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RESEARCH ARTICLE

Bee System-Based Self Configurable Optimized Resource Allocation Technique in Device-to-Device (D2D) Communication Networks

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ABSTRACT With the exponential growth of mobile devices and high capabilities of intelligence, global communication network traffic is expected to experience remarkable growth in the next few years, as it leads us to poor network experience. The Device-to-Device (D2D) is a prominent solution to further expand the user experience and network performance. To improve it many nature-inspired computing algorithms are widely used. In line with this, we use swarm-based algorithms for network performance improvement. In this paper, we propose a swarm optimization-based resource allocation methodology for D2D communication, especially since we are focusing on the bee fly pattern to optimize the resource available resources within the network's proximity area. Where all bees are working together to find the best optimal availability of the network's services, hereafter mobile users get served with a respective set of resources. If the performance is not up to the pre-defined threshold value then the system adds another set of available network resources and relay nodes. It leads to relay-assisted D2D pair communication based on the bee fly pattern. It improves the D2D mobile pair's user experience in terms of energy, delay, and mobility support. To validate our results we compare our outcome with state-of-the-art works and provide detailed observations subject to various listed parameters.

INDEX TERMS Device-to-device communication, resource allocation, performance analysis, quality of service (QoS), quality of experience (QoE).

I. INTRODUCTION

The mobile communication network is one of the most popular communication systems. The Device-to-Device (D2D) communication network is a promising method to enhance the performance of networks. It enables the network devices for direct transmission within the closely located users [1], [2], it may happen without or at least network dependency. The initial studies have proven that direct communication improves spectrum reuse, throughput maximization, energy consumption, coverage, and minimum end-to-end latency, user performance in terms of Quality of Service (QoS) and Quality of Experience (QoE). Thereafter it motivated the researchers to add it and became an integral part of Fifth Generation (5G) network technology [3], [4], [5], [6], [7]. The 5G and beyond (5GB) communication system is supported by an all-IP backbone. It consists of mobile users, radio access technologies (RAT), and network hardware such as eNBs, mobile switching center (MSC), mobile databases, mobility management devices, etc. [8], [9], [10]. The current era of 5G research was not enough for user-based QoS/QoE. 5GB networks provide used for better amalgamation of device-centric communication technology, it is an emerging concept to improve cellular network performance with intelligent gNBs, and dynamic network database support [11]. It is the core motivation behind cloud-based

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network embodiment with 5G technologies, where a centralized cellular network is not capable of overcoming the cutting-edge network issues [12]. The full cloud-supported strategy is an illuminating exploration into hardware pools, distributed architecture, and automatic deployment within the network service area [13]. It was a paradigm phase shift from network-dependent communication to limited-network and cloud-based communication and focused on the new era of D2D communication [14], [15], [16], [17], [18].

Nowadays network schema is overlapped with device-centric communication and D2D network services, as they are supported by a 5GB cellular communication system. In device-centric networks, service providers transform the architecture into a data center, and user application dependent, where all functions and network service applications are used to run at the back-end of cellular networks [19], [20]. In modern cellular networks, the coverage area follows the extreme densification of the mobile base station of the next-generation evolve node base station (gNB) (as discussed in 3GPP) [21]. It consists of RAN, RAT, MME, and other peripheral network hardware for efficient cellular communication [22]. The state-of-the-art cellular communication schema is discussed in Figure 1, where two mobile users are communicating with each other. It has the following steps:

- The source mobile node initiates a call, it must be delivered to the target mobile node.
- It must reach nearby serving gNB, as the cellular network broadcasts the signal request message within the coverage area to show the network's availability.
- The acting/serving gNB performs computing and is greedy for required network information, this information is available in the network database.
- Thereafter call is forwarded to the mobile switching center to route the call toward the destination mobile node.
- As the call reaches to destination side, the mobile switching center forwards to the respective gNB (where the target mobile node is residing).
- The target gNB delivers the call to the destination/target mobile node and also monitors the performance parameters.

Remaining part of the paper is organized as follows: The modern state-of-the-art work is available in Section II, here we discussed device-to-device communication, network resource allocation methodology, and the use of swarm optimization in the domain of network resource allocation. The motivation for this paper and proposed work is discussed in Section II. In Section III, we discuss our main contributions (proposed work), we introduce a bee-fly pattern-based resource allocation methodology for device-to-device communication, and relay-assisted device-to-device communication procedure, where system optimizations and mobility support are key attributes. The mathematical model and system-level formulation for the proposed work subject to various parameters are discussed in Section IV. The result and discussion of the proposed work are highlighted in Section V. Section VI is used for conclusions and followed by listed references.

II. STATE-OF-THE-ART WORKS

In this section, we discuss current state-of-the-art work related to D2D communication, its importance in cellular communication systems, and resource allocation problems in D2D communication. Finally, the nature-inspired communication system works to improve the QoS and QoE in D2D communication networks [23].

A. DEVICE-TO-DEVICE (D2D) COMMUNICATION

Device-to-device (D2D) communication is one of the most important modern cellular communication systems, where mobile users are seeking high bandwidth for multimedia communication [24], [25]. The D2D communication technology often refers to that allows mobile user equipment to communicate with each nearby corresponding mobile node with/minimum or without the involvement of network infrastructures such as access points or mobile base stations [26], [27]. The early evidence of it was visible in [28], where authors propose FlashLinQ, as a synchronous peer-to-peer wireless PHY/MAC network architecture. The proposed work leverages the fine-grained parallel channel access offered by OFDM and incorporates an analog energy-level-based signaling scheme that enables signal-to-interference ratio (SIR)–based distributed scheduling. It was the first road map for D2D communication and also highlighted its possibilities in real life. D2D is a promising communication methodology, it is used to offer ultra-low latency (up to the lowest possible limit). It has many real-time applications in modern cellular networks such as the fifth generation and beyond cellular networks, mobile vehicular networks, mobility-based cognitive radio [26], [29], [30], [31]. The authors of [32] proposed characteristics of D2D communication including its usage cases, architecture, technical features, and areas of active research. Ahead of it, the D2D pair security is also an important aspect of the research. In [33] authors proposed an extensive review of security solutions aiming to enhance the performance of D2D communication systems and focus on recent advances in various D2D domains such as the discovery process, mode selection schemes, interference management, power control techniques, and finally the mode selection for D2D applications in 5G technologies. Nowadays D2D is not only limited to QoS/QoE-based applications. The IoT is a useful application of it. The authors of [30] proposed a fast and secure device-to-device continuous authentication protocol that relies on device features (token, battery, and location), and also mitigates denial of service (DoS) attacks using shadow IDs and emergency keys. Moreover, it takes the sensor movement into account while preserving privacy, where the author has given poor attention to coverage probability. The authors of [34] proposed an interference functional and Laplace transform-based analysis using stochastic geometry to evaluate the expectation over

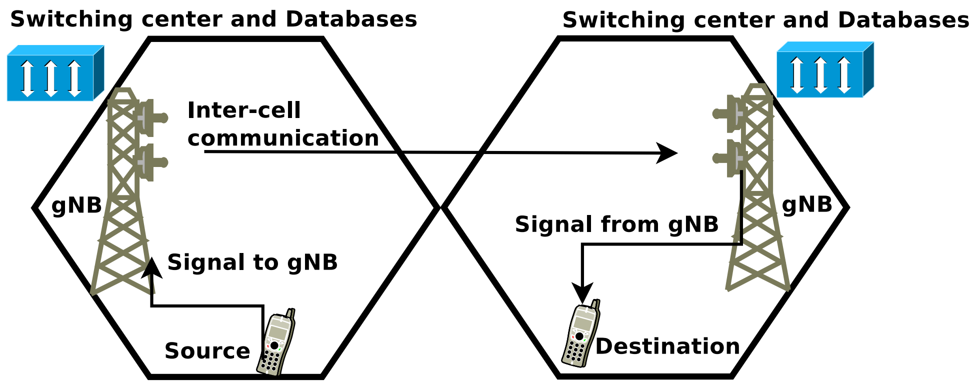


FIGURE 1. Mobile base station assisted cellular communication, it consist of D2D communication. D2D communication pair may also assisted by a relay node, and relay node selection is a random process.

interference, which is further used to derive the coverage probability expressions for device-to-device (D2D)links.

B. RESOURCE ALLOCATION METHODOLOGIES

Device-to-device (D2D) communication recently gained massive attention in the research community to improve the capacity and coverage of cellular systems [34]. Meanwhile, it provides coordination and interference between D2D and cellular users, where cellular network plays a crucial role in realizing D2D communications [35], [36]. The authors of [35] proposed a game-theoretic resource allocation scheme, termed "GALLERY", to address this problem. Unlike existing works that typically treat D2D users as players, they characterize base stations (BSs) as players competing for the resource allocation quota of D2D demand and define the utility of each player as the payoff gained from both cellular and D2D. However, they did not consider the actual performance of mobile nodes. Therefore in [37] author proposed a more efficient resource allocation methodology using the game theory procedure, where resource allocation is formulated as a coalition formation game to maximize the D2D system throughput. Unlike the existing works where users randomly join a coalition, they utilize the priority sequences to guide the order that which cellular users switch from the coalition. Still, resource allocation partially supports full-duplex communication. To overcome these challenges, authors of [38] proposed resource allocation problems for multi-user full-duplex device-to-device (D2D) underlay communication, considering both perfect channel state information (CSI) and statistical CSI scenarios. In a perfect CSI scenario, the weighted sum-rate maximization problem under cellular users' minimum rate constraints is formulated as a mixed-integer programming problem. Parameter optimization is another major issue in D2D resource allocation, thus authors of [31] proposed an alternating optimization method to address the formulated problem efficiently. Numerical results show that the proposed work can significantly increase the throughput of cellular networks. However, socially aware resource allocation needs more importance. Therefore in [39] authors discussed a social relationship in the continuum space in the resource allocation for D2D communications, which considers the complex social connections in the social domain. Then a social group utility maximization game is formulated to maximize the social group utility of each D2D user, which quantitatively measures the joint performance of social and physical domains. Here the author theoretically investigates the Nash Equilibrium of the proposed game and further proposes a distributed algorithm based on the switch operations of the resource allocation vector.

C. BEE FLY PATTERN AND NETWORKING

The bees algorithm, also known as the Bee Colony Optimization (BCO) or Artificial Bee Colony (ABC) algorithm, is a nature-inspired optimization technique based on the foraging behavior of honeybees [40], [41]. It was introduced by Dervis Karaboga in the year of 2005 as a way to solve optimization problems in real-time computing. The algorithm takes inspiration from the way bees forage for food in a hive. Bees perform three primary roles, i.e. employed bees, onlooker bees, and scout bees. Here we provide an overview of how the ABC algorithm works [42], [43], [44].

1) Initialization phase: The algorithm starts by initializing a population of solutions (bees) randomly within the problem's search space.
2) Employed bee phase: In this phase, each employed bee explores a particular solution in the search space. The quality of the solution is evaluated using an objective function. The employed bees then perform local searches around their current solutions to find better solutions nearby.
3) Onlooker bee phase: Onlooker bees "watch" the employed bees and choose solutions based on their quality. The probability of selecting a solution is proportional to its fitness. This phase promotes the sharing of information among the bees.
4) Scout bee phase: In this phase, scout bees identify solutions that are not improving over a certain number of iterations and abandon them. The scout bees then

explore new random solutions to replace the abandoned ones.

5) Update phase: After completing the employed bee, onlooker bee, and scout bee phases, the algorithm updates the best solution found so far.
6) Termination criterion: The algorithm continues iterating through the phases until a termination criterion is met, which can be a maximum number of iterations, reaching a certain fitness level, or some other stopping condition.

The ABC is applied to various optimization problems, such as function optimization, parameter tuning, clustering, and network resource optimization. The major advantages of its ability to explore a wide solution space efficiently are due to the exploration-exploitation balance achieved through the different bee roles. However, like any optimization algorithm, the performance of the bees algorithm depends on the specific problem at hand, the parameter settings, and the tuning efforts. It's also worth noting that while the bees algorithm is inspired by natural processes, it might not always outperform other optimization techniques on all types of problems. As with any optimization algorithm, it's essential to experiment and fine-tune parameters to achieve the best results for a given problem. The bee's optimization is also applicable in "Networking" and it is not treated as actual insects like honeybees also uses the abbreviations as "Backend as a Service" (BaaS). BaaS is a cloud computing service model that provides a platform for developers to build and deploy backend server functionalities for applications without the need to manage the underlying infrastructure. BaaS platforms offer various services that are crucial for building and running applications, such as database management, user authentication, push notifications, storage, and more. These platforms abstract away the complexities of managing servers and infrastructure, allowing developers to focus on building the front end and business logic of their applications such as Firebase, AWS Amplify, Backendless, etc. Bees exhibit a unique flying pattern that is characterized by their ability to maneuver swiftly and precisely. Honeybees, in particular, are known for their complex flight behaviors, which include various types of movements and patterns. Here are some key aspects of a bee's flying pattern Hovering and Precision, Straight Flight, Waggle Dance, Circular Flight, Spiral Flight, Scanning and Exploration, and Avoidance Maneuvers.

D. SWARM OPTIMIZATION IN RESOURCE ALLOCATIONS

Nature is the mother of all types of unsolved problems. In the current decade, nature-based computing is widely used in mathematics and computing. It was the core objective of nature-inspired computing. Slowly it moved towards networks and communication systems [45], [46]. The authors of [47] proposed an in-depth survey on many novel swarm intelligence optimization algorithms, which have strong applicability and achieved good experimental results in solving complex practical problems. These algorithms are the same as natural systems, and this inspiration shows the desirable properties of being adaptive, scalable, and robust. Therefore, the swarm intelligent algorithms (PSO, ACO, ASFA, ABC, SFLA) are widely used in the performance optimization of mobile wireless sensor networks due to their cluster intelligence and biological preference characteristics. Same time they also proposed comprehensively analyzing and summarizing the current swarm intelligence optimization algorithm and key technologies of mobile wireless sensor networks and also discussed their application of the swarm intelligence algorithm.

E. MOTIVATION AND OBJECTIVE OF THE PAPER

In this paper, we propose an intelligent Device-to-Device (i-D2D) communication system for modern cellular networks. It is a fundamental road map for a six-generation cellular network, where we have native support for D2D communication. Furthermore, we introduce an efficient mobility management procedure for dynamic mobile users. We analyze our proposed works with respect to performance parameters i.e. energy consumption, and associated delay, and finally compare the results with state-of-the-art networks. To improve the listed parameter we proposed the following contributions, which enhance the QoS and QoE. The contributions are listed in the subsequent section.

F. PROPOSED CONTRIBUTIONS

In this paper, we are proposing the following threefold contributions as follows. As per our best of knowledge, these contributions are novel and unique.

- Available network resources play a crucial role in D2D communication. It must provide a balance between over-utilization and under-utilization. As the mobile node network's signal passes through gNB, the available network allocates a set of performance resources to the mobile node. Using these resources node achieves real-time QoS and QoE. In this paper, we proposed a novel nature-inspired method to utilize the available network resources, and it is optimized with respect to various parameters. Here we called the i-D2D method. To propose it we are using bee-fly patterns, where all bees work together to find the best source of food. In this paper, we are applying the same procedure in network systems like D2D communication. During the D2D pair-based communication, if the mobile node changes its position then the network's performance may reduce. To overcome this issue the networks will add a relay node. This proposed relay node selection procedure is another contribution of the paper.
- Resource allocation methodology has various parameter-based dependencies, such as node mobility, bandwidth consumption, signaling strength, and energy consumption. In this paper, we propose a parameter-based mathematical optimization procedure for our novel resource allocation strategies subject to listed parameters. After

the resource allocation, individual parameters are being optimized. Thus it is a parameter-based optimized system model.
- Effectiveness, efficiency, and performance of scientific contribution are validated by system-level simulation, mathematical optimization, and hardware-based deployment. To check the outcome we are using the system-level simulation and mathematical optimized formulation to analyze the scalability and robustness of the contribution. Thereafter we are comparing the obtained results from the available state-of-the-art works. In this paper we are comparing the results with available state-of-the-art work as listed in [27] and [38] and we abbreviate them as "SoA-1" and "SoA-2", respectively.

In next section we discuss our contribution in details.

III. PROPOSED BEE FLY-BASED INTELLIGENT D2D (I-D2D) RESOURCE ALLOCATION METHODOLOGY

In this paper, we propose a novel bee fly pattern-based resource allocation methodology for D2D communication. It is an advanced procedure over to modern cellular network environments such as 5G specifications. The 4G networks are not well designed and deployed to handle the massive amount of network traffic, although they follow a network-centric communication methodology. However, it was the prime motivation for 5G and device-centric communication methodology. As the 5G network is being deployed, people became aware of its associated research challenges such as high delay, poor user experience, and cost-effectiveness (with respect to user perspective). The D2D communication system has the following cutting-edge deployment dimensions, such as peer-to-peer communication. Conventional point-to-point (P2P) communication using the peer-to-peer system frequently over-switch the client and server responsibility, and it was the first landmark in D2D networking. In P2P cooperative communication, devices act as relays to extend cell coverage, and in multiple-hop communication, work as an extension of peer-to-peer cooperative communication where multiple devices form an ad-hoc mesh network to enable data routing between devices.

We have seen multiple pieces of evidence where the D2D communication procedure has many critical challenges. Nowadays researchers are looking forward to solving many complex problems using nature-inspired computing. Bee's flying pattern is one of them. In the next section, we will discuss our proposed resource allocation procedure using the bee fly pattern.

A. PROPOSED BEE FLY PATTERN-BASED INTELLIGENT ALGORITHM FOR RESOURCE ALLOCATION

To improve the efficiency of resource allocation methodology our contribution is divided into two parts, first, the bee fly pattern-based intelligent resource allocation methodology, and second, a novel relay selection methodology where node mobility has the top priority [48]. Resource allocation and relay node selection techniques improve QoS and QoE of communication channels subject to various performance parameters [49]. The proposed resource allocation methodology has the following steps:

1) Network enables communication device (mobile user/ mobile node) to send a request message to associated Next Generation Node B (gNB). The communication signal is received by the associated network's hardware. This information signal is a very light packet i.e. HELLO-PACKET.
2) The serving gNB must allocate available network resources to mobile nodes. This resource allocation will lead to a better network experience for mobile nodes, and it will improve the QoS/QoE.
3) Associated gNBs work with other nearby gNBs to allocate an optimal amount of resources to serve mobile users. As the mobile nodes are randomly distributed among the network coverage area, therefore connected gNB may be overloaded (over-utilized). Once they find the best available resource and corresponding gNB, the service request is forwarded to the respective gNB. In 4G/LTE/LTE-A the mobile gNBs have intelligent capabilities and follow the extreme densification of mobile Base Stations (BS).
4) The working-together methodology of gNBs is mapping with bee fly pattern, where all bees perform a search operation to find the food (Honey), thereafter they exchange the gained information and optimize the solution with respect to availability, quality, and quality. Finally, all bees move to the chosen location to collect the available food i.e. Honey.
5) Once network resource and serving gNB are allocated (by the system) to the requested mobile node, the gNB monitors performance parameters for a specific mobile node (including the target mobile node), if the performance parameter between source and destination nodes is above the pre-decided threshold value then gNB push the communication to D2D mode, else manage to increase the allocated network resources.
6) As the D2D pair is established, the associated gNB continuously monitors the performance parameters. Allocated additional bandwidth and spectrum subject to user requirement, if there D2D mode of communication is not established.
7) Once the associated gNB is fully exhausted with available network resources (overload or over-utilization of gNBs) the D2D communication pair will break. Thereafter performance will drop, or the call terminate.

In this paper, we are explaining the above-discussed procedure using an subroutine (Algorithm 1). In Algorithm 1, we use the function D2D(), and it shows the procedure for D2D communication. This function is used to establish the communication which is using device-to-device communication. The D2D term is used for Device-to-Device communication.

Algorithm 1 Proposed Resource Allocation Algorithm Using Bee-Fly Pattern. It Provides the Optimal and QoE-Based Resource Allocation

```
Result: Setup: D2D(···) and D2D(R)
Input:En(n,eb), Dl(n,eb), Bw(n,eb), Si(n,eb);
Compute: Per(En(·), Dl(·), Bw(·), Sig(·))
if Per(Dl, En, Bw, Sig) > Ther then
    D2D(n, m);
    if Per(n, m)< Ther then
        D2D(·R···)
        If the performance of the network is poor then
          associated gNB add more resources to
          activate the D2D communication pair until
          they are not exshuast.
    else
        D2D(·) or D2D(R) ;
    end
end
```

In Algorithm 1, the D2D() and D2D(R) represent the device-to-device mode of communication and device-to-device mode with relay node assistant communication, respectively. En(n,eb), Dl(n,eb), Bw(n,eb), Si(n,eb) show the energy consumption, delay calculation, bandwidth consumption, and signal strength between the mobile node (source node) and associated gNB. The function Per() is used to define the performance of networks, it takes the parameter as delay, energy, bandwidth, and signal strength. In this paper, we set listed parameters as the performance of the communication system. They are the prime objective of 5G core objectives. The D2D(n, m) is used to show D2D communication between the source and target nodes, and Per (n, m) shows the performance between source and destination nodes.

The proposed nature-inspired D2D communication procedure is described as follows: The Algorithm 1 has objective of device-to-device mode communication establishment and maintaining the device-to-device pair with additional resource allocation from associated gNB. This algorithm takes the inputs as energy consumption between the mobile nodes and associated gNB (En (n, eB)), the delay between source and serving gNB (Dl (n, eB)), singling strength between the mobile node and nearby serving gNB is calculated by Si(n, eNB), it will take two parameters like the number of mobiles nodes such one or two, as the D2D take a maximum of two mobile nodes, its value is one of the nodes is currently sending the hello packet to gNB. In line with the same, Bw(n,eB) computes the bandwidth consumption between the mobile nodes and serving mobile BS, it will also follow the concept of spectrum utilization, capacity theorem, and 4G/LTE/LTE-A bandwidth formulation. As the link utilization, bandwidth consumption, network delay, signal strength, and energy consumption are beyond the threshold value, the network selects D2D communication. This performance is computed by the Per () function, it will take the parameters as Dl, En, Si, and Bw. Once the system instates a D2D pair of communication, throughout the network associated gNBs will monitor the performance of the D2D pair. If the performance is less than a pre-defined value then eNB adds more resources to improve the system performance. We call them D2D pair of communication and D2D pair with relay-assisted communication, respectively. The performance of communication will be monitored continuously, and it help us to improve the QoS and QoE. The network gNB has the limit to serve the devices and it is subject to available resources. In this paper, we consider up-link utilization, down-link utilization, bandwidth consumption, and communication delay as performance parameters.

B. PROPOSED RELAY SECTION PROCEDURE AND RELAY-ASSISTED D2D COMMUNICATION

The bee-fly pattern follows a resource allocation procedure, as the performance degrade then serving gNB allocate more resource until they get exhausted. It is subject to node mobility, network interference, interface, and other performance parameter, here system performance may decrease. Thereafter D2D pair may be supported by relay nodes. The relay node is a random mobile node, it follows the stochastic random Markov model. The mobile user can move in any direction with equal movement probability, the proposed relay selection procedure has the following steps:

1) D2D pair follow the device-to-device communication procedure. Its performance is monitored by respective gNBs. If the performance reduces then gNB adds more available network resources.
2) The gNB also has limited available network resources. Meanwhile, if the D2D pair has a poor user experience, therefore network decides to add another node as a relay node in between the D2D pair. This relay node section procedure is self-configurable.
3) Associated gNB compute and identify the nearby available mobile nodes. This identification is done using spectrum re-usability and by sharing procedure. Also, compute the nodes within the proximity area to the D2D pair. If the selected node has minimum spectrum sharing then pick that node as a relay node. This node will pass the communication signal to adjacent nodes (corresponding nodes to the D2D pair).
4) It results in the relay-assisted D2D pair-based communication. To find the most suitable relay node, gNB scans the proximity area and chooses the best relay node. The overall performance is observed by gNB.

The relay node selection and working procedure are discussed in Algorithm 2.

The result of procedure as shown in Algorithm 2. It is relay-assisted D2D communication, and it is shown by D2D (R). It computes the energy, delay, bandwidth, and signal strength between the source node and target node, it is shown by En(n, m), Dl(n, m), Bw(n, m), Si(n, m), respectively.

Algorithm 2 Proposed Relay Node Selection and Management Algorithm Where Relay Node Selection Based on Performance Parameters

```
Result: Setup: D2D(R) //Relay node assisted D2D
        communication
Compute:En(n, m), Dl(n, m), Bw(n, m), Si(n, m);
Optimize: Per(En(n, m), Dl(n, m), Bw(n, m), Sig(n,
m))
if Per(Dl, En, Bw Sig for D2D pair) > Ther then
    D2D(n, D2D(R), m) It supports the relay
      node-assisted D2D pairs.;
    if Per((n, D2D(R), m))< Ther then
        D2D(· · · · )
        If the performance of the network is poor then
          associated gNB add more resources to
          D2D(R) communication pair until get
          exhausted. In the worst case, the D2D pair
          breaks and follows the traditional D2D
          communication.
    else
        D2D(·) or traditional mode of
          communication.;
    end
end
```

The proposed algorithm optimizes the performance with respect to energy, delay, bandwidth, and signal strength. The Per() function computes the performance based on the listed parameter between the D2D pair. If the performance is poor than the threshold value then add a relay node, and allocate some additional resources, until resources are exhausted. In this process gNB has an important role, it continuously monitors the performance of source and target mobile nodes including relay nodes. This measurement is based on bandwidth consumption, up-link, and down-link capacity, SNR ratio, and communication delay. The proposed work having the working of D2D and D2D(R) mode of communication where objective is optimal, minimum and fair utilization of available network resources. The proposed resource allocation follow the bee fly pattern. It has many advantages such as least network utilization, minimum delay and latency, efficient energy consumption, improved QoS and QoE.

The effectiveness, efficiency, scalability, adaptability and optimization is a set of major factors to validate the proposed contribution. In this paper we consider the Call-to-Mobility ratio (CMR) to overcome it. If the system is performance good in high CMR leads to good performance. In our results and discussion section we analyze this in detail. If the performance is not improving with relay nodes then the call will handover traditional mode of communication as proposed in LTE/LTE-A. In this paper, we consider performance parameters threshold values as equivalent to LTE/LTE-A specifications and these parameters are discussed by Cisco in [50], and state-of-art work listed in [51].

IV. MATHEMATICAL FORMULATION AND OPTIMIZATION PROCEDURE

In this section, we describe the mathematical model for the proposed and traditional D2D communication system. This system formulation model shows the optimization and dependency with respect to various parameters. It also helps us to compute the analytical results, where we consider system configuration as shown in Figure 2.

A. SYSTEM MODEL

Here, we use a classical network scenario of seven cell-based complete cellular communication topology [29]. The traditional seven-cell-based network topology has major three types of cell movements. They are classified into current-cell-to-neighbour-cell, neighbour-cell-to-current-cell, neighbour-cell-to-neighbour-cell. In Figure 3 we show all three types of movements, and seven cell-based topologies consist of all three listed patterns. Therefore we map the seven cell-based topologies with three cell-based network cell patterns. Multiple mobile users are available in the network service area, they have good network signal quality. Mobile nodes are free to move in any direction. The mobile network follows the random walk stochastic geometry and the current network configuration is dependent on the past and future position of the mobile node. The mobile nodes are connected with nearby associated gNBs through up-link and down-link connectivity, and their signal gain as per the LTE/LTE-A network specifications, also respecting the interference, capacity theorems, interfaces, and interference.

In our proposed system, we focus on inter-cell and intra-cell node mobility. As the mobile node follows the random cell structure consisting of cellular band and mmWave band, there are two kinds of modes of communication selected by each pair D2D communication, such as D2D pair without relay node, and D2D pair with relay nodes. In both of them, we have the up-link and down-link spectrum resources of one cellular user. The mobile eNBs are equipped with omnidirectional antennas for cellular communications. We assume that cellular users share their up-link resources with D2D communications when the cellular access mode is selected by D2D pairs, and one cellular user's spectrum resource can be shared with multiple D2D pairs to achieve the maximum spectral efficiency, we also assume that a D2D pair shares no more than one cellular user's up-link resource to reduce the interference caused by D2D communications and decrease the corresponding complexity. During the communication, gNB estimates the performance of called and caller users and thereafter determines the relay node selection procedure. The associated gNB pushes the communication towards D2D-based communication and if performance is poor the network adds relay nodes to improve the QoE. Here we can define the state changes as shown in Figure 4. The mode of communication changes from a D2D pair to a D2D pair with relay nodes or reverse of it, we consider the node movement probability is p. In the remaining part of the

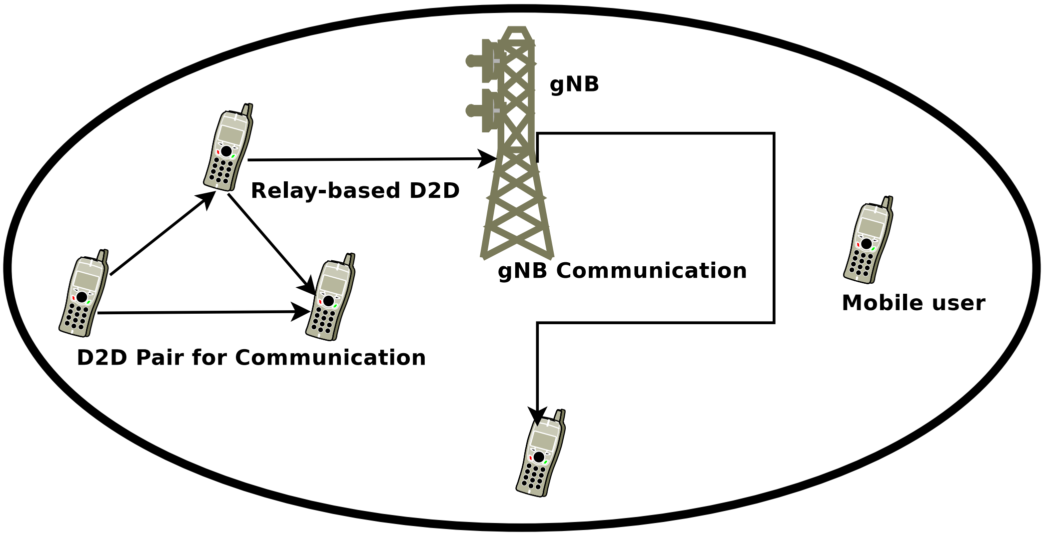


FIGURE 2. Mobile base station assisted cellular communication, D2D communication, D2D pair-based relay node assisted communication procedure.

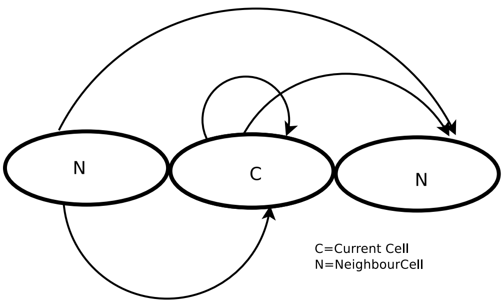


FIGURE 3. Three cell-based cellular communication movement model. It is mapped with seven cell-based schema.

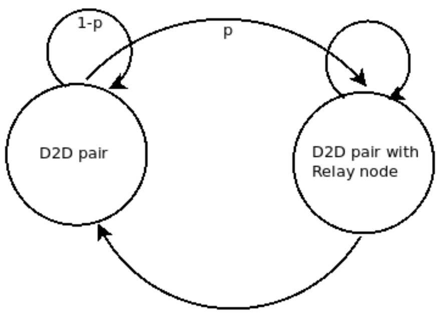


FIGURE 4. State space Markov model for mode switching between D2D pair and D2D with relay node assistance.

paper, we consider the same line of state change, where the mode of the D2D pair changes as per the performance of networks.

B. USER MOBILITY MODEL

In cellular communication systems, node mobility is a fundamental aspect of networks. It allows a user to move in any direction for a better network experience. Here we consider a general seven-cell-based network topology. Let, node movement probability be p. A mobile user moves within the network service area SA, The initial location area coordinates are $p_1(x_1, y_1, z_1)$ (over the 3D plain), the current position of mobile nodes $p_2(x_2, y_2, z_2)$, thus the computed distance is $d = |p_1p_2| = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$. The hop counts between source and destination nodes is Ξ, as a dependent factor subject to D2D pair or D2D pair with the relay nodes. Assume, i is the index for the initial position indicator of the user. Now the node mobility coefficient M of the user is computed in equation (1),

$$M = d \sum_{i}^{D} p_i \int_{0}^{d} \Delta t dt, \tag{1}$$

where Δt is the call duration between the source and destination node, and D is all possible movement directions. In the proposed methods associated gNB allocates a set of network resources to improve the user experience. Therefore the performance is fully subject to call arrival and departure rates such as λ, and μ, respectively. With every movement of the user and associated movement probability will change, it will affect system performance (with respect to seven cell-based network topology). These probabilities will depend on call arrival and departure values. p_i, p_{i+1}, p_{i-1}, where i is index for cells.

C. LINK UTILIZATION MODEL

In cellular networks, mobile users are served by eNB, with up-link and down-link connections. The service provider has N number of active eNB in SA. A mobile user location at position x_i, and $x_i \subset SA$, and all eNBs are randomly deployed based on population density. Let, g_{d2d} and $g_{d2d(R)}$ are signal gain, R_{d2d} and $R_{d2d(R)}$ are the transmission rate, α_{d2d} and $\alpha_{d2d(R)}$ are the percentage of resource allocation D2D pair and D2D pair with relay nodes, respectively. The Bd_{d2d} and $Bd_{d2d(r)}$ is the bandwidth utilization during D2D and D2D with relay node connections. Then link utilization LU

computed D2D cellular networks is shown in equation (2),

$$LU_{d2d} = \max_{\alpha_{d2d}, Bd_{d2d}} \left(\frac{E_{d2d} R_{d2d}}{P_{d2d} + Pmn} \right). \quad (2)$$

The link utilization in the D2D pair with the relay node of communication is in equation (3),

$$LU_{d2d(R)} = \max_{\alpha_{d2d(R)}, Bd_{d2d(R)}} \left(\frac{E_{d2d(R)} R_{d2d(R)}}{P_{d2d(R)} + Pn, n^{`}} \right). \quad (3)$$

Here, the $Bd(.)$ is bandwidth consumption in a D2D pair of communication, n and $n^{`}$ show the mobile node and target node respectively. In this work, there will be two state changes, one D2D mode; another D2D mode with relay node, or vice-versa. This mode selection is fully subject to performance parameters and their outputs, as we discussed in the previous section. The state change Markov model is shown in Figure 4. Let, the mobile node change the states as follows, D2D pair to D2D pair relay mode, D2D pair to again D2D pair, D2D relay to again D2D relay, and D2D relay to D2D pair mode of communication. The major state probability change is shown in equation (4),

$$\Pi_{D2D}^{D2D(R)} = \frac{p_{d2d}}{p_{d2d} + p_{d2d(R)}}. \quad (4)$$

The equation (4) shows rate change from D2D pair mode to D2D with relay node. Similarly, equation (5) shows the rate of D2D pair with relay to D2D mode of communication.

$$\Pi_{D2D(R)}^{D2D} = \frac{p_{d2d(R)}}{p_{d2d} + p_{d2d(R)}} \quad (5)$$

Thereafter overall link utilization of communication setup is shown in (6) The overall link utilization is,

$$LU = \Pi_{D2D(R)}^{D2D} LU_{D2D} + \Pi_{D2D}^{D2D(R)} LU_{D2D(R)}, \quad (6)$$

The $P_{.}$ is the minimum power allocation for communication, it depends on the network service provider. The power location is dependent on hardware type, local setup power, and interference power allocation. $R_{.} = \alpha_{.} Bd \log_2 (1 + \frac{g.P_{.}, Bd_{.}}{\alpha_{.} D.Bd_{.}})$, $R_{.} = \alpha_{.} Bd \log_2 (1 + \frac{g.P_{.}, Bd_{.}}{\alpha_{.} DBd_{d}})$. Here . shows the D2D or D2D(R) value, subject to conditions. It provides the maximum data rate and its upper bound will be set by the service provider. $P_{.} \leq P_{.}^{max}$ and $P_{.} \leq P_{C}^{max}$. Here we are considering a generic formulation procedure. It takes inputs as D2D pair-based communication or D2D pair with relay node communication. In the proposed work, network link utilization varies with respect to current conditions, D2D pair has less link initialization, where eNB has control over communication. Mean link utilization during the communication is shown in equation (7). It is the overall mean of link utilization with D2D mode and D2D(R) mode.

$$LU_{D2D} = \int_0^{H,t} p_i \lambda_i \mu_j \Pi_{D2D}^{D2D(R)} LU_{D2D}.SA.dt + \int_0^{H/2, \Delta t} p_i \lambda_{i \pm 1} \mu_{j \pm 1} \Pi_{D2D}^{D2D(R)} LU_{D2D}.SA.dt. \quad (7)$$

In equation (7), we have the following general assumptions as follows, $t > \Delta t$ and $\lambda \pm 1, \mu \pm 1$ is forward and backward user-cell movement call arrival/ departure rates. The SA shows the total network service area, as mentioned in [4] and [29]. The signal strength of D2D networks is computed as in equation (8),

$$Sig_{d2d} = \left(\frac{2.g_{d2d}.(h - 1 + \Xi)D + Bw_{d2d}}{d} + R_{d2d} . \frac{2(\Xi.\mu - 1 + \Xi)d}{d} + n^2.LU_{d2d}.R_{d2d} \frac{\Xi \lambda_i p_i}{Sa_{\Delta t}} S_{req} S_{rep} \right). \quad (8)$$

Same line we can compute for D2D pair with relay nodes in equation (9),

$$Sig_{d2d(R)} = \left(\frac{2.g_{d2d(R)}.(h - 1 + \Xi)D.\lambda + Bw_{d2d(R)}}{d} + R_{d2d} . \frac{2(\Xi.\mu - 1 + \Xi)d}{d} + n^2.LU_{d2d(R)}.R_{d2d(R)} \frac{\Xi \lambda_i p_i}{SA_{\Delta t}} S_{req} S_{rep} \right). \quad (9)$$

In equation (9) S_{req}, S_{rep} represents the route request and route reply message for communication.

D. DELAY CALCULATION

In the proposed D2D resource allocation procedure the eNB will select the mode of communication subject to network performance, such as D2D or D2D with a relay node. During this process, networks select some amount of the network's resources. If performance is not up to the mark then relay-assisted D2D communication system. If the additional resource is required then the delay will increase. The total time is computed with processing and propagation time, as it creates the delay constraint. So total time is $T = T_{pros} + T_{prop}$. The mobile user (in D2D() of D2D(R) mode of communication) is independent, while user mobility and hop count aspect the T. Therefore total delay in cellular communication is written in equation (10),

$$T_C = M\, p_i \left(\Pi_c \sum_{i=1}^{H} \int_0^{\Delta t} T\, dt + \Pi_c \int_0^{\Delta t} T dt \right) U_T. \quad (10)$$

Now we are computing the delay for the proposed work. It is shown in equation (11). It is the average delay between the D2D and D2D with relay nodes (maximum of one relay node; the number of relay pairs and normal pairs is equal),

$$T_{pro} = M.p_i \left(\Pi_{D2D}^{D2D(R)} \sum_{i=1}^{H} \int_0^{\Delta t} \Delta t dt + \Pi_{D2D(R)}^{D2D} \int_0^{\Delta t} T\, dt \right), \quad (11)$$

where the maximum value of $\phi = 2$, because it has only two-hop communication. $U_T = C_T = 2(T_{Prop} + T_{Proc})$ is link round-trip time is packet transmission between UE-to-gNB and CN-to-gNB, respectively. It is twice of propagation delay and processing delay.

E. ENERGY CONSUMPTION

The energy consumption in cellular networks and device-to-device communication systems is divided into two parts; network energy adaptation and hardware energy consumption. In this work, we focus on network energy consumption only. The network energy depends on three important components, such as network update energy (NU), packet build energy (PB), and packet transmission energy (PT) for communication. These factors are proportional to hop count during communication, and user mobility factor. Thus the total energy consumption for cellular networks is shown in equation (12),

$$E = \sum_{i=1}^{H,d} \sum_{j=0}^{M} \Big(NU + PB + PT\Big). \tag{12}$$

Further, we can elaborate the following as follows, $NU = 2\xi U_b + C$. The unit energy for binding varies from various transmission media (subject to hardware manufacturers) and device manufacturers' models. Here C shows a constant amount of startup energy for individual devices. Further, we can explain as follows in equation (13),

$$PT = \sum_{i=1}^{H} \Big(D_p + S_{req} + S_{rep}\Big). \tag{13}$$

Here D_p is the size of data packets, and the singling cost for link update incurs with the transmission cost and processing costs. Then the cost per unit of distance must be computed with respect to time and mobility. For the same, we consider the full network to be timely slotted and the length of slot is t. Let $E_{i,j}$ denote the energy consumption on link $L_{i,j}$ and it will depend on distance, user mobility, bandwidth utilization, hop count, distance, and user mobility. Then the energy consumption in cellular communication is written in (14),

$$EC_{CC} = 2\sum_{i=1}^{\xi} \sum_{j=0}^{M} \Big(NU + PB + PT\Big). \tag{14}$$

Now we are computing the energy consumption in D2D pair of communication in equation (15),

$$EC_{d2d} = \Pi_{d2d}^{d2d(R)} \sum_{i=1}^{\xi} \sum_{j=0}^{M} \Big(NU + PB + PT\Big) + \Pi_{d2d(R)}^{d2d} \sum_{j=0}^{M} PT. \tag{15}$$

F. SIGNALING COST

Here we are calculating the signaling cost for the proposed D2D resource allocation methodology. We consider the mobile node sends the connection signal to a nearby associated gNB, further processed by gNBs and other network hardware, and finally diverted towards the destination gNB and mobile nodes. The network push to D2D pair-based communication (or relay-assisted) is subject to performance parameters.

In our proposed work we can define two layers of signaling costs such as best case and worst case. In the best case, the D2D communication pair is stable no need for additional network resources. The second D2D pair has poor network performance and the system is allocating an additional set of network resources. To accommodate the additional network resource the gNB exchanges several signals between nearby gNBs (to identify the over-utilized and under-utilizing gNBs) and it leads to high signaling cost [4]. Therefore first we are computing the signaling cost as in equation (16). It is the signaling cost per unit distance.

$$C_{sig}^{d} = \frac{T_c + T_P}{d}. \tag{16}$$

It is observed that all mobile switching centers (MSCs) are interlinked with the wire-line link and they follow the medium access control (MAC) protocol. So, T_C is dependent on the proportionality constant, the number of hops, and the per-hop update transmission cost. Then, the per-unit signaling cost for D2D communication is computed in equation (17),

$$C_{signal} = LU\,\Pi_{D2D}^{D2D(R)} \Pi_{D2D(R)}^{D2D} .p_i Bd.SA.M.\Delta t. \tag{17}$$

G. RELAY SELECTION AND PERFORMANCE CALCULATION PROCEDURE

The proposed work is dependent on performance calculation. If the performance is not up to the mark then the network assigns another set of available resource, which may lead to relay-assisted D2D pair communication. To accommodate the additional set of resources, the network may need more time. Thus the required time for the relay section is shown in equation (18), and it is denoted by (D_R),

$$\begin{aligned} D_R = M p_i\Big(\Pi_{d2d}^{d2d(R)} \sum_{1}^{H} \int_0^{\Delta t} Tdt + \Pi_{d2d(R)}^{d2d} \int_0^{\Delta t} Tdt\Big) \\ + M p_i\Big(\Pi_{d2d(R)}^{d2d} \int_0^{\Delta t} Tdt + \Pi_{d2d}^{d2d(R)} \int_0^{\Delta t} Tdt\Big). \end{aligned} \tag{18}$$

Now we compute the energy consumption for the relay section as follows shown in (19),

$$\begin{aligned} E_{d2d(R)} = \sum_{0}^{M,p_i} \Big(NU+PB+PT\Big) + \sum_{0}^{M,h,p_i} \Big(NU + PB + PT\Big) \\ + p_i \lambda_j \mu_j Bd. \end{aligned} \tag{19}$$

In line with same now we compute the signal strength for the D2D pair or D2D(R) towards the associated gNB, as they are shown in equation (20),

$$\begin{aligned} S_{d2d/d2d(R)} = \int_0^{H,\Delta t} p_i \lambda_i \mu_j \Pi_{d2d}^{d2d(R)} LU_{d2d} SA.dt \\ + \int_0^{H',\Delta t} p_i \lambda_{i\pm1} \mu_{j\pm1} \Pi_{d2d(R)}^{d2d} LU.SA.dt. \end{aligned} \tag{20}$$

We compute maximum on base stations $b = \max_{SA \in B_t^{on}} G_T G_R P_b$, where B_t^{on} is the number of active gNB at a given time t, G_T, G_R and P_b is the gain of a transmission, receiver and transmission power of eNB, respectively. The call arrival per unit area is $\lambda(j)$, service rate per unit area $\mu(j)$, thus the traffic rate is written in equation (21),

$$\gamma(j) = \frac{\lambda(j)}{\mu(j)}. \tag{21}$$

Now we compute the load density of gNBs as follows in equation (22),

$$gNB(\ell) = \frac{\gamma(j)}{gNB_{\Delta t}^{on}}. \tag{22}$$

In device-level bandwidth allocation, the average intensity of network signal, and call arrival rate of potential traffic in different service areas should be obtained either via theoretic analysis or actual data collection. We can represent it using an $M/M/m(m)$ queuing model, thus we can model the average amount of traffic in a certain service area can be written in equation (23),

$$TrSA = \frac{\sum_{m=1}^{T} \frac{m\gamma(m)}{m!}}{\sum_{m=0}^{T} \frac{\gamma(m)}{m!}}, \tag{23}$$

where m is an index of network performance indicator. The bandwidth allocation is $Bd = \sum_{a=1}^{SA} b_c^{T,\Delta t}$. Then bandwidth consumption between D2D pair is shown in equation (24),

$$Bd_{d2d(R)} = \int_0^{H,\Delta t} \lambda_i \mu_j \Pi_c^u Bd\ SA\ dt + \int_0^{3,\Delta t} p_i \lambda_i \mu_j \Pi_{d2d}^{d2d(R)} Bd\ SA\ dt. \tag{24}$$

Now we can write the overall performance metric function as in equation (25) $P(CN/UE)$ is,

$$P(d2d) \Rightarrow ||E_{d2d} \wedge E_{d2d}|| \wedge ||D_{d2d}|| \wedge ||Sig_{d2d}|| \wedge ||Bd_{d2d}||. \tag{25}$$

Now we can formulate the condition for D2D pair communication using relay nodes in equation (26),

$$D2D(R) = \begin{cases} True, & \text{if } P(d2d) > Thrs \Rightarrow D2D\ pair \\ False, & \text{else } D2D(R) \end{cases} \tag{26}$$

In modern wireless communication systems, delay and latency are some of the most important parameters, and they must be optimized. In this paper, we are also optimizing it. In equation (27), $\vec{\mathbb{H}}(k)$ is the Hassian Matrix for optimization. It is written in the Laplase transform of 2^{nd} order derivative for the associated delay function. The complete explanation and derivative is as follows in equation (27),

$$\vec{\mathbb{H}} = \nabla^2 \vec{W}_d = \begin{bmatrix} \frac{\partial^2 \vec{W}_d(k)}{\partial k_1} & \frac{\partial^2 \vec{W}_d(k)}{\partial k_2} & \frac{\partial^2 \vec{W}_d(k)}{\partial k_3} & \cdots & \frac{\partial^2 \vec{W}_d(k)}{\partial k_m} \\ \frac{\partial^2 \vec{W}_d(k)}{\partial k_1 \partial k_2} & \frac{\partial^2 \vec{W}_d(k)}{\partial k_2^2} & \frac{\partial^2 \vec{W}_d(k)}{\partial k_3 \partial k_2} & \cdots & \frac{\partial^2 \vec{W}_d(k)}{\partial k_m \partial k_2} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{\partial^2 \vec{W}_d(k)}{\partial k_1 \partial k_m} & \frac{\partial^2 \vec{W}_d(k)}{\partial k_m \partial k_2} & \frac{\partial^2 \vec{W}_d(k)}{\partial k_m \partial k_3} & \cdots & \frac{\partial^2 \vec{W}_d(k)}{\partial k_m^2}. \end{bmatrix} \tag{27}$$

Therefore, overall communication delay is based on D2D pair signalling setup delay, as express in equation (28),

$$T_d \Delta t = \Delta T(\vec{W}_d(k)) \pi M \Xi.d.D. \tag{28}$$

The $\vec{\mathbb{H}}$ is the input matrix for delay functions, and $\vec{W}$ is calculated for every D2D pair concerning user location i and j within the network service area SA. In line with $\vec{\mathbb{H}}$, we can compute the output of Taylor expansion. Then output function O is written in equation (29). For more accurate results we consider the error as ϵ,

$$O = \sum_{j=1}^{i} \vec{W}_{j,d} X_j + \epsilon. \tag{29}$$

V. SIMULATION RESULTS AND DISCUSSION

In this section, we are elaborating the results of performance analysis with respect to our proposed works. Initial parameters are taken from [4], [29], [52], and [53]. We consider the simulation setup as follows. The hop counts are between the mobile nodes and the target mobile node is 2, if we consider the relay nodes-based communication then 3. The mobile node is free to move in any possible direction in Independent Identical Distribution (IID) patterns thus movement direction is 6, initial node movement probability is 0.01. The basic call duration is 180 seconds, the distance from the last location to nearby gNB is 20 meters, and the call arrival and departure rate as $\lambda_i = 0.01, \mu_i = 0.001$, respectively, the service area is $100Km^2$, the number of gNBs is 50 and D2D pair and D2D pair with relay nodes are 100 and 50, respectively. Here we consider result parameters such as communication delay. It shows the delay and latency associated with delivering the first packet to the destination mobile node. Energy consumption by source and destination nodes, call-to-mobility ratio (to validate the scalability of work), and user movement probability. The Figure 5 shows the efficiency of the proposed works, in terms of delay in a millisecond. Here we compare the results with two other works SoA-1 and SoA-2. We consider the simulation parameters as follows. $\lambda_i = 0.01, \mu_i = 0.001$, respectively, service area is $100Km^2$, number of gNBs are 50, D2D pair is 100, D2D pair with relay $= 200$, system setup delay is 10 milliseconds. Hardware delay is negligible. The

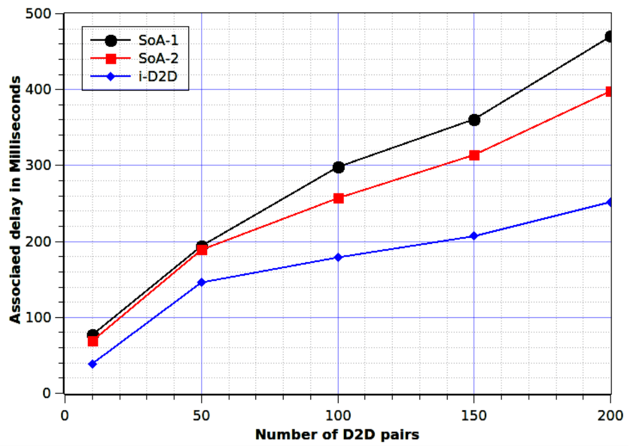


FIGURE 5. D2D pairs versus network associated delay in milliseconds.

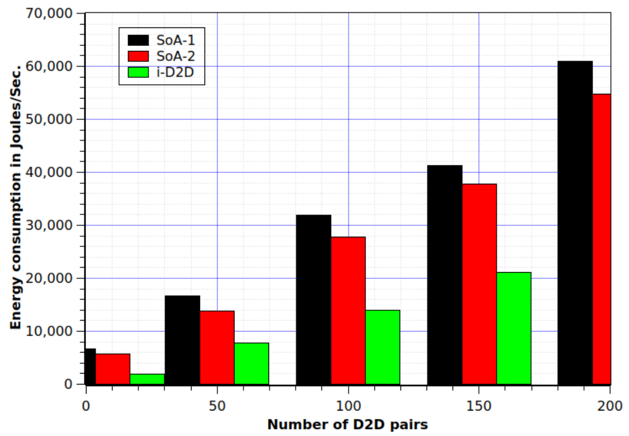


FIGURE 6. D2D pairs versus energy consumption in Joules/Second.

proposed work having better performance nodes is 100 and 50, respectively. In this Figure, we can observe that the proposed work has the least delay because it uses only one level of signal exchange from nearby eNBs, traditional and SoA works have multi-level signal exchange and iterative signal exchange. The proposed work supports single-hop communication as compared to multi-hop communication, therefore it produces less delay with respect to other state-of-the-art works such as SoA1 and SoA2. Energy consumption is another important parameter in computing the performance of mobile cellular communication networks. Its parameter is also valid in Device-to-Device communication, Ad-hoc networks, and Sensor networks, it leads to green networking and energy-efficient networking. Therefore in this paper, we consider energy consumption as an important parameter. In Figure 6 we map the energy consumption in the proposed work, SoA-1, and SoA-2 versus several available D2D pairs within the network service area. Here, the number of D2D pairs varies from 0 to 200 units, where 50 percent of D2D pairs are using relay-assisted communication. Other simulation values are as follows, λ_i, μ_i are 0.01 and 0.001 respectively, call duration is 180 seconds, number of active mobile nodes and gNBs are 100 and 200, respectively.

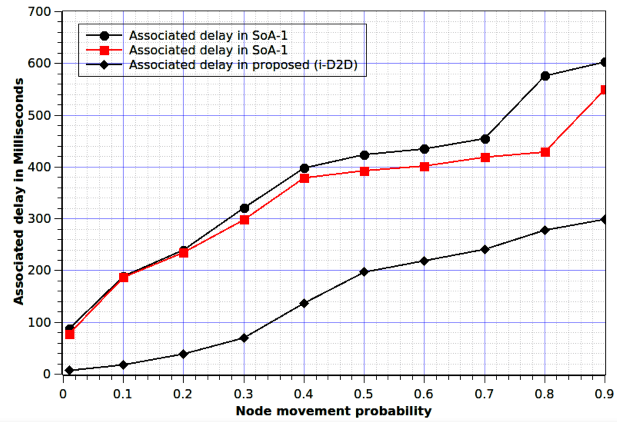


FIGURE 7. Node movement probability versus associated networks delay in milliseconds.

The node movement probability is 0.1. In this Figure, we can observe that the proposed work has better results compared to other modern works such as SoA-1 and SoA-2. The proposed works allocate available resources as per the requirement of the network, and allocate more available resources subject to maintaining the QoS and QoE. The scheme is greedy for performance and does not look for any pre-defined methodology. On the other hand proposed work in SoA-1 and SoA-2 work does not support performance-oriented resource allocation. Also, resource allocation is not dynamic as per the user's requirement. Therefore it consumes more energy as compared to the proposed works. The cellular network offers great freedom for node mobility. In this paper, we also focus on the same attribute. In Figure 7 we show the efficiency of the proposed work with respect to communication delay in milliseconds. Here, we offer great freedom to mobile nodes and we represent it as node movement probability, which varies from 0.01 to 0.9 (least dynamic to the highly mobile node). In the Figure 7, we can observe that the proposed work offers a great improvement over the other state-of-the-art work. Here the proposed work has the least delay, because it offers available resources in the slots, as per the requirement of the mobile node. It never allows over-utilization of the network resource, and always prefers optimal utilization of network services. In this simulation setup, we consider the following parameters. Up-link gain 45dBm, down-link gain 43 dBm (as per the LTE-A and 5G), the service area is 1000 square Km, and the number of active gNb, mobile nodes, D2D pair, and D2D with relay nodes are 100, 10000, 200, and 150, respectively. Call arrival and departure dates are 0.001, and 0.1, respectively. Movement probability starts from 0.01 and IID directions are 6. In this paper, we consider that up-link and down-link gain are slightly different because they are highly influenced by physical attenuation, and this fact is globally accepted. In our proposed work we consider two modes of resource allocation, D2D pair and D2D pair with relay nodes. The energy consumption by a fixed pair of D2D nodes, where at most 40 percent of the pairs are available with relay node pair. This indicate mobile nodes

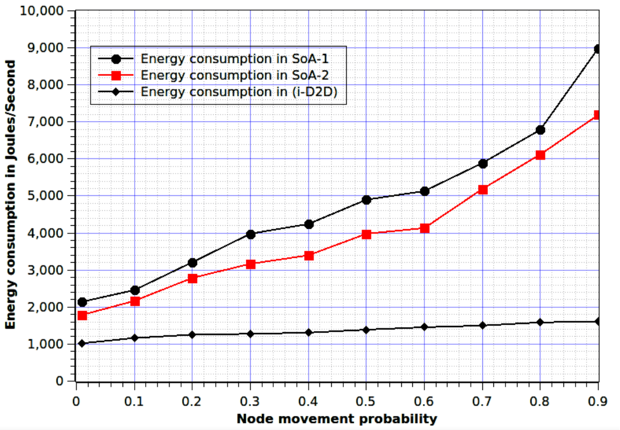


FIGURE 8. Node movement probability versus energy consumption per second for ten pairs of D2D communication.

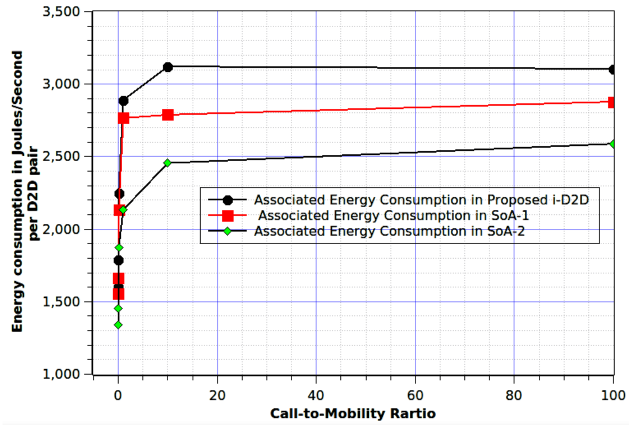


FIGURE 9. Call-to-mobility ratio versus energy consumption per second for every pair of D2D communication.

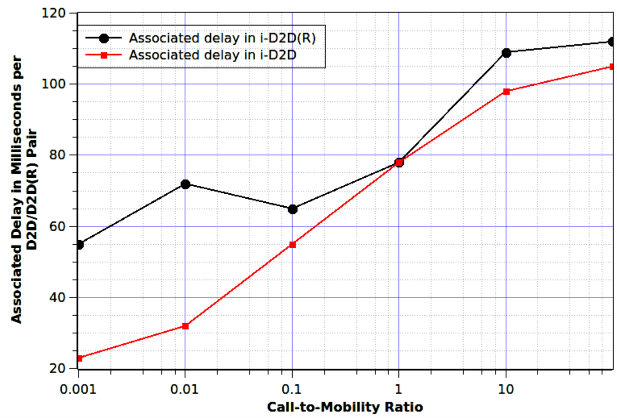


FIGURE 10. Call-to-mobility ratio versus energy consumption per millisecond for every pair of D2D communication.

are moving very frequently (within network coverage area). As mobile nodes are frequently moving therefore QoE and QoS will decreased (it will be observed by eNBs). The associated eNBs allocate another set of available network resources. If the performance is still poor then network will add a relay node. As we set 40 percent of D2D pair having relay nodes, refer that nodes are highly dynamic, a fair utilization of network resources and eNB performance monitoring system. In Figure 8 we simulated this scenario where we are showing node movement probability versus energy consumption (in Joules) per second for 10 units of a D2D communication pair. In this Figure, we can observe that the proposed work produces better results compared to SoA-1 and SoA-2 works. The proposed work always consumes the least energy because it prefers to maintain the D2D pair with a high degree of probability and a tendency to add the relay nodes subject to network performance. It also follows the greed-based networks resource allocation strategy, therefore proposed work has the least energy consumption. We consider the following setup for simulation. The service area is 1000 square Km, node movement probability is 0.45, and gNB, active users are 100 and 1000, respectively. Call arrival and departure rates are 0.1 and 0.5, respectively. The Call-to-Mobility Ratio (CMR) is a very important parameter to validate the scalability, robustness, and working conditions of a network. Therefore, in this paper, we are emphasizing it very clearly. In Figure 9 we show the energy consumption per D2D pair versus CMR. Here the call duration is 180 seconds, initially call follows D2D pair-based communication after 60 seconds the call moves to D2D pair with relay nodes-based communication. It happens because of node mobility, as the position of the node changes then the additional signaling energy is required to maintain the QoS and QoE. In this condition, the proposed work produces better results as compared to other SoA-1 SoA-2 works. In the proposed work we allocate the available network resources subject to the requirement of mobile nodes as compared to under and over-utilization of available network resources. If they need additional support the network is dedicated to doing the same. To simulate this setup we consider call arrival and departure rates to be 0.01 and 0.1, respectively, later it increases gradually. We set the CMR values from 0.01 to 100 (least active to highly active node, with a high degree of all arrival and departure rates). We can observe that the proposed work has a better result because it is fully dependent on network conditions. Here we consider the normal setup as discussed initially. The proposed resource allocation methodology allocates network benefits subject to the greediness of performance, other hand traditional techniques do not care for performance, node mobility, and CMR. In Figure 10 we represent the CMR and energy consumption per millisecond for every pair of D2D communication networks. This is an important parameter because it validates the performance of the proposed work if the user is highly dynamic and avails the optimal amount of network resources. We can observe that proposed work procedures have better results because they always check the network conditions with respect to node mobility coefficient, and select the initial simulation parameter. Now we are setting the parameters for simulation purposes. Active eNBs are 200, mobile nodes in the coverage area are 1000, D2D pairs are 100 (initial), up-link and down-link signal strengths are

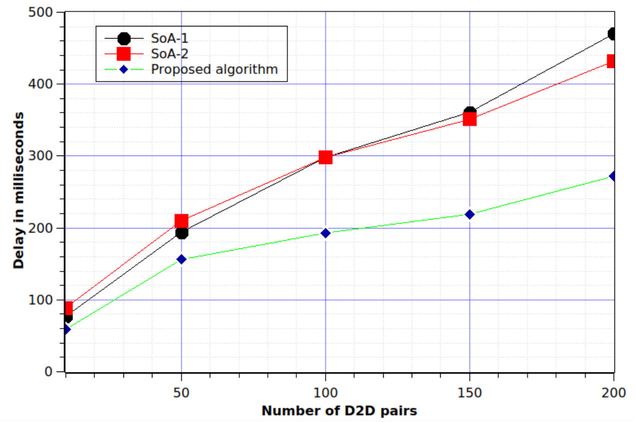


FIGURE 11. Number of D2D pairs versus network delay in milliseconds. Here we consider active eNBs = 200, mobile nodes = 1000, D2D pairs = 100 (initial), up-link and down-link signal strengths are 50 and 55 dB, network service area 100 square Km, and cell size is 500 square meters.

50 and 55 dB, network service area is 100 square Km, and cell size is 500 square meters. The backbone communication is supported by MoIP and MoTCP protocol infrastructure. In Figure 11 we show the performance of proposed work with respect to SoA-1, and SoA-2, with different setups, where call arrival and departure rates are 0.1 and CMR is 0.20. We can observe that the proposed work has overall performance improvement over the other compared methodology. We get these results because of efficient energy consumption, effective mobility management, performance-oriented QoE, and QoS.

VI. CONCLUSION AND FUTURE WORKS

In this paper, we proposed a bee fly pattern-based resource allocation procedure for Device-to-Device communication systems underlined to mobile cellular networks. As the mobile node initiates the call, the associated gNB gathers information about the network's conditions from nearby mobile base stations and thereafter finds an optimal procedure to serve the mobile user. This procedure is the same as the working of a bee to find the optimal food. The serving base station allocates a fair amount of network resources to mobile nodes and monitors the network's performance, also pushing the communication toward D2D mode. If the performance of the D2D pair is not satisfactory, then gNB allocates another set of available resources and selects a relay node in between the D2D pair. We observed the efficiency and effectiveness of the proposed work compared to available state-of-the-works in terms of delay, energy consumption, and network workloads. In this work we validate the proposed contribution through system-level simulation and mathematical model. In future we aim to deploy it through hardware-based chip in a realistic cellular networks traffic. The proposed work open a new dimension of swarm algorithms in cellular communication, where researchers can work for resource optimization, communication delay and latency, energy consumption and efficiency, fault tolerance liked performance parameters.

REFERENCES

[1] M. Noura and R. Nordin, "A survey on interference management for device-to-device (D2D) communication and its challenges in 5G networks," *J. Netw. Comput. Appl.*, vol. 71, pp. 130–150, Aug. 2016.

[2] P. Mach, Z. Becvar, and T. Vanek, "In-band device-to-device communication in OFDMA cellular networks: A survey and challenges," *IEEE Commun. Surveys Tuts.*, vol. 17, no. 4, pp. 1885–1922, 4th Quart., 2015.

[3] B.-J. Chang and S.-H. Liou, "Adaptive cooperative communication for maximizing reliability and reward in ultra-dense small cells LTE—A toward 5G cellular networking," *Comput. Netw.*, vol. 115, pp. 16–28, Mar. 2017.

[4] S. K. Biswash and D. N. K. Jayakody, "Performance based user-centric dynamic mode switching and mobility management scheme for 5G networks," *J. Netw. Comput. Appl.*, vol. 116, pp. 24–34, Aug. 2018.

[5] R. N. Mitra and D. P. Agrawal, "5G mobile technology: A survey," *ICT Exp.*, vol. 1, no. 3, pp. 132–137, Dec. 2015.

[6] B. J. Mampilly and V. S. Sheeba, "Detection and classification of power system fault in IEEE 30 bus network using wavelet transform and novel hybrid bees Bayesian optimization algorithm based improved convolution neural network (ICNN)," *Sustain. Energy Technol. Assessments*, vol. 60, Dec. 2023, Art. no. 103413.

[7] J. Hipólito, W. E. Magnusson, and F. Baccaro, "Optimizing survey effort for Euglossine bees in tropical forests," *Perspect. Ecol. Conservation*, vol. 21, no. 3, pp. 253–262, Jul. 2023. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2530064423000470

[8] F. S. Shaikh and R. Wismüller, "Routing in multi-hop cellular device-to-device (D2D) networks: A survey," *IEEE Commun. Surveys Tuts.*, vol. 20, no. 4, pp. 2622–2657, 4th Quart., 2018.

[9] I. F. Akyildiz, S. Nie, S.-C. Lin, and M. Chandrasekaran, "5G roadmap: 10 key enabling technologies," *Comput. Netw.*, vol. 106, pp. 17–48, Sep. 2016.

[10] K. Sheth, K. Patel, H. Shah, S. Tanwar, R. Gupta, and N. Kumar, "A taxonomy of AI techniques for 6G communication networks," *Comput. Commun.*, vol. 161, pp. 279–303, Sep. 2020.

[11] M. Wang, T. Zhu, T. Zhang, J. Zhang, S. Yu, and W. Zhou, "Security and privacy in 6G networks: New areas and new challenges," *Digit. Commun. Netw.*, vol. 6, no. 3, pp. 281–291, Aug. 2020.

[12] S. K. Biswash and D. N. K. Jayakody, "Energy-efficient node-to-node communication scheme for fog-based cellular networks," *IET Commun.*, vol. 14, no. 10, pp. 1595–1602, Jun. 2020.

[13] S. K. Biswash and D. N. K. Jayakody, "A network performance-based device driven communication scheme for 5G networks," *Internet Technol. Lett.*, vol. 1, no. 3, p. e27, May 2018.

[14] S. Babu and S. K. Biswash, "Fog computing-based node-to-node communication and mobility management technique for 5G networks," *Trans. Emerg. Telecommun. Technol.*, vol. 30, no. 10, p. e3738, Oct. 2019.

[15] M. H. Shahid, A. R. Hameed, S. Ul Islam, H. A. Khattak, I. U. Din, and J. J. P. C. Rodrigues, "Energy and delay efficient fog computing using caching mechanism," *Comput. Commun.*, vol. 154, pp. 534–541, Mar. 2020.

[16] F. O. Catak, M. Kuzlu, E. Catak, U. Cali, and D. Unal, "Security concerns on machine learning solutions for 6G networks in mmWave beam prediction," *Phys. Commun.*, vol. 52, Jun. 2022, Art. no. 101626.

[17] S. Zhang and D. Zhu, "Towards artificial intelligence enabled 6G: State of the art, challenges, and opportunities," *Comput. Netw.*, vol. 183, Dec. 2020, Art. no. 107556.

[18] E. Kaya, B. Gorkemli, B. Akay, and D. Karaboga, "A review on the studies employing artificial bee colony algorithm to solve combinatorial optimization problems," *Eng. Appl. Artif. Intell.*, vol. 115, Oct. 2022, Art. no. 105311.

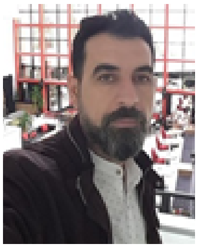
[19] *5G Network Architecture—A High-Level Perspective*, Huawei, Shenzhen, China, 2019.

[20] M. Mukherjee, L. Shu, and D. Wang, "Survey of fog computing: Fundamental, network applications, and research challenges," *IEEE Commun. Surveys Tuts.*, vol. 20, no. 3, pp. 1826–1857, 3rd Quart., 2018.

[21] D. Moltchanov, A. Ometov, and Y. Koucheryavy, "Analytical characterization of the blockage process in 3GPP new radio systems with trilateral mobility and multi-connectivity," *Comput. Commun.*, vol. 146, pp. 110–120, Oct. 2019.

[22] J. W. Won and J. M. Ahn, "3GPP URLLC patent analysis," *ICT Exp.*, vol. 7, no. 2, pp. 221–228, Jun. 2021.

[23] S. Somesula, N. Sharma, and A. Anpalagan, ''Artificial bee optimization aided joint user association and resource allocation in HCRAN,'' *Appl. Soft Comput.*, vol. 125, Aug. 2022, Art. no. 109152.
[24] M. N. Tehrani, M. Uysal, and H. Yanikomeroglu, ''Device-to-device communication in 5G cellular networks: Challenges, solutions, and future directions,'' *IEEE Commun. Mag.*, vol. 52, no. 5, pp. 86–92, May 2014.
[25] Z. Chang, Y. Hu, Y. Chen, and B. Zeng, ''Cluster-oriented device-to-device multimedia communications: Joint power, bandwidth, and link selection optimization,'' *IEEE Trans. Veh. Technol.*, vol. 67, no. 2, pp. 1570–1581, Feb. 2018.
[26] T. Zhang, H. Fan, J. Loo, and D. Liu, ''User preference aware caching deployment for device-to-device caching networks,'' *IEEE Syst. J.*, vol. 13, no. 1, pp. 226–237, Mar. 2019.
[27] H. Kebriaei, B. Maham, and D. Niyato, ''Double-sided bandwidth-auction game for cognitive device-to-device communication in cellular networks,'' *IEEE Trans. Veh. Technol.*, vol. 65, no. 9, pp. 7476–7487, Sep. 2016.
[28] X. Wu, S. Tavildar, S. Shakkottai, T. Richardson, J. Li, R. Laroia, and A. Jovicic, ''FlashLinQ: A synchronous distributed scheduler for peer-to-peer ad hoc networks,'' *IEEE/ACM Trans. Netw.*, vol. 21, no. 4, pp. 1215–1228, Aug. 2013.
[29] S. K. Biswash, ''Device and network driven cellular networks architecture and mobility management technique for fog computing-based mobile communication system,'' *J. Netw. Comput. Appl.*, vol. 200, Apr. 2022, Art. no. 103317.
[30] N. Bahadori, M. Nabil, and A. Homaifar, ''Antenna beamwidth optimization in directional device-to-device communication using multi-agent deep reinforcement learning,'' *IEEE Access*, vol. 9, pp. 110601–110613, 2021.
[31] W. Qu, G. Li, and Y. Zhao, ''On the coverage problem in device-to-device relay networks,'' *IEEE Commun. Lett.*, vol. 23, no. 11, pp. 2139–2143, Nov. 2019.
[32] U. N. Kar and D. K. Sanyal, ''An overview of device-to-device communication in cellular networks,'' *ICT Exp.*, vol. 4, no. 4, pp. 203–208, Dec. 2018.
[33] M. H. Adnan and Z. A. Zukarnain, ''Device-to-device communication in 5G environment: Issues, solutions, and challenges,'' *Symmetry*, vol. 12, no. 11, p. 1762, Oct. 2020.
[34] Y. Sun, F. Wang, and Z. Liu, ''Coalition formation game for resource allocation in D2D uplink underlaying cellular networks,'' *IEEE Commun. Lett.*, vol. 23, no. 5, pp. 888–891, May 2019.
[35] J. Huang, Y. Sun, and Q. Chen, ''GALLERY: A game-theoretic resource allocation scheme for multicell device-to-device communications underlaying cellular networks,'' *IEEE Internet Things J.*, vol. 2, no. 6, pp. 504–514, Dec. 2015.
[36] T. Thepsongkroh, P. Phunchongharn, and K. Akkarajitsakul, ''A game theoretical resource allocation for relay-assisted device-to-device communication networks,'' in *Proc. Int. Conf. Inf., Commun. Eng. (ICICE)*, Nov. 2017, pp. 484–487.
[37] J. Lee and J. H. Lee, ''Performance analysis and resource allocation for cooperative D2D communication in cellular networks with multiple D2D pairs,'' *IEEE Commun. Lett.*, vol. 23, no. 5, pp. 909–912, May 2019.
[38] S. Li, Q. Ni, Y. Sun, and G. Min, ''Resource allocation for weighted sum-rate maximization in multi-user full-duplex device-to-device communications: Approaches for perfect and statistical CSIs,'' *IEEE Access*, vol. 5, pp. 27229–27241, 2017.
[39] Y. Zhao, Y. Li, Y. Cao, T. Jiang, and N. Ge, ''Social-aware resource allocation for device-to-device communications underlaying cellular networks,'' *IEEE Trans. Wireless Commun.*, vol. 14, no. 12, pp. 6621–6634, Dec. 2015.
[40] D. Karaboga, B. Akay, and N. Karaboga, ''A survey on the studies employing machine learning (ML) for enhancing artificial bee colony (ABC) optimization algorithm,'' *Cogent Eng.*, vol. 7, no. 1, Jan. 2020, Art. no. 1855741, doi: 10.1080/23311916.2020.1855741.
[41] C. Jiang, S. Yang, P. Nie, and X. Xiang, ''Multi-objective structural profile optimization of ships based on improved artificial bee colony algorithm and structural component library,'' *Ocean Eng.*, vol. 283, Sep. 2023, Art. no. 115124.
[42] M. K. Devi and K. Umamaheswari, ''Modified artificial bee colony with firefly algorithm based spectrum handoff in cognitive radio network,'' *Int. J. Intell. Netw.*, vol. 1, pp. 67–75, 2020. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2666603020300099
[43] H. Nasrinpour, A. Bavani, and M. Teshnehlab, ''Grouped bees algorithm: A grouped version of the bees algorithm,'' *Computers*, vol. 6, no. 1, p. 5, Jan. 2017. [Online]. Available: https://www.mdpi.com/2073-431X/6/1/5
[44] J. Wang, Y. Liu, S. Rao, X. Zhou, and J. Hu, ''A novel self-adaptive multi-strategy artificial bee colony algorithm for coverage optimization in wireless sensor networks,'' *Ad Hoc Netw.*, vol. 150, Nov. 2023, Art. no. 103284.
[45] S. K. Biswash and C. Kumar, ''Ant-system-based location management scheme for wireless cellular networks,'' *IET Commun.*, vol. 5, no. 9, pp. 1192–1198, Jun. 2011.
[46] S. K. Biswash, M. Sarkar, and S. Nagaraj, ''Bee system-based energy efficient base station operation in mobile cellular networks,'' in *Proc. Int. Conf. Comput., Netw. Commun. (ICNC)*, Feb. 2015, pp. 357–362.
[47] L. Cao, Y. Cai, and Y. Yue, ''Swarm intelligence-based performance optimization for mobile wireless sensor networks: Survey, challenges, and future directions,'' *IEEE Access*, vol. 7, pp. 161524–161553, 2019.
[48] A. Hamza, A. H. Darwish, and O. Rihawi, ''A new local search for the bees algorithm to optimize multiple traveling salesman problem,'' *Intell. Syst. Appl.*, vol. 18, May 2023, Art. no. 200242. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2667305323000674
[49] D. Qin, Z. He, X. Zhao, J. Liu, F. Zhang, and L. Xiao, ''Area and power optimization for fixed polarity Reed–Müller logic circuits based on multi-strategy multi-objective artificial bee colony algorithm,'' *Eng. Appl. Artif. Intell.*, vol. 121, May 2023, Art. no. 105906. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0952197623000908
[50] *Cisco 4G LTE and Cisco 4G LTE-Advanced Network Interface Module Software Configuration Guide*, Cisco, San Jose, CA, USA, 2015.
[51] L. Tello-Oquendo, I. Leyva-Mayorga, V. Pla, J. Martinez-Bauset, J.-R. Vidal, V. Casares-Giner, and L. Guijarro, ''Performance analysis and optimal access class barring parameter configuration in LTE—A networks with massive M2M traffic,'' *IEEE Trans. Veh. Technol.*, vol. 67, no. 4, pp. 3505–3520, Apr. 2018.
[52] S. K. Biswash and D. N. K. Jayakody, ''A fog computing-based device-driven mobility management scheme for 5G networks,'' *Sensors*, vol. 20, no. 21, p. 6017, Oct. 2020. [Online]. Available: https://www.mdpi.com/1424-8220/20/21/6017
[53] A. Jovanović, A. Stevanović, N. Dobrota, and D. Teodorović, ''Ecology based network traffic control: A bee colony optimization approach,'' *Eng. Appl. Artif. Intell.*, vol. 115, Oct. 2022, Art. no. 105262.



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