

Supply chain grid—Optimizing SC Coordination Management Based on Time Petri Nets

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Abstract –To improve the time efficiency of supply chain coordination management, a goods flow trigger time solving method which applies grid technology to supply chain coordination management is proposed. It can acquire the corresponding earliest and latest trigger time of each process, using the accessibility analysis algorithm model based on the time Petri nets to make simulation calculation, so that the flow efficiency is improved with comparing the trigger time between traditional method and grid technology. The advantage of grid technology applied in the supply chain coordination management can be embodied.

Keywords –supply chain collaborative management; grid; grid supply chain; time Petri nets; trigger time

1. Preface

With the global economic integration and market internationalization, enterprise has undergone a fundamental change with its competition environment. The market competition has transferred the original tangible products and services to the invisible competition for culture, technology, brand and competition which between single enterprises has turned to enterprise and its supply chain. In the complex supply chain, information state between enterprises has upgraded from disorder, decentralization or heterogeneous into orderly integration, and information communication and collaboration between member enterprises, which is an important prerequisite for supply chain coordination management. However, the supply chain of the traditional informatization level is not high; it is hard to realize information in a timely, accurate and safe transmission that brings the supply chain a lot of trouble.

Solving resources sharing of distribution is the core of grid as a new technology. Through sharing to realize real-time control of enterprise's resources so as to allocate reasonably. This paper through the grid technology to achieve information sharing, combine with time problem, simplify the workflow, and realize the grid supply chain collaboration management optimization to some extent.

2. Theory Overview and Research Status

2.1 Definition of Grid

The concept of grid is extended from the power network. In 1998, Ian Foster gave the definition that the Grid is to realize the purpose of large scale equivalence resources sharing which is not limited to the simple file exchange but emphasis on more computing power, software, data and other resources to directly access. A more extensive definition was provided by Tsinghua University academician Li Sanli that the grid is an integrated environment of computation and resource, or rather a computational resources pool, which can fully absorb all kinds of computing resources, and then put them into a widely available, reliable and standard economical computing power. Internet mainly provides people with email and web browsing function. Nevertheless, grid lets people transparently use calculation and storage function which seem much stronger. Plainly speaking, the grid is such a technology that a new stage of Internet, integrating the whole Internet into a huge super computer so as to fulfill the sharing of various information resource.

2.2 Definition of Grid Supply Chain

On the basis of previous studies, author puts forward the following description about combination grid technology with supply chain management. The grid supply chain regards each enterprise in whole supply chain as a node of each grid structure applied grid technology, integrating all messages of nodes, realizing transfer, exchange and sharing between messages, consequently achieving the maximum use of resources. The supply chain management system model in grid environment is shown as figure 1.

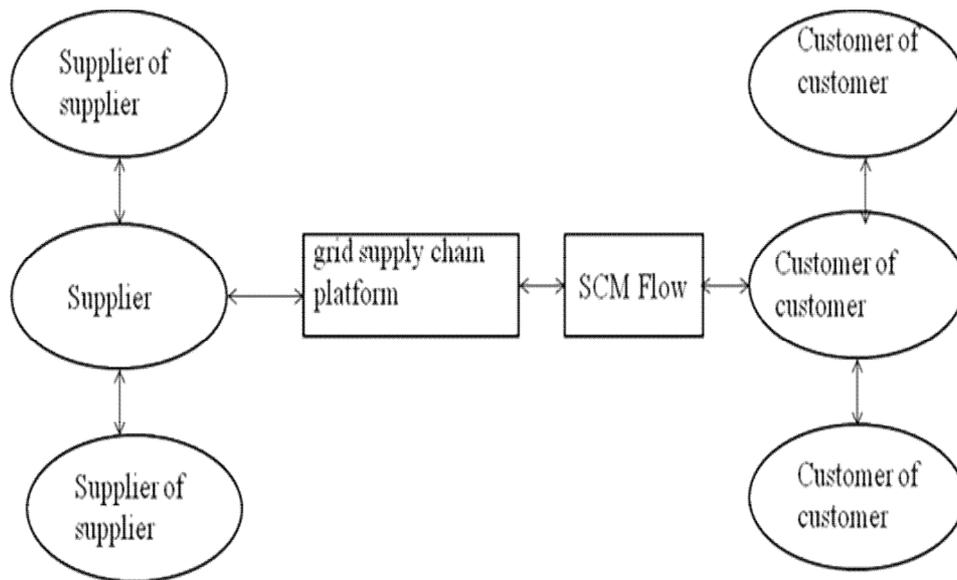


Figure 1. Supply Chain Management System Mode

2.3 Related Works

2.3.1 Research Status of Grid

The current foreign study on the grid, especially to the United States mainly used in the following respects:

Firstly, GIG is generally in the military aspects of the grid plan. Secondly, Globus is one of the most influential grid computing projects, aimed at a greater degree of realization of information resources sharing and interoperability. Thirdly, PIG is a high performance computing, high-performance physical and mass data storage in grid environment. China's Grid research condition has developed into six Grid projects which include China National Grid (CN Grid), the National Natural Science Funds Grid (NSFC Grid) and Shanghai Education Scientific Research Grid.

2.3.2 Research Status of Petri Nets

Petri nets is put forward as a network structure in 1962 by the German Dr. Carl Adam Petri. Senior Petri nets are appeared on the foundation of Petri nets within 50 years like time Petri nets, non-ferrous and stochastic Petri nets. Based on supply chain modeling method of Petri nets can describe the dynamic characteristics of the system, which logistics, information flow and cash flow are well embodied in supply chain. Relevant researchers attached great importance to Petri nets and numerous research results were received.

3. Significance of Grid Supply Chain Coordination Management

3.1 Traditional Supply Chain

3.1.1 Traditional Model of Supply Chain

The traditional model of supply chain is too single as a result of lack of communication between enterprises in supply chain, causing information distortion and delay, thereby go against the long-term development of an enterprise. The traditional supply chain message transmission is described as figure 2

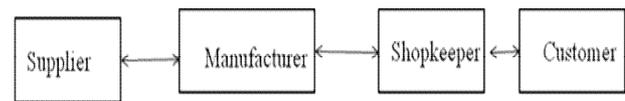


Figure 2. information transmission in traditional supply chain

3.1.2 Problem of Grid Supply Chain Coordination Management

Informationization level of current Chinese manufacturing enterprises is not high. There are disadvantages in supply chain management explained as below.

- (1) Insufficient chain agility
- (2) Low resource utilization rate
- (3) Heterogeneity in node information system
- (4) Signal distortion

3.2 Grid Supply Chain

3.2.1 Model of Grid Supply Chain

In grid environment, all resources information can be better, faster and more effective communication shall be gained in the supply chain. Supply chain message transmission is shown in figure 3.

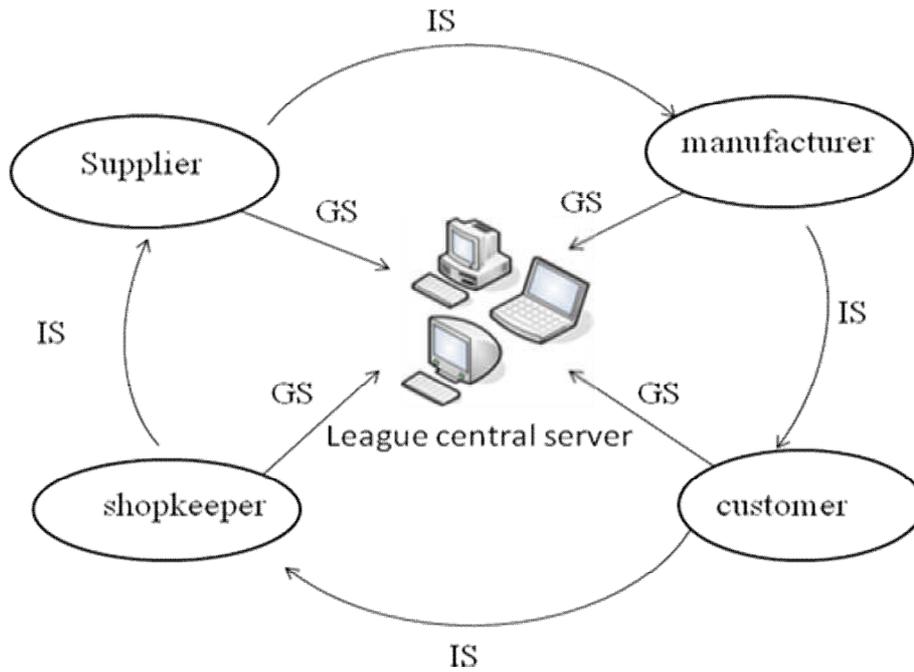


Figure 3. information transmissions in traditional supply chain

3.2.2 Advantage of Grid Supply Chain Coordination Management

- (1) Fast response
- (2) High integration and sharing
- (3) Realizing resource sharing
- (4) Strong data processing ability

4. Goods Process Modeling Based on Time Petri Nets

4.1 Time Petri Nets (TPN)

4.1.1 Definition

TPN contains six elements (P, T, B, F, M, SI).

- (1) $P = \{ P_1, P_2, \dots, P_m \}$ is nonempty finite set of position.
- (2) $T = \{ T_1, T_2, \dots, T_n \}$ is nonempty finite set of transfer.
- (3) $B: P \times T \rightarrow N$ is Correlation equation afterward.
- (4) $F: T \times P \rightarrow N$ is Correlation equation forward.
- (5) M_0 is an initial mark (P, T, B, F, M_0 constitutes Petri nets).
- (6) SI is $\forall_i \in T, SI(t) = [SEFT(t), SLFT(t)]$ and static time interval, where SEFT(t) is the earliest firable time makes t enabled, SLFT(t) the latest firable time makes t enabled.

4.1.2 Accessibility Analysis of Time Nets

CS-class[9] is a triple (M , D , ST), where M is a mark and D is trigger interval , that is the start time interval set. For one enabled transition t_i , $D(t_i)$ represents start time interval. $D(t_i) = [EFT(t_i), LFT(t_i)]$, taking $EFT(t_i)$ as the earliest firable time of t_i in current state , $LFT(t_i)$ is the latest firable time of t_i in current state ; ST is CS-class's time stamp and time interval , initial state of nets is describes as $C_0 = (M_0, D_0, ST_0)$, M_0 is an initial mark. D_0 contains all M_0 transition of corresponding static time interval , $ST_0 = [0, 0]$. ST_i indicates the time interval of nets' running states from C_0 to C_i .

4.1.3 Accessibility Analysis Algorithm of Petri Nets

Accessibility analysis of Petri Nets is the analysis on its reachability tree, which is established on the foundation of the time variables of the timestamp; actually the method of reachability tree is a permutation by transforming the state's order or sequence. Algorithm rules are as follows.

An enabled transition t_j is called a collection of all enabled transition in C_k . In addition, supposing all firable transition collection in $F_r(C_k)$ and $MLFT(C_k)$ defines $F_r(C_k)$ the minimum of the latest firable time. Here firable transition that belongs to $F_r(C_k)$ is divided into two classes.

- (1) The transition which has been firable before time Petri nets arriving at C_k , called OLD.

(2) The transition which produces new friable in C_k , called NEW.

Supposing the trigger of $t_f \in F_r(C_k)$ makes C_k transform into C_{k+1} , then assume $C_k = (M_k, D_k, ST_k)$, and $C_{k+1} = (M_{k+1}, D_{k+1}, ST_{k+1})$. Following is the trigger rules of transition.

Step1. Calculate t_f 's $\wedge D_k$ new value ,

$$\wedge D_k(t_f) = [EFT(t_f), MLFT(C_k)] , ST_{k+1} = \wedge D_k(t_f)$$

Step2. for the transition which has been firable before C_{k+1} , $t_j (t_j \neq t_f)$, recalculate its D_{k+1} , we have :

$$D_{k+1}(t_j) = [\max(EFT_k(t_j), EFT(t_f)), LET(t_j)]$$

Step3. calculate the D_{k+1} value of transition which produced new friable after trigger t_f , if $t_i \neq t_f$, then $D_{k+1}(t_j) = SI(t_j) + ST_{k+1}$; if t_f is still friable after triggering, then $D_{k+1}(t_f) = SI(t_f) + ST_{k+1}$.

The last step is dealing with t_f , indicating that treat the transition which is still enable after self trigger as the new one.

4.2 Time Petri Nets Model of Goods Workflow

The trigger time can manifest the response rate of enterprises to customer and market. In other words, the trigger time in advance more reflects much better agility of supply chain, effectively improve operation efficiency of enterprises in the supply chain, and therefore take trigger time as measure index to evaluate flow time of goods in supply chain model.

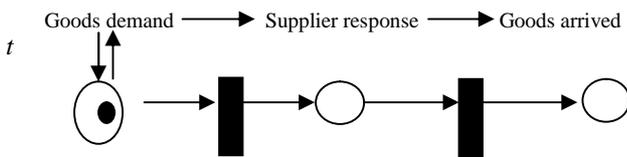


Figure 4. TPN Model

In figure 4, warehouse is shown by a circle and transition is signified by directed line segment. This model is a theoretical basis of the example modeling behind.

4.3 Example

Simply speaking, an enterprise and two suppliers are involved in the case. This company produces product A and needs raw material B and C, two suppliers are in charge of providing raw materials, which material B is remanufactured when goods is in no available state and material C is directly delivered from warehouses when goods is in stock. Supply chain TPN model based on grid environment is as shown in figure 5. Table 1 is the symbol description of figure 4 and table 2 is description

of figure 5, where available with up branch and out of stock with down branch state flow is analyzed.

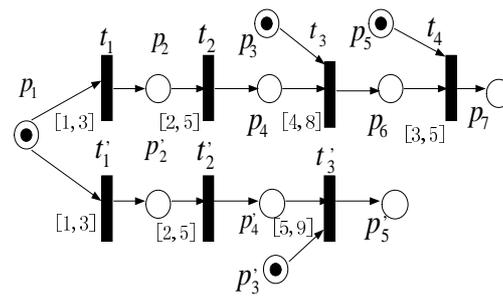


Figure 5. Traditional Supply Chain TPN Model

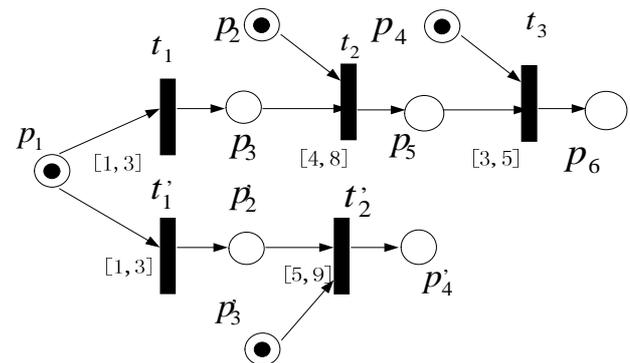


Figure 6. TPN Model in Grid Environment

Table 1. Symbol Description Of Figure 5

House ↕	Description ↕
P_1 ↕	Producer ↕
t_1 ↕	Product B ↕
t_1' ↕	Product C ↕
P_2 ↕	Order B ↕
P_2' ↕	Order C ↕
t_2 ↕	Order B transmission ↕
t_2' ↕	Order C transmission ↕
P_3 ↕	Facility for product B ↕
P_3' ↕	Product C in warehouse ↕
P_4 ↕	Order B formed by supplier ↕
P_4' ↕	Facility for transporting C ↕
t_3 ↕	Start to produce B ↕
t_3' ↕	Transport B ↕
P_5 ↕	Facility for transporting B ↕
P_5' ↕	Raw material C arriving at producer ↕
P_6 ↕	Finished product B ↕
t_4 ↕	Transport B ↕
P_7 ↕	Raw material B arriving at producer ↕

Table 2. Symbol Description Of Figure 6

House \leftrightarrow	Description \leftrightarrow
$P_1 \leftrightarrow$	Producer \leftrightarrow
$t_1 \leftrightarrow$	Getting order grid data of B from supplier \leftrightarrow
$t_1' \leftrightarrow$	Getting order grid data of C from supplier \leftrightarrow
$P_2 \leftrightarrow$	Facility for product B \leftrightarrow
$P_2' \leftrightarrow$	Product B in warehouse \leftrightarrow
$P_3 \leftrightarrow$	Order B formed by supplier \leftrightarrow
$P_3' \leftrightarrow$	Facility for transporting C \leftrightarrow
$t_2 \leftrightarrow$	Start to produce B \leftrightarrow
$t_2' \leftrightarrow$	Transport product C \leftrightarrow
$P_4 \leftrightarrow$	Facility for transporting B \leftrightarrow
$P_4' \leftrightarrow$	Raw material C arriving at producer \leftrightarrow
$P_5 \leftrightarrow$	Finished product B \leftrightarrow
$t_3 \leftrightarrow$	Transport product B \leftrightarrow
$P_6 \leftrightarrow$	Raw material B arriving at producer \leftrightarrow

Calculating the time raw material B needs in the traditional TPN model under out of stock.

$$C_0 : ST_0 = [0,0]$$

$$D_0 = \{D_0(t_1) : [1,3]\}, MEFT(C_0) = 3$$

Trigger t_1 then generate $C_1 : ST_1 = [1,3]$

$$NEW = \{t_2\}, OLD = \emptyset$$

$$D_1 = \{D_1(t_2) : [3,8]\}, MLFT(C_1) = 8$$

Trigger t_2 then generate $C_2 : ST_2 = [3,8]$

$$NEW = \{t_3\}, OLD = \emptyset$$

$$D_2 = \{D_2(t_3) : [7,16]\}, MLFT(C_2) = 16$$

Trigger t_3 then generate $C_3 : ST_3 = [7,16]$

$$NEW = \{t_4\}, OLD = \emptyset$$

$$D_3 = \{D_3(t_4) : [10,21]\}, MLFT(C_3) = 21$$

C_3 is a condition that supplier provides manufacturer with raw material B. The time interval is [10, 21] from receiving orders to the delivery by suppliers.

Similarly calculate the time material B needs in supply chain TPN model under the grid environment.

$$C_0 : ST_0 = [0,0]$$

$$D_0 = \{D_0(t_1) : [1,3]\}, MEFT(C_0) = 3$$

Trigger t_1 then generate $C_1 : ST_1 = [1,3]$

$$NEW = \{t_2\}, OLD = \emptyset$$

$$D_1 = \{D_1(t_2) : [5,11]\}, MLFT(C_1) = 11$$

Trigger t_2 then generate $C_2 : ST_2 = [5,11]$

$$NEW = \{t_3\}, OLD = \emptyset$$

$$D_2 = \{D_2(t_3) : [8,16]\}, MLFT(C_2) = 16$$

Namely the amount of time interval shrinks to [8, 31] from order to delivery under the condition of grid environment.

Similarly, the time interval can be calculated in stock for raw materials C which is cut from [8, 17] to [6, 12] in grid environment.

Analysis summary: this case analysis is under condition of goods available and out of stock. Taking the process of available product B as an example, the result is obtained by flow time comparison between traditional model and grid model as below.

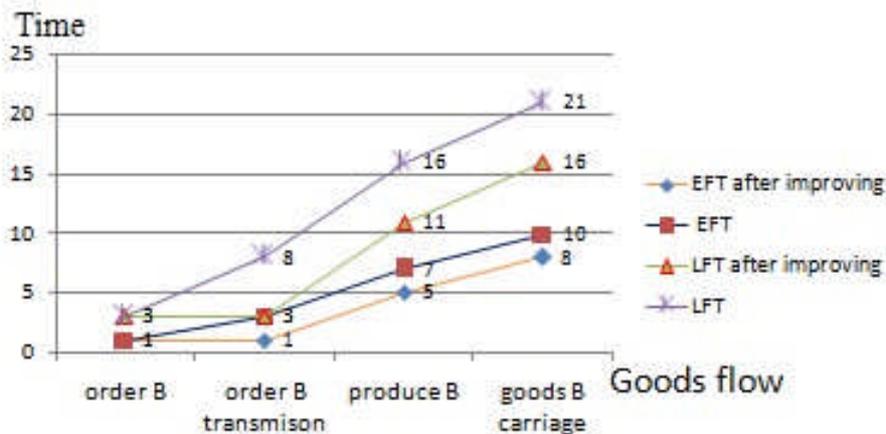


Figure 7. Comparison Diagram of Goods Flow and Trigger time

Tendency chart distinctly told us, for product B, the earliest and latest fireable time is obviously decreased after improving. The transmission efficiency is enhanced from cargo demand, supplier response to cargo arrival by enterprises, giving rise to a certain extent of flow optimization during coordination management. The feasibility and effectiveness of the grid supply chain coordination management can be fully demonstrated,

reflecting superiority of the grid supply chain in cooperative management.

5. Conclusions

In this paper, a solving method of the flow time of supply chain coordination management is proposed based on previous research, analyzing goods flow in grid supply chain based on time Petri nets model with case study,

taking trigger time as measure parameter, effectively improving transmission efficiency and reasonably optimizing cooperation management through grid technology. This is inadequacy in this article that data transmission efficiency and reasonably optimizing cooperation management through grid technology. There is inadequacy in this article that data transmission and calculated amount between firms are larger in reality. The succeeding study will make program for Petri nets model combined with computer programming technology, so as to handle data more promptly and intelligently and advantages of grid supply chain cooperation management can be embodied better.

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