Real-time information sharing model of product supply chain based on Internet of Things

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Abstract: In order to overcome the problems of poor information security and low sharing efficiency existing in the traditional product supply chain information real-time sharing model, this paper proposes a new product supply chain information real-time sharing model based on Internet of Things technology. Set the information double chain storage mode, calculate the data writing speed of the Internet of Things, determine the optimal block size of the product supply chain through the difficulty control algorithm, and optimise the anti tampering ability of the model to the information when there are attacks in the supply chain. Using the supply chain technology to establish the underlying peer-to-peer network, the dual chain storage of regional product information data sharing, building product information real-time sharing model. Experimental results show that compared with the traditional model, this model has higher security and sharing efficiency, and the sharing efficiency is always above 90%.

Keywords: Internet of Things technology; product supply chain; information real-time sharing; model building; tamper proof; difficulty control algorithm.

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1 Introduction

At present, there is a lack of information management in the operation of enterprises, and the actual demand information cannot be transmitted and shared in time (Ghouri and Mani, 2019; Peng et al., 2018). The speed of product supply not only determines the sales volume of products, but also has a key impact on the overall economic benefits of products. Supply chain sharing model can realise multi terminal sharing query of product logistics information, improve the effectiveness of product logistics query and the rationality of supply chain call. With the rapid development of computer technology today, relying on computer technology to study product supply chain sharing model can effectively improve the query speed of product supply information and the effectiveness of product logistics supply information, which is of great significance to promote the development of product supply technology.

Li et al. (2019) designed an integrated supply chain collaboration model based on knowledge sharing. Through the design of exchange service data interface, supply business layer and EAI integration unit, the basic module of the model is designed. The application of the model is completed through three steps: supply chain integrated processing, collaborative database building and data cycle process design. However, the model has the problem of weak data tamper resistance. Naher and Hashem (2019) use AngularJs and HTML technology to present a good visual access interface to users, uses spring MVC, maven, mybatis to complete the overall architecture of the project, and achieves permission control through redis and Shiro technology. Facing the supply chain, a logistics information real-time sharing model based on B/S with the characteristics of e-commerce is established. However, the practicability of the model is poor, and the probability of enterprise selection is small. Shiraishi et al. (2019) proposed a real-time information sharing model of product supply chain based on tamper proof defect measurement data. Through the application layer, data layer, contract layer, network layer, incentive layer and consensus layer of blockchain, the function of recording information, message verification and reaching node consensus is realised. According to the function of each structure layer, the steps of creating user group, member authentication public key transfer, user joining user group, anonymous authentication identity and transaction public key registration are taken to improve the integrity and security of defect measurement data and realise the real-time information sharing model of product supply chain. However, the implementation process of the model is complex, and it cannot be widely used.

In order to solve the problems of the traditional model, this paper constructs a product supply chain information real-time sharing model based on Internet of Things technology:

1 Clear product supply chain management related content, in order to better complete the supply chain information sharing.

2 Taking Internet/Intranet technology as the core, combined with the structure and function of Internet of Things, the double chain storage mode of information is set. Optimise the anti tampering ability of the model to the information when the supply chain has attack behaviour. By using supply chain technology, the product information of double chain storage area is shared, and the real-time sharing model of product information is constructed.

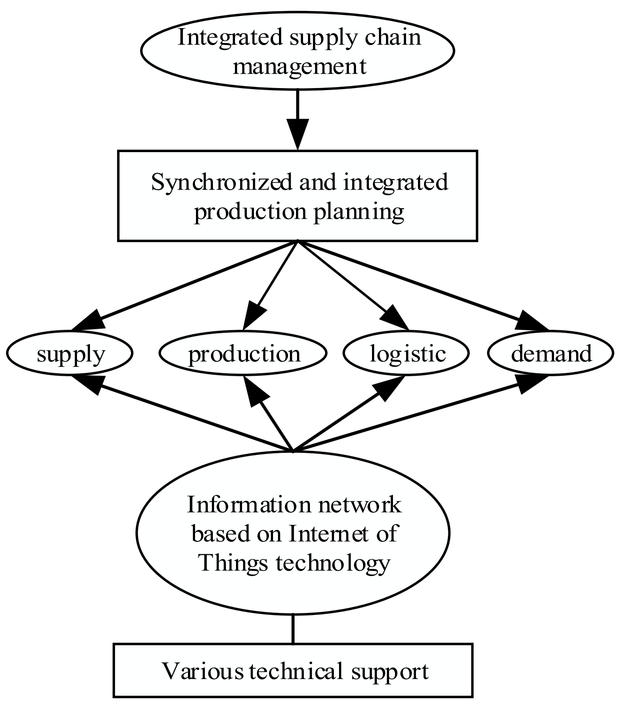
3 Experimental verification, taking the sharing information security and sharing efficiency as the experimental comparison index, the model in this paper is compared with the traditional model.

2 Construction of product supply chain information real time sharing model based on Internet of Things technology

2.1 Product supply chain management

The purpose of supply chain is to reduce the total operating cost and improve the service quality of enterprises (Zheng and Hu, 2019; Xiong et al., 2020). Figure 1 shows the content of product supply chain management.

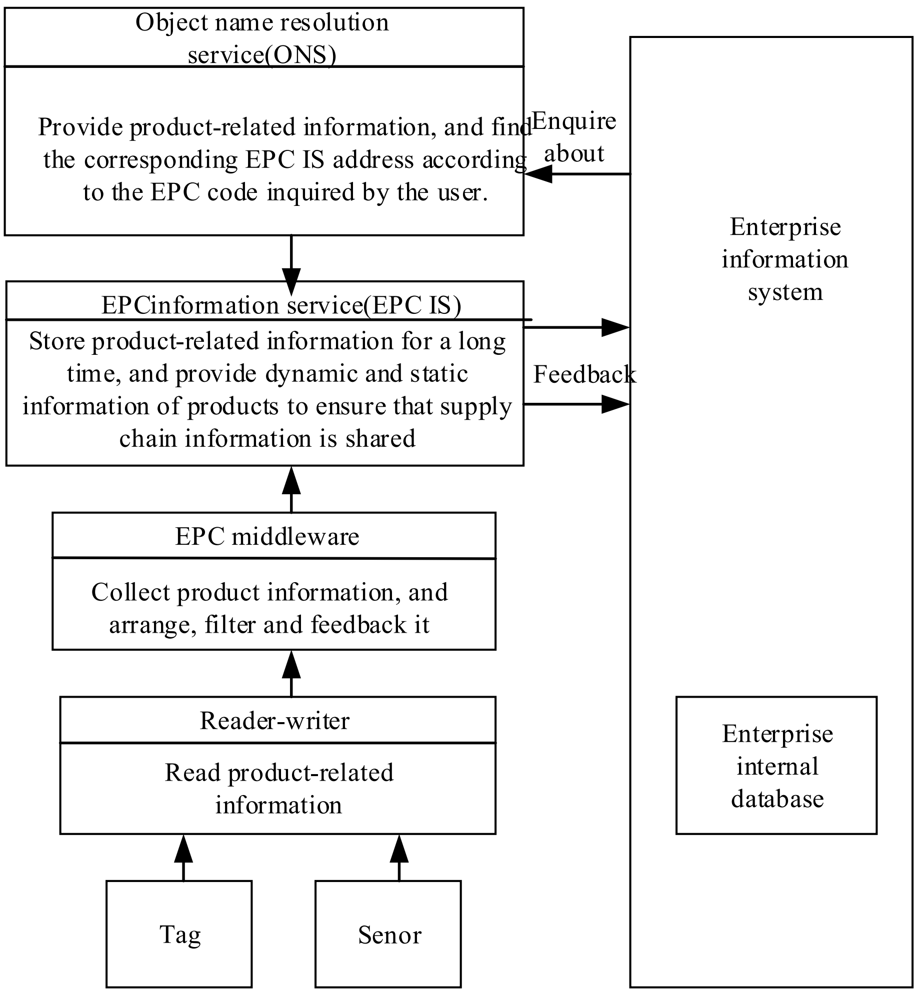
Figure 1 Content of product supply chain management



2.2 Structure and function of Internet of Things

RFID technology is the core part of the Internet of Things. The data information in the Internet of Things is collected in advance through RFID radio frequency technology, and then processed (Tsai et al., 2019). Figure 2 shows the structure and functions of Internet of Things.

Figure 2 Structure and function of Internet of Things



Based on the analysis results of the structure and function of the Internet of Things, the Internet of Things technology is used to set up the double chain storage mode of information, so as to improve the effectiveness of real-time information sharing.

2.3 Setting information double chain storage mode based on Internet of Things technology

In order to improve the security of information storage in the real-time information sharing model and ensure the effectiveness of information query and sharing, this paper uses the Internet of Things technology to set up a double chain storage mode in the sharing model. When the information in the network is extracted, the information is cached in the information extraction pool, waiting for new blocks to be generated. After a new information block is generated, the information is packaged from the extraction pool into the block according to the amount of information extracted and the query content, and the block information is verified by the integrated network (Rejeb et al., 2019). In the above data storage process, the generation speed and block capacity of new blocks determine the data writing speed of the Internet of Things:

$$v_t = \left(\frac{C_2 - C_1}{C_2} \right) \times |t_1 - t_2| \tag{1}$$

In formula (1): v_t represents the speed of data written by the Internet of Things; t_1 is the actual block time; t_2 is the target block time; C_1 is the capacity of the new block; C_2 represents the capacity required for actual information. Where $|t_1 - t_2|$ is the network time delay. According to formula (1), the actual block generation time is affected by the target block generation time and the network time delay, so it is necessary to determine the optimal block size. This paper uses the difficulty control algorithm to determine the optimal block size, the process is as follows:

$$D = C_2 \times \left(\frac{d_{i+1} - d_i}{k_1} \times \max\left(1 - \frac{T - T'}{v_t} - k_2 \right) \right) \tag{2}$$

In formula (2): D is the optimal block size; d_{i+1} is the data mining difficulty of the next block; d_i represents the data mining difficulty of the current block; T and T' respectively represent the block generation time of the current block and the next block; k_1 and k_2 represent two specific constant values. When d_{i+1} is smaller, it proves that the difficulty of data mining is lower and the time for generating new blocks is shorter. On this basis, in order to ensure the security of the shared model, the computing power of the model for information when there is an attack in the model is calculated according to the stale rate, the process is as follows:

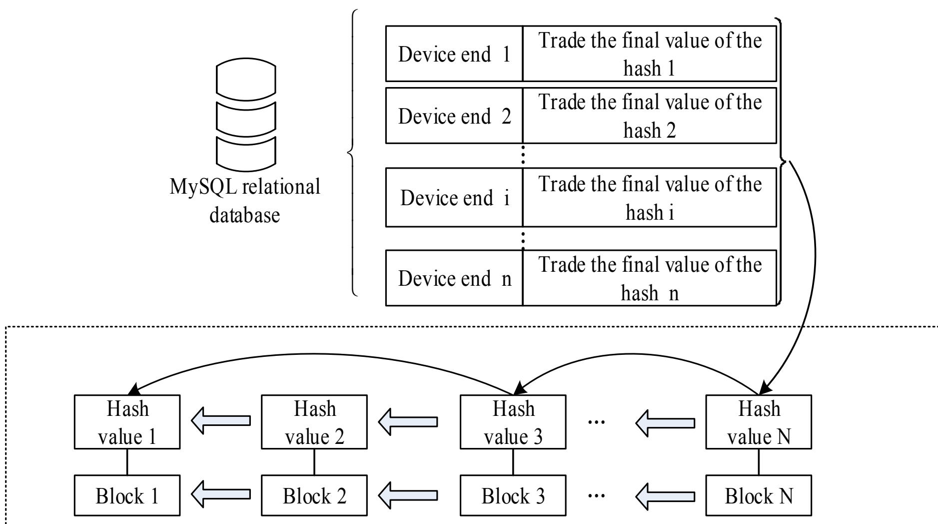
$$\begin{cases} \beta = \left(\dfrac{v_t}{|t_1 - t_2|} \right)^3 \\ \varphi = \dfrac{(1-\beta) \times D}{\beta^2} \end{cases} \tag{3}$$

In formula (3): β represents the obsolescence rate of the Internet of Things; φ represents the computing power of the model for information when there is an attack.

Since the attack program needs to master more than 50% of the entire network computing power in order to break the effective data in the model's defensive tampering area product information, this article reduces the network delay time to a certain extent and improves the data read and write speed. Establish a double-chain storage method (Angeles, 2019).

In the double chain storage mode, MySQL relational database is used to store the product information on the chain, query the hash value, and save the hash value at any time (Abdel-Basset et al., 2018; Savari et al., 2020; Bensaali et al., 2018). After the parent hash value is added to the data, all the corresponding data can be found under the condition that only the corresponding address of the last data is known, and the possibility that the model is tampered with or destroyed can be reduced (Zhang et al., 2018). The double chain storage structure is shown in Figure 3.

Figure 3 Schematic diagram of double chain storage structure



In the double chain storage structure designed in this paper, each block contains the data information in the previous block, so as to form a chain storage structure. The last transaction hash in the storage structure is used as the parent hash next time new data is written. In this way, the parent hash can be obtained from each hash value, and all hash values can be found forward layer by layer. The process is as follows:

$$S_i = \begin{cases} f\left(S_i, h_{i-1}\right), if \quad i > 0 \\ S_i \quad , if \quad i = 0 \end{cases} \tag{4}$$

In formula (4): S_i represents the stored product information i; h_{i-1} represents the previous hash value corresponding to S_i (Ray et al., 2019); $f(\cdot)$ represents encapsulation to generate new data.

Input information in the storage centre, the message belongs to the corresponding access structure, and calculate the corresponding hash value:

$$h = H\left(u_1 \| \cdots \| u_n\right) \tag{5}$$

On the basis of the above analysis, $r \in Z_q$ is randomly selected, and the private key of the corresponding user can be formed through the following formula calculation:

$$SK_u = \begin{cases} \{SK_1, SK_2\} \\ h\left(\prod_{i/[1,m]} g^{t_{i,j}}\right), g^r \end{cases} \tag{6}$$

On the basis of the above operation, if $r \in Z_q$ is selected randomly, there are:

$$C_1 = \begin{cases} SK_u \\ \{SK_1, SK_2\} \end{cases} \tag{7}$$

Then the output ciphertext can be expressed in the following form:

$$C = \{S, S_1, S_2, S_3\} \tag{8}$$

Input ciphertext $C = \{S, S_1, S_2, S_3\}$ and *C*, and calculate output plaintext data f as follows:

$$M = \frac{C_1 \cdot e(C_3, SK_2)}{e(C_2, SK_1)} \tag{9}$$

The ciphertext *C* and the decryption key SK_U can be expressed in the following forms:

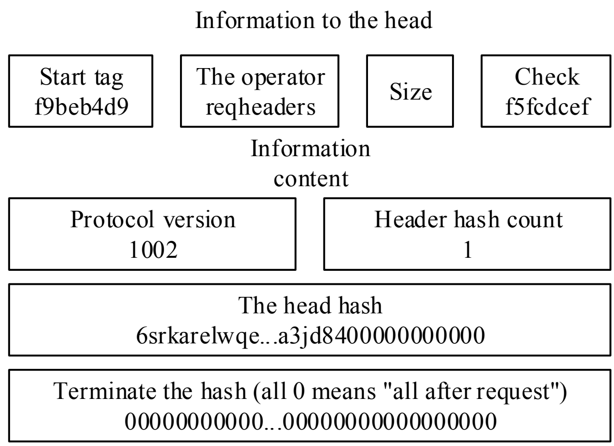
$$C = \left\{ S, C_1 = M \cdot Y^s, C_2 = g^s, C_3 = \left(\prod_{i\in[1,m]} g^{t_{i,j}}\right)^s \right\} \tag{10}$$

According to the above steps, the Internet of Things technology is used to set the information double chain storage mode to complete the safe storage of product supply chain information.

On the basis of the above research, this paper constructs a low-level peer to peer network based on the supply chain technology. In a peer-to-peer network, the clients in each region are treated as an equal node and have the same rights in information access and sharing. When new nodes are connected to the network, the location and status of other nodes in the network should be made clear so as to achieve supply chain synchronisation. Therefore, it is necessary to write down the IP addresses of several nodes that can provide DNS services, scan the active nodes in the network and record their IP information by DNS nodes. When there are new nodes trying to join the supply chain network, they can send random requests to DNS nodes to get the location and status information of other active nodes in the network. However, some nodes may not be online because of the strong activity of nodes, so the model cannot return the IP address list of the active nodes until the new node request is responded. But in this process, the data returned by the DNS node may be attacked by other software or programs, so when the node is online, the other nodes connected to the node will issue IP address and port number, using a centralised way to verify the status of nodes (Ansari and Sun, 2018; Shiraishi et al., 2019).

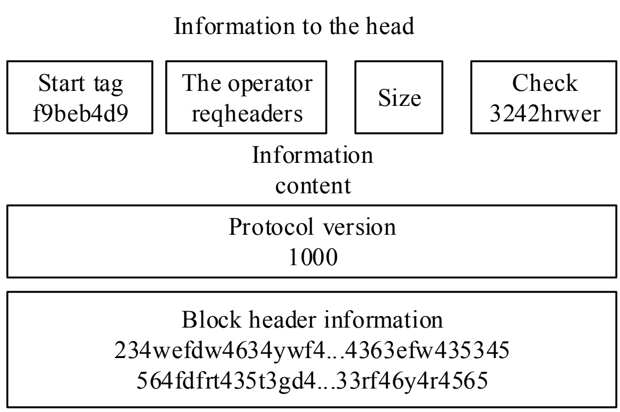
After getting the IP of other nodes, the new nodes try to send their own version information, including but not limited to model version, blocks that have been synchronised, and so on. After receiving the message, the node replies its version to the new node. After the two sides confirm the message, the nodes establish a successful connection, which requires the node to run time synchronisation. After the node joins the supply chain network for the first time, the node also needs to download all block data on the longest supply chain in the network. After a node is chunked, the node randomly selects a node in the network to synchronise blocks, and the new node sends a request header message to the synchronous node, as shown in Figure 4 (Jiang et al., 2020).

Figure 4 Request header information



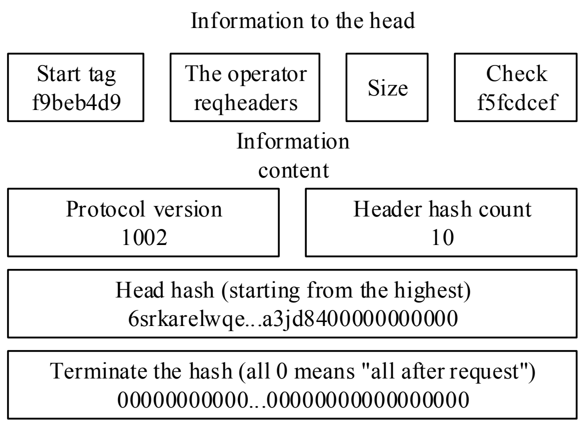
In the request header information header hash value field, the new node fills in its own block header hash, and fills in 0 in the cut-off hash value field to request the maximum number of block headers. After receiving the information shown in Figure 4, the synchronisation node replies to the header information, and the reply content is shown in Figure 5 (Rathore et al., 2018).

Figure 5 Reply message



After receiving the reply from the synchronisation node, the new node judges the correctness of the header hash according to the consensus mechanism and the target number. Repeat the above steps until the number of hash values returned by the synchronisation node is less than the set header information. When the obtained header information belongs to the optimal supply chain in the network, the new node sends the request data to obtain the complete block information. The request block information is shown in Figure 6 (Ahmad et al., 2019).

Figure 6 Request block information



The new node judges the accuracy of blocks according to the order in the supply chain. When the next block to be verified has not been obtained, the waiting time of the model needs to be set. If the block information has not been received, the new node will disconnect and send requests to other nodes until the complete information is obtained.

According to the above information real-time sharing mechanism, the double chain storage of regional product information is shared, and the design of regional product information real-time sharing model based on supply chain technology is completed.

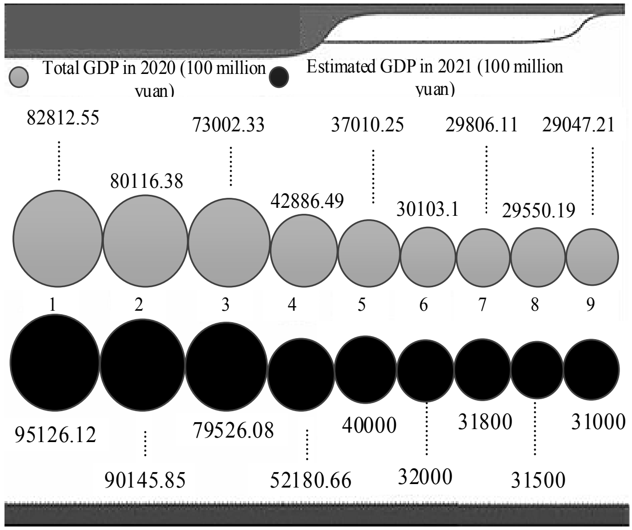
3 Experimental results and analysis

In order to verify the sharing effectiveness of the constructed model, comparative verification experiments are carried out.

3.1 Experimental data

Four computers with the same model and configuration were used in the experiment. According to the statistics of GDP information of product circulation in 9 different provinces, the regional product information for the experiment is shown in Figure 7.

Figure 7 Experimental data



3.2 Experimental index

According to the above experimental information, comparative verification experiments were carried out. The overall experimental scheme is set as follows: Taking the sharing security and sharing efficiency as the experimental comparison indexes, the model in this paper is compared with the model in Li et al. (2019) and the model in Naher and Hashem (2019).

1 *Shared security*: shared security refers to the probability of information being intruded in the process of real-time shared transmission. Therefore, the lower the intrusion rate, the higher the shared security of the model. The calculation formula of intrusion rate is as follows:

$$R = \frac{r_b}{e_i} \times 100\% \tag{11}$$

In the formula, r_b is the number of successful intrusions and e_i is the total number of intrusions.

2 *Sharing efficiency*: sharing efficiency refers to the percentage of data transmitted by different models in unit time to the total data during sharing transmission. The higher the sharing efficiency is, the stronger the application performance of the model is. The calculation formula of sharing efficiency is as follows:

$$W = \frac{y}{p_i} \times 100\% \tag{12}$$

In the formula, y represents the amount of data successfully transmitted, and p_i represents all the data to be transmitted.

3.3 Comparison of shared security

Taking the sharing security as the experimental comparison index, this model is compared with two traditional models, which can fully verify the security performance of the model. The comparison results of the three models are shown in Table 1.

Table 1 Comparison results of sharing security of different models

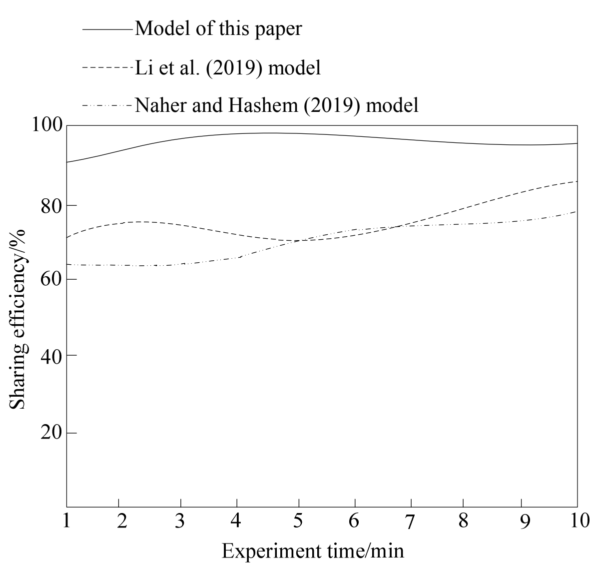
Experiment time/min	*Invasion rate/%*		
	Model of this paper	*Li et al. (2019) model*	*Naher and Hashem (2019) model*
2	0.63	4.21	6.84
4	0.54	5.13	8.56
6	0.81	5.78	7.48
8	0.45	6.20	8.45
10	0.52	6.28	6.23

From the comparison results of sharing security in Table 1, it can be seen that the intrusion rate of this model is lower than that of the two literature comparison models. The minimum intrusion rate of this model is 0.45%, and the minimum intrusion rates of Li et al. (2019) and Naher and Hashem (2019) methods are 4.21% and 6.23%, respectively, which are higher than that of this model. Therefore, this model has high sharing security.

3.4 Comparison of sharing efficiency

The comparison results of sharing efficiency of the three models are shown in Figure 8.

Figure 8 Comparison results of sharing efficiency



From the comparison results of sharing efficiency in Figure 8, it can be seen that the sharing efficiency of this model has always maintained a high level, basically maintained at more than 90%, while the highest sharing efficiency of the two literature comparison models does not exceed 85%, indicating that the sharing efficiency of this model has been significantly improved.

4 Conclusion

In order to improve the sharing performance of product supply chain information, a real-time sharing model of product supply chain information based on Internet of Things technology is proposed. The performance of the model is verified from both theoretical and experimental aspects. The model has high sharing security and efficiency in the process of real-time sharing of product supply chain information. Specifically, compared with the model based on knowledge sharing, the sharing intrusion rate is significantly reduced, and the minimum intrusion rate is only 0.45%; compared with the model based on angularjs and HTML technology, the sharing efficiency is greatly improved, and always remains above 90%. Therefore, it fully shows that the proposed sharing model based on Internet of Things technology can better meet the demand of real-time information sharing in product supply chain. In the future research work, we should further improve the efficiency of information sharing to meet the increasing amount of supply chain data.

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