# Intimacy and Influence Based Scheduling Algorithm for Vehicle-to-Grid Network

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**Abstract:** The increasing number of Electric Vehicles (EVs) makes vehicle communication and vehicle charging linked together to form a part of the intelligent transportation system, which promotes the development of Vehicle-to-Grid (V2G) and Vehicular Ad Hoc Network (VANET). At the same time, the charging behavior of electric vehicles affects the energy distribution and storage of each charging pile. Scheduling technology plays an important role in the field of power and communication. The charging behavior is closely related to vehicle communication and will eventually affect vehicle scheduling. Therefore, analyzing the relationship between user charging and user communication is the basis of vehicle scheduling. In order to solve the problem, Intimacy and Influence based Connected Dominating Set Scheduling Algorithm (IICDSA) is proposed in this paper to adjust the charging behavior of users to realize vehicle scheduling: Firstly, V2G network model is constructed to describe the vehicle communication network, and then, Intimacy Measurement algorithm based on Relationship of Attribute (IMRA) is designed to analyze the relationship between users; secondly, Influence Walk algorithm based on the Intimacy between Users (IWIU) is designed to measure the user influence; at last, Connected Dominated Set Scheduling algorithm based on user Influence and user Location (CDSSIL) is designed to schedule users in groups. Furthermore, the simulation results show that the algorithm reduces the system scheduling cost and improves the utilization of charging pile.

**Key words:** Electric vehicle, vehicle-to-grid, VANET, CDS scheduling, intimacy, influence.

## 1. Introduction

With the expansion of the scale of EVs, vehicles' charging and communication behavior become more frequent, which makes vehicle charging technology and vehicle communication technology develop rapidly. The frequent charging of vehicles accelerates the consumption of electric energy and brings great instability to the power grid. In order to solve this problem, V2G technology using electric vehicle battery as the response load will play an important role in the future smart grid (SG) to enhance the energy stability of the grid [1], [2]. At the same time, the frequent information exchange between vehicles promotes the development of VANET [3], [4]. Therefore, V2G and VANET are combined to become a part of intelligent transportation system.

However, due to the security and the stability requirement the extensive deployment of V2G in power grid still has lots of technical problems to be solved, and the vehicle scheduling problem in V2G is the important research topic [5]. Reasonable dispatching strategy can effectively reduce the energy waste of power grid and maintain the stability of power grid. On the contrary, unreasonable dispatching strategy will lead to the instability of power system and endanger the security of the grid.

In vehicle charging activities, electric vehicles will understand charging information through communication network, so as to realize their own charging demand. Therefore, studying the relationship between information dissemination and vehicle scheduling, analyzing user charging demand and establishing information scheduling model is of great significance to the research of V2G scheduling. Location and social relations are closely linked in V2G scheduling. Therefore, location-based social network technology has become a solution. Location-based social network (LBSN) enables users to record and share their locations anytime and anywhere, which is a high quality information source [6].

In this paper, in order to regulate vehicle scheduling to maintain the stability of the system, Intimacy and Influence based Connected Dominating Set Scheduling Algorithm (IICDSA) is put in place to reduce dispatching cost and charging station utilization, and construct a system to regulate the collective scheduling behavior of users, which reduces the power cost of the system and improves the utilization of the charging station. In addition, users' influence measurement and vehicle scheduling strategy based on user connected dominating set are two important subproblems:

Question 1: How to measure the intimacy between users and the influence of users in the network? The intimate relationship between users and the influence of users will affect the charging behavior of users and ultimately affect the stability of the charging system.

Question 2: How to maximize the benefits of vehicle scheduling? Vehicle charging behavior will affect the service operation and system stability of each charging station. Bad scheduling strategy will greatly damage the stability of power system and the personal interests of users. It is necessary to design the vehicle scheduling strategy.

In order to answer the first question, an influence measurement algorithm with both attributes and density affinity is designed. For the second question, vehicle set scheduling strategy based on user connected dominating set is designed. Specifically, the contributions of this paper are summarized as follows:

1) Intimacy Measurement algorithm based on Relationship of Attribute (IMRA) is designed to analyze the relationship between users.
2) Influence Walk algorithm based on the Intimacy between Users (IWIU) is designed to measure the user influence.
3) Connected Dominated Set Scheduling algorithm based on user Influence and user Location (CDSSIL) is designed to schedule users in groups
4) Furthermore, simulation experiments show that the scheduling algorithm has better effect on reducing the total cost and improving the utilization of charging stations.

The remainder of this work is presented as follow. Related Work is presented in Section 2. In Section 3, Intimacy and Influence based Connected Dominating Set Scheduling Algorithm (IICDSA) is designed to construct the user scheduling set. The simulation experiment analysis is discussed in Section 4, and at last, the conclusion is given in Section 5.

## 2. Related Work

V2G scheduling can be divided into two aspects: one is the selection of charging and discharging time when the vehicle stops at the charging station according to factors such as electricity price, power grid supply and demand, the first kind of scheduling has rich research results. C. Chen et al propose an innovative RTP-based residential power scheduling scheme for smart grids [7], the result shows that the scheme can effectively save expenses for users. C. Wu proposes a scheduling strategy based on game theory to regulate the impact of charge discharge interaction between electric vehicles and charging stations on power grid frequency mediation [8]. The other is the selection of charging station according to factors such as distance and queuing time. P. Liu et al propose a joint route selection and charging/discharging decision algorithm to minimize the cost of all EVs in a vehicular energy network [9].

In the V2G communication network, the information of charging and discharging will be obtained by the users through social network. The information capacity of different users is different. Each user is both the receiver and the disseminator of information. In this paper, the maximum amount of information that users can bear and spread in the network is called influence [10]. The common method of influence maximization analysis is to analyze the structure of social networks [11]. Many researchers have studied the network structure of nodes and edges. Domingos and Richardson first propose the problem of impact maximization as an algorithmic problem for analyzing social network [12], [13]. Kempe et al. describe the influence maximization problem as a discrete optimization problem and proved it to be a NP-hard problem [14]. At the same time, In order to accurately quantify the influence of each node, some scholars propose the influence measurement algorithms, such as PageRank, LeadersRank and HITS [15]-[17]. However, the measure of the influence on the algorithm only depends on the relationship between each node, the user between potential information mining is too little, in terms of influence on measurement accuracy is not enough.

In summary, the characteristics of user social networks are studied, and the data characteristics in the network are extracted as the mining target of scheduling [18]. current algorithms ignore user social influence, and lack of sufficient mining of potential information in the network. Single attribute represents the characteristics of a user in a certain dimension, therefore, the attribute information hidden in the network, such as friend relationship and interaction frequency, will reflect the user's social ability and social influence to a certain extent. However, the traditional measurement algorithm ignores the relationship between user attributes and affinity density, and cannot accurately reflect the information transmission ability of nodes in the network. Therefore, it is of great significance to mine the influence of network attributes on node characteristics for the study of network diffusion mechanism.

## 3. Intimacy and Influence Based Connected Dominating Set Scheduling Algorithm (IICDSA)

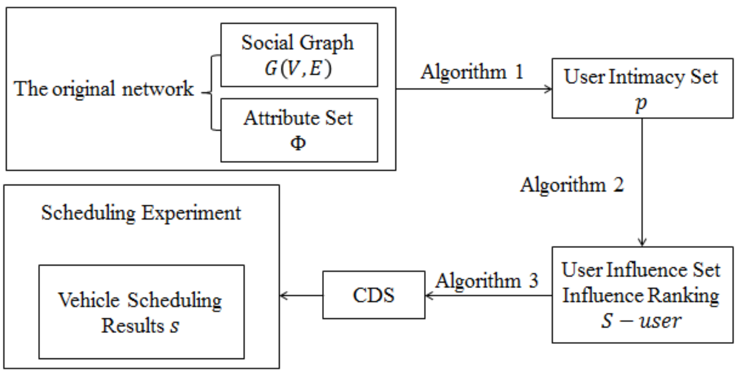



Fig. 1. The frame of the Intimacy and Influence based Connected Dominating Set Scheduling Algorithm (IICDSA): The IICDSA is mainly composed of 3 algorithms: Intimacy Measurement algorithm (Algorithm 1), Influence measurement algorithm (Algorithm 2), and Connected Dominated Set Scheduling algorithm (Algorithm 3).

In order to analyze the relationship between intimacy, influence and user communication in communication network, this part transforms the research of communication network into the research of graph model, and introduces the Intimacy and Influence based Connected Dominating Set Scheduling Algorithm (IICDSA). The proposed algorithm is composed of 3 algorithms: Intimacy Measurement algorithm based on Relationship of Attribute (IMRA) (Algorithm 1), Influence Walk algorithm based on the Intimacy between Users (IWIU) (Algorithm 2), and Connected Dominated Set Scheduling algorithm based on user Influence and user Location (CDSSIL) (Algorithm 3), at last, through cluster clustering, the system vehicle scheduling is realized. The algorithm flow chart is shown in Fig. 1.

## 3.1. Communication Network Modeling

The V2G communication network model is defined as Table 1.

Table 1. Social Network Definition

| SYMBOL | Description |
|---|---|
| $CN(V, E, \Psi)$ | V2G Communication Network |
| V | User set |
| E | Edge set<br>($e_{ij} = 1$, means the user $u_i$ and $u_j$ have social relationship) |
| $\lvert V\rvert$ | The total number of users |
| $\lvert E\rvert$ | The total number of edges |
| $\Psi$ | Attributes Set. (It represents a set of attributes $\varphi_i \in \Psi$) |

## 3.2. Intimacy Measurement Algorithm Based on Relationship of Attribute (IMRA)

In order to analyze the intimacy between friends, it is assumed that the probability of a user's influence on a single friend is related to the number of friends a user has, which is the idea of the Weight Cascade Model (WCM) [19]. Similarly, it can also be applied to the impact of attributes on users. The impact principles are as follows:

1) Single attribute represents the characteristics of a user in a certain dimension. For the relationship set of a single user, the more relationships with the same attribute, the smaller the impact of the attribute on the intimacy between users. At the same time, users with different attributes show different characteristics in this dimension. Therefore, classification calculation can be carried out. The intimacy of $u_i$ on its neighbor $u_j$ under the attribute $a_s$ can be calculated:

$$p_{i,j}^{a_s} = \begin{cases} \frac{1}{n_i} & ,\text{when } a_s^i = a_s^j \\ \frac{1}{d_i - n_i} & ,\text{when } a_s^i \neq a_s^j \end{cases} \tag{1}$$

In Eq.(1), the number of nodes with the same attribute as node $i$ denotes as $n_i$. The degree of node $i$ denotes as $d_i$.

2) It is assumed that the influence of each attribute on user intimacy is independent of each other. The intimacy between $u_i$ and $u_j$ under $n$ attributes will be calculated as follows:

$$p_{i,j} = \prod_{s=1}^{n} p_{i,j}^{a_s} \tag{2}$$

According to Eq.(1) and Eq.(2), the intimacy can be calculated as Algorithm 1.

**Algorithm 1: Intimacy Measurement algorithm based on Relationship of Attribute (IMRA)**

Input: The communication network $CN(V, E, \Psi)$, and the attribute set $a_s$ ($|s|$ represents the number of attributes).
Output: Closeness Set $p$
begin:
1: Initialize user intimacy set $p = 1$.

2: Calculate the number $(n_i)$ of $u_i$ with $a_s$, $\left(i \in (0,|V|)\right)$
3: Calculate the degree of nodes in network $d_i$, $\left(i \in (0,|V|)\right)$.
4: Calculate the intimacy between $u_i$ and $u_j$, $(i,j \in (0,|V|), and\ i \neq j)$
For $s = 0\ to\ m$ do
if $a_s^i == a_s^j\ (i,j \in [0,|V|)\ and\ i \neq j)\ \ do$
$p_{i,j} = p_{i,j} * \frac{1}{n_i}$
else do
$p_{i,j} = p_{i,j} * \frac{1}{d_i - n_i}$
End for
5: Return the user intimacy set $p$
end

### 3.3. Influence Walk Algorithm Based on the Intimacy between Users (IWIU)

Information spreads through the social relationship between users, so the intimacy between users will determine the influence of users. In this paper, the influence of each node can be calculated by the Influence Walk algorithm based on the Intimacy between Users (IWIU). The influence of each node can be calculated as follows:

$$inf^{t+1}(v) = c \cdot p \cdot inf^{t}(v) + (1-c)\frac{1}{N} \tag{3}$$

In Eq.(3), The importance of $u_v$ is expressed by $inf(v)$, $c$ represents the jump factor, and $p$ is user intimacy set, $N = |V|$. Each node sets the initial influence value as 1, (it means $inf^0(v)$) and it swims along the intimacy between nodes with the probability of $(1-c)$, and the probability of accessing other nodes is $c$, at the same time, $t$ represents the number of iterations.

**Algorithm 2: Influence Walk algorithm based on the Intimacy between Users (IWIU)**

Input: The user set $V$, attribute-based intimacy matrix $\vec{P}$
Output: User final influence set $s$.
begin:
1: Initialize the initial user influence $inf^0(i) = 1$, $\left(i \in (0,N)\right)$, initialize the number of iterations $t = 0$
2: Calculate the user influence set $inf^t(v)$
While($r > \delta$) do ($\delta$ represents the threshold)
$inf^{t+1}(v) = c \cdot p \cdot inf^t(v) + (1-c)\frac{1}{N}$
End while
3: Sort users by influence $S-user(1) \geq S-user(2) \geq \cdots S-user(N-1) \geq S-user(N)$
4: Return the sorted user set $S-user$
end

### 3.4. Connected Dominated Set Scheduling Algorithm Based on User Influence and User Location (CDSSIL)

The third part is to group users in V2G network. This section introduces Connected Dominated Set Scheduling algorithm based on user Influence and user Location (CDSSIL). The intimate relationship and location relationship between users will affect the charging behavior of users in V2G network. The weight between users is calculated as follows:

$$w_{ij} = \alpha p_{ij} + \beta / distance(i,j) \tag{4}$$

The weight between users represents the current comprehensive relationship of vehicles, then, the average of the user's weight is calculated as Eq.(5):

$$\overline{w_i} = \frac{\sum_{k=0}^{|N_i|} w_{ik}}{|N_i|} \tag{5}$$

The user's choice of charging station depends on the degree of trust between users. In this paper, the degree of trust between users is expressed by credibility $Trust$. The credibility $Trust$is defined as Eq.(6):

$$Trust_{ij} = \begin{cases} 0, when\ w_{ij} < \overline{w_i} \\ 1, when\ w_{ij} \geq \overline{w_i} \end{cases}, (i, j \in V) \tag{6}$$

When $Trust_{ij} = 0$, $u_i$ is trusted to $u_j$, otherwise both parties are not trusted. Then, the scheduling connected dominated set $CDS$ is constructed by the social relationship and the credibility between users. The Algorithm 3 is described as follows:

**Algorithm 3: Connected Dominated Set Scheduling algorithm based on user Influence and user Location (CDSSIL)**

Input: Communication Network $CN(V, E)$, User Intimacy Matrix $p_{ij}$, User Influence Set $Inf(i)$
Output: Connected Domination Set (CDS)
begin
1: Compute the user weight set.
   $w_{ij} = \alpha p_{ij} + \beta / distance(i, j)$
2: Compute the average of the weight.
   $\overline{w_i} = \frac{\sum_{k=0}^{V} w_{ik}}{V}$
3: Initialize the credibility between users $Trust_{ij} = 0$ , $(i, j \in [0, N))$.
4: Calculate the credibility set.
     for $i = 0$ $to$ $N$ do
       for $j = 0$ $to$ $N$ do
         if $p_{ij} \geq \overline{p_i}$ do $(Trust_{ij} = 1)$
         else $Trust_{ij} = 0$
     end for
   end for
5: Initialize $CDS = \emptyset$
6: Construct Connected Dominated Set (CDS)
   for $i = 0$ to $N$ do
     $k =$ Inf(i)
     for j=0 to $|V|$ do
         if $s_{ij} = 1$ do k.append(j)
     CDS.append(k)
   end for
   return CDS
end

The users are divided into different groups by Algorithm 3, and then the group center is calculated by K-means clustering, the distance between the center point and each charging station is measured, and the scheduling allocation is carried out according to the location and charging situation of each charging station.

## 4. Simulation Analysis

### 4.1. Simulation Experimental Settings

The experiment is implemented by Pycharm based on Python, which runs on the Windows 7 operating system with Intel(R) Core(TM) i3-7100U 2.50GHz and 8GB of RAM.

The focus of this paper is to verify the effectiveness of each scheduling algorithm, and the use of real road network will be very complex. In order to simplify the experimental environment and facilitate the simulation effect, the simulation scene used in this paper is a square area. The square side length is 100km, which is a network traffic topology composed of a grid with side length of 1km. Among them, the connecting line between each grid represents a passable Road, and its intersection can be distributed with charging stations or electric vehicles. Charging stations are set in the road network. Among them, the distribution rule of charging stations is to divide the road network into equal areas, and then take a random node in each area as the charging station. Electric vehicles are randomly distributed in the road network with a certain probability.

Some real networks are selected to simulate the V2G communication networks, such as Facebook network [20]. It includes interpersonal relationship between users and multiple attributes of each user. These networks are shown in Table 2. They have been repeatedly applied to influence analysis, privacy protection and user behavior prediction [21]. In this paper, nodes are used to represent the users participating in V2G, and edges represent social relationship. Two anonymous networks were selected, and 50 attributes were randomly selected from the network for experiments

Table 2. Dataset List

| SN | $\|V\|$ | $\|E\|$ | Number of Stations | Maximum number of charges |
|---|---|---|---|---|
| $N_1$ | 1045 | 53499 | 8 | 140 |
| $N_2$ | 755 | 60050 | 6 | 130 |

## 4.2. Experimental Evaluation

In order to test the experimental effect of the scheduling algorithm, this paper considers the scheduling evaluation of the algorithm from two aspects: the utilization efficiency of the charging station ($e_S$), the total cost of electric vehicles ($c_{EV}$) and charging success rate (δ). The simulation experiment compares Random Scheduling (RS), the Shortest Distance Scheduling (SDS) and IICDSA.

In this paper, the number of electric vehicles that can successfully obtain charging opportunities after the algorithm completes the electric vehicle scheduling is defined as $N_{charge}$, the charging success rate (δ) is calculated as follows:

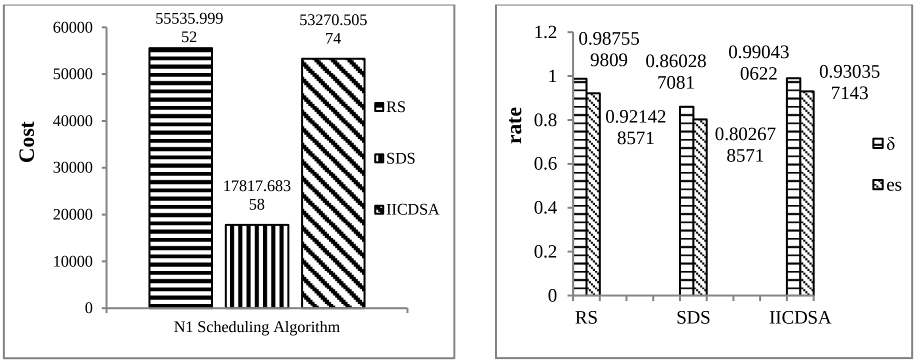
$$\delta = \frac{N_{charge}}{|V|} \tag{7}$$

At the same time, the number of charging points used is defined as $p_{charging}$, The total parking space of the charging station is $|P|$, the utilization efficiency of the charging station ($e_S$) is calculated as follows:

$$e_S = \frac{p_{charging}}{|P|} \tag{8}$$

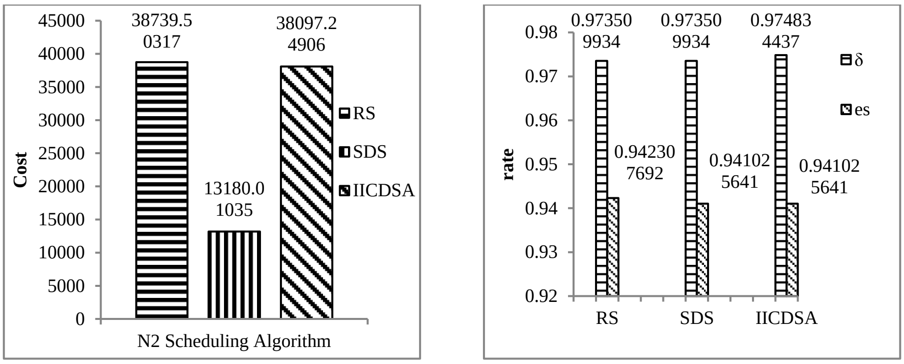
The scheduling experimental results of networks $N_1$ and $N_2$ are shown in Fig. 2 and Fig. 3. Fig. 2(a) and Fig. 3(a) show the cost of 3 scheduling algorithms in $N_1$ and $N_2$. Fig. 2(b) and Fig. 3(b) show the utilization efficiency of the charging station ($e_S$) and the charging success rate (δ) of the 3 scheduling algorithms in $N_1$ and $N_2$. Because of the randomness of RS algorithm, the cost of RS algorithm is the highest. SDS algorithm schedules vehicles according to the distance between the user and the charging station, so its cost is the least. However, because it only considers the distance between the vehicle and the station, it does not consider the actual situation of the charging station, therefore, the charging success rate (δ) and the utilization efficiency of the charging station ($e_S$) of SDS is much lower than RS and IICDSA.

In summary, IICDSA effectively reduces the overall loss cost of users, improves the utilization rate of charging station and user charging rate, and improves the utilization of charging system resources.




(a)Cost of scheduling algorithms (b)Utilization efficiency and the success rate

Fig. 2. The effect of scheduling experiment of the $N_1$




(a)Cost of scheduling algorithms (b)Utilization efficiency and the success rate

Fig. 3. The effect of scheduling experiment of the $N_2$

## 5. Conclusion

In this paper, in order to study the role of information in vehicle scheduling, the two emergent fields, V2G technology and VANET technology are combined to construct an information scheduling model. Based on the model of V2G and vehicle communication, Intimacy and Influence based Connected Dominating Set Scheduling Algorithm (IICDSA) is proposed to maximize charging system benefits by adjusting the user's location and intimacy and constructing the user connected dominating set. Firstly, Intimacy Measurement algorithm based on Relationship of Attribute (IMRA) is designed in V2G network through the relationship among attributes in Algorithm 1; secondly, Influence Walk algorithm based on the Intimacy between Users (IWIU) is used to analyze the Information dissemination of user in Algorithm 2; at last, Connected Dominated Set Scheduling algorithm based on user Influence and user Location (CDSSIL) is designed to group users and perform group scheduling. Simulation results have validated the performance of the proposed scheduling algorithm in terms of system cost and charging station utilization.

The algorithm in this paper explores the relationship between user social interaction and vehicle scheduling in V2G network, which is used to reduce the total cost of user system in charging system and improve the efficiency of the system. However, the scheduling model does not consider user services, such as user security. Therefore, in the follow-up work, we will consider the intelligent service problem of the scheduling model, how to improve users' satisfaction in the scheduling process and ensure users' privacy in the scheduling process.

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## Conflict of Interest

The authors declare no conflict of interest.

## Author Contributions

Jianyu Hu completed the experimental part and analyzed the data; Jing Zhang wrote the paper; Hongrui Nian guided the writing and checked the paper and experimental data. all authors had approved the final version.

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