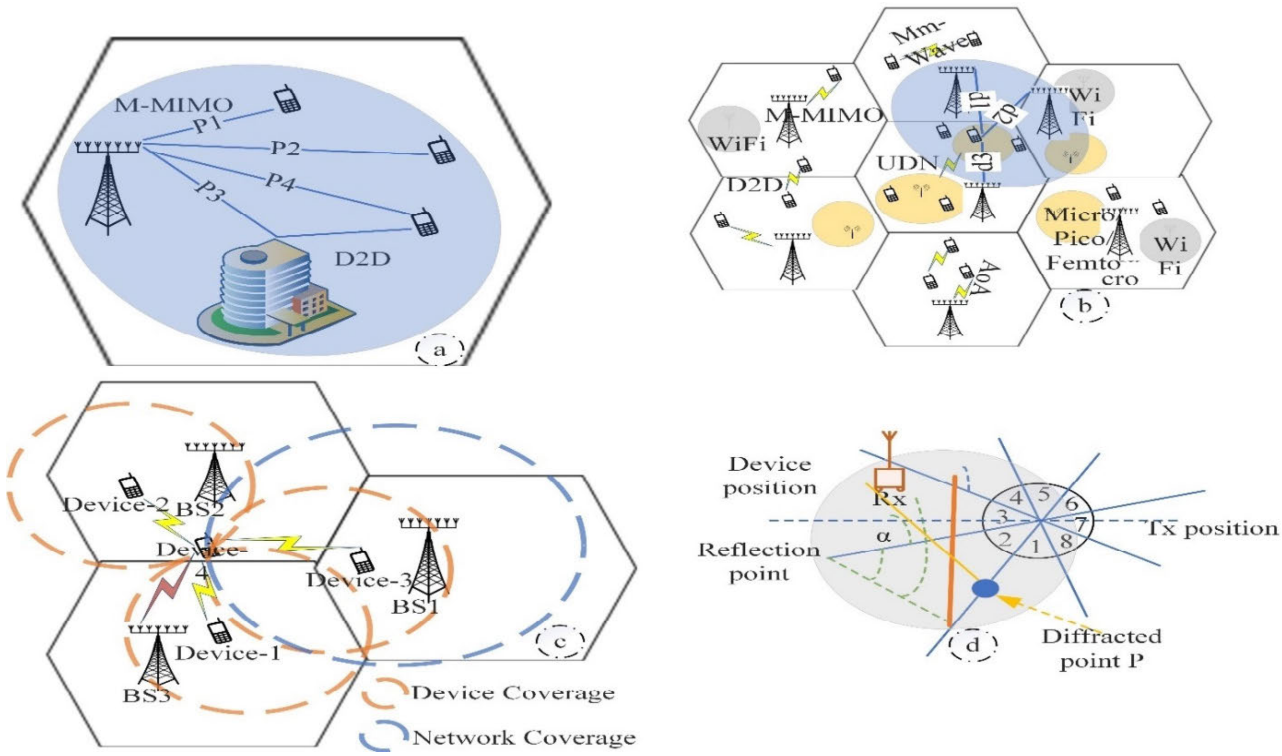

FIGURE 4. Positioning technologies based on four envisioned technologies in 5G networks.

Current LTE systems permit devices to be associated with fast mobility [53]. For instance, in fast vehicles, LTE systems can keep up devices associated up to velocities of 350 to 500 km/h through the country areas [54]. The LTE system module regulates and deals with the individual user's mobility inside the system is known as the Mobility Management Entity (MME) that oversees the mobility-associated information among devices and the serving system [36]. They separated the LTE coverage zone into groups of eNBs called discovery areas, and every discovery area has a sole identity called discovery area identity. Similarly, they additionally clustered these discovery areas into the discovery areas list. **Figure 2** illustrates an illuminating case of how the cells and discovery areas are gathered to frame the discovery areas list. Discovery areas-1 comprises of cell1 to cell9, and discovery areas-2 comprises of cell10 to cell21. As presented in the 3GPP specification [55], once a device registers with the system, the MME allows a particular discovery area list, which involves a lot of discovery areas to the user's present position. In this manner, the device is allotted a discovery area list when it travels beyond the current discovery area list by a procedure called discovery areas update, started by the device

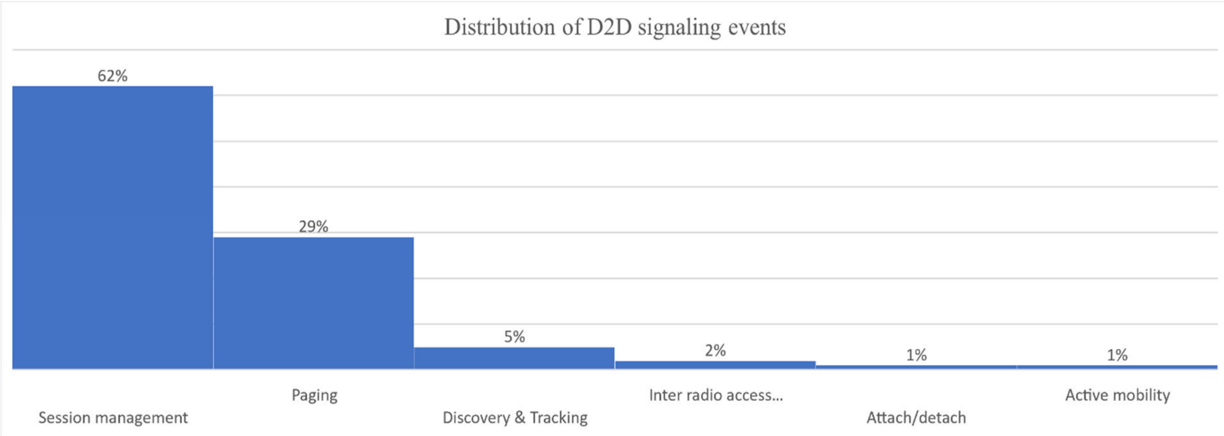

FIGURE 5. Distribution of D2D signaling events in the LTE network. Positioning technologies based on four envisioned technologies in 5G networks.

through its assisting cell. There is an alternative procedure started by MME, named Paging.

The system utilizes this procedure to discover a particular device inside the system to advance the approaching information packets. In simply, the MME transmits Paging signals to decide the specific assisting cell of a device inside the system. MME servers handle all discovery area updates and Paging signaling and process all discovery area updates and Paging demands effectively. However, MME is troubled by excessive signaling heaps because of a large quantity of mobility and link management. This procedure has high costs of signaling for devices and networks [56]–[58]. During typical active hours, MME can manage a signaling load of more than 500 devices and a maximum of 1500 devices under outrageous circumstances [59]. Simultaneously, this procedure consumes high power of around 10mW in smart devices. A data set gathered from the metropolitan market uncovers that high signaling heaps on MME brought about by discovery area update and paging strategies that cost approximately 34% of the signaling burden on the MME [60], [61].

IV. OVERHEAD REDUCTION PARAMETERS

In this section, signaling overhead reduction parameters are discussed, that includes group-based and frequency correlation based parameters.

A. GROUP BASED DEVICE DISCOVERY

D2D communications are a new paradigm in communication systems that allows peer-to-peer communication among devices and fixed infrastructures. The distributed framework, high mobility, and growing the number of devices in D2D result in an issue, for example, discovery signaling overhead. In a distributed environment, where devices must adapt to erratic changes. Such autonomic systems present sole difficulty in signaling overhead. Intelligent hybrid D2D communications based on the coordination of various technologies, for example, Wi-Fi, Wi-MAX, Bluetooth is used to accomplish successful D2D communications. Such systems establish a central element of the intelligent transportation system. In the high-density area, devices form groups in the D2D system to enhance communications and to characterize secrete keys for the utilization of symmetric cryptography to guarantee the data exchange [62]. There are two probabilities for the discovery signal: the reception of the discovery signal and the loss of the discovery signal. These are categorized into two categories; discovery signals and without groups of discovery signals, as explained in **Figure 6**. It is concluded from **Figure 6** that without grouping, devices transmit more discovery signals randomly, cause signaling overhead. That results in a high probability of discovery signals loss and consumes high energy, incurred high delay, and a smaller number of discovered users.

B. FREQUENCY CORRELATION

Dynamic OFDMA frameworks have assured the performing attributes for multiple D2D communications situations [63]. For instance, the downlink of the wireless system is utilizing OFDM as a transmission arrangement. As devices roam around a cell, there is a chance of spatial diversity for subcarriers. Thus, the low gain sub-carrier is assigned to some devices, and the remaining resources have high gain. This possible performance enhancement comes at the expense of the signaling overhead only [64]. It happens because after computation base station knows the particular sub-carrier allocations. However, the devices must be communicated regarding the assignments by discovery signal after finalizing the computation. Therefore, there is a cost associated with dynamic OFDMA methods. It has been demonstrated in [64] that the distinction between the hypothetical performance and the sensibly reachable performance is high. This happens if the transmission bandwidth is divided into several subcarriers and if a massive number of devices currently exist in the cell. Henceforth, plans which can decrease the signaling effect are necessary.

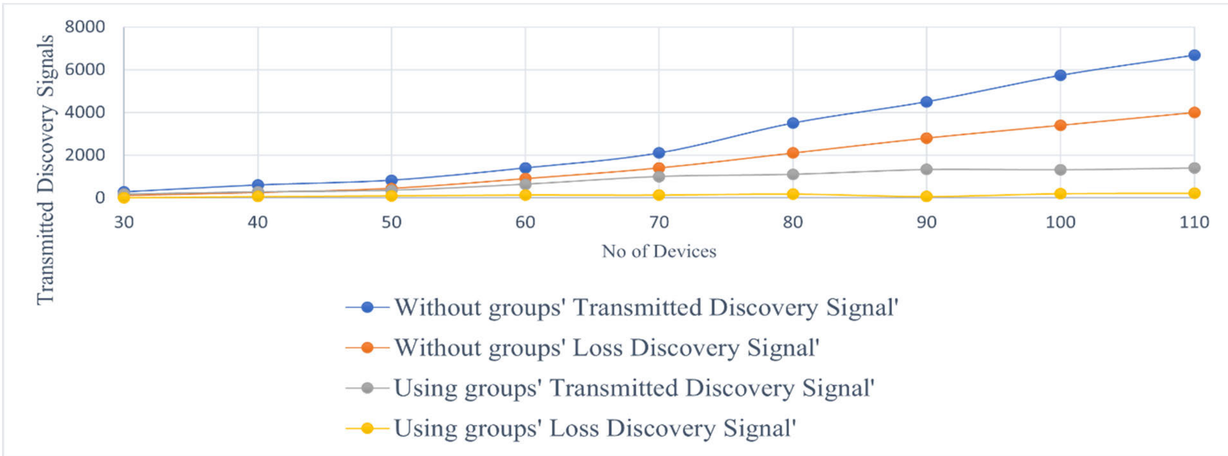

FIGURE 6. Types of D2D discovery signals; successfully transmitted and lost discovery signals.

V. SIGNALING OVERHEAD

The transmitted device discovery signal from D2D and D2B or vice versa is received at the destination after some processing. At each processing step, signaling overhead occurs. There are three steps: encoding overhead, sender processing overhead, and decoding and receiver processing overhead. All these steps are explained mathematically in **Figure 7**. To reduce the signaling overhead efficient solutions are required.

A. END-TO-END LATENCY

A delivery time of discovery signal for D2D is known as E2E latency. An E2E latency consists of a sum of transmission delay, processing delay, propagation delay, and queuing delay. As the number of devices increases, the discovery signal increase proportionally causes more discovery signal overhead. For example, when the delay is compared by transmitting 4 and 40 discovery signals, it results in a delay of 0ms and 1ms, respectively. We simulated different types of delays with the various number of discovery signals and compare their performance. The result shows that the queuing delay is larger as compared to other delays due to buffer overflow and provided significant signaling overhead. The effect of the discovery signal on the signaling overhead is simulated and analyzed as well. Simulation results verified that signaling overhead increases linearly with the discovery signals. To reduce E2E latency, signaling overhead reduction is inevitable.

Cooperative device discovery [63] in D2D communications has significant importance, as the accessibility of area location can empower numerous applications. For example, in asset tracking, firefighter location, search and rescue, and emergency services. We consider the case wherein a large number of devices, called anchor devices, get their directions by means of GPS or by introducing them at focuses with known directions. The rest of the target devices must decide their own directions utilizing the anchor devices and estimate

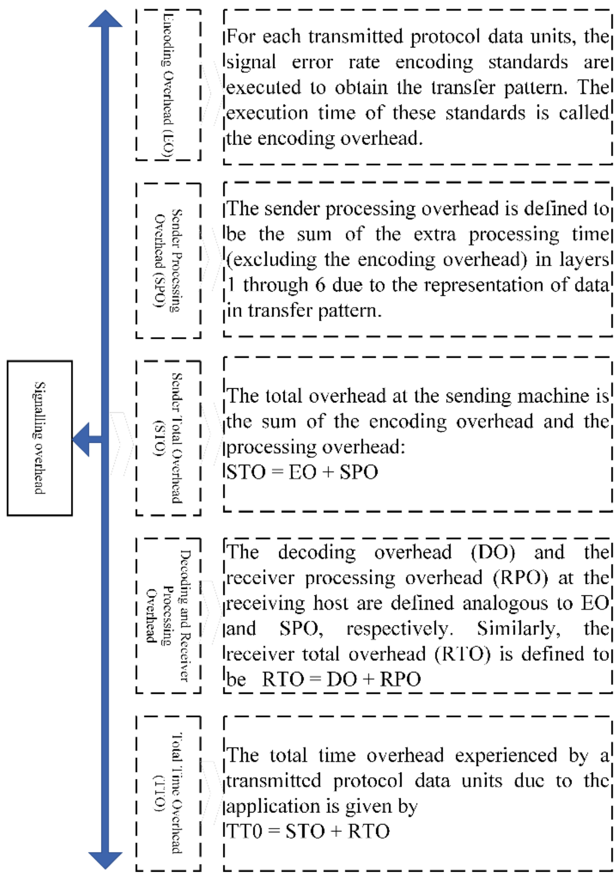

FIGURE 7. Classification of signaling overhead within communication networks.

between device distances. The distance can be acquired utilizing the time of arrival (TOA), time difference of arrival (TDOA), or received signal strength (RSS). If the reference device transmits with high power; it will communicate with all the anchor devices. However, it is desirable to use energy-saving devices for long-range communication. For this situation, every device has accessible noisy estimations of its distance to a few neighboring devices. This system is also called cooperative discovery [47]–[51]. This is completely conveyed that each objective device is responsible to discover itself utilizing only data from its neighborhood. Numerous methods for cooperative device discovery exist in the literature [65]–[69], but most of them provided location estimate only, without related vulnerability. These strategies are known as deterministic that provides the posterior distributions of the position estimates [70]. As the number of cooperative devices increases, signaling overhead decreases significantly.

Transmitted discovery signals in the D2D communications get performance loss at the receiver because of buffer overflow that results in congestion. To deal with such discovery signals performance loss, and give reliable D2D communications between end devices, an automatic repeat request methodology is required where transmitting devices sets a clock after immediately transmitting a discovery signal and waits for the affirmation from the receiver devices. If the affirmation is not received, then the sender re-transmits the discovery information. The discovery signal loss in the system triggers the re-transmission of the information signal, prompting poor discovery data transmission use, as the re-transmitted signals again gobble up the system resources right from the source device to destination devices. Furthermore, a period to deliver the discovery signal to its destination devices is expanded if the discovery signal is dropped and re-transmission is required. This increase in time is much progressively articulated if the discovery signal is dropped at a relay device from where the goal is just a couple of relays away. For moving D2D networks, where the discovery signal drop rate is high, a greater number of re-transmissions are essential. This makes the impact of re-transmission signaling overhead considerably large [71], [72].

VI. SIGNALING OVERHEAD MEASUREMENT

Evaluation of the signaling overheads with CSI-based radio resource management for D2D communications is vital. In which device transmissions can be thought of as uplink transmission when the receiver is not part of the serving base station. Subsequently, medium access control ideas for the LTE uplink can be anticipated to consider a D2D-empowered system. There are two main applications that cause signaling overhead measurement: scheduling request and channel gain measurement request.

A. SCHEDULING REQUEST

A basic condition for a device to get radio resource is the type of information to be transmitted at the serving base station. Such knowledge is accomplished in LTE by evaluation methods of buffer status reports. It is activated once new information fetches previously empty buffers. The information buffers are grouped at the receiver side into four for reporting to reduce the signaling overhead [73]. Altering one of these groups to allude to cooperative discovery signals, a buffer status report containing the related identification will unambiguously recognize D2D traffic. Signals related to the cooperative device discovery applications rely upon discrete signal size. Hence, some of the discoverers utilize more amount of information, and it can be changed to indicate the fixed size of a specific signal in the buffer. As such, a solitary buffer status report can precisely depict the demand for resources to transmit a signal without the requirement for periodical updates. Some cooperative discovery applications may create a parodic signal of various sizes and, subsequently, expected buffer status. Thus, by methods for linking such classes to a particular-buffer size indicator, the transmission of buffer status report probably will not be required before every payload transmission. Rather the scheduler can foresee device A, which has recently transmitted such traffic, as eager to transmit in the individual pre-designed intervals. In a situation where a device does not have any uplink transmissions, and a buffer status report containing cooperative discovery signals traffic is activated, then its first requirement is to acquire radio resources for the transmission of the buffer status report. Expecting that the device can always maintain an associated state and acquiring protocol plans from the LTE uplink transmission. This should be possible by sending a scheduling request on pre-designed resources in the physical uplink control channel [74], [75]. Every resource block allocated for such purpose can convey up to 12 devices scheduling requests, multiplexed by code division. When a device receives a device scheduling request, it performs this demand by resource allocation for the transmission of the buffer status report on the physical uplink shared channel. Signaling comprises 132 bits of coded control data for a bandwidth of 20MHz takes up to 66 resource elements in a downlink control channel. Whereas the transmission of the buffer status report expects 6 to 12 resource elements in the physical uplink shared channel relying upon the picked coding and modulation scheme. The base station decides the number of resources required for the transmission, and the scheduling algorithm figures out the number of resource blocks that must be allocated, then a scheduling quota is assigned to the device.

B. CHANNEL GAIN MEASUREMENT

A CSI-based scheduler requires significant channel gains information to measure the channel gain. In LTE, a user transmits a sounding reference signal in the physical uplink shared channel with the goal of channel quality estimation. These pilot signals inhabit the last symbol in a frame designed for sounding reference signal transmission. At least four resource blocks are reserved in such a manner, which is likewise the most appropriate setting for the considered network. From one viewpoint, utilizing less bandwidth requires higher power absorption and results in a higher number of devices. If a device has few resources for data transmission, then the device instantaneously transmits sounding reference signals. Up to 16 devices might be multiplexed on a similar resource block by code division. As CSI-based plans need data about each potential D2D connection in the framework, every single potential receiver in the framework attempts to assess the transmitter channels. The transmission of a reference signal can be activated by utilizing a field in the scheduling request given for the transmission of buffer status reports. Under these assumptions, non-transmitting devices A need to screen the and attempts to distinguish power influence by testing each reference signal sequence, as they do not know it exactly. Under a high feedback burden, in any case, this is the case regardless of whether the exact reference signal formations are known in advance.

VII. RADIO RESOURCE OVERHEAD ANALYSIS

In the multi-user OFDM-based framework, arbitrarily distributed devices simultaneously transmit to- and receive from a base station (known as eNB). The transmission from the devices is asynchronous with no interference cancellation plans to overcome multi-devices synchronization errors. Thus, to address the device synchronization errors, they adopted guard sub-carriers. In the LTE, the frequency-domain transmission is in contagious sub-carriers called resource blocks, whereas the time domain transmission is in frames. Additionally, the eNB is responsible for allocating resource blocks (RBs) to devices (known as discovery resource assignment) just as of embedding guard transmissions of various devices. For discovery resource assignment, radio resource overhead consists of three components cyclic prefix, discovery resource assignment, and synchronization error reduction overhead among different devices in the framework. The last factor alludes to the way that the synchronization error is liable to without grouping loss in discovery signal devices that transmit in neighboring sub-carriers. A cyclic prefix (CP) with length (L) which causes the radio resource overhead is calculated as

$$CP = \frac{CP_L}{CP_L + DS} \tag{1}$$

where DS is a data symbol. It can be clearly noticed from (1) that the radio resource overhead because of the cyclic prefix is fixed and free of the real synchronism level. Nonetheless, in an asynchronism communication situation, the proactive assortment of the cyclic prefix size is a difficult issue.

The estimation of the radio resource overhead because of the discovery resource allocation is progressively evaluated [76]. To manage this challenge, the authors in [76] presented a model for the sub-carrier distribution as a set of complex resource allocation. Using this scheme, after the resource assignment the accessible bandwidth is represented by a combination of K-free sub-bands, wherein sub-band, a portion of p(k) resource blocks has been utilized. Recall that as per considered framework the minimum allocation unit is one resource block [77]. To give an example, in **Figure 8**, a generic discovery resource assignment has assigned the accessible spectrum to 6 devices (D1 to D6). Consider, a spectrum that consists of recourse blocks (RB) and total $N(RB)$ are utilized for information transmission in a sub-frame. Obviously, resource blocks within the given bandwidth will be $RB(BW) \geq N(RB)$, and total utilized resource blocks are $\sum_{k=1}^{K} N_{RB}(k) = N(RBs)K$, where $N_{RB}(k)$ is the number of resource blocks utilized for information transmission in sub-band k. Subsequently, the guard band $N(GB)$ required for a sub-frame is liable to K. The values of CP are determined using the parameters $p(k)$ and $N_{RB}(k)$ as:

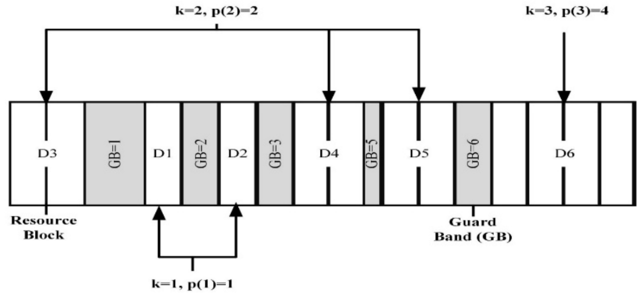

FIGURE 8. Discovery resource assignment.

$$CP = \frac{\sum_{k=1}^{K} N_{RB}(k)}{p(k)}. \tag{2}$$

Generally, the number of guard subcarriers in every guard band is identified with the devices that broadcast to the adjacent sub-carriers, since the allocation of the devices in space influences the synchronization errors, such as the guard magnitude. Let the number of guard sub-carrier $Z(G_{SC})$ be the required carriers in the guard band $N(GB)$. The total $Z(G_{SC})$ required are calculated as

$$Z\left(G_{SC}\right) = \sum_{k=1}^{N(GB)} Z\left(G_{SC}\right)(k). \tag{3}$$

Therefore, the overhead introduced because of guard subcarrier are represented by $Z(G_{SC})(loss)$, and is calculated as

$$Z\left(G_{SC}\right)(loss) = \frac{Z\left(G_{SC}\right)}{\mathrm{N\,(RB)\,(Z\,(G_{SC}))+Z\,(G_{SC})}}. \tag{4}$$

Using (1) and (3), total signaling overhead (SO) is calculated as

$$SO = Z\left(G_{SC}\right)(loss) + CP\,(loss)\left\{1 - Z\left(G_{SC}\right)(loss)\right\}, \tag{5}$$

where $CP\ (loss)$ can be calculated as

$$CP\,(loss) = \frac{P_s}{P_{in} + \sigma_x^2}, \tag{6}$$

where P_S the signal power, P_{in} the interference signal power and σ_x^2 is the variance of additive white noise [78]. The signaling overhead depends upon the guard sub-carrier and cyclic prefix. Therefore, as the number of transmission increases, signaling overhead increases significantly.

To initiate a D2D communications, device discovery and radio resource allocation is a critical task particularly when devices are in high mobility. Therefore, to maintain the QoS and continuous connectivity a lot of signaling load involves, and an efficient mobility management procedure is required to discover and tracking the neighbor devices. In this procedure, an effective radio resource technique is to be used that causes signaling overhead. In 5G and beyond systems, two mobility management methods exist device discovery and beaconing. Since devices' density and traffic increases exponentially with high mobility, hence device discovery and beaconing increase the signaling burden and energy consumption in power-limited devices. The signaling overhead requirement is to meet the service requirements like accuracy, latency, and battery life. The discovery area update and signaling measures in the LTE system are important to maintain congestion avoidance. To alleviate the signaling overhead different solution proposals have been recommended and some of them are discovery position update, combined mobility management and signaling, and SDN-based mobility management techniques. Signaling overhead reduction parameters are elaborated by group-based device discovery and frequency correlation. Classification of signaling overhead is mentioned with E2E latency and cooperative device discovery.

VIII. FUTURE WORK

In the future, signaling overhead reduction techniques can be used to reduce signaling congestions in dense devices communications, device discovery, and mobility management. In the mobility management solutions, signaling overhead has a vital role. Enhancement of signaling overhead creates congestion and causes enhancement of latency in D2D communication. In multicell D2D communications, a lot of cell selections and handover occurs, therefore signaling congestion and overhead occurs. In the future, to efficiently manage these issues, research on resource management, cell selection, and handover schemes is required. Besides, mobility management is a vital problem in a D2D communications mode. In the exponential growth of devices and data per device, signaling requirements increase drastically. Therefore, this challenge needs extensive research for careful resource management. In device discovery, device tracking is also one of the major research areas. Device tracking is also required to predict the device's movement in a better way. A lot of objects or even humans are moving randomly and create a mobility pattern. These random movements cause signaling congestion and demand an effective solution.

IX. CONCLUSION

The discovery area update and signaling measures in the LTE system are important to keep the footprint of all devices throughout the network. The marvelous multiply of high mobility devices will badly affect the D2D performance due to abundant of signaling. This will also affect the associated network KPIs and device experiences. To alleviate the signaling overhead different solution proposals have been recommended. This survey article has studied these elucidations in terms of discovery position update, combined mobility management and signaling, and SDN-based mobility management techniques. Signaling overhead reduction parameters are elaborated by group-based device discovery and frequency correlation. Classification of signaling overhead is mentioned with E2E Latency and cooperative device discovery. Signaling overhead measurement is explained with scheduling request and channel gain measurement, and radio resource overhead analysis are also discussed.

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