Research on the Pricing Decision of the Resources of Industry Chain in the Internet of Things

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***Abstract*—Resource pricing is an important tache of the internet of things industry chain. Firstly, the complex relationship in the transaction process of each subject of resources pricing is analyzed based on the supernetwork theory. The pricing relationship structure is designed, on the basis of considering single level and multi-level network. Secondly, the resource pricing supernetwork model of the Internet of things industry chain is constructed. At the same time, the variational inequality is used to optimize the action and target of different levels of transaction subject, coordinate profit distribution, and propose the supply equilibrium state of the resource pricing supernetwork model, so that each subject can achieve optimal profits. Finally, according to the improved projection algorithm, the resource pricing supernetwork model is simulated and the equilibrium solution is obtained. The result verifies the validity of the model. It provides an important reference value for the resource pricing decision of the Internet of things industry chain.**

Keywords—internet of things; supernetwork; resource pricing; variational inequality

I. INTRODUCTION

The emergence of the internet of things caused a wave of new information, is an important stage in the development of information technology. In recent years, the internet of things industry has been highly valued by all countries, and is in the rapid development period [1]. According to the function of every member enterprise in the internet of things industry chain, the internet of things industry chain consists of five parts: the chip and technology suppliers, the application equipment manufacturers, the system integrator, the network operator and the terminal users. As the product resources, actual product, technology or service is flowing in the five parts, and its setting of price influences the stability and development of the industry chain.

In terms of pricing issues, different scholars did a series of research from different perspective. Nagurney studied the pricing problems of different subjects in competition and cooperation each in single level of e-commerce related industry chain, which made decisions for pricing decision through coordinating the target between each subject and each level [2]. Tiezhu Zhang made a conclusion of internet relationship of distributed industry chain and each part of them by researching two layers of internet structure of one manufacturer and multiple retailers [3]. By combining the game theory with the theory of two levels of decision-making, Wei Chen got the pricing model of double layer resource which can optimize each other between levels [4]. Xiao-li Zhao established a model of profit factor cooperation and profit distribution from different perspective, and studied the effect of price on profit distribution for both parties in the partnership with other scholars [5]. Dong studied the supply chain network which has independent goals, and explained the target for the network balance [6]. Xiang Peng described the price change process in the game for member enterprises in the upstream and downstream based on sales, purchase pricing and building dynamic network model [7]. In the above study, the pricing decisions generally focused on two levels or single level network, rarely involved pricing each other between multiple layers. In pricing decisions, people seldom considered the relationship between members in the same level and different level who affect the decision. Meanwhile, conflict between independent decision subjects or conflict of independent decision subject with the whole will easily cause bankruptcy or breaking of members in the industry chain, also will make influence on member enterprise and the whole industry chain. As shown in the Table I.

TABLE I. RESEARCH CONTENT COMPARISON

Research perspectives	Research analysis
Pricing subject	Literature 2 and 5 studied the pricing of different subject in a single level.
	Literature 3, 4, 6, 7 studied the pricing of different subject between the two levels.
Pricing basis	Literature 2 with a single level of the target as the pricing basis for every subject in the study of pricing.
	Literature 3 and 4 took into account the profit distribution of different subjects in the study of pricing.
	Literature 4, 6, 7 with the overall objective of the system as the pricing basis for every subject in the study of pricing.
Pricing method	Literature 3, 4 used the method of two layer planning pricing. Literature 5 and 7 used the method of game pricing.

It has a complex network of multi-level and various relations among all members and layers in the internet of things industry chain. At the same time, in the resource pricing decisions, it needs to not only consider the relationship between the members, but also coordinate goal of the members and the whole. In this situation, the general network cannot solve this case, and prone to confusion with the concept and the subject, however supernetwork can well solve this problem. So using supernetwork combined with variational inequality, analyze the structure of complex networks, describe the mutual influence in different decision subject in chief and its behavior target, and solve the system in an equilibrium state by the variational inequality, coordinate

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This work is supported by National Nature Science Foundation of China (No.70873029); Heilongjiang Province Natural Science Foundation funded project (No.G201203, G201302); Heilongjiang Province postdoctoral research start-up funding project (No. LBH-Q12065);

each target of every subject and the entire network, and solve price decision problem in multi-level network.

II. THE SUPERNETWORK STRUCTURE FOR RESOURCES PRICING IN INTERNET OF THINGS INDUSTRY CHAIN

In the transaction activities, the transaction relationship of each member in the Internet industry chain has formed a supernetwork structure. This network has multiple layers structure, there is a different relationship with each member enterprise in each level, and it has a complicated relationship between layer and layer. First, product resources flows in turn from the chip and the technology supplier in upstream to network operators in downstream, enterprises in the upper provide product resources what they produce for the enterprises in the lower, the enterprises in the lower purchase product resources as raw materials from enterprises in the upper, enterprises in intermediate level in the industry chain has a dual identity, that is buyers and sellers. Second, each layer has many enterprises, each enterprise is an independent individual, it can auto-select transaction with various enterprises in adjacent layers, every enterprise in the same level has a competitive relationship. So it formed a supernetwork with features like multi-network nested, various levels characteristics, multi-dimensional traffic, multi-standard, coordination and optimization between layer and member, member and member. As shown in Fig. 1.

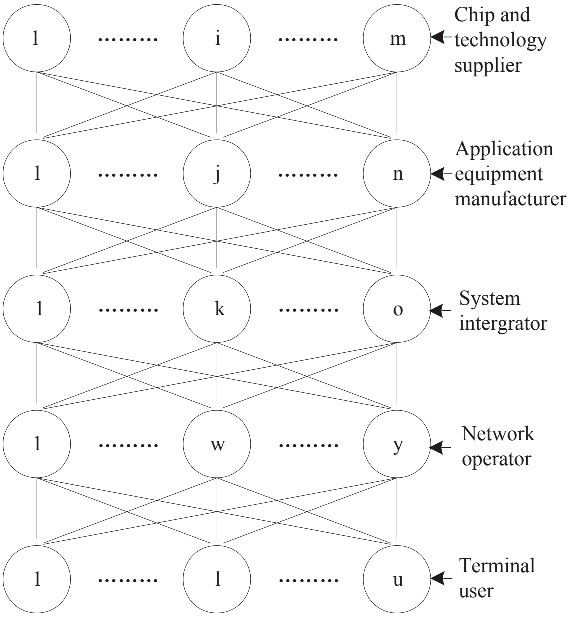

Fig. 1. The supernetwork structure for relation of resource pricing in internet of things industry chain

III. BUILDING MODEL FOR RESOURCES PRICING IN THE INTERNET OF THINGS INDUSTRY CHAIN

A. Basic assumptions of the model

First, the industrial chain will be layered and labeled, the chip and technology supplier, the application equipment manufacturers, the system integrator, the network operator and the terminal users are numbered as 1,2,3,4,5, the number of enterprises in each layer is in numbered as m, n, o, y, u, each enterprise of each layer is numbered as i, j, k, w, l. Set the function of production cost is f, demand function is d, the subscript letter is productive enterprises. Set the final profit function is z**,** the first subscript is digital serial number, the second subscript is letters. Set p is the price, the first subscript is digital serial number, the second subscript and third subscript, in turn, is letter for the sellers and the buyers. Q is a set of vectors, superscript is digital number, q is components of Q, represent transaction volumes of product resources, the first subscript is product resources for manufacturing enterprises, the second subscript is the buyers for product resources. Set c is the transaction cost function, the first subscript is product resources for manufacturing enterprises, the second subscript is the buyers for product resources, all superscript * is the optimal solution in the equilibrium state.

B. Transaction subjects' behavior and their optimal goal

In resources pricing in the internet of things industry chain, they have similarities in transaction subject's behavior and targets in each level, for the convenient to study, it takes application equipment manufacturers and the terminal users for example, and detailed analyze their behavior and optimal goal, the rest of the transaction subject are similar with application equipment manufacturers, so it won't detailed analyze in this paper. Anyone of the application equipment manufacturers j $(j = 1, 2 \ldots n)$ can be selected as the research target, analyze j, and then study behaviors and optimization of all application equipment manufacturers .

For application equipment manufacturer j, f_j as the production cost function, production costs are various, including search goods cost, raw material cost, equipment maintenance cost, etc. When the fixed costs is a constant, f_j is the function of numbers of order for integrator .Set q_{jk} as transaction volumes of product resources from system integrators k provided to application equipment manufacturer j, q_{jk} is component of vector $Q^2 \in R_+^{no}$. Competition between companies in the same layer, also has an impact on f_j, and f_j is related with the quantity ordered by other application equipment manufacture, then, set f_j as:

$$f_j = f_j(Q^2), \forall j \tag{1}$$

To make assumptions for f_j, f_j is nonnegative function which is continuously differentiable.

When application equipment manufacturer j make trade with chip and technology suppliers i, it also can produce certain transaction costs, the costs associated with transaction volume, recorded as:

$$c_{ji} = c_{ji}(q_{ij}), \forall i, j \tag{2}$$

To make assumptions for c_{ji}, c_{ji} is nonnegative function which is continuously differentiable.

When application equipment manufacturer j make trade with system integrators k, it also can produce certain transaction costs, the costs associated with transaction volume, recorded as:

$$c_{\mathrm{jk}} = c_{\mathrm{jk}}(q_{jk}), \forall j,k \tag{3}$$

To make assumptions for c_{jk}, c_{jk} is nonnegative function which is continuously differentiable.

Set p_{2jk} as the price of one unit product resources from application equipment manufacturer j sold to system integrators k, the subscript 2 is the variable of second level, q_{jk} is transaction of application equipment manufacturer j and system integrators k $(k = 1,2\cdots o)$, q_{jk}^{*} is transaction of product resources after the model reaches equilibrium state, that is optimal transaction volume of application equipment manufacturer j and system integrators k, q_{jk} formed $Q^2 \in R_{+}^{no}$.

So, the total costs of application equipment manufacturer j is the sum of production costs, the chip and technology suppliers transaction costs, and integrators transaction costs, and transaction is the product of unit price of product resources p_{2jk} and transaction volume of system integrators. So, the maximum profit of application equipment manufacturer in the process of product resource deals , that is:

$$\max z_{2j} = \sum_{k=1}^{o} p_{2jk} q_{jk} - f_j(Q^2) - \sum_{i=1}^{m} c_{ji}(q_{ij}) - \sum_{k=1}^{o} c_{jk}(q_{jk}) \tag{4}$$

Among them, there is $q_{jk} \geq 0$ in $\forall j = 1,2\cdots,n; k = 1,2\cdots o$, which indicates that the transaction volume of the application equipment manufacturer j and system integrators k is a value greater than or equal to zero.

For $j = 1,2,\cdots n$, the goal function z_{2j} is convex function on j .According to the properties of the variational inequality, the solution of z_{2j} is satisfied with their corresponding variational inequality.

$$\begin{aligned} &\sum_{j=1}^{n}\sum_{k=1}^{o}\Big(\frac{\partial f_j(Q^{2*})}{\partial q_{jk}} + \frac{\partial c_{jk}(q_{jk}^{*})}{\partial q_{jk}} - p_{2jk}\Big) \times (q_{jk} - q_{jk}^{*}) \\ &+\sum_{i=1}^{m}\sum_{j=1}^{n}\frac{\partial c_{ji}(q_{ij}^{*})}{\partial q_{ij}}(q_{ij} - q_{ij}^{*}) \geq 0(\forall(\mathrm{Q}^2, q_{ij}, p_{2jk}) \in G_2) \end{aligned} \tag{5}$$

Among them, $G_2 \equiv \{(Q^2, q_{ij}, p_{2jk}) \mid q_{jk} \geq 0, q_{ij} \geq 0, p_{2jk} \geq 0, \forall i, j, k\}$

In the internet of things industry chain, network operators is in an important position, because of many characters, such as large enterprise scale and fewer numbers of enterprises, they have some monopolies in the process of transaction, in order to get advantage, they influence pricing of downstream enterprise by this kind of monopoly. System integrator is the upstream enterprise which direct contact with network operators, so when analyzing the behavior of the system integrator and the optimal goal, it need to consider the influence of monopoly on it.

Set β as coefficient of monopoly, the function of the loss made by monopoly influence is s_{kw}, so defined as s_{kw}:

$$s_{kw} = \beta s_{kw}(q_{kw}), \forall k, w \tag{6}$$

For terminal users, the decision is not only based on the price of the product, but also based on the product transaction costs for their own. In order to conveniently study, it selects any one of the terminal users l $(l = 1,2,3...u)$ as the research target.

When terminal users l trade with network operators w, it also can produce certain transaction costs, these costs is associated with transaction volume, recorded as:

$$c_{lw} = c_{lw}(q_{wl}), \forall l, w \tag{7}$$

h_5 $(h_5 \in R_{+}^{u})$ is end-user demand price, d_l is demand function for terminal users l, d_l not only related to their own, but also related to the price h_5 of other terminal users payed:

$$d_l = d_l(h_5), \forall l \tag{8}$$

To assume d_l, d_l as the continuous monotone decreasing function.

The total cost of the terminal users to purchase the product is equal to the sum of the cost for the product itself and the transaction costs, for the terminal users l:

$$p_{4wl}^{*} + c_{lw}(q_{wl}^{*})\begin{Bmatrix} = h_{5l}^{*}, q_{wl}^{*} > 0 \\ \geq h_{5l}^{*}, q_{wl}^{*} = 0 \end{Bmatrix} \tag{9}$$

So, the demand equilibrium condition of the terminal users l is:

$$d_l(h_5^{*})\begin{Bmatrix} = \sum_{w=1}^{y} q_{wl}^{*}, h_{5l}^{*} > 0 \\ \leq \sum_{w=1}^{y} q_{wl}^{*}, h_{5l}^{*} = 0 \end{Bmatrix} \tag{10}$$

According to the nature of the variational inequality, the terminal users l $(l = 1,2,3...u)$ is transformed into the form of the variational inequality:

$$\begin{aligned} &\sum_{w=1}^{y}\sum_{l=1}^{u}\Big(\frac{\partial c_{lw}(q_{wl}^{*})}{\partial q_{wl}} + p_{4wl}^{*} - h_{5l}^{*}\Big) \times (q_{wl} - q_{wl}^{*}) \\ &+\sum_{l=1}^{u}\Big(\sum_{w=1}^{y} q_{wl}^{*} - \frac{\partial d_l(h_5^{*})}{\partial h_{5l}}\Big) \times (h_{5l} - h_{5l}^{*}) \geq 0(\forall h_{5l} \in G_5) \end{aligned} \tag{11}$$

Among them, $G_5 \equiv \{(h_{5l}) \mid h_{5l} \geq 0, \forall l\}$

C. The win-win equilibrium state of supernetwork model of resources pricing in the internet of things industry chain

It took application equipment manufacturer and terminal users as example in above, analyzed the behavior of pricing subject and their optimal goal, and it will explore the win-win equilibrium state of the supernetwork model the internet of things industry chain in below paper.

The win-win equilibrium state of supernetwork model of resources pricing in the internet of things industry chain, that is $(Q^{1*},Q^{2*},Q^{3*},Q^{4*},p^*_{1i},p^*_{2j},p^*_{3k},p^*_{4w},h^*_{5l}) \in G$, which is able to satisfy the demand of its own interests regarding chips and technology suppliers, application equipment manufacturer, system integrators, network operators and terminal users, that is when the $(Q^{1*},Q^{2*},Q^{3*},Q^{4*},p^*_{1i},p^*_{2j},p^*_{3k},p^*_{4w},h^*_{5l}) \in G$ satisfy the sum of all the transaction subject variational inequality, the super network model of resources pricing in the internet of things industry chain can reach the win-win equilibrium state:

$$
\begin{aligned}
&\sum_{i=1}^{m}\sum_{j=1}^{n}\left(\frac{\partial f_i(Q^{1*})}{\partial q_{ij}}+\frac{\partial c_{ij}(q^*_{ij})}{\partial q_{ij}}-p^*_{1ij}\right)\times(q_{ij}-q^*_{ij})\\
&+\sum_{j=1}^{n}\sum_{k=1}^{o}\left(\frac{\partial f_j(Q^{2*})}{\partial q_{jk}}+\frac{\partial c_{jk}(q^*_{jk})}{\partial q_{jk}}-p_{2jk}\right)\times(q_{jk}-q^*_{jk})\\
&+\sum_{i=1}^{m}\sum_{j=1}^{n}\frac{\partial c_{ji}(q^*_{ij})}{\partial q_{ij}}(q_{ij}-q^*_{ij})+\sum_{j=1}^{n}\sum_{k=1}^{o}\frac{\partial c_{kj}(q^*_{jk})}{\partial q_{jk}}(q_{jk}-q^*_{jk})\\
&+\sum_{k=1}^{o}\sum_{w=1}^{y}\left(\frac{\partial f_k(Q^{3*})}{\partial q_{kw}}+\frac{\partial c_{kw}(q^*_{kw})}{\partial q_{kw}}+\frac{\partial s_{kw}(q^*_{kw})\beta}{\partial q_{kw}}-p_{3kw}\right)\times(q_{kw}-q^*_{kw})\\
&+\sum_{w=1}^{y}\sum_{l=1}^{u}\left(\frac{\partial f_w(Q^{4*})}{\partial q_{wl}}+\frac{\partial c_{wl}(q^*_{wl})}{\partial q_{wl}}-p_{4wl}\right)\times(q_{wl}-q^*_{wl})\\
&+\sum_{k=1}^{o}\sum_{w=1}^{y}\frac{\partial c_{wk}(q^*_{kw})}{\partial q_{kw}}(q_{kw}-q^*_{kw})\\
&+\sum_{w=1}^{y}\sum_{l=1}^{u}\left(\frac{\partial c_{lw}(q^*_{wl})}{\partial q_{wl}}+p^*_{4wl}-h^*_{5l}\right)\times(q_{wl}-q^*_{wl})\\
&+\sum_{l=1}^{u}\left(\sum_{w=1}^{y}q^*_{wl}-\frac{\partial d_l(h^*_5)}{\partial h_{5l}}\right)\times(h_{5l}-h^*_{5l})\ge 0\\
&(\forall(Q^{1*},Q^{2*},Q^{3*},Q^{4*},p^*_{1ij},p^*_{2jk},p^*_{3kw},p^*_{4hw},h^*_{5l})\in G)
\end{aligned}
\tag{12}
$$

Among them $G \equiv \{(Q^1,Q^2,Q^3,Q^4,p_{1ij},p_{2jk},p_{3kw},p_{4hw}) \mid q_{ij} \ge 0, q_{jk} \ge 0, q_{kw} \ge 0, q_{wl} \ge 0, p_{1ij} \ge 0, p_{2jk} \ge 0, p_{3kw} \ge 0, p_{4wl} \ge 0, h_{5l} \ge 0, \forall i, j, k, w, l, h\}$ 。

In order to ensure that there is a solution to the variational inequality, according to the existence conditions of the solution of variational inequality [8, 9], sets above feasible sets of the variational inequality as compact:

$$G_s \equiv \{(Q^1,Q^2,Q^3,Q^4,Q^5,p_{1ij},p_{2jk},p_{3kw},p_{4hw},p_{5wl}) \mid s_1 \ge Q^1 \ge 0, s_2 \ge Q^2 \ge 0, s_3 \ge Q^3 \ge 0, s_4 \ge Q^4 \ge 0, s_5 \ge p_{1ij} \ge 0, s_6 \ge p_{2jk} \ge 0, s_7 \ge p_{3kw} \ge 0, s_8 \ge p_{4hw} \ge 0, s_9 \ge h_{5l} \ge 0, \forall i, j, k, w, l\}$$

Here, $s=(s_1,s_2,s_3,s_4,s_5,s_6,s_7,s_8,s_9) \ge 0, Q^1 \le s_1, Q^2 \le s_2, Q^3 \le s_3, Q^4 \ge s_4, p_{1ij} \le s_5, p_{2jk} \le s_6, p_{3kw} \le s_7, p_{4hw} \le s_8, h_{5l} \le s_9$ that means all the elements in all of the vectors are less than or equal to the corresponding amount in s, so G_s is subset for the bounded closed convex, the solution of the variational inequalities:

$$\left\langle F(X^s), X - X^s \right\rangle \ge 0, \forall X^s \in G_s \tag{13}$$

It has at least one existence. At the same time, in line with the assumption that all above functions are continuous and differentiable nonnegative functions, there is a unique optimal solution.

IV. NUMERICAL EXAMPLES

Below it will verify the validity of the model by examples, for the convenience of calculation, select the part of the enterprise as an example, which is the four level structures with application equipment dealers, system integrators, network operators and terminal users as the subject, each level contains two enterprises.

The required functions as follows, application equipment dealer:

$$f_1(q) = 4q_1^2 + 3q_1 + 2q_1q_2, f_2(q) = 4q_2^2 + 3q_2 + q_1q_2 \tag{14}$$

$$c_{jk}(q_{jk}) = 2q_{jk}^2 + 5q_{jk}, j = 1, k = 1,2 \tag{15}$$

$$c_{jk}(q_{jk}) = 4q_{jk}^2 + 5q_{jk}, j = 2, k = 1,2 \tag{16}$$

System integrators:

$$f_1(q) = 3q_1^2 + 8q_1 + 2q_1q_2, f_2(q) = 3q_2^2 + 8q_2 + 2q_1q_2 \tag{17}$$

$$c_{kw}(q_{kw}) = 2.5q_{kw}^2 + 2q_{kw}, k = 1, w = 1,2 \tag{18}$$

$$c_{kw}(q_{kw}) = 3q_{kw}^2 + 5q_{kw}, k = 2, w = 1,2 \tag{19}$$

$$s_{kw}(q_{kw}) = 4q_{kw}^2 + 2.2q_{kw}, k = 1, w = 1,2 \tag{20}$$

$$s_{kw}(q_{kw}) = 3.4q_{kw}^2 + 1.5q_{kw}, k = 2, w = 1,2 \tag{21}$$

Network operators:

$$f_1(q) = 4q_1^2 + 3q_1 + 2q_1q_2, f_2(q) = 4q_2^2 + 3q_2 + q_1q_2 \tag{22}$$

$$c_{wl}(q_{kw}) = 6q_{wl}^2 + q_{wl}, w = 1, l = 1,2 \tag{23}$$

$$c_{wl}(q_{kw}) = 2q_{wl}^2 + 6q_{wl}, w = 2, l = 1,2 \tag{24}$$

Terminal users:

$$d_1 = -3h_1 + 2h_2 + 1500, d_2 = -3h_2 + 2h_1 + 1500 \tag{25}$$

$$c_{lw}(q_{wl}) = 3q_{wl}^2 + 1.5q_{wl}, w = 1, l = 1,2 \tag{26}$$

$$c_{lw}(q_{lw}) = 2.5q_{wl}^2 + 2q_{wl}, w = 2, l = 1,2 \tag{27}$$

Above, $q_1 = q_{11} + q_{12}$; $q_2 = q_{21} + q_{22}$

By using the improved projection algorithm, the solution is solved by MATLAB, and the equilibrium solution $\beta = 0$ are shown in Table II:

TABLE II. NUMERICAL EXAMPLE EQUILIBRIUM SOLUTION

Application equipment manufacturers	$q_{11} = 88.6631, q_{12} = 80.5741, q_{21} = 88.6631, q_{22} = 80.5741$ $p_{11} = 2.1221 p_{12} = 2.0021, p_{21} = 2.1004, p_{22} = 2.2001$
System integrator	$q_{11} = 84.5446, q_{12} = 80.4137, q_{21} = 84.5446, q_{22} = 80.4137$ $p_{11} = 2.5231, p_{12} = 2.8651, p_{21} = 2.6731, p_{22} = 2.6232$
Network operator	$q_{11} = 93.5894, q_{12} = 93.5894, q_{21} = 75.6647, q_{22} = 75.6647$ $p_{11} = 3.5447, p_{12} = 3.6417, p_{21} = 3.5463, p_{22} = 3.6547$
Terminal users	$h_1 = 4.3132, h_2 = 4.7421$

Using game pricing method to solve the above examples, the paper got the profit of each level subject and overall profits in order to verify the validity of the method, at the same time, calculated the each subject profits and the whole profits under the model of supernetwork model according to the equilibrium solution of Table II. By comparison, it can find that the overall profit of the system increase about 8.32% compared with that of the game pricing method, and each subject profit distribution is more uniform under the supernetwork model.

The equilibrium solution from Table II is that various manufacturers in supernetwork of resources pricing in the internet of things industry chain achieve the noncooperative Nash equilibrium in competitive environment, is a result of the game, is equilibrium solution for various manufacturers in supernetwork of resources pricing in the internet of things industry chain when they make independent decision to pursue their own utility maximization, it is very difficult to achieve the accurate equilibrium point in the actual process, it can provide a reference for the individual manufacturers to make decisions in complete competition environment. The internet of things industry chain extend longitudinally long, have transaction subject with many levels, in the actual production and transaction, manufacturers at the upper end of the industry chain have less sensitive for market information than downstream manufacturers, they tend to cannot grasp the price and output, which makes them at disadvantage in transaction, they can make their own plan according to other manufacturers' decision through the supernetwork model of resources pricing in internet of things industry chain. As shown in Fig. 2, the X axis is the number of the transaction volume approaches to the balance between application equipment dealer 1 and system integrator 1, 1-2, 2-1, 2-2 of the Y axis represents the application equipment dealer 1 and system integrator 2, application equipment dealer 2 and system integrator 1, and application equipment dealer 2 and system integrator 2. The Z axis is the corresponding transaction volume, as can be seen from Figure 1, with transaction volume tends to balance between the application equipment dealer 1 and system integrator 1, the transaction volume between other manufacturers is changing in time. Using the Internet of things industry chain resource pricing model, they can make their own relatively favorable decisions based on the changes in the strategy of other manufacturers.

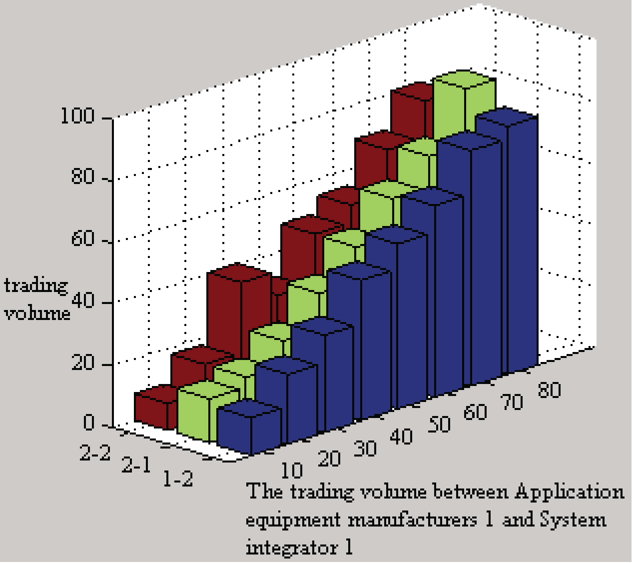

Fig. 2. The change of equilibrium volume

Network operator monopoly factors also affect the resource pricing of the internet of things industry chain. Set operators of monopoly factor as $\beta = 0.1$, 0.15, 0.2, 0.25, 0.3, 0.35. 0.4, 0.45, when $\beta = 0$, the profits of system integrators and application equipment dealers is the denominator, when $\beta = 0.1$, 0.15, 0.2, 0.25, 0.3, 0.35. 0.4, 0.45, the profits of system integrators and application equipment dealers is the numerator, get profit ratio, The impact of monopoly factor by the ratio of profit changed along with the change of β can be analyzed. As shown in the Table III.

TABLE III. THE CHANGES IN PROFIT RATIO ALONG WITH β

β	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45
Application equipment manufacturers 1	0.9012	0.8321	0.8014	0.7654	0.7211	0.6854	0.6542	0.6211
Application equipment manufacturers 2	0.9234	0.8847	0.8324	0.7804	0.7414	0.7023	0.6781	0.6424
System integrator 1	0.9864	0.9841	0.9821	0.9793	0.9772	0.9753	0.9721	0.9691
System integrator 2	0.9893	0.9876	0.9821	0.9805	0.9798	0.9761	0.9732	0.9710

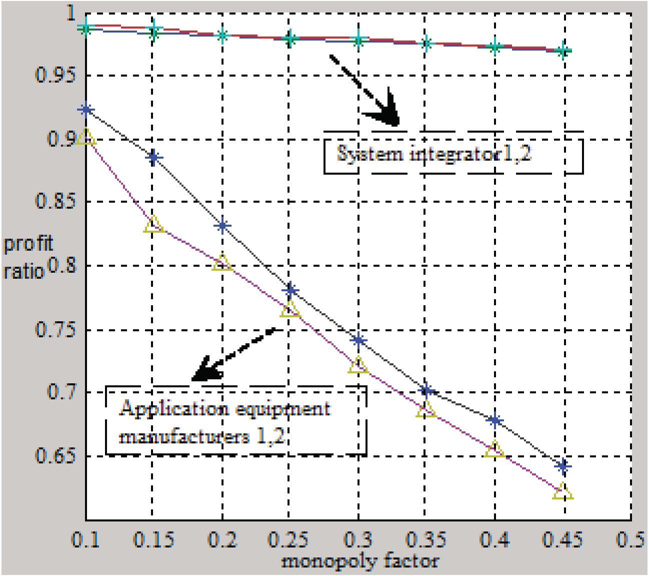

Fig. 3. The change of profit ratio

Fig. 3 shows that, it is the changes in profits of system integrators 1, 2 and profit ratio when $\beta = 0$, and the changes in profits of the application equipment dealer 1, 2 and profit ratio when $\beta = 0$ along with the increase of β. Can be seen from the figure that with the increase of β, the profit ratio of system integrator 1, 2 changed small, the two curve is basically overlap and in a stable situation, verified that the impact is little on the profits of the system integrators with increase of β. And the profit ratio of application equipment manufacturers 1, 2 is gradually reduced, the curve showed a downward trend. The main reason for this situation is that when the increase of β , the transaction between system integrators and network operators is at a disadvantage, resulting in lower prices and rising costs. At this point, if the system integrators want to reach a certain level of profit, they will seek to a lower price seller, lower the price of application equipment manufacturers and reduce their profit. The analysis results showed that the impact of monopoly of network operators is little on the system integrators they contacted with, but is big on the application equipment manufacturers in the upstream industry chain, if this situation will exist for a long time, the application equipment manufacturers cannot make a profit or even a loss, and easy to cause adverse consequences like the fracture of the industrial chain. It can solve the problem in a certain extent by strengthened the government supervision for the internet of things industry, and established the internet of things industry alliance coordinate with the pricing of the industry chain.

V. CONCLUSION

In resources pricing in the internet of things industry chain, its structure has the complex characters, and involved the problems such as the behaviors of each enterprise in five levels and the balance of the industrial chain. The research results show that the supernetwork theory has incomparable advantages compared with other tools in solving problems of complex multi-level and multi-objective network. Based on resource pricing relations in supernetwork structure, this article build the resources pricing model in the internet of things industry chain, optimize pricing behavior and target of decision subject, make the resources pricing in internet of things industry chain in an equilibrium state. At the same time, through analyzed the example , it concluded the equilibrium solution of perfect competition environment, provided the pricing basis for individual manufacturers under the competitive environment, validated the feasibility and effectiveness of the model, analyzed the monopoly of network operators, concluded that the impact of monopoly will pass along the industry chain to the top, make the upstream enterprises in industry chain profit less or even cannot profit, long-term monopoly even can cause industry chain rupture, gave the direction to solve the problem, provided scientific and effective guidance for resources pricing in the internet of things industry chain. In the next step of research, we should pay attention that the enterprises in the industrial chain have some certain of customer loyalty and governmental leading behavior, so we should add loyalty and government policy leading in the factors which affect the price.

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