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An Approach of Resource Allocation for Vehicle-to-Vehicle Communication using Cuckoo Search based Grey Wolf Optimization

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Abstract: Vehicles in networks can experience rapid channel changes due to their high mobility, which can greatly affect the effectiveness of resource allocation methods. Hence, it is crucial to consider these variations in developing resource allocation techniques for D2D-enabled vehicular networks. To address this issue, this study suggests a CS-GWO based method for power allocation and spectrum sharing, which is optimized for enhancing the performance of V2I and V2V connections, and is also resistant to channel variations. The suggested algorithms aim to maximize the ergodic capacity of V2I links while assuring dependable performance for each V2V connection. This research could prove beneficial in developing future vehicular communication systems.

***Keywords**: CS-GWO, Device-to-Device (D2D), Grey Wolf Optimization, Signal-to-Interference-Plus-Noise Ratio (SINR), Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Device (V2X).*

1. Introduction

Vehicle-to-everything (V2X) communication allows vehicles to connect with other entities such as other vehicles, infrastructure, pedestrians, and cloud services. This technology seeks to improve road safety, traffic efficiency, and environmental effect. Nevertheless, contemporary V2X communication protocols, such as IEEE 802.11p, have some drawbacks. Scalability, channel access latency, quality-of-service (QoS) assurances, and connection length are among the limits.

In order to address the constraints faced by V2X communication technologies, the 3rd Generation Partnership Project (3GPP) has initiated measures to bolster V2X services in Long Term Evolution (LTE) networks. These networks possess extensive coverage and can support direct device-to-device (D2D) underlay communications. This enables efficient and dependable V2V and V2I communication, whereas also meeting the different QoS necessities of V2X communication, and offering resistance to high flexibility.

Although IEEE 802.11p networks face restrictions in coverage and connectivity duration when it comes to V2I communication, cellular networks have centralized control over network resources, ensuring optimal performance. Furthermore, cellular networks can facilitate proximity-based D2D links, allowing for direct local message dissemination with reduced latency and power consumption. This makes them highly appropriate for delay-sensitive V2V communication.

D2D-enabled cellular networks have several advantages over other V2X communication technologies. They can provide efficient and reliable V2V and V2I communication with low latency and reduced power consumption. They can also support a wide range of vehicular communication applications with diverse QoS requirements, such as safety-critical messages and infotainment services. Moreover, D2D-enabled cellular networks can be easily integrated with existing cellular infrastructure, making them a cost-effective solution for enabling V2X communication.

The purpose of our study is to suggest a resource management plan that can support both V2I and V2V links within a cellular architecture that is D2D-enabled. We achieve V2I connectivity by utilizing the macro cellular link, while V2V connectivity is supported through a localized D2D link. The objective is to capitalize on the dual benefits of D2D-enabled cellular networks, which include resource utilization efficiency and improved QoS.

In order to overcome the challenges presented by the difficulty of monitoring rapidly changing wireless channels, our proposed resource management plan relies on the statistical information of the channel's slow fading parameters instead of instantaneous CSI. Additionally, we have taken into account the varied QoS requirements for V2I and V2V links, which correspond to their respective supported applications. Our primary objective is to achieve high link capacity for V2I connections, while placing a greater emphasis on link reliability for safety-critical information transmitted through V2V connections.

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The contributions of our proposed approach can be summarized as follows:

Joint Optimization of V2I and V2V Links: Our approach addresses the challenge of optimizing both the total and minimum ergodic capacities of V2I links, considering the long-term average over fast fading. By simultaneously optimizing V2I and V2V links, we aim to enhance the overall system performance and resource utilization.

Guaranteed Quality of Service (QoS): We ensure that a minimum QoS is maintained for both V2I and V2V links. This means that the proposed resource allocation scheme takes into account the specific QoS requirements of each link, guaranteeing that the allocated resources are sufficient to meet these requirements.

Reliable V2V Link Communication: We pay special attention to maintaining the reliability of V2V links by ensuring that the received Signal-to-Interference-plus-Noise Ratio (SINR) outage probability remains below a minimal threshold. This helps to mitigate the impact of fading and interference, thereby improving the reliability of V2V communication.

Integration of Cuckoo Search GWO-Optimized Algorithm: To tackle the resource allocation challenge effectively, we incorporate the cuckoo search GWO-optimized algorithm. This algorithm is known for its efficiency and robustness in solving optimization problems. By leveraging its capabilities, our proposed approach achieves practical and effective resource management, leading to improved QoS in D2D-enabled cellular networks supporting V2I and V2V connections.

In summary, our proposed approach offers a comprehensive solution for optimizing resource allocation in D2D-enabled cellular networks. By considering both V2I and V2V links, ensuring QoS requirements, and incorporating the cuckoo search GWO-optimized algorithm, we contribute to efficient resource management, enhanced system performance, and improved reliability in such networks.

In conclusion, our proposed scheme provides a practical solution for efficient resource management and improved QoS in D2D-enabled cellular networks that support both V2I and V2V connections. The proposed scheme is ideal for addressing the difficulties caused by rapidly changing wireless channels in vehicular communication systems. This is due to the fact that we have incorporated varying QoS requirements, employed statistical channel information instead of instantaneous CSI, and utilized the Cuckoo search GWO-optimized algorithm.

The following is an outline of the remaining sections in this paper. Section III provides the methods for resource allocation and capacity enhancement that are recommended by the authors. Section IV presents the simulation results obtained using MATLAB. Finally, the paper concludes with a summary of the findings in Section V.

2. Literature Review

D2D communication is a technique that enables direct communication between devices in close proximity without using a cellular network. This can enhance communication efficiency and minimise network congestion. There are two types of operation in D2D communication: dedicated mode and reuse mode. In dedicated mode, D2D users have their own spectrum, however in reuse mode, D2D users share the spectrum with cellular users. Current research has focused on exploiting the dedicated mode to increase D2D communication's proximity, hop, and reuse benefits [5] [6]. However, D2D communication is not yet suited for usage in vehicle communication since it is predicated on base stations or D2D transmitters having perfect channel state information (CSI) [7]. Because of vehicle motion, the channel in D2D communication can vary fast, making it difficult to foresee and plan for the immediate CSI (Channel State Information) at the transmitters. This issue of channel unpredictability must be appropriately handled in D2D-enabled vehicle communication systems. The authors suggested strategies in references [8] and [9] for maximising the capacity of V2I connections while accounting for the SINR ratio outage risk of V2V links. According to reference [8,] the approach for V2V networks comprises spectrum and power allocation with delayed feedback of channel state information (CSI). The emphasis in reference [9] is on resource allocation and management that maximises the total and minimum ergodic capacity of V2I connections while taking SINR outage probability of V2V links into account utilising enormous channel information. The authors of [10] suggested a heuristic location-dependent uplink resource allocation method for D2D terminals that uses spatial resource reuse without needing comprehensive channel state information, resulting in decreased signalling overhead. Because of the exploitation of spatial resources without the necessity for complete CSI, terminals have minimal signalling overheads. Resource allocation approaches for approving and not enabling spectrum sharing among V2V links have been proposed in [11] and [12] by taking criteria for the dependability and transmission latency of the V2V lines into account. However, in [13-16], the channel allocation algorithms are applied to standard D2D systems rather than V2X communications. In [17], the evolved node B (eNB) is expected to have real-time channel state information for the cellular and D2D links. This assumption is correct for cases in which D2D users are fully stationary or have slower mobility, but it is incorrect for fast moving D2D-based V2X communication due to rapid changes in vehicle channel conditions. Furthermore, frequent mode selection may need a large amount of computation, resulting in high network costs. Several investigations [18-20], on the other hand, concentrated on boosting the overall user rate.

In this paper, we are defining both V2I and V2v connectivity under D2D cellular structure. It is difficult to track rapidly varying wireless channels, in the V2V and V2I communication resource management on slow fading channels statistics is crucial to achieve best outcome for ensuring QoS. Hence V2I connections high-capacity link is prioritized as a resource and V2V link safety given as preference. Large-scale fading information from the channel is utilized in vehicular communication systems to manage resource allocation for both V2V and V2I links. The objective is to maintain the SINR below a certain level to ensure effective communication. This may be accomplished, among other things, by modifying the transmission power, frequency, and modulation scheme.

3. System Modeling

The scenario [21] in this paper is shown in Fig. 1. M number of V2I connections are meant to be initiated by M single-antenna vehicles in the highway scenario. V2V users share the V2I spectrum to minimise resource conflicts in congested areas. Because of the vehicle network's service heterogeneity, high V2I channel capacity must be assured to accommodate bandwidth-intensive applications. K number of V2V linkages are established between vehicles, and the architecture must be very reliable in order for regularly produced safety warnings to be successfully relayed across neighbouring vehicles.

This article describes a vehicle networking communication scenario with single-cell coverage, where the base station serves as the centre and the radius is R_c. The length of the covered road section is L, and the distance between the center of the road and the base station is D, satisfying $D^2 + (L/2)^2 = R_c^2$.

The V2I link set is denoted by $M = \{1,2,\dots,M\}$, the V2V link set by $K = \{1,2,\dots,K\}$, and the overall bandwidth is denoted by $F = \{1,2,\dots,F\}$ resource blocks (RB).

This paper considers resource sharing between V2V and between V2V and V2I. To minimise the system's exposure to interference signals, this paper adopts the multiplexing mode of V2V direct link multiplexing V2I uplink spectrum resources. When the V2V direct link reuses the V2I uplink spectrum resources, the channel power gain from the transmitter of the m^{th} V2I link to the base station through the f^{th} RB is $g_{m,I}(f) = \alpha_{m,I}\left|h_{m,I}(f)\right|^2$, $h_{m,I}$ are small-scale fading components, $\alpha_{m,I}$ are large-scale fading effects such as path loss and shadowing. Likewise, the k^{th} V2V channel's link gain g_k and the interference gain $g_{k'k}$ between the k^{th} V2V vehicle and the k'^{th} V2V vehicle may be specified, from the m^{th} V2I transmitter to the k^{th} V2V vehicle through the f^{th} RB. The first V2V receiver's interference channel $g_{m,k}$ is routed to the base station through the k^{th} V2V receiver's interference channel $g_{m,k}$ [21] [22].

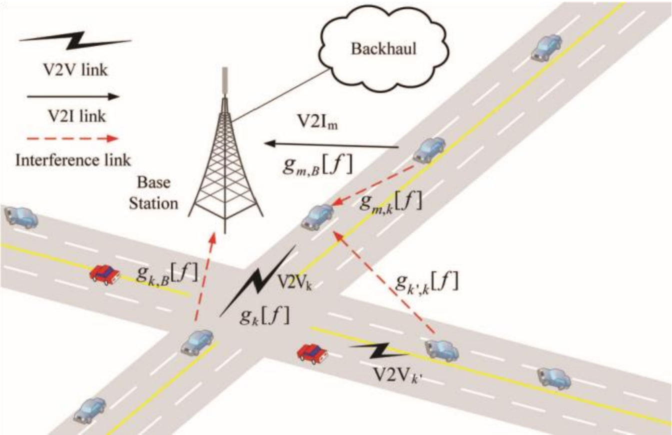

Fig. 1. Vehicle Communication in highway scenario [21]

The SINR of V2I and V2V links is denoted as:

$$\gamma_{m,f}^{i} = \frac{P_{m,f}^{i} g_{m,I}[f]}{\sigma^2 + \sum_k \mu_{k,f}^{v} P_{k,f}^{v} g_{k,B}[f]} \tag{1}$$

$$\gamma_{k,f}^{v} = \frac{P_{k,f}^{v} g_k[f]}{\sigma^2 + \sum_{m,k'\neq k}\left(\mu_{k',f}^{v} P_{k',f}^{v} g_{k',B}[f] + \mu_{m,f}^{i} P_{m,f}^{i} g_{m,k}[f]\right)} \tag{2}$$

Where, $P_{k,f}^{v}$ represents the transmission power, σ^2 is the noise power, $\mu_{m,f}^{i} \in (0,1)$, when $\mu_{m,f}^{i} = 1$ means that V2I is transmitting through the f^{th} RB(resource block). Because correct CSI is difficult to get due to the fast movement of vehicles, this research solely considers large-scale fading and path loss. For the high reliability of V2V, the threshold is set. In order to achieve high spectrum utilization, the V2I link uses the uplink orthogonal spectrum for communication and V2V link sharing. The V2I link and the V2V link can access multiple RBs.

A. Problem Formulation

The paper's objective is to look at ways to utilise available spectrum more efficiently in a dense vehicle environment, with an emphasis on multiplexing V2I uplink resources for V2V users. The aim of this paper is to formulate a resource allocation challenge that targets the enhancement of V2I channel capacity, while considering factors like diverse services, dependable V2V users, vehicle speed, and communication overhead. The problem is then represented with a particular equation defined in [21].

$$\begin{aligned}
&\boldsymbol{C_1}: \quad \max_{\substack{\{\mu^i_{m,f},\mu^v_{k,f}\}\\ \{P^i_{m,f},P^v_{k,f}\}}} \textstyle\sum_m \sum_f \mu^i_{m,f} \log_2\left(1+\gamma^i_{m,f}\right)\\
&\boldsymbol{C_2}: \quad s.t.\ \mu^v_{k,f} P_r\left\{\gamma^v_{k,f} \le \gamma^v_0\right\} \le p_0, \ \ \forall k,f\\
&\boldsymbol{C_3}: \quad \textstyle\sum_m \mu^i_{m,f} = 1, \quad \forall f\\
&\boldsymbol{C_4}: \quad \textstyle\sum_f \mu^i_{m,f} \le F, \sum_f \mu^v_{k,f} \le F, \forall m,f\\
&\boldsymbol{C_5}: \quad \mu^i_{m,f}, \mu^v_{k,f} \in \{0,1\}, \quad \forall m,k,f\\
&\boldsymbol{C_6}: \quad \textstyle\sum_f \mu^i_{m,f}, P^i_{m,f} \le P^i_{max}, \sum_f \mu^v_{k,f}, P^v_{k,f} \le P^v_{max}\ , \forall m,k\\
&\boldsymbol{C_7}: \quad P^i_{m,f} \ge 0, P^v_{k,f} \ge 0, \quad \forall m,k,f
\end{aligned} \tag{3}$$

Where γ_0 is the minimal SINR necessary to build a reliable V2V link and p_0 represents the outage threshold. The maximum transmission power of the V2I and V2V transmitters is P^i_{max} and P^v_{max}, respectively. Constraint $\boldsymbol{C_2}$ indicates the V2V link's minimal reliability requirement, with the probability computed as a function of the mobile channel's random fast fading. Constraint $\boldsymbol{C_3}$ limits the distribution of orthogonal spectrum over V2I connections. $\boldsymbol{C_4}$ and $\boldsymbol{C_5}$ emulate the previously assumed ability of V2I and V2V to access multiple RBs. Constraints $\boldsymbol{C_6}$ and $\boldsymbol{C_7}$ ensure that the maximum power limit of V2I and V2V connections is not exceeded.

B. *Resource Allocation Algorithm*

The optimization problem of V2I channel capacity and V2V reliability is essentially a combinatorial problem. Aiming at this problem, a solution algorithm based on the GWO-CSA optimization is presented. On this basis, an improved algorithm with significantly improved performance is proposed, and resource allocation is carried out according to the corresponding algorithm.

The authors of [23] solved the sharing problem of a single RB by combining the bipartite graph with the Hungarian matching method. However, the bipartite graph only allows one edge to connect two vertices, which is not suitable for V2V links to multiplex multiple V2I links and connect to multiple RBs for secure message transmission, and it is difficult to achieve the performance of traversing the optimal combination. Therefore, this paper presents a resource allocation mechanism utilizing the GWO-CSA. First, V2V is clustered according to the interference situation to reduce interference and ensure communication reliability, and find a V2V set suitable for spectrum sharing. After the V2V cluster is clustered, the transmission power is optimized. Finally, resource allocation is carried out through GWO-CSA, and modeling is carried out based on 3-dimensional matching theory to find the optimal weight to ensure certain V2V communication reliability. Under the premise of achieving maximum V2I channel capacity.

1) *Power Allocation in V2V Links*

To optimize the dependability of V2V connections, the distribution of transmission power can be implemented in the subsequent manner:

$$P_i = \left(\frac{gamma_i}{\sum gamma_j}\right) * P_{total} \tag{4}$$

Where, P_i is the transmission power of V2V link i, $gamma_i$ is the channel gain of V2V link i, $\sum gamma_j$ is the sum of the channel gains of all V2V links, and P_{total} is the total available transmission power.

2) *Resource Allocation in V2I Links*

To achieve the maximum possible V2I link throughput, the allocation of resources can be based on the sum ergodic capacity of all V2I links. To solve this optimization problem, the following formulation can be used:

$$\begin{gathered}
\max \sum \log_2\left(1 \ + \ P_i * \frac{h_i}{N_i}\right)\\
subject\ to\colon \sum (P_i) \le P_{total}
\end{gathered} \tag{5}$$

Where, P_i is the transmission power of V2I link i, h_i is the channel gain of V2I link i, N_i is the noise power of V2I link i, and P_{total} is the total available transmission power.

Joint resource allocation in V2V and V2I links: To jointly allocate resources to V2V and V2I links, a multi-objective optimization problem can be formulated, which aims to maximize the overall system performance while satisfying the QoS requirements of all links. The optimization problem can be formulated as:

$$\begin{gathered}
\max \sum \log_2\left(1 \ + \ P_i * \frac{h_i}{N_i}\right) + w * \sum \rho_j\\
subject\ to\colon \sum (P_i) \le P_{total}
\end{gathered} \tag{6}$$

Where, P_i, h_i, N_i, and ρ_j are as defined above, w is a weight parameter that balances the trade-off between the V2I and V2V links, and P_{total} is the total available transmission power.

C. *Considerations Drawn from Previous Research Work*

The authors of [24] offered optimal resource allocation for maximum cumulative CUE capacity and minimum CUE capacity, as indicated in equations (7) and (8), respectively.

$$\max_{\substack{\{\rho_m,k\}\\ \{P^c_m\},\{P^d_k\}}} \sum_{m\in\mathcal{M}} \mathbb{E}\left[\log_2\left(1+\gamma^c_m\right)\right] \tag{7}$$

$$\max_{\substack{\{\rho_{m,k}\} \\ \{P_m^c\},\{P_k^d\}}} \min_{m \in \mathcal{M}} \mathbb{E}[\log_2(1+\gamma_m^c)] \tag{8}$$

Where, m is the number of CUE and $\mathcal{M}$ is symbolized for CUE set. γ is symbolized for decay exponent. P_m^c and P_k^d signify transmit powers of the m^{th} CUE and the k^{th} DUE, respectively [24].

We used the GWO-CSA method for optimal resource allocation in this paper, which outperforms the work of [24].

D. Fitness Function

The objective/fitness function judges whether each V2V cluster may be the optimal solution in the process of GWO-CSA optimization or is helpful to the search for the optimal solution. Define the fitness function $X(t)$, and use the GWO-CSA algorithm to optimize to find the corresponding t so that $X(t)$ is the largest. As mentioned above, V2V links are clustered, and the ultimate goal is to obtain the maximum capacity of V2I links, then the fitness function corresponds to the following formula:

$$X(t) = \sum_{m} \sum_{f} P_{m,f}^{i} \log_2\left(1+\gamma_{m,f}^{i}\right) \tag{9}$$

The problem of maximizing V2I capacity is transformed into finding t such that $X(t)$ is maximized.

E. Grey Wolf Optimization with Cuckoo Search Algorithm (GWO-CSA)

The GWO-CSA method was developed by updating the Grey Wolf Optimization (GWO) [25] algorithm and employing a population-based approach, cuckoo search algorithm (CSA). GWO is a metaheuristic algorithm derived on grey wolf hunting behaviours. To achieve a quicker convergence rate, the GWO location update in the GWO-CSA algorithm is adjusted to account for the CSA update equation. GWO-CSA successfully optimizes the fitness function for optimal resource allocation.

To update the position in the GWO-CSA method, the generalised equation of GWO is updated, and therefore an extra term is placed in the numerator, as shown in Equation (10) [26]:

$$\vec{G}(t+1) = \frac{\vec{G}_1 + \vec{G}_2 + \vec{G}_3 + \vec{G}_4}{4} \tag{10}$$

Where $\vec{G}_1, \vec{G}_2, \vec{G}_3$ symbolize the hunt agents based on the best hunt agent G_α, the second and third best hunt agents G_β and G_δ [27]. Where, $\vec{G}_4$ is the anticipated position vector using the CSA update method [27].

Cuckoo search is a metaheuristic method that is based on reproductive performance, i.e. breeding, and cuckoo flying distinctiveness. Each egg in the nest represents a solution that is swapped out for a better one. This activity is used to update locations in the proposed GWO-CSA algorithm, which is specified as follows:

$$\vec{G}_4 = \vec{G}_{\mathrm{t}} + \gamma \oplus Levy\ (\lambda) \tag{11}$$

Where $\vec{G}_{\mathrm{t}}$ symbolizes the position of agent in the presenter petition, and γ is the step size, which ranges from 0 to 1 and is multiplied by the input. The Levy flight equation, which produces an arbitrary walk, is stated as $Levy \sim v = (t - \lambda)$, where λ is a constraint with values in the interval $[1, 3]$. The inclusion of a fourth term ($\vec{G}_4$) in the proposed algorithm improves its effectiveness in exploring the Levy flight search space.

Pseudo Code for Cuckoo Search GWO

```
$Initialize\ Grey\ Wolf\ Population\ G_i = (i = 1,2, \ldots., n)$
$Assign\ parameters\ a, A\ and\ C$
$Calculate\ the\ fitness\ value\ of\ each\ agent$
$Find\ the\ values\ of\ G_\alpha, G_\beta\ and\ G_\delta$
$G_\alpha\ Agent\ with\ the\ best\ position\ in\ the\ population$
$G_\beta\ Agent\ with\ second\ best\ position\ in\ the\ population$
$G_\delta\ Agent\ with\ the\ third\ best\ position\ in\ the\ population$
$while\ (t <\ Maximum\ number\ of\ iterations)$
$for\ each\ agent$
  $Find\ the\ positions\ of\ the\ available\ search\ agents\ by\ Equation\ (11)$
  $update.$
$end\ for$
$Update\ parameters\ a, A\ and\ C$
$Calculate\ the\ fitness\ value\ of\ each\ agent$
$Calculate\ G_\alpha, G_\beta\ and\ G_\delta\ parameters$
$t\ =\ t + 1$
$end\ while$
$return\ G_\alpha$
```

4. Results and Discussion

This section contains simulation findings that verify the proposed GWO-CSA-based resource allocation approach for vehicular networks. The multi-lane road of a single region is represented in this work, with the BS located in the centre of the road, as shown in Fig. 1. The spatial Poisson process determines how vehicles land on the road, while vehicle density is dictated by vehicle speed. Select k V2V links and m V2I links at random from the developed vehicles.

TABLE I. SIMULATION PARAMETERS [5], [24]

Parameter	Value
Carrier frequency	2 GHz
Bandwidth	10 MHz
Cell radius	500 m
BS antenna height	25 m
BS antenna gain	8 dBi
BS receiver noise figure	5 dB
Distance between BS and highway	35 m

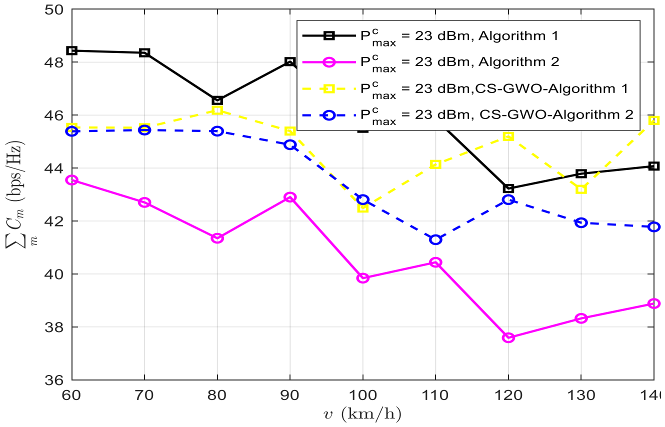

Fig. 2. Sum ergodic capacity of CUEs

The graph in Fig. 2 shows that as vehicle speed increases, the total V2I channel capacity decreases. This is likely because at higher speeds there is less traffic on the road, leading to less opportunity for communication between infrastructure and vehicles. To develop the reliability of the V2V connection in this scenario, the authors suggest increasing the V2V transmit power to counteract the higher route loss of the V2V signal channel. However, this approach also creates an additional interference from the V2V link towards the V2I link, which reduces the V2I link's channel capacity. To mitigate this interference, the authors may suggest limiting the maximum permitted transmission power of the V2I connection.

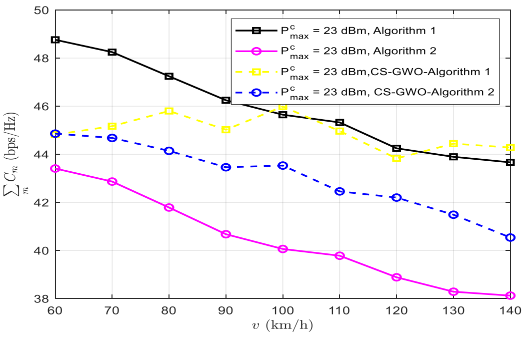

Fig. 3. Sum ergodic capacity of CUEs with channel number=2e2

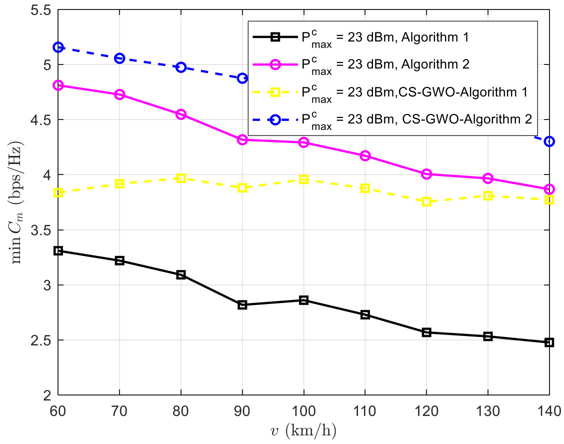

Fig. 4. Minimum ergodic capacity of CUEs with channel number=2e2

The results shown in Figures 3 and 4 show the effect of increasing vehicle speeds on the minimum and total ergodic capacities of all CUEs in the simulation scenario. The findings show that as vehicle speeds increase, both the minimum and total capacity decrease. This is due to minimal traffic, increasing vehicle distances, and less dependable V2V communications due to reduced received power. As a consequence, there's a decrease in disturbance from CUEs, which reduces the power allotted to them and, as a result, their capabilities.

Furthermore, the data show that Algorithm 1 has a greater overall ergodic capacity than Algorithm 2, whereas Algorithm 2 has a higher minimum ergodic capacity. This is because Algorithm 1 is meant to maximise overall capacity, but Algorithm 2 prioritises minimal capacity as its goal.

Fig. 3 demonstrates that when the maximum transmit power is increased, both algorithms experience a consistent effect on the sum capacity enactment of user equipment in relation to the rise in vehicle speed. Nonetheless, the same does not apply to the minimum capacity of user equipment, which is illustrated in Fig. 4. At low speeds, boosting the maximum transmit power by 6 dBm produces substantial benefits for both algorithms, resulting in a 40% rise at 60 km/h. However, at extremely high speeds, such as 140 km/h, the impact of increased power is limited, particularly for Algorithm 1.

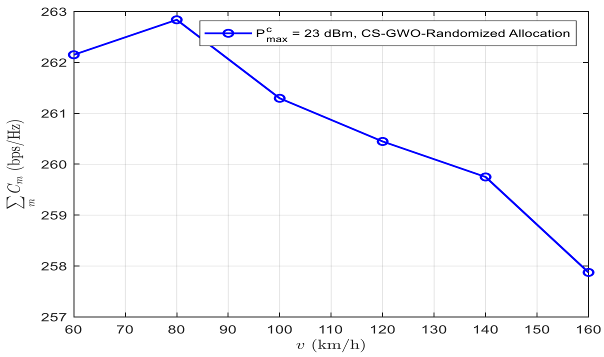

Fig. 5. Sum ergodic capacity of CUEs with channel number=2e2

The effect of adjusting vehicle speed on the total capacity of V2I communication was investigated using a randomised method, and the results are shown in Fig. 5. According to the data, when vehicle speed rises, the aggregate capacity of V2I decreases for both methods. This decline is due to decreasing highway traffic density, which needs an increase in V2V transmit power to maintain reliable V2V networks. As a result, the maximum allowable transmit power of V2I connections is limited, which leads to higher V2V link interference and lower capacity. For both methods, the drop in V2I sum capacity is nearly linear in relation to vehicle speed. The cumulative V2I capacity may be enhanced by raising the maximum transmit power of vehicular connections to 23 dBm, and this enhancement is equally spread across various vehicle speeds.

TABLE II. COMPARATIVE ANALYSIS OF PROPOSED WORK UNDER 100 CHANNEL NUMBERS AS AVERAGE CAPACITY

Speed	Algorithm 1[24] bps/hz	Algorithm 2[24] bps/hz	Randomized resource allocation [21]	Randomized GWO-CS Resource allocation[	Cs-GWO-Algorithm 1 bps/hz	Cs-GWO-Algorithm 2 bps/hz
70 km/h	48	42.8	110	263	45	45
100 km/h	45	40	105	262	46	43.9
120 km/h	44	39	95	260	44	42
140 km/h	43.7	38	80	259	44.3	40

The table II compares the speed performance of six different algorithms: Algorithm 1, Algorithm 2, Randomized resource allocation, Randomized GWO-CS resource allocation, Cs-GWO-Algorithm 1, and Cs-GWO-Algorithm 2. The speed is measured in bps/hz (bits per second per hertz) for different speeds: 70 km/h, 100 km/h, 120 km/h, and 140 km/h.

Here's an explanation of the results based on the table:

Algorithm 1: At 70 km/h, Algorithm 1 achieves a speed of 48 bps/hz. The speed decreases as the speed increases, reaching 43.7 bps/hz at 140 km/h.

Algorithm 2: Similarly, Algorithm 2 achieves a speed of 42.8 bps/hz at 70 km/h and decreases to 38 bps/hz at 140 km/h.

Randomized resource allocation: This algorithm achieves a high speed of 110 bps/hz at 70 km/h and gradually decreases to 80 bps/hz at 140 km/h.

Randomized GWO-CS resource allocation: This algorithm starts with a speed of 263 bps/hz at 70 km/h and decreases to 259 bps/hz at 140 km/h.

Cs-GWO-Algorithm 1: The Cs-GWO-Algorithm 1 maintains a relatively stable speed performance, with 45 bps/hz at 70 km/h and 44.3 bps/hz at 140 km/h.

Cs-GWO-Algorithm 2: Similar to Cs-GWO-Algorithm 1, this algorithm maintains consistent speed performance, with 45 bps/hz at 70 km/h and 40 bps/hz at 140 km/h.

From the results, it appears that the randomized resource allocation and randomized GWO-CS resource allocation initially have higher speeds but decrease as the speed increases. Algorithm 1 and Algorithm 2 also exhibit a decreasing trend in speed. On the other hand, the Cs-GWO algorithms (both Algorithm 1 and Algorithm 2) demonstrate more stable speed performance across different speeds.

TABLE III. COMPARATIVE ANALYSIS OF PROPOSED WORK UNDER 100 CHANNEL NUMBERS AS MINIMUM CAPACITY

Speed	Algorithm 1[24] bps/hz	Algorithm 2[24] bps/hz	Cs-GWO-Algorithm 1 bps/hz	Cs-GWO-Algorithm 2 bps/hz
70 km/h	3.4	4.8	3.9	5.3
100 km/h	2.9	4.2	3.9	4.8
120 km/h	2.6	4	3.9	4.6
140 km/h	2.5	3.9	3.8	4.3

Table III compares the speed performance of four different algorithms: Algorithm 1, Algorithm 2, Cs-GWO-Algorithm 1, and Cs-GWO-Algorithm 2. The speed is measured in bps/hz (bits per second per hertz) for different speeds, specifically 70 km/h, 100 km/h, 120 km/h, and 140 km/h.

Here's an explanation of the results based on the table:

Algorithm 1: At 70 km/h, Algorithm 1 achieves a speed of 3.4 bps/hz. As the speed increases, the algorithm's performance also improves, reaching 2.5 bps/hz at 140 km/h.

Algorithm 2: Similarly, Algorithm 2 achieves a speed of 4.8 bps/hz at 70 km/h and improves its performance to 3.9 bps/hz at 140 km/h.

Cs-GWO-Algorithm 1: The Cs-GWO-Algorithm 1 starts with a speed of 3.9 bps/hz at 70 km/h and maintains the same performance level at higher speeds, with 3.9 bps/hz at 140 km/h.

Cs-GWO-Algorithm 2: Cs-GWO-Algorithm 2 starts with a speed of 5.3 bps/hz at 70 km/h and decreases slightly to 4.3 bps/hz at 140 km/h.

From the results, it appears that Algorithm 2 initially has a higher speed than Algorithm 1 but both algorithms converge towards similar performance levels as the speed increases. The Cs-GWO algorithms (both Algorithm 1 and Algorithm 2) start with similar speeds and maintain their performance relatively consistent across different speeds.

5. Conclusion

The focus of this research is on resource allocation in D2D-based vehicular networks, where numerous V2V connections share the same spectrum as a single V2I link and the BS only can retrieve the slow-fading CSI of all vehicular links apart from those that terminated at the BS. To address this issue, the study utilizes the cuckoo search technique and grey wolf optimization algorithms to distribute V2V connections in such a manner that the overall and minimum ergodic capacity of V2I links is maximized while ensuring the dependability of all V2V links. In future research, we hope to decrease network signalling cost by designing a low-complexity randomized method that adjusts to all vehicular networks' slow fading CSI.

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