Early Warning Information Release Algorithm of Internet of Vehicles Based on AHP and Fuzzy Evaluation Model

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Abstract. The security problems caused by the intelligent vehicle network emerge in endlessly. However, the research on the information release of the existing vehicle network focuses on the release mode of the early warning information, without considering the importance division of the early warning information. Aiming at these problems, message queuing telemetry transport (mqtt) is introduced to transmit the network data of the Internet of vehicles, analytic hierarchy process (AHP) is introduced to divide the factors influencing the early warning information into levels, fuzzy evaluation model is introduced to evaluate the importance of the early warning information, and the design is adapted to the characteristics of the Internet of vehicles. Alert information publishing scheme. The experimental results show that the average arrival time of high-level emergency warning information divided by AHP and fuzzy evaluation model increases by nearly 50% with the number of warning information, and the proportion of high-level emergency warning information response within the threshold time is three times higher, which shows that the scheme plays an important role in the distribution of the Internet of vehicles warning information.

1. Introduction

With the rapid development of the Internet of vehicles, the endless security problems have caused people a considerable degree of trouble, and whether to obtain the corresponding early warning information in time has become a hot topic.

As the Internet of vehicles it is a relatively new interactive network, the research of its information release problem is also in the development stage. In recent years, scholars at home and abroad also put forward some solutions. Nagaosa et al. Proposed a land vehicle emergency early warning system, which can provide reliable special short-range communication by using the characteristics of digital broadcasting on the ground, and can be used for the earthquake emergency early warning of land vehicles in earthquake early warning [1]. On the basis of the above, Nishino et al. Also proposed a global navigation satellite system based information early warning system, through the speaker connected to the vehicle for information reception and transmission [2] and other different ways of information transmission. All of the above schemes are based on the interconnection of digital broadcasting and vehicle hardware to achieve early warning. The hardware infrastructure of the Internet of vehicles is complex, widely distributed, and the security cannot be guaranteed, which cannot adapt to large-scale Internet of vehicles early warning information release. Xinyang Yang [3] et al. Put forward a routing algorithm based on vehicle geographic location information to realize information distribution of Internet of vehicles based on IPv6. This scheme can effectively solve vehicle data transmission, solve network address translation (NAT) and other functions on road side unit (RSU), but also because RSU is widely distributed, it is unable to prevent from coming from The external physical intrusion, the security is not strong, and the early warning information transmission...
is based on IPv6 protocol, unable to adapt to the high-speed mobile Internet of vehicles network environment. Jiang Ma et al. Proposed a large-scale distributed subscription publishing system based on TCP/IP protocol network, which solved the problem of unstable publish subscription under many to many asynchronous communication [4], but still could not cope with the frequent link changes in the Internet of vehicles network. To sum up, the main disadvantages of the existing technology are as follows:

A. with the rapid movement of vehicles in the Internet of vehicles, the network topology changes rapidly and dynamically, and the link changes frequently. The network protocol is specially improved, which is different from the traditional Internet. The existing Internet of vehicles early warning information release strategy can not deal with the problems of high-speed link instability and rapid network topology change.

B. the content of warning information of the Internet of vehicles is diverse, and the attributes of different warning contents have different degrees of importance. The existing release strategy only improves the release efficiency of warning information, does not consider the importance discrimination of warning information, and the warning information of different degrees of importance needs to match with different release strategies. The traditional single information release strategy is difficult to meet the requirements.

According to the above analysis, we believe that users prefer to receive more important early warning information in the shortest time. Therefore, before the release of early warning information, it is necessary to determine the urgency of the early warning information. After determining the urgency of the early warning information, the early warning can be matched with the corresponding release strategy to achieve the rapid release of high emergency early warning information. In recent years, scholars at home and abroad have done a lot of research on information release strategies [5-11], but they have not combined with the characteristics of the Internet of vehicles network and need to be improved.

2. Internet of Vehicles Early Warning Information Release Scheme
In this paper, mqtt protocol is introduced as the transmission protocol of early warning information release according to the characteristics of the Internet of vehicles, such as diversity, real-time, fast topology change, and so on. At the same time, this paper introduces AHP and fuzzy evaluation model to solve the problem that there are many contents of warning information and the importance is difficult to be divided. AHP comprehensively divides the factors that affect the critical degree of warning information, obtains the relative weight among the factors, and establishes the evaluation index system. The fuzzy evaluation model is based on fuzzy mathematics, and passes the evaluation index system. The final evaluation results are obtained by overall analysis in a quantitative and qualitative way [15-18]. By setting the quality of service (QoS) level of mqtt protocol [19-20], the early warning information of different evaluation results can be matched with different QoS and publishing strategies to achieve the goal of rapid release of important early warning.

3. Early Warning Urgency Division Algorithm Based on AHP Fuzzy Evaluation
Step 1: the early warning information data released by the Internet of vehicles is uniformly formatted as "early warning information". The specific content is: threat level, vulnerability type, arrival time, and city. Use AHP to clarify the system structure, as shown in Figure 1.
The waiting time of early warning information can be obtained by calculating the difference between the arrival time and the current time. The indicators of early warning information can be divided into threat level indicators, vulnerability type indicators, waiting time indicators and city indicators. Under the first level indicators, the specific data affected can be divided into the second level indicators, and the comprehensive evaluation indicator system can be divided by using AHP.

Step 2: using AHP to calculate the weight coefficient of evaluation indexes, many evaluation indexes are divided into corresponding levels in the system structure. The hierarchy of evaluation index system is shown in Table 1.

**Figure 1.** Architecture of Internet of Vehicles Early Warning Information Distribution System

| symbol | Level          | meaning                        |
|--------|---------------|--------------------------------|
| A      | Target layer  | Specific objectives to be addressed |
| B      | Criterion layer | Multiple factors affecting the goal |
| C      | Index layer   | Final evaluation results       |

The comprehensive evaluation index of the Internet of vehicles early warning information release is composed of many factors. According to the mutual subordination, the final evaluation index level is shown in Table 2.
Table 2. Hierarchy and Meaning of the Evaluation Index System of the Internet of Vehicles Early Warning Information

| symbol | meaning                |
|--------|------------------------|
| A      | Emergency level        |
| B1     | Threat level           |
| B2     | Vulnerability types    |
| B1     | Waiting time           |
| B1     | City                   |
| C1     | Threat level L1        |
| C2     | Threat level L2        |
| C3     | Threat level L3        |
| C4     | Threat level L4        |
| C5     | Threat level L5        |
| C6     | Software vulnerabilities|
| C7     | Hardware vulnerabilities|
| C8     | Wait short time        |
| C9     | Wait medium time       |
| C10    | Wait long time         |
| C11    | First-tier cities      |
| C12    | Provincial capital cities|
| C13    | Other cities           |

Construct the judgment matrix, set the proportion of the evaluation index in the decision-making of this goal through the proportion scale table, and then establish the judgment matrix. The proportion scale table is shown in Table 3.

Table 3. Scale Table and Its Meaning

| scale | meaning                                      |
|-------|----------------------------------------------|
| 1     | The two factors are of the same importance   |
| 3     | The former is slightly more important than the latter |
| 5     | The former is obviously more important than the latter |
| 7     | The former is highly more important than the latter |
| 9     | The former is extremely more important than the latter |
| 2, 4, 6, 8 | Characterizing the intermediate value of the comparative grade between two factors |
| Reciprocal | If the importance ratio of factor i to factor j is $a_{ij}$, then the importance ratio of factor j to factor i is $a_{ji} = 1/a_{ij}$ |

According to a large number of experimental data, the scale method is used to compare the evaluation factors in pairs, and A-B judgment matrix is obtained, as shown in Table 4.

Table 4. Judgment Matrix of A-B

|     | A  | B1 | B2 | ... | Bn |
|-----|----|----|----|-----|----|
| A   |    | 1  |    | ... |    |
| B1  |    | 1  | $a_{12}$ | ... | $a_{1n}$ |
| B2  | $a_{21}$ | 1 | ... | ... | $a_{2n}$ |
| ... |    |    |    | ... | ... |
| Bn  | $a_{n1}$ | $a_{n2}$ | ... | ... | 1 |

Matrix factor $a_{ij} = B_i/B_j$ indicates the influence degree of factor $B_i$ and factor $B_j$ on $a$ in the evaluation index of influencing a layer. According to the judgment matrix A-B, the same level factors
are calculated through the calculation of the matrix column vector by the hierarchical single sorting algorithm. For the relative importance weight of the factors in the previous level, the algorithm is described as follows.

**Algorithm 1 Hierarchical Single Sorting Algorithm, HSSA**

Input: \( \psi_j \) A-B matrix is \( A \), matrix order \( n \)

Output: relative weight \( \tilde{w}_i \)

1. Sum matrix by row: \( w_i = \sum_{j=1}^{n} \frac{a_{ij}}{n} \)
2. Vector normalization: \( \tilde{w}_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \)
3. return \( \tilde{w}_i \)

The returned column vector \( \tilde{w}_i \) is the weight value of layer B under layer A. At the same time, in order to ensure that the weight meets the requirements, the comparison algorithm of average random consistency index is used to test the consistency of the judgment matrix. The selection of average random consistency index is shown in Table 5.

**Table 5. Matrix Scale Table and Its Corresponding RI Value**

| Matrix order | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|--------------|---|---|---|---|---|---|---|---|---|
| RI value     | 0 | 0 | 0.58 | 0.90 | 1.12 | 1.24 | 1.34 | 1.41 | 1.45 |

By calculating the maximum eigenvalue, the consistency index of the matrix is obtained. The corresponding RI value is selected from the matrix scale table, and the matrix consistency ratio \( CR \) is calculated. In general, through the comparison of \( CR \), when \( CR \leq 0.1 \), it is considered that the matrix inconsistency is within the allowable range, and the \( \tilde{w}_i \) calculated by the hierarchical single sorting algorithm can be used as the relative weight. The algorithm is described as follows.

**Algorithm 2 Consistency Checking Algorithm, CCA**

Input: A-B matrix is \( A \), matrix order \( n \), average random consistency index RI

Output: matrix consistency ratio \( CR \)

1. Maximum characteristic root: \( \lambda_{max} = \frac{(AW_i)_i}{\sum_{i=1}^{n} mw_i} \)
2. Consistency indicators: \( CI = \frac{\lambda_{max} - n}{n-1} \)
3. Matrix consistency ratio: \( CR = CI / RI \)
4. return \( CR \)

Step3: Calculate the evaluation matrix \( R \), select the semi trapezoid distribution function according to the statistical results to calculate the membership degree of evaluation factors to each evaluation level. Set the factor set \( U \) and comment set \( V \) of the fuzzy evaluation model. According to the structure of the early warning information, set the factor set that affects the early warning information of the publishing system as \( U = \{u_1, u_2, u_3, \ldots, u_n\} \), where \( u_i (i = 1,2,3,\ldots, n) \) is the evaluation index factor, \( n \) is the number of evaluation factors on the same criteria level. Set the comment set to three levels \( V = \{v_1, v_2, \ldots, v_m\} \) where \( v_j (j = 1,2,\ldots, m) \).

The membership function is used to calculate the membership degree to get the evaluation matrix \( R \). The algorithm is described as follows.
Algorithm 3 Fuzzy Comprehensive Evaluation Algorithm, FCEA

Input: evaluation factor set \( U \), comment set \( V \)
Output: fuzzy comprehensive evaluation set \( B_i \)

1. Degree of membership: \( r_j = \begin{cases} 1 - r_{j-1} & v_{j-1} < \mu_i \leq v_j \\ \frac{v_{j+1} - \mu_i}{v_j - v_{j+1}} & v_j < \mu_i < v_{j+1} \\ 0 & \mu_i \leq v_{j-1} \text{ or } \mu_i \geq v_{j+1} \end{cases} \)

2. Evaluation matrix: \( R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} \)

3. Fuzzy comprehensive evaluation set: \( B_i = w_i \cdot R_i \)

4. return \( B_i \)

The final evaluation results can be obtained through the numerical analysis of \( B_i \).

4. Strategy of Early Warning Release Based on Emergency Degree of Internet of Vehicles

Select the QoS level of the alert information. The QoS provided by mqtt protocol can set the quality of service for sending messages, as shown in Table 6.

Table 6. Message Service Quality Comparison Table

| QoS | meaning                      |
|-----|------------------------------|
| 0   | Message sent at most once    |
| 1   | Message sent at least once   |
| 2   | Message received only once   |

This scheme judges the urgency of the current alert information by evaluating the release of the current alert, which is recorded as \( P \). According to table 7, the QoS value of threat level \( L = \{L1, L2, L3, \ldots, Ln\} \) of different early warning information is set according to different degrees of emergency, \( n \) is the number of threat levels. Different urgency levels correspond to different release strategies, which are recorded as \( T \). The three evaluation levels of \( P \) correspond to the release strategy in Table 7 for early warning information release.

Table 7. Emergency Release Strategy Table of Internet of Vehicles Distribution Center

| Emergency level | QoS | Publishing strategy | T   |
|-----------------|-----|---------------------|-----|
| low             | 0   | Continue publishing | 0   |
| medium          | 1   | Send intermediate warning | 1   |
| high            | 2   | Send advanced warning and give priority to high emergency warning information | 2   |

5. Experimental Results and Analysis

Experimental study on the impact of the emergency degree of early warning information on the release of early warning information of the Internet of vehicles. The experimental evaluation standard is the number of high emergency early warning information received by the vehicle terminal. The experimental data comes from the network vehicle vulnerability database and part of the early warning information platform database. There are 100000, 1 million and 10 million vehicle early warning information data in the data set. Firstly, the data set is divided into low to high emergency data sets by using AHP and fuzzy evaluation model, which are recorded as \( C \), \( C = \{C1, C2, C3\} \). As shown in Experiment 1 in Figure 2, it can be seen from the experimental results that, with the increase of the total number of issued early warning information, the average response time of the high emergency
early warning information in the system model that has been evaluated and divided is far lower than that of the system center that has not been divided, when the number of early warning reaches ten million or even nearly 50% earlier.

![Figure 2](image1.png)

**Figure 2.** The Average Response Time of the Quantity of Early Warning Information to the Emergency Degree

As shown in Experiment 2 of Figure 3, it can be seen from the experimental results that at the same time length $t = \{t_1, t_2, t_3, ..., t_n\}$, the response ratio of high emergency warning information divided by the model is much higher than that of the undivided system center, and within the threshold time $t_5$, the former can respond completely, while the latter can respond less than 1/3.

![Figure 3](image2.png)

**Figure 3.** Response Ratio of High Emergency Early Warning Information

6. **Conclusion**

Aiming at the emergency degree of early warning information that is not considered in practice, this paper introduces the analytic hierarchy process (AHP) and fuzzy evaluation model, analyzes the factors that affect the early warning information of the Internet of vehicles by mathematical modeling, evaluates the early warning information in three layers, divides the emergency degree, and determines
its QoS and release strategy according to different emergency degree. Simulation experiments show that the strategy greatly reduces the average response time of high emergency.

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