

Study and Application for Data Access Control in IoT based on Analytic Hierarchy Process

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Abstract. With the increasing scale of Internet of Things, the problem of congestion is brought about in the process of data access and control, and the important data cannot be updated in time. In view of the above problems, the paper proposes the model of device attribute priority based on analytic hierarchy process. It quantifies the importance of each attribute, and the solution of the model in the smart home scene is given. Finally, the model is applied in the data access control of IoT. The result shows that the data packets can be received and processed in priority order, which alleviates the problem of congestion when large quantities of data are accessed, and also keeps important data being updated in time.

1. Introduction

With the scale of IoT is getting bulky, the amount of various types of devices is constantly increasing [1]. More redundant nodes are usually deployed for better coverage and data collection. The node is often in the state of oversampling^[2] in order to acquire more sampling data. This will not only bring about the problem of congestion, but also huge burden on resources such as connections and storage.

While the above conditions happen, the data can not be dropped simply and randomly, which may lead to parts of important data dropped and the real-time data loss. The data also can not be processed at random, which results in update-delay due to delaying the processing of important data. Thus, the importance of various types of device data should be quantified in order, and then the data can be processed in priority order.

The remainder of this paper is organized as follows: Section 2 introduces the related study for this research. Section 3 proposes the model of attribute priority based on AHP and the flow chart of algorithm is also given in this section. The solution of the model is taken as an example as shown in Section 4. Section 5 gives the implementation and application for the model. Then, concluding remarks are provided in Section 6.

2. Related Work

In view of the above problems, they have been studied at home and abroad. From the point of view of the security and reliability of data access, paper [3] considered the limitation of CPU of the device itself and storage of the database. The data were also received in the specified time period. It alleviated the problem of congestion to a certain extent, but could not receive important data selectively according to the actual situation. In paper [4], a method of device attribute selection using granular computing was given under the specific circumstances. Unfortunately, the constraint conditions considered were not complete and the model also could not be dynamically extended. In paper [5], the model of massive data security processing was given. It solved the problem of secure data storage, but issues of the concurrency and the congestion are not considered.

The paper proposes a general model of device attribute priority based on analytic hierarchy process. The priority of attributes can be solved according to different conditions in the specific scenario. It can also be applied to solve the problem of congestion when large amounts of data are accessed in the network.

3. Analytic Hierarchy Process Model

The devices are often in the state of oversampling, because various types of sensors constantly acquire the information and send them, which results in congestion and brings about the huge burden on resources such as connections and storage. Thus, based on different conditions, a general model should be built to quantify the importance of each type of sensor data and the corresponding priority can be solved according to it. Analytic hierarchy process^[6] can calculate the weight of each criteria according to different rules. Therefore, the model of the device attribute priority can be built based on AHP.

3.1 Device Attribute Priority Model

Different factors in different scenarios can affect the priority of each type of sensor data. Therefore, the corresponding model should be built according to different rules and the priority of each attribute should also be solved at last. The specific model is shown in Fig. 1 based on AHP.

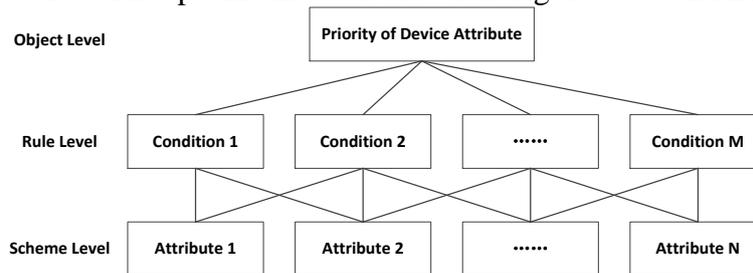


Fig. 1 Priority model of attributes

As shown in Fig. 1, the model is established with three levels including objects, rules and schemes. The level of objects is the priority queue of each device attribute. The level of rules lists the corresponding conditions according to different scenes and applications. Conditions are recorded as $Condition_1, Condition_2 \dots Condition_m$ separately. At the bottom, the level of schemes lists each attribute under the corresponding scenario and each attribute is recorded as $Attribute_1, Attribute_2 \dots Attribute_n$.

The importance of two elements compared is different in order to build a comparison matrix and determine the comprehensive weight coefficient. In the actual application scenario, there are usually many device attributes and criterions. If we compare them without any principle, this will not only increase workload, but also affect the accuracy of the result. Therefore, it's necessary to determine the general classification of the importance of each attribute and each criterion, which can unify the principle of comparison of attributes and criterions, reduce the workload in the construction process and ensure the accuracy of the priority.

The following three principles and one attention should be followed in the process of constructing matrix in the scheme level:

Principle One: The importance of the attribute involving the security aspect should be the highest, such as the smoke value detecting fire, because these values involve the safety of life and property and have the priority of being received.

Principle Two: The importance of the attribute requiring real-time should be secondary high, such as the infrared value in the door access system. The reason is that we should process the received data and response to the instruction in time to ensure the requirement of real-time, but it's less important than the attribute involving the security aspect.

Principle Three: The importance of other general attributes is the lowest, such as the humidity value detecting the room environment. These data are usually used to be saved and displayed.

Attention: In different scenes, the importance of the two attributes may be different and depends on the specific scene.

When the matrix is constructed in the rule level, the importance of each condition depends on the resources of software and hardware. For example, while the connection of the server is sufficient and other resources are insufficient, then, the importance of the resource of connection is the lowest.

The comparison matrix can be built through the above principles. Then the consistency decision must be made. After passing the test, the weight coefficients can be determined, which are separately

represented as $W_1, W_2 \dots W_n$. The corresponding matrix is denoted as $A = (a_{ij})_{n \times n}$. The solving steps are as follows:

Step One: Calculate $O_i = \sqrt[n]{\prod_{j=1}^n a_{ij}}, i, j = 1, 2, \dots, n$ with Matrix A by row.

Step Two: Normalize O_i using the expression of $W_i = \frac{O_i}{\sum_{i=1}^n O_i}, i = 1, 2, \dots, n$, in which

$\bar{W} = (W_1, W_2, \dots, W_n)^T$ is the characteristic vector of the matrix A .

Step Three: Calculate the maximum eigenvalue using $\lambda_{\max} = \sum_{i=1}^k \frac{(AW)_i}{nW_i}$, in which the parameter $(AW)_i$ represents the i th element of AW .

We can obtain the final expression of the device attribute priority through the coefficients. The expression is shown as (1).

$$Level_n = \left\lfloor \frac{W_n}{\min(W_1, W_2 \dots W_N)} + \frac{1}{2} \right\rfloor, n = 1, 2, \dots, N \tag{1}$$

where $\lfloor \cdot \rfloor$ means rounding down and $Level_1, Level_2 \dots Level_n$ are represented as the corresponding priority of each attribute.

Through the expression above, we can infer from it that the priority is higher when the proportion of comprehensive weight is occupied more. Thus, during the process of data access, data can be processed in priority order.

3.2 Algorithm Flow Chart

The weight of each attribute is quantified by AHP, and then the corresponding priority level is obtained according to the above expression. The specific flow chart is shown in Fig. 2.

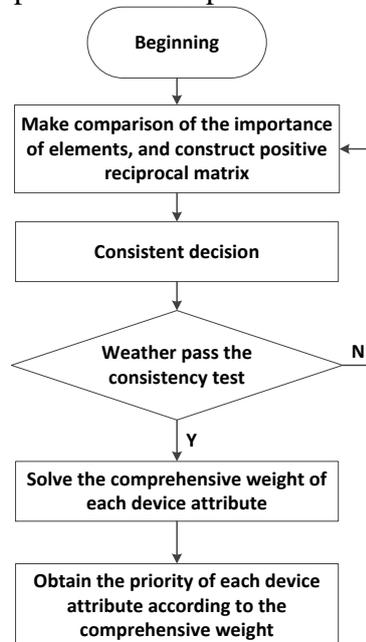


Fig. 2 The flow chart of solving the priority of each attribute

Fig. 2 shows the flow chart for solving the priority of each device attribute. Firstly, the importance of each device attribute and each criterion is compared, and the positive reciprocal matrices can be constructed according to it. Then, the consistency decision is made until the consistency judgement is passed. Finally, the comprehensive weight of each attribute can be calculated, and the priority can also be obtained according to the level expression.

4. Model Solving

In order to prove that the model can be applied to the actual scene of IoT, the scene of smart home [9] is selected as a typical application to solve the model. In this scenario, there are many types of sensors, such as temperature[10], light, smoke, infrared and PM2.5^[11], which can be selected as the five schemes in the scheme level. If there is dynamic expansion, the solution steps will be the same.

Because the devices in smart home are consisted of terminal nodes, gateways and the platform[12], the rules which can affect the priority will include physical channel resources, network performance resources, CPU resources, application connection resources and data storage resources[13]. Therefore, according to Fig. 1, the level model of this scene can be specified as shown in Fig. 3.

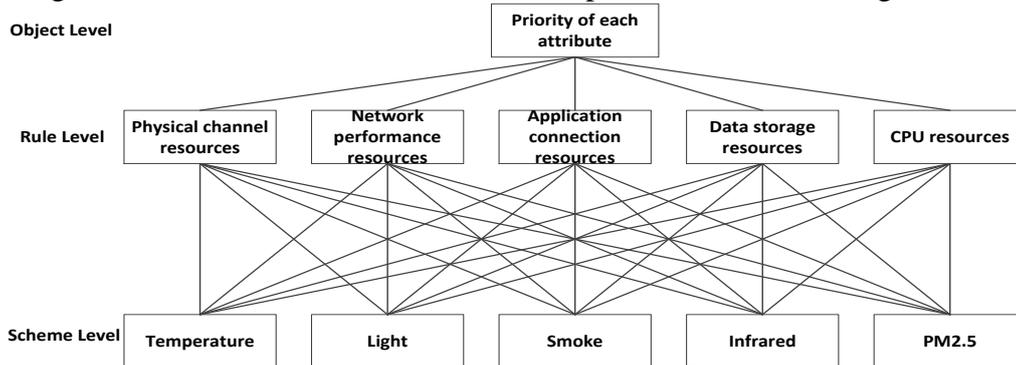


Fig. 3 The model of smart home scene

According to the above representation, the scheme level and the rule level from left to right can be recorded as $Attribute_1, Attribute_2 \dots Attribute_5$ and $Condition_1, Condition_2 \dots Condition_5$ respectively. Thus, six positive reciprocal matrices can be obtained through comparing the importance of each device attribute relative to each criterion and each criterion relative to the object, where the matrix of the attribute relative to the condition from left to right is recorded as $AC_i, i = 1, 2, \dots, 5$ and the matrix of the condition relative to the object is as CL . Here, the matrix AC_4 is taken as an example, and the rest will be similar to this solution.

The process of constructing the specific matrix AC_4 is given as follows: Since the smoke sensor is used to detect fire, which involves security, then, the importance of it will be the highest. The infrared sensor is applied in the door access system and needs the high demand of real-time, so the importance is secondary high according to principle two. The types of temperature, light and PM2.5 are used for detecting indoor environment, and the data are saved in the database for inquiries. For that, the importance is relatively low. According to the above principles and analysis, AC_4 can be constructed below:

$$AC_4 = \begin{pmatrix} 1 & 3 & 1/8 & 1/6 & 1/5 \\ 1/3 & 1 & 1/9 & 1/7 & 1/4 \\ 8 & 9 & 1 & 4 & 5 \\ 6 & 7 & 1/4 & 1 & 3 \\ 5 & 4 & 1/5 & 1/3 & 1 \end{pmatrix}$$

According to the above steps, we can obtain the largest eigenvalue $\lambda_{\max} = 5.4096$, consistency index $CI = 0.1024$, consistency ratio $CR = 0.0914 < 0.1$, which can pass the consistency test. The

normalized eigenvector is $W_4 = \begin{pmatrix} 0.0529 \\ 0.0330 \\ 0.5362 \\ 0.2451 \\ 0.1328 \end{pmatrix}$.

The solution of the remaining five matrices is similar to the above, and the results of them can be calculated respectively. The results are shown in Table 1.

Table 1. Results of the remaining five matrices

Matrix	λ_{\max}	CI	CR	Normalized eigenvectors
AC_1	5.3193	0.0798	$0.0713 < 0.1$	$W_1 = (0.0475 \ 0.0351 \ 0.5405 \ 0.2454 \ 0.1315)^T$
AC_2	5.3517	0.0879	$0.0785 < 0.1$	$W_2 = (0.0541 \ 0.0336 \ 0.5422 \ 0.2261 \ 0.1440)^T$
AC_3	5.2610	0.0653	$0.0583 < 0.1$	$W_3 = (0.0484 \ 0.0359 \ 0.5467 \ 0.2262 \ 0.1428)^T$
AC_5	5.3174	0.0794	$0.0708 < 0.1$	$W_5 = (0.0471 \ 0.0349 \ 0.5717 \ 0.2156 \ 0.1307)^T$
CL	5.2277	0.0569	$0.0508 < 0.1$	$W_6 = (0.0939 \ 0.0392 \ 0.0756 \ 0.5205 \ 0.2708)^T$

Through the above results, we can obtain the weight of temperature, light, smoke, infrared and PM2.5, respectively 0.0505, 0.0340, 0.5472, 0.2350, 0.1333. Then, the corresponding priority[14] obtained according to the calculation of the expression are 2,1,16,7,4 respectively. We can infer from the result that the order from high to low is smoke, infrared, PM2.5, temperature and light, which is consistent with the actual. Smoke sensors are used in fire warnings, which involves safety issue, and therefore have the highest priority. On the contrary, light sensors are dispensable at night, and have the lowest priority. Infrared sensors are generally used in access control systems requiring real-time^[15], and thus the priority is higher, but slightly lower than the warning level. PM2.5 and temperature are parameter values of the room environment, whereas PM2.5 is concerned with human health, and the priority of it is higher than the temperature.

5. Implementation and Application for the Model

At present, the data are not received and processed in the order of priority in IoT. They are handled only in accordance with the order of arrival, which is called general random mode. This will result in a low total data processing due to congestion and other factors, and also prevent important data from updating in time. In contrast, the priority mechanism can increase the total amount of data processing, and keep important data updating in time.

In the Eclipse[16] platform, a new HTTP Server[17] is created, and the priority order is written to the server. At the same time, the number of concurrent connections is reduced in order to simulate a congested scene[18]. Start the server, and send twenty thousand packets, including temperature, light, smoke, infrared and PM2.5. Finally, the statistical chart of the number of packets of each attribute received using the general random mode and the priority model respectively is obtained. The results are shown in Fig. 4.

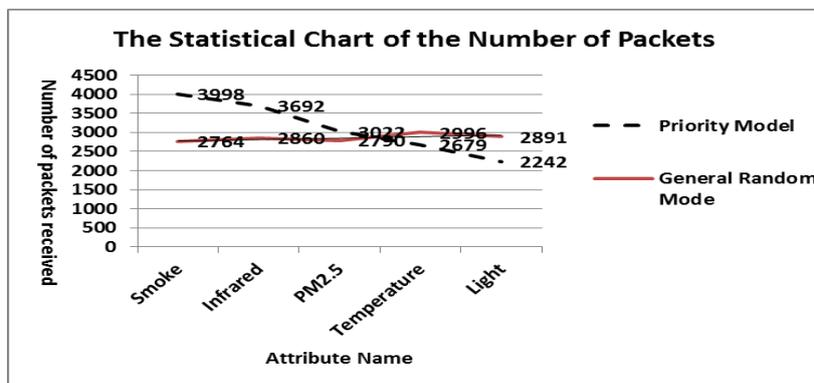


Fig. 4 The statistical chart of the number of packets

From Fig. 4, in the case of network congestion, the priority model can receive and process 15633 data packets and the general random mode can only handle 14301 packets. The total amount of packets

is increased by 9.3%, which alleviates the packet loss caused by congestion. The reason is that the data can be handled in priority order, and avoid data competition which results in packet loss.

If we compare two sets of data for each attribute, the number of smoke, infrared and PM2.5 packets is increased by 44.6%, 29.1% and 8.3% respectively compared with the general random mode, and the number of temperature and light is decreased by 10.6% and 22.4% respectively. This is because the hardware and software resources that process packets with lower priority are preferentially assigned to packets of higher priority and make important data update in time.

From the trend of each attribute, the number of packets received using the priority model is decremented in the order of priority, and the general random mode is more uniform to receive packets. The result shows that the priority mechanism can make important data processed first, which meets the requirements of practical application scenarios.

6. Conclusion

In IoT, nodes are often in the state of oversampling in order to achieve wide coverage and collect more data, which brings about huge burden on resources such as CPU and results in congestion. Therefore, the paper builds the model of the device attribute priority based on analytic hierarchy process. It quantifies the importance of each attribute and the solution of the priority of attributes in the smart home scene is given. According to the calculation, the order of five attributes is smoke, infrared, PM2.5, temperature and light.

Finally, it is applied to data access control of IoT. The result shows that the method can receive and process packets in priority order, which alleviates the congestion problem of large data access and guarantees the normal operation of the system. It also keeps important data being updated in time.

References

- [1] Farzad Samie. IoT Technologies for Embedded Computing: A Survey[C].Hardware/Software Codesign and System Synthesis,2016
- [2] Karimunnisa Begum,Sunanda Dixit. Industry WSN using IoT:A survey[C]. Electrical,Electronics, and Optimization Techniques(ICEEOT),2016:499-504
- [3] Se Won OH. Study on Access Permission Control for the Web of Things[C]. 17th International Conference on Advanced Communication Technology,2015:574-579
- [4] Yang Liu. Multiple/Cross-layered Access Management in Internet of Things[D]. Dalian University of Technology,2014
- [5] Guigang Zhang. Security Processing Model Research Based on Massive IoT Data[J]. Journal of Chinese Computer Systems,2013(09)
- [6] Jian An, Xiaolin Gui. A Crowdsourcing Assignment Model Based on Mobile Crowd Sensing in the Internet of Things[J]. IEEE Internet of Things Journal, 2015:358-369
- [7] Jiadong Wang. The Cycle Consistency Matrix Approach to Absorbing Sets in Separable Circulant-Based LDPC Codes[J]. IEEE Transactions on Information Theory,2013
- [8] Jibin Lan. Research on the Priorities of Fuzzy Analytical Hierarchy Process[J]. Systems Engineering -Theory & Practice, 2006(09)
- [9] Diqi Zhu. The Architecture Design and Implementation for IoT Gateway of Smart Home System[D]. School of Engineering Science University of Chinese Academy of Sciences,2015
- [10] Sunil Kumar Maddikatla. An Accurate All CMOS Temperature Sensor for IoT Applications [C]. IEEE Computer Society Annual Symposium,2016:249-354
- [11] Yang Xu. Internet of Things Based Information Support System for Multi-Agent Decision[J]. Journal of Software,2014(10)
- [12] Ke Xu. Toward Software Defined Smart Home[J].IEEE Communication Magazine, 2016: 116-122

- [13] Se Won OH. Decentralized Access Permission Control using Resource-oriented Architecture for the Web of Things[C]. 16th International Conference on Advanced Communication Technology, 2014:749-753
- [14] Shubha Rao V. Priority based optimal resource reservation mechanism in constrained Networks for IOT applications[C]. Wireless Communications, Signal Processing and Networking (WiSPNET), 2016:1228-1233
- [15] Haichuan Yang. Design and Implement of Security System in Smart Home Based on Internet of Things[D]. Shanghai Jiaotong University,2013
- [16] Marco Wagner. Introducing a Harmonized and Generic Cross-platform Interface between a Vehicle and the Cloud[C].IEEE 17th International Symposium,2016
- [17] Divyavani Palle. Design and Development of CC3200-based CloudIoT for Measuring Humidity and Temperature[C].Electrical,Electronics,and Optimization Techniques,2016
- [18] Meriam Bouzouita. On the risk of congestion collapse in heavily congested M2M networks[C]. Networks, Computers and Communications (ISNCC), 2016