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A Geographic Routing Protocol Based on Node Scoring and Intersection Evaluation

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Abstract: *VANET has a good application prospect in the current vehicle communication. As one of MANET, it has the characteristics of dynamic network topology and indirect connection, which makes the wireless connection between nodes unstable. Aiming at this problem, we propose a routing protocol combining link stability, node density and distance scale. When data packets are transmitted to the intersection, the optimal adjacent intersection is selected to determine the forwarding path, which improves the geographical forwarding of data packets located at the intersection. Through simulation, we find that the proposed geographic routing protocol based on node scoring and intersection evaluation (GRNSIE) has good routing performance in PDR and latency when compared with GPSR, GyTAR and GROOV.*

Keywords: *Ad hoc network, Vehicle communication, Link stability, Geographic routing*

1. Introduction

VANET is an indispensable part of modern transportation system [1]. It is mainly divided into two structures: V2V and V2I [2]. V2V can enable vehicles to exchange data packets with other vehicles in the vicinity and monitor real-time information from other vehicles. V2I can be used in applications that support Internet access. The communication system generally consists of three parts: on-board unit (OBU), roadside unit (RSU) and wireless communication protocol.

VANET has the characteristics of high mobility and indirect connection [3]. Frequent disconnection and rapid movement of vehicles will lead to unstable communication between vehicles. Using RSU deployment is a way to solve this problem. However, the cost of RSU deployment is high, and it is difficult to realize the full deployment of RSU in some urban and rural areas lacking fixed infrastructure [4].

The existing researches show that the traditional mobile ad hoc network protocols are ineffective when applied to vehicular network. For instance, some topology-based routing protocols include AODV [5], DSR [6], OLSR [7] and so on. Considering the rapid movement of vehicle nodes and the dynamic topology, these routing protocols are extremely unstable in the process of data routing.

With the continuous progress of positioning technology, geographical routing protocols have received significant attention in the dissemination of information [8]. Geographic routing protocols have gradually developed into the mainstream technology of VANET, which use local location information [9]. In geographic routing protocols, a node has a set of single-hop neighbor nodes, and they use different strategies to select the optimal forwarding node. In addition, because forwarding decisions are made dynamically, each node will select the best neighbor based on the topology at that time [10].

In this paper, GRNSIE protocol considering link stability, node density and distance scale is proposed. The protocol mainly has two phases :(1) when the vehicle carrying the data packet is located between two intersections, the optimal next hop transmission vehicle is selected; (2) when the vehicle arrives at the intersection with the data packet, the optimal adjacent intersection is selected through the intersection selection mechanism.

The rest of the paper is organized as follows. Section 2 presents an overview of the relevant geographic routing protocols. Section 3 describes the details of the proposed routing protocol. Section 4 compares different routing protocols through simulation. Section 5 summarizes the whole paper.

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2. Related works

GPSR [11] protocol consists of two ways of forwarding data packets. Greedy forwarding refers to always selecting the node closest to the destination among neighbors. When greedy forwarding encounters a routing void, it needs to use the right-hand rule to transmit the data packet to the next neighbor node through the perimeter mode, so as to solve the local optimal issue. Due to the unbalanced load, the void boundary nodes are under great pressure. As a result, the energy consumption of the nodes on the void boundary is faster and the hole becomes larger [12]. To solve the dynamic void problem, an algorithm [13] is proposed to update the processing method of the void boundary.

Geographic routing over VANETs (GROOV) [14] protocol considers different terrains and densities of expressways and cities. When the vehicle receives the beacon information from the intersection coordinator, it will switch to the prediction mode to predict the location of the neighbor node at the next moment. However, it is wrong to calculate the link quality through the average acceleration. The link quality between nodes depends on the relative speed rather than the acceleration. GyTAR [15] protocol dynamically selects intersections according to traffic density and distance to destination. When packets are transmitted between intersections, the node calculates the location of each neighbor using information such as speed and direction. Then the node will select the next hop neighbor based on the analysis. However, due to the uncertainty in future driving maneuvers, location prediction is a difficult task.

EGSR [16] protocol assumes that vehicles can obtain the geographic locations of its neighbors and destination. The path is determined by minimum weight using the weighted street map [17]. However, EGSR does not consider routing path expiration. GeoSVR [18] protocol proposes: optimal and restricted forwarding. The optimal forwarding method solves the problem of local optimization in sparse network by applying Dijkstra algorithm to find the path with the minimum weight. However, Dijkstra has the worst performance among large city maps because of the high computational complexity of finding connected paths in weighted whole graphs [19].

The routing protocols listed above are based on different routing metrics. However, these protocols have some problems that deserve improvement. GRNSIE calculates the link stability based on the relative speed between vehicles and combines link stability, node density and distance scale to select the optimal next-hop transmission node. This effectively reduces the possibility of link disconnection during data transmission and improves the packet delivery rate.

3. The proposed method

3.1. Forwarding Area

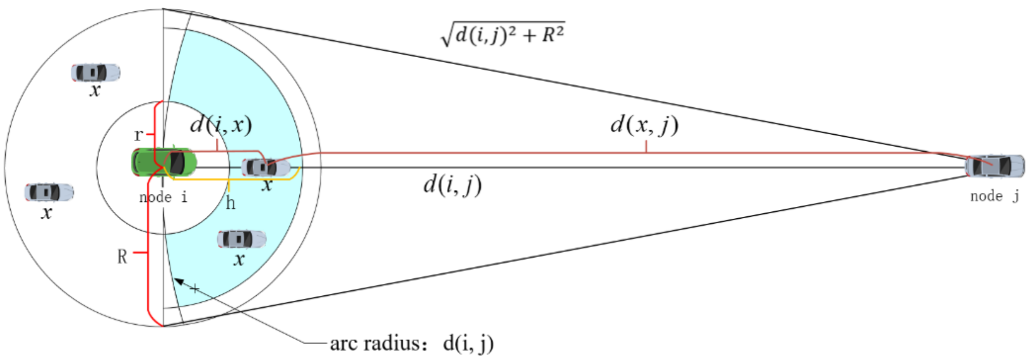

Figure 1: Forwarding area.

Figure 1 shows the schematic diagram of the forwarding area. The shaded part in the figure shows the forwarding area of the node i. Wherein, node i is the node currently carrying the data packet, and node j is destination. The maximum distance that nodes can keep connected is R. $d(i,j)$ represents the distance from i to j. And the neighbor node is denoted as x. $d(x,j)$ represents the distance from x to j.

When neighbor node x of node i meets the distance condition of the following formula (1), it indicates that node x is candidate node.

$$\begin{cases} r \le d(i,x) \le h \\ d(x,j) \le d(i,j) \end{cases} \tag{1}$$

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3.2. Routing Metrics between Intersections

The vehicle node carrying data packets will calculate Score values of nodes in current forwarding area and select the node with the highest Score value as next-hop node. The Score value considers three factors, namely link stability (S), node density (ND) and distance scale (DS). The three influencing factors are described below.

3.2.1. Link Stability (S)

Each vehicle node can obtain the speed of its neighbor nodes by periodically broadcasting beacon messages. The link stability is defined in terms of the speed v of the vehicle node. Assuming that the speed v of vehicle subjects to normal distribution, μ is the mean value of the speed and σ^2 is the variance of the speed, then the probability density function $f(v)$ corresponding to the vehicle speed v can be expressed as formula (2):

$$f(v) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(v-\mu)^2/2\sigma^2} \tag{2}$$

The probability distribution function $F(v)$ can be expressed as formula (3):

$$F(v \le v_0) = \frac{1}{\sigma\sqrt{2\pi}} \int_0^{v_0} e^{-(v-\mu)^2/2\sigma^2} dv \tag{3}$$

The probability distribution function of data communication in T time is formula (4):

$$F(T) = 2\int_0^{\frac{2R}{T}} f(\Delta v) d\Delta v \tag{4}$$

Take the derivative of $F(T)$ to compute $f(T)$ .The probability density function of data communication in T time is formula (5):

$$f(T) = \frac{4R}{T^2 \sigma_{\Delta v}\sqrt{2\pi}} e^{-(2R/T-\mu_{\Delta v})^2/2\sigma_{\Delta v}^2} \tag{5}$$

Among formula (5), R is the maximum wireless communication distance of the vehicle.Δv is the speed difference between the vehicle node C_1 currently carrying packet and the vehicle node C_2 in the forwarding area. $\mu_{\Delta v}$ is the mean value of the speed difference Δv. $\sigma_{\Delta v}^2$ is the variance of the speed difference Δv.

Assuming that vehicle nodes C_1 and C_2 communicate and the time that the two vehicle nodes can maintain the connection is denoted as t_{link}. The calculation of link stability S of vehicle node C_2 is shown in formula (6):

$$S = \int_0^{t_{link}} \frac{4R}{T^2 \sigma_{\Delta v}\sqrt{2\pi}} e^{-(2R/T-\mu_{\Delta v})^2/2\sigma_{\Delta v}^2} dT \tag{6}$$

3.2.2. Node Density (ND) and Distance Scale (DS)

$$ND = \frac{N_{neigh}}{N_{total}} \tag{7}$$

$$DS = \frac{\sqrt{(x_1-x_2)^2+(y_1-y_2)^2}}{R} \tag{8}$$

N_{neigh} indicates how many neighbors the candidate node has and N_{total} represents the total number of nodes. Then the node density is calculated as shown in formula (7).

DS represents the distance scale between the node currently carrying the packet and the candidate node. Note that the position of the node currently carrying the data packet is (x_1, y_1) and the position of the candidate node is (x_2, y_2). Then the distance scale between the two nodes is calculated as shown in formula (8).

3.2.3. Calculation of $Score$ Value

When the node currently carrying packet obtains information about speed and location from its neighbor, the node calculates $Score$ values of all neighbor nodes in its forwarding area, and the source node prefers to choose the neighbor with the maximum Score.

The calculation of $Score$ is shown in formula (9):

$$Score = S + ND + DS \tag{9}$$

3.3. Routing Metrics at Intersections

When the packet is transmitted to the intersection node, to select the next intersection, the node currently carrying data packets first finds the location of adjacent intersections through the street map, and then calculates the BJ value of each adjacent intersection. The intersection chosen by GRNSIE is the one with the highest BJ value. Data routing at intersections considers three factors, namely distance, direction and traffic flow.

3.3.1. Distance Factor (DT)

The distance factor between intersections is calculated as shown in formula (10):

$$DT = \begin{cases} log\frac{Dis_{(s,d)}}{Dis_{(j,d)}} & ,Dis_{(s,d)} \geq Dis_{(j,d)} \\ 0 & ,Dis_{(s,d)} < Dis_{(j,d)} \end{cases} \tag{10}$$

Where, $\mathrm{Dis}_{(s,d)}$ is the distance from the node currently carrying the packet to the destination, and $\mathrm{Dis}_{(j,d)}$ is the distance from the adjacent intersection to the destination.

3.3.2. Direction Factor (Dir)

In figure 2, the node V1 currently carrying data packets is located at the intersection J1, and the intersections adjacent to the intersection J1 are J2, J3, J4, and J5. The destination node is V2. Denote the direction between the current intersection and each adjacent intersection as $\overrightarrow{\mathrm{D_n}}$, and the transmission direction of the data packet as $\overrightarrow{\mathrm{D_p}}$.

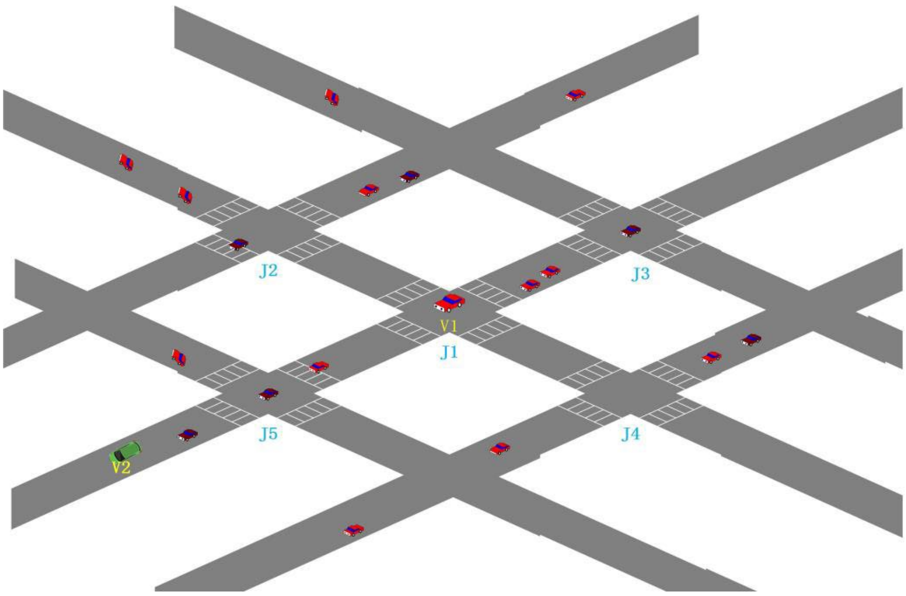

Figure 2: Adjacent intersections.

The calculation of direction factor is shown in formula (11):

$$Dir = \frac{\pi - arccos\left(\frac{\overrightarrow{D_n}\cdot\overrightarrow{D_p}}{|\overrightarrow{D_n}|\cdot|\overrightarrow{D_p}|}\right)}{\pi} \tag{11}$$

$\arccos\left(\frac{\overrightarrow{\mathrm{D_n}}\cdot\overrightarrow{\mathrm{D_p}}}{|\overrightarrow{\mathrm{D_n}}|\cdot|\overrightarrow{\mathrm{D_p}}|}\right)$ is the angle between the two directions. The quality of the transmission link is measured by calculating the included angle between $\overrightarrow{\mathrm{D_n}}$ and $\overrightarrow{\mathrm{D_p}}$.The interval of Dir is $[0,1]$.

3.3.3. Traffic Flow Factor ($Traffic$)

The calculation of traffic flow factor is shown in formula (12):

$$Traffic = \min\{\ N_{avg}/N_{con}\ ,1\ \} \tag{12}$$

Among formula (12), $\mathrm{N_{avg}}$ represents the number of vehicle nodes within a unit length on the road and $\mathrm{N_{con}}$ represents the degree of connectivity within the wireless transmission range of the vehicles.

3.3.4. Calculation of BJ Value

Based on the above analysis, the calculation of BJ is shown in formula (13):

$$BJ = DT + Dir + Traffic \tag{13}$$

When the packet is transmitted to the intersection, the node currently carrying the data packet will calculate the BJ value of the adjacent intersection, and the intersection with the largest BJ value will become the optimal intersection.

4. Simulation Results and Analysis

The experiment is simulated using NS3, and generates the motion trajectories of urban roads and vehicles through the traffic simulation software SUMO. The MAC (medium access control) layer protocol is IEEE802.11p and routing protocols included in the comparison include GPSR, GyTAR and GROOV. The simulation parameters of the model are shown in Table 1.

Table 1: Simulation Parameters.

Parameters	Value
Network simulator	NS3
Mobility model	SUMO-Krauss
Simulation area	1.5km×1.5km
Simulation time	300s
Vehicle velocity	0-90km/h
Transmission range	250m
MAC protocol	IEEE 802.11p
Data channel rate	6Mbps
Number of vehicles	50-250
Packet generation rate	4packets/s
Packet size	512bytes
Beacon interval	0.2s
Values (r; h)	(50;220)

4.1. Packet Delivery Ratio (PDR)

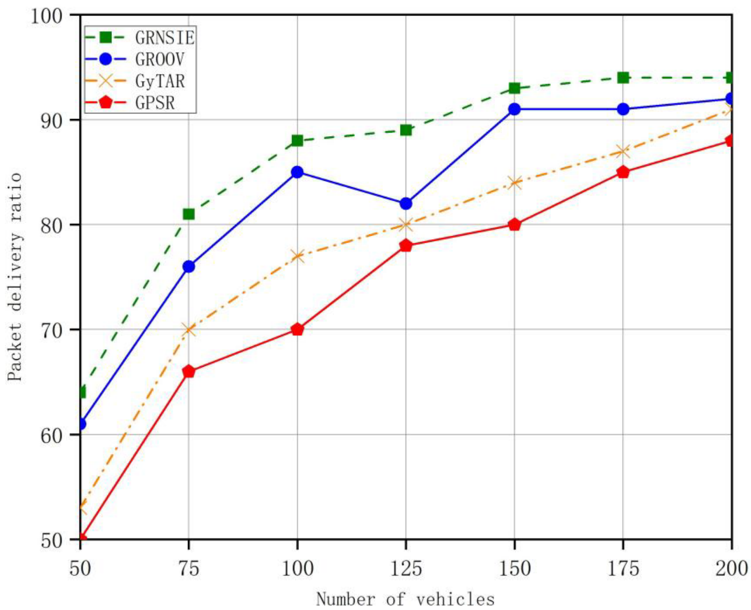

Figure 3: Changes of PDR with the number of vehicles.

Figure 3 shows that as the number of nodes increases, the PDR of each protocol will also increase, because the connectivity between nodes improves. GPSR protocol has the lowest PDR due to its greedy selection. The GROOV protocol calculates the feasibility of the node and PDR is improved compared to the GPSR protocol. However, the quality of the connection between two nodes depends on the relative

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speed between the nodes rather than the speed change rate, so its PDR is lower than the GRNSIE protocol proposed in this paper. The GyTAR protocol does not take link stability into consideration when selecting nodes, so the link stability is worse than the GRNSIE protocol.

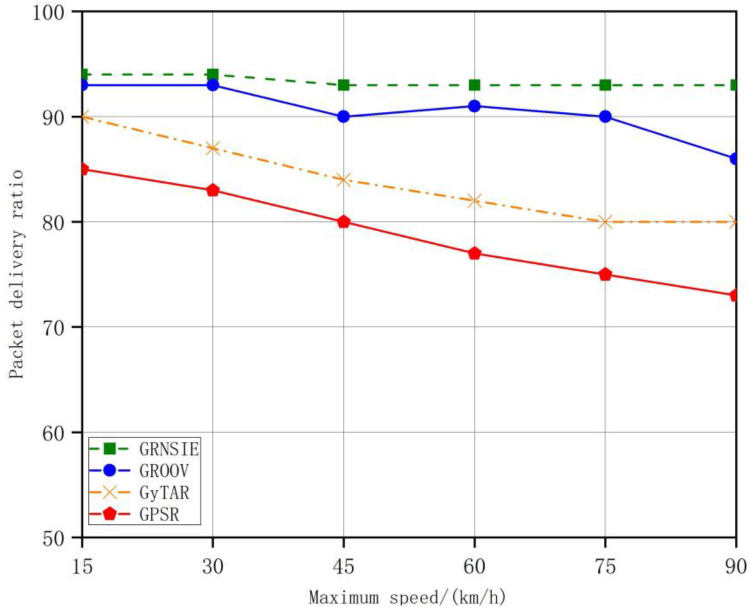

Figure 4: Changes of PDR with the maximum speed.

Keep the number of nodes in the network constant. In this experiment, the number of nodes is set to 150. As shown in the figure 4, GRNSIE protocol is least affected by increased vehicle speed, because GRNSIE protocol selects the optimal adjacent intersection to ensure the correctness of direction. The GROOV protocol also considers the connection quality, which is evaluated by the speed change rate of nodes. However, it incorrectly evaluates the connection quality. Since the GyTAR protocol does not consider the link stability, so its PDR decreases with the increase of the node speed.

4.2. Average End-to-End Delay (Latency)

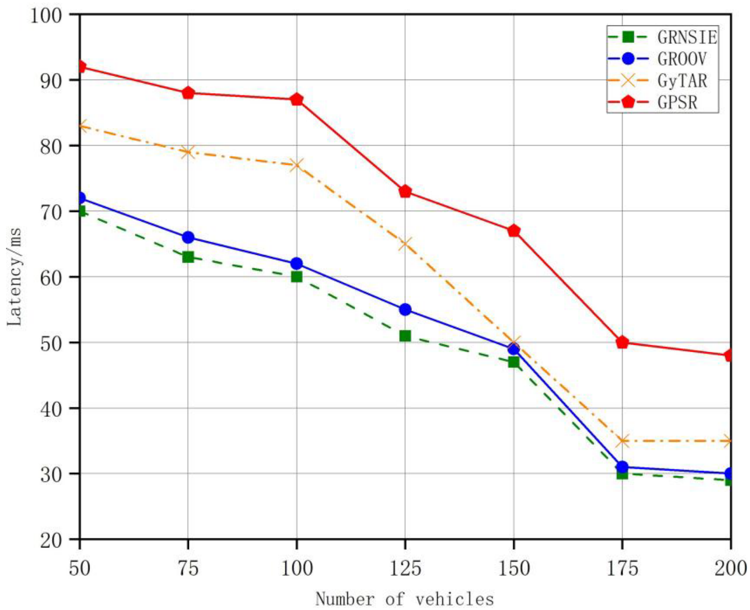

Figure 5: Changes of latency with the number of vehicles.

Figure 5 shows changes of latency with the number of vehicles. The GPSR protocol is a greedy algorithm and data packets are prone to detours, so latency of GPSR protocol is the largest among the four protocols. When the GROOV protocol calculates the direction factor, it does not consider the road form in the urban environment, which may cause misjudgment of the direction. The GyTAR protocol

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calculates the intersection score and selects the intersection with the highest score. In the case of high traffic density, some intersections may have forwarding conflicts, and latency will increase accordingly. The GRNSIE protocol considers the urban road form and reduces the possibility of packet detour forwarding by selecting the optimal next hop node and the optimal adjacent intersection. Therefore, latency is relatively small when the number of nodes is different.

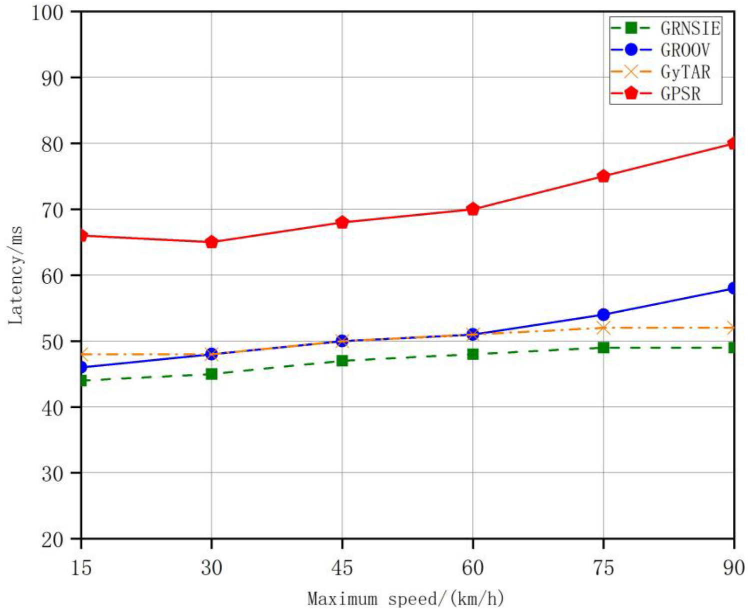

Figure 6: Changes of latency with the maximum speed.

Keep the number of nodes constant. The number of nodes is set to 150. As shown in the figure 6, with the increase of node speed, latency of each protocol increases. As the speed increases, the possibility of communication link disconnection increases, so the probability of packet detour forwarding increases. Therefore, latency increases. The GRNSIE protocol is least affected by the increase of node movement speed, because the link stability and node density are considered when GRNSIE calculates node Score. The GPSR protocol always selects the local optimal node, the local optimal route does not mean the global optimal route, and the detour of the data packet leads to an increase in latency.

5. Conclusions

We propose GRNSIE based on node scoring and intersection evaluation, which divides the delivery process of data packets into two cases: When the packet is transmitted between intersections, factors such as link stability, node density and distance scale are considered comprehensively in the forwarding area. When the packet arrives at the intersection, the adjacent intersections are evaluated by calculating BJ value, and the node between the current intersection and the intersection with the highest BJ value is finally selected as the next hop transmission node. Simulation results show that GRNSIE has higher PDR and lower latency. Since the GRNSIE protocol is based on VANET, the energy problem is not considered. In the future research, the energy consumption of routing protocol can be studied so that it can be applied to some energy-constrained MANET.

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