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Multiple Attribute Decision Making Based Relay Vehicle Selection for Electric Vehicle Communication

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Abstract. Large-scale electric vehicle integration into power grid and charging randomly will cause serious impacts on the normal operation of power grid. Therefore, it is necessary to control the charging behavior of electric vehicle, while information transmission for electric vehicle is significant. Due to the highly mobile characteristics of vehicle, transferring information to power grid directly might be inaccessible. Relay vehicle (RV) can be used for supporting multi-hop connection between SV and power grid. This paper proposes a multiple attribute decision making (MADM)-based RV selection algorithm, which considers multiple attribute, including data transfer rate, delay, route duration. It takes the characteristics of electric vehicle communication into account, which can provide protection for the communication services of electric vehicle charging and discharging. Numerical results demonstrate that compared to previous algorithm, the proposed algorithm offer better performance in terms of throughput, transmission delay.

1 Introduction

As the energy crisis and environmental pollution becoming more and more se-rious, electric vehicles (EV) are used more widely as an important means to resolve the crisis [1]. However large-scale EV integration into power grid and charging randomly will cause serious impacts on the normal operation of power grid. Therefore, it is necessary to control the charging behavior of EV by communicating with power grid, obtaining the status, the battery remaining amount, location, speed and other information of EV can assist us to schedule their provisioning properly.

Information transmission network structure of electric vehicle accessing to power grid consist of on board unit(OBU), Road side unit(RSU), data processing center and Dispatch center. Vehicle manufactures have been equipped with navigation and infotainment equipment for the electric vehicle, and wireless technology to support vehicle to vehicle and vehicle to RSU communication which provided by, e.g. IEEE 802.11p, vehicle ad hoc network(VANET) [2]. VANET provide communications among nearby vehicles and nearby fixed roadside equipment [3]. And it has many own characteristics. VANET forms a dynamic topology due to the high speed of the vehicles and requires real time packet transfer; the node of VANET is regular in the sense because the vehicles move on the fixed roadways at high speeds; channel fading property; channel bandwidth limited severely. These characteristics pose various challenges in choosing optimal RV.

The problem of RV selection for VANET has been studied in previous literatures. In [4], a relay selection algorithm based on link stability use link duration (Link Expiration Time, LET) and route duration (Route Expiration Time, RET) to characterize the stability of link between vehicles. In [5], the authors propose a new RV selection algorithm which selects the minimum load RVs to result in the load balancing. In [6], based on the position of vehicles and IEEE 802.16j, the authors developed an analytical model for locating and selecting the optimal RV, which can get higher capacity. Reference [7] proposes a decentralized joint relay selection and power allocation algorithm for a wireless relay network based on coalitional Game theory. Reference [8] considers the various attributes of candidate RV, e.g. moving speed, the received signal strength (RSS), RET between SV and RV, and chooses the optimal relay based on the maximum weighted value.

In this paper, a RV selection based on multiple attribute decision making is proposed. The advantage of this decision making technique is that it considers multiple attribute, which can take many aspects of system into account such as data transmission rate and delay which characterize real-time, RET characterize the link stability.

The rest of this paper is organized as follows. The proposed scheme is presented in the Section 2. Multi-attribute decision is used to solve the optimization problem in Section 3. Numerical results are given in Section 4. Finally, we conclude the paper in Section 5.

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2 System model

In this section, the network model and channel model we consider in this paper are described.

2.1 Network model

In this paper, a VANET application scenario including of multiple SVs, multiple RVs, and one RSU is considered, as shown in Figure. 1. VANETs provide communication between OBUs in nearby vehicles, and between OBUs in vehicles and RSUs, which are fixed equipment located on the road. When SV is out of the communication range of RSU, RV is referred to as a particular type of vehicles which are capable of offering relaying functions to vehicles. For convenience, in this paper, we consider only two-hop connections from the SV to the RSU.

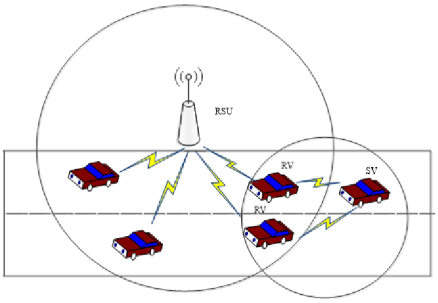

Figure 1. Network Model

2.2 Channel model

In this paper, considering the high speed mobility characteristic of EV, the communication channel in VANET is modeled as Nakagami fading channel with the channel characteristics h1 following the probability distribution function (pdf) [9]:

$$f(h_1)=\frac{2m^m}{\Omega(d)^m\Gamma(m)}h_1^{2m-1}\exp\left(-\frac{m}{\Omega(d)}h_1^2\right) \quad (1)$$

Where m is the Nakagami fading parameter ($m\geq 1/2$), and $\Gamma(\cdot)$ is the gamma function [10], $\Omega(d)$ denotes power loss due to transmission distance d, and can be expressed as [11]:

$$\Omega(d)=\frac{P_tG_tG_rh_t^2h_r^2}{d^\theta L} \quad (2)$$

Where P_t is the transmission power, G_t and G_r are antenna gains of the transmitter and receiver, respectively, h_t and h_r are the antenna heights of transmitter and receiver, respectively, θ is the path loss exponent, and L is the system loss.
The channel between SV and RV can be modeled as a cascaded Nakagami fading channel with the number of cascade being 2 and follow the channel pdf as [11]:

$$f(h_2)=\frac{2}{h_2\Gamma(m_1)\Gamma(m_2)}G_{0,2}^{2,0}\left[\frac{m_1m_2h_2^2}{\Omega_1\Omega_2}\Bigg|_{m_1,m_2}^{-}\right] \quad (3)$$

Where, $G_{0,2}^{2,0}$ is the Meijer G-function [10], $\Omega_l=E\left[h_l^2\right]$ and $m_l=\Omega_l^2/E((h_l-\Omega_l)^2)\geq 1/2, l=1,2$, The SNR can be calculated as $E(h^2)\frac{E_s}{N_0}$, where h is the gain of associated channel, E_s is the average transmission power, N_0 is the power of noise.

3 The RV Selection algorithm

In this section, a utility based RV selection algorithm is proposed for VANET.

3.1. Basic idea

In this paper, the proposed RV selection algorithm involve four steps: (1) SV receive the RSS, the available bandwidth and connection delay from RSU, and determine whether need RV; (2) when the SV cannot transfer the data to the RSU directly, SV will broadcast the information containing the user service requirements of bandwidth, delay and others, and request to obtain the available information of neighbor RV; (3) if the condition qualify the demand of SV, RV should send the information to SV which include location information, bandwidth, delay; (4) based on the information from RV, SV determine the candidate RVs; (5) finally, according to the multi attribute optimization RV selection algorithm, calculate the utility function of RVs and choose optimal RV.

3.2 Multiple attribute decision making (MADM)

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The relay selection function can be seen as an optimization problem, where the goal is to selection an optimal relay that guarantees information sent to RSU and maximizes the performance of system. The MADM model provides a solution to the problem of choosing an alternative from a finite set of options characterized in terms of their attributes. Multiple attribute decision making method mainly includes three steps: normalization method for attribute ratings, attribute weighting and comprehensive ranking scheme [12].

1. Normalization method for attribute ratings

Different units may be used for comparing attributes which cause computational problems. Therefore, optimal normalization techniques are necessary to perform inter-attribute and intra-attribute comparisons. Attributes can be divided into two types: benefit attributes and cost attributes [13]:

In this paper，the communication between EV and RSU need to provide high-bandwidth, low-latency messages, so ,we consider the factors which affect the performance of relay, such as data transmission rate, delay, the stability between SV and relay link .

- Normalization of data transmission rate

The data transmission rate between SV and RSU express as:

$$R_{S-RSU} = \min(\mathrm{R}_{S-i}, \mathrm{R}_{i-RSU}) \quad (4)$$

Where, R_{S-i} is the data transmission rate between SV and candidate RV, R_{i-RSU} is the data transmission rate between RV and RSU. And according to the Shannon equation, they can express as:

$$R_{S-i} = B^R \log_2\left(1+\gamma_{S-i}\right) \quad (5)$$

$$R_{i-RSU} = B^R \log_2\left(1+\gamma_{i-RSU}\right) \quad (6)$$

Where， γ_{S-i} and γ_{i-RSU} denote the signal to noise ratio(SNR) of link between the SV and the i th candidate RS, and from i th candidate RS to RSU, respectively.
Normalization data transmission rate express as：

$$l_{i1}^V = \frac{R_{S-RSU}}{\max(R_{S-i}, R_{i-RSU})} \quad (7)$$

- Normalization of delay

We assume there is two-hop connection from the SV to the RSU, so the connection delay for SV to access RSU equals the sum of the connection delays corresponding to each link. The normalized total connection delay can be expressed as:

$$l_{i2}^V = \bar{D}_{S,V_i} + \bar{D}_{V_i,R} \quad (8)$$

Where, $\bar{D}_{S,V_i}$ and $\bar{D}_{V_i,R}$ denote the normalized connection delay for the SV to access to the i th candidate RV, and for the i th candidate RV to access the RSU, respectively, and can be expressed as follows:

$$\bar{D}_{S,V_i} = \frac{D_{req}^{\max} - D_{S,V_i}}{D_{req}^{\max} - D_{req}^{\min}} \quad (9)$$

$$\bar{D}_{V_i,R} = \frac{D_{V_i,R}^{\max} - D_{V_i,R}}{D_{V_i,R}^{\max} - D_{V_i,R}^{\min}} \quad (10)$$

Where, D_{S,V_i} and $D_{V_i,R}$, denote the connection delay of the i th candidate RV and the RSU, respectively, $D_{V_i,R}^{\min}$, $D_{V_i,R}^{\max}$ define the minimum and maximum connection delay required for the RS to access to the infrastructure.

- Normalization of RET

In this paper, the link stability is characterized by the parameter of RET. At instant t , let (x_s, y_s) and (x_i, y_i) denote the position of SV and i th candidate RS, respectively, r denotes the maximum transmission range of the candidate RV. The LET of the link between SV and the i th candidate RV can be expressed as [14]:

$$LET_{S,V_i} = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2} \quad (11)$$

Where, $a = v_i\cos\theta_i - v_s\cos\theta_s$, $b = x_i - x_s$, $c = v_i\sin\theta_i - v_s\sin\theta_s$, $d = y_i - y_s$.

The LET between the i th RV and RSU can be calculated as:

$$LET_{V_i,R} = \frac{d_{V_i,R}\cos\theta_{V_i,R} + \sqrt{R_0^2 - d_{V_i,R}^2\sin^2\theta_{V_i,R}}}{v_i} \quad (12)$$

Where R_0 denotes the maximum wireless transmission range of RSU, $\theta_{V_i,R}$ denotes angle between the connection line of the i th RV and RSU and the moving direction of i th RV.

Hence, the RET of the route between SV and RSU can be expressed as:

$$RET_i = \min(LET_{S,V_i}, LET_{V_i,R}) \quad (13)$$

Normalization of RET can be expressed as:

$$l_{i3}^V = \frac{RET_i}{\max(RET_1, RET_2, \ldots, RET_N)} \quad (14)$$

2. Attribute Weighting

The attribute weight is used to reflect the relative importance of each attribute, the attribute more important, the greater the weight. In general, MADM model requires the weight information based in a basic scale. Basic weights are expressed by $\boldsymbol{\omega} = \left[\omega_1, \omega_2, \ldots, \omega_j, \ldots, \omega_n\right]$, where ω_j is the weight of j th attribute. Hence, basic weights are normalized to 1 expressed as $\sum_j \omega_j = 1$.

3. Scheme ranking comprehensive

Gather the decision information by some way, sort and select the optimal scheme. In this paper, simple additive weighting is used. So the utility function can be express as:

$$Q_i^V = w_B l_{i1}^V + w_D(1 - l_{i2}^V) + w_R l_{i3}^V \quad (15)$$

According to (16), the candidate RV with the highest Q_i^V should be chosen as the destination RV, namely:

$$i^* = \arg\max_i \left(Q_i^V\right), \quad i = 1, 2, \ldots, N \quad (16)$$

4 Numerical example

In the section, the performance of the proposed RV selection algorithm is evaluated in MATLAB, and compared with previous algorithm proposed in [4]. We consider a straight road of 1Km, where vehicles (source vehicles and RV vehicles) are located randomly and one RSU placed in the middle of road. The electric vehicles move along the road with the random velocity varied from 80 Km/h to 120Km/h. The number of total vehicles range from 20 to 60. We choose the number of SV and RV being 20 and 40, respectively.

Figure 2 shows the average throughput of all the vehicles versus the simulation time. It can be seen from the figure that the proposed scheme is superior to the maximum LET selection algorithm in average throughput. This is because the date transmission rate of candidate RV is chosen as an important factor for proposed algorithm, result a relatively higher throughput.

The transmission delay of various algorithms is given in Figure 3. It can be seen from the figure, the transmission delay increase with the increase of the number of vehicle. The reason is that the probability of collision and packet retransmission times increase for larger vehicle numbers. Compared with maximum LET algorithm, the proposed algorithm has lower average delay.

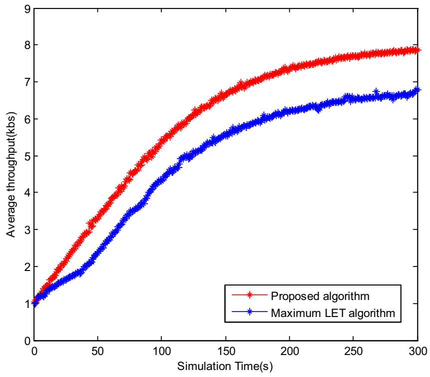

Figure 2 Average throughput

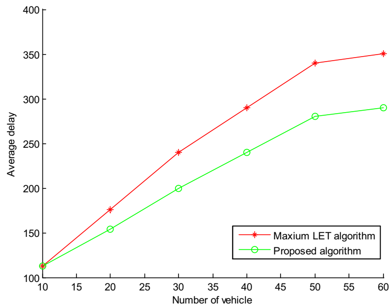

Figure 3 Average transmission delay

5 Conclusion

In this paper, a multiple attribute decision making theory based RV selection algorithm is proposed for the information transmission network electric vehicle to RSU. We choose three attributes: data transmission rate, delay, the stability between source vehicle and RSU via RV, and apply simple additive weighting method for evaluating the performance of available RSs. Simulation results demonstrate that the proposed scheme offers better average throughput and average delay of source vehicles.

Acknowledgment

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