Complex Network-oriented Analysis on Business Service Ecosystem

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Abstract—Service-oriented approach has changed the pattern of providing products and services in business area. Through supply chain on the online platform, many business entities (consumers and providers) can now make business transactions in a more extensive and convenient way. As huge business entities and their complex correlations exist and evolve continuously, this system is regarded as Business Service Ecosystem (BSE). It is critical to discern BSE’s topology structure and evolution rule, to support its management. In this paper, first, key features and business correlation model of BSE are investigated; then, a Complex Network-oriented Analysis Framework (CNOAF) is proposed, which aims to solve the above problem, and a Time-based Correlation Bipartite Graph is established as the core model to deal with correlation; finally, an empirical study of marine logistic service indicates the effectiveness of CNOAF, and several valuable insights are obtained for its development.

Keywords-service management; business service ecosystem; business correlation; complex network

I. INTRODUCTION

Business service has developed rapidly with the deepening of Service-oriented Architecture (SOA). The pattern of providing products and services has been reformed. One typical mode is e-commerce, where business entities consist of customers, sellers, logistics carriers, payment providers and insurance agents, etc. Through online platform, they can make business transactions in a more extensive and convenient way.

As business entities join and leave continuously and their cooperation correlations evolve dynamically, this highly-dynamic system is regarded as Business Service Ecosystem (BSE). In a general view, comparing BSE with Traditional Business Mode (TBM), on one hand, as to business scope, BSE provides an online platform to support business dialogues among broader entities, but in TBM, it is difficult for some entities far from each other to cooperate; on the other hand, as to business process, BSE provides an online mechanism to integrate different links of supply chain, thereby TBM can be implemented in a more convenient and efficient way.

Previous works [1, 2, 3, 4] mentioned the huge transform with SOA, and these works [5, 6, 7, 8, 9] focused on business area. In these works, Peltoniemi et al. [5] discussed the concept of business ecosystem at an earlier age. Zhang et al. [6] presented Service-oriented Enterprise (SOE) and business ecosystem to discuss the development of enterprise mode. Li et al. [7] proposed Service-oriented Business Ecosystem (SOBE) and its architecture, through analyzing service elements and characteristics. Hammadi et al. [8] presented the composability problem of business service. Above works didn’t involve the systematic analysis method for BSE, while it is important for further and deep research of business service. Tian et al. [9] presented a framework for the modeling and analysis of business model, consisting different components, but the proposed case about business-to-business service ecosystem didn’t represent effective data information and result. This paper starts from this viewpoint to discern BSE’s topology structure and evolution rule, which aims to reveal its nature for a more stable development, meanwhile, a real business ecosystem is introduced for the empirical study.

According to the above summary of related works and our viewpoint, three issues are proposed for this paper.

(1) How to model this new organized pattern of business supply chain?

(2) What methods can be utilized to analyze the model established in (1)?

(3) What evolution mechanism can be gained through the model and methods for the real business system?

From a global perspective on BSE, a Complex Network-oriented Analysis Framework (CNOAF) is proposed to guide subsequent analysis.

For issue (1), business correlation model of BSE is established to represent the new organized pattern, and key features of BSE are investigated.

For issue (2), complex network method is applied to analyze the above model, and some insights (topology structure and evolution rule) of BSE are obtained.

For issue (3), a typical business service ecosystem about Marine Logistic Service (MLS) is investigated.

The remainder of this paper is organized as follows: Section II presents business correlation model and key features of BSE. Section III introduces the Complex Network-oriented Analysis Framework (CNOAF) and the involved methods. Section IV introduces a marine logistic service system as the empirical study. Section V presents the conclusions and future works.

II. BUSINESS SERVICE ECOSYSTEM

In this section, business correlation model of BSE is presented firstly, and then key features which differ from traditional business mode and web service are analyzed.

A. Business Correlation Model

**Business Service Ecosystem** (BSE) represents the new organized pattern of service-oriented supply chain in business area, it consists five elements as follows.

\[ \text{BSE} = \langle SI, SP, SP, SC \rangle \]

**Service Individual** (SI) represents service entity in
BSE, including service consumers and service providers.

**Service Population** (SP) represents the aggregation of service individuals with the same function and different QoS, e.g., transport service, payment service.

**Service Flow** (SF) contains abstract service flow and concrete service flow.

**Abstract Service Flow** (ASF) represents the service composition of different service populations, e.g., production assembly service flow consists of manufacture, delivery and assembly.

**Concrete Service Flow** (CSF) represents the service composition of different service individuals, i.e., each SP in ASF selects a specific SI, e.g., manufacturer A is selected to provide manufacture service.

**Service Correlation** (SC) contains three types of correlations respectively between SIs, SPs and SFs.

\[ SC = < SCoSIs, SCoSPs, SCoSFS > \]

**Service Correlation of SIs** (SCoSIs) represents the business relationships, e.g., cooperative partners, business alliances, special agent, etc.

**Service Correlation of SPs** (SCoSPs) represents the service composition relationships and reflects the SF’s structure, i.e., sequence, selection, concurrence and loop.

**Service Correlation of SFs** (SCoSFs) represents the flow relationships, i.e., service resources sharing and reusing in different ASFs or CSFs, e.g., production assembly service and logistic service both require payment service, or multi logistic service instances will share transport capacity. In this scenario, service providers should develop a strategy to distribute and schedule service resources [13].

Through above analysis, business correlation model of BSE can be depicted graphically as Figure.1.

**B. Key Features of BSE**

Three typical and prominent features of BSE are summarized and explained in the following.

**Reduced Location Distance:** Comparing BSE with TBM, service providers are less sensitive to location distance, as the online platform provides a mechanism of communication and security; comparing BSE with web service, in web service location of service provider affects the transmission rate of service, while in BSE, it affects the transportation cost [12].

**Clear Business Boundary:** As the flow characteristic of business service, service providers from different locations provide differentiated business functions, then they can integrate into business flow, so main businesses of different providers are clear and independent.

**Sensitive Trust and Security:** As the characteristics of open and dynamic in BSE [14], consumers become more sensitive to trust and security, they need to balance the risk and convenience through BSE [8, 12, 15].

### III. COMPLEX NETWORK-ORIENTED ANALYSIS FRAMEWORK

In order to discern BSE’s topology structure and evolution rule, a complex network-oriented analysis framework (CNOAF) is proposed as Figure.2.

![Figure 2: Complex Network-oriented Analysis Framework](image)

There are three layers to deal with business system.

- **Model-Layer:** the approach is to model real business system as business correlation model of BSE.
- **Operation-Layer:** complex network is applied to analyze BSE; meanwhile, it contains concrete analysis methods and measurement indicators.
- **Solution-Layer:** through operation-layer, indicators’ values and insight of real business system are obtained.

For Model-Layer, business correlation model of BSE has been introduced in Section II, Operation-Layer and Solution-Layer are introduced respectively as follows.

Complex network analysis is a basic theory and method to research network structure. It abstracts network as a graph, consisting of nodes and edges; node represents entity and edge represents a certain relation between entities. Based on the graph representation, some analysis methods can be utilized, e.g. bipartite graph, and some indicators can be calculated, e.g. node degree, clustering coefficient, centrality, etc [11, 12], which reflect different aspects’ characteristics of the network.

#### A. Time-Based Correlation Bipartite Graph

Bipartite graph is the basic method to deal with entities and their relations [16], based on it, Time-Based Correlation Bipartite Graph (TBCBG) is proposed to deal with complex service correlations in BSE. The whole process is shown as Figure.3.

![Figure 3: Time-Based Correlation Bipartite Graph](image)
There are two parts: the left side is the Cross-SPs Network, i.e. SP-SP Network; the right side is the In-SP network, i.e. SI-SI Network. The transform process is achieved through correlation projection.

It is explained in more detail as follows.

(1) Define service population as $S_P$, and the $i^{th}$ service individual in $S_P$ is $S_{li}$. As Figure 3. shows, on the left side, there are two service populations, i.e., $S_P$ and $S_R$, service individuals are respectively presented as $S_{li}$ and $S_{lj}$, where $i = 1, 2, 3, ..., l$, $k = 1, 2, 3, ..., l$, $l \in N^+$ is the number of $S_P$ and $j = 1, 2, 3, ..., J_l$, $l = 1, 2, 3, ..., L_k$, $j_i, j_k \in N^+$ are the number of $SI$.

(2) As mentioned in Section II, business service has location and main business, so SI can aggregate with the same location or same main business, e.g., agents in Shanghai or agent alliance with selling the same product.

(3) As mentioned in Section II, service correlation consists of three types, hereinto, COCoSFs reflects business flow structure, COCoSs involves scheduling problem optimization, COCoSs is a more complex and general problem, this paper focuses on the analysis of COCoSs. On the left side (SP-SP Network), different SI from $S_P$ and $S_R$ may cooperate to form regular customers relationship, that is depicted with an edge between these two SIs; while some SIs may never have an interaction. On the right side (SI-SI Network), through edge’s projection, SI-SI Network in the corresponding SP can be obtained, the edge reflects that these two SIs have the same cooperative partner; moreover, weight of the edge can represent the number of common partners.

(4) In addition, with the development of BSE, new individuals will join and eliminated individuals will quit, meanwhile, COCoSs will add or delete. This reflects the dynamic of BSE, i.e. time-varying characteristic.

Through above Time-Based Correlation Bipartite Graph, COCoSs can be represented both Cross-SPs and In-SP, some measurements are proposed in the following.

B. Evolution Mechanism

Indicator system is presented to evaluate BSE, which can promote its development and management. It consists of macroscopic type, dynamic type and network type.

Macroscopic Type

It assesses BSE’s scale, including horizontal scale and vertical scale, where horizontal scale represents the number of SP, i.e. $N(SP)$, and vertical scale represents the number of SI in each SP, i.e.,

$$N(SI) = \{N(SP), \cdots, N(SP), \cdots, N(SP)\}$$

Dynamic Type

It assesses the evolution trend of each SP and the influence of each other.

(1) SP’s Evolution Trend

For SP, each trend forms a discrete-time series, where time domain can be year, quarter, etc; value domain can be the number of new SI.

(2) Influence of Each Other

It can be measured by Granger Causality Test [17] and Pearson Correlation Analysis [18]. Firstly utilize “Granger Causality Test” to discover causality relation of SP qualitatively, and then utilize “Pearson Correlation Analysis” to calculate the strength of influence. Pearson correlation coefficient is defined as follows:

$$\rho_{XY} = \frac{\sum X \cdot Y - \sum X \cdot \sum Y}{\sqrt{\sum X^2 - (\sum X)^2} \cdot \sqrt{\sum Y^2 - (\sum Y)^2}}$$

Where $X$ and $Y$ respectively represent two vectors of value sequence, $N$ represents the common number of value sequence. There are positive and negative correlation, $|\rho_{XY}| < 0.4$ indicates low linear correlation; $0.4 \leq |\rho_{XY}| < 0.7$ indicates significant linear correlation and $0.7 \leq |\rho_{XY}| < 1$ indicates high linear correlation.

Network Type

(1) General Trait

Use common indicators of complex network analysis to assess correlations, including degree distribution, mean shortest path length and clustering coefficient, etc.

(2) Concentration Rate

This paper chooses the indicators of HHI and PI (Herfindahl-Hirschman Index) [19] measures the rate of homogeneous and heterogeneous individuals. For BSE, it is defined and transformed as follows:

$$HHI = \frac{\sum \frac{n(i,d)}{N} \cdot d}{N} = \frac{\sum d n(d)}{N}$$

d is correlation degree, i.e. the number of cooperative partners, and $D$ is the maximum of $d$, $n(d)$ is the number of SI who has $d$ degree, $N = \sum n(d)$ is the total SI number of $SP$, thus $HHI = \frac{1}{N}$. It is easy to know, higher HHI indicates higher differentiation and heterogeneity of correlations, i.e. higher concentration. $HHI=1$ indicates monopolization; conversely, lower HHI indicates lower differentiation and higher homogeneity of correlations, i.e. lower concentration. $HHI=1/N$ indicates completely homogeneous, i.e., individuals have the complete same cooperation partners. If $HHI$ value is far more than $1/N$, it indicates the heterogeneity, in general, $HHI=1$ is impossible in real-world.

PI (Pareto Index) measures resources occupation distribution. For BSE, it is defined as the proportion of SI whose degree ranks in the first 20%., i.e., correlation degree ranges from 1 to $D$, then the first 20% ranges from 1 to $20D$.

$$PI = \frac{\sum n(d)}{N} \cdot d^2 \leq 20\% \cdot D$$

Thus, $PI = [0,1]$. Higher PI indicates more obvious power law characteristic, generally, $PI > 80\%$ satisfies the power law, i.e. Pareto’s Law or the principle of 80/20.

(3) Individual Influence

It assesses the largest and smallest influential SI in SP. In this paper, a novel method is adopted to measure the comprehensive influence as follows.

$$P(S_{li}) = \frac{d_{ij}}{\sum_{d_{ij}}} \cdot i = 1, 2, 3, ..., l, I \in N^+$$

$$C(S_{li}) = 2d_{li} / d_{ij}(d_{ij} - 1)$$

$$I(S_{li}) = \alpha \times P(S_{li}) + (1 - \alpha) \times C(S_{li})$$

$d_{ij}$ is the correlation degree of $S_{li}$, $P(S_{li})$ measures degree proportion of $S_{li}$ in $SP$; $C(S_{li})$ measures clustering coefficient of $S_{li}$, where $l_{ij}$ is the connected number among SIs which are connected by $S_{li}$. Thus, comprehensive influence of $S_{li}$ in $SP$ is
defined as $I(S_i|y_j)$ with the integration of $P(S_i|y_j)$ and $C(S_i|y_j)$, and the scale factor is $\alpha = [0,1]$.

Through above indicator system, an integrated and overall insight of BSE is obtained. Analysis of this insight reflects the evolution mechanism of BSE.

IV. EMPIRICAL STUDY

Many business flows in different business areas have developed into BSE, e.g., e-commerce, scientific flow [20], etc. In this paper, Marine Logistic Service (MLS) with URL (http://en.shippingchina.com) [21] is presented. Its major function is to provide an online service platform to support marine logistic. The time period for research is selected from Jan 1, 2006 to Jan 1, 2012. After data filtering and cleaning, the empirical study of MLS is presented on the basis of CNOAF.

**Macrosopic Observation and Analysis**

Through analyzing MLS platform, the major business flow is obtained and presented as Figure.4.

![Figure 4: Major Business Flow of MLS](image)

Except customs and harbor, there are seven major business entities, i.e. $N(SP) = 7$, including Cargo Shipper (CS), Freight Forwarder (FF), Ship Owner (SO), Ship Agency (SA), Port Service (PS), Relevant Industry (RI) and Other Transport (OT). Arrows represent service request direction and texts on arrow represent primary service requests. Moreover, the statistics of $N(SI)$ in each SP is shown as Table.1.

<table>
<thead>
<tr>
<th>SP</th>
<th>CS</th>
<th>FF</th>
<th>SA</th>
<th>SO</th>
<th>PS</th>
<th>RI</th>
<th>OT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N(SI)$</td>
<td>13996</td>
<td>32626</td>
<td>4913</td>
<td>143</td>
<td>4221</td>
<td>5112</td>
<td>3832</td>
</tr>
</tbody>
</table>

Data Analysis:

From Table.1 and Figure.4, it can be observed that Ship Owner (SO) is the core provider as the smallest number and the operation threshold of high capital, the head of MLS flow and SO’s peripheral nodes have a more amount. Freight Forwarder (FF) has the maximum amount, because it acts as the first node of MLS supply chain to provide agency service to shipper. The above data statistic of BSE conforms to real offline scene.

**Dynamic Observation and Analysis**

(1) SP’s Evolution Trend

Based on the registration data of each SI, new registration quantity distribution of service individual in quarter interval is presented as Figure.5.

![Figure 5: New Registration Quantity Distribution of Service Individual in Quarter Interval](image)

Data Analysis:

From Figure.5, several important time-points can be discovered and investigated, including:

- 2006: From the first quarter of 2006, new registration quantity in each SP began to grow. It was the time when this platform [21] created.

- 2008: From the first quarter to the fourth quarter of 2007, new registration quantity of each SP grew fast; especially, shipper and freight forwarder grew dramatically, because 2007 was the most active time of import and export trade in China since the policy of reform and opening-up, however, from the first quarter of 2008, new registration quantity of each SP dropped and the growth obviously slowed down, because lots of things happening in 2008 affected import and export trade, such as international finance crisis, snowstorm in China, etc.

- 2010: From the first quarter of 2010, new registration quantity of shipper grew dramatically, and the growth of other SPs tended to be stable with small fluctuations, because the economy of the whole world began to thaw and recover in 2010.

(2) Influence of Each Other

Apply “Granger Causality Test” and “Pearson Correlation Analysis” proposed in Section III to above trends, and two granger causality relations are obtained.

- Growth of Shipper granger causes growth of Freight Forwarder and the correlation coefficient is 0.9113, which indicates high linear correlation between them, i.e., the rapid growth of Shipper may cause the rapid growth of Freight Forwarder in a large extend.

- Growth of Relevant Industry granger causes growth of Ship Agency and the correlation coefficient is 0.8252. The same explanation as shown above.

**Network Observation and Analysis**

In this paper, three typical SP are selected, i.e. Freight Forwarder (FF), Ship Agency (SA) and Ship Owner (SO). According to the business flow of MLS in Figure.4, there exist correlations between FF and SO, and between SA and SO. Data of correlations is mined from the cooperative relations recorded in the platform. Therefore, four networks are established, including FF-SO Network, SO-FF Network, SA-SO Network and SO-SA Network, wherein, the former represents research object, and the latter represents object cooperated.

(1) General Trait

Based on the left side of Time-Based Correlation Bipartite Graph (TBCBG), correlation degree $d_{ij}$ of $SI$ is calculated. Correlation degree distributions of FF
cooperating with SO and SO cooperating with FF are respectively shown in Figure 6. Correlation degree distributions of SA cooperating with SO and SO cooperating with SA are respectively shown in Figure 7. (HC: Horizontal Coordinate; VC: Vertical Coordinate)

This cooperation mode is regarded as “Agency Cooperation”. It is because that ship owner would establish its own ship agency in one port or cooperate with some third-party ship agencies. Comparing with “Upstream-Downstream Cooperation”, there are more than 60% ship agencies cooperate with one ship owner, these ship agencies may be the banker of ship owner, or the third-party ship agency.

- SO-FF Network, SO-SA Network: There is no obvious distribution feature. In general, the number of cooperative partners (FF and SA) by Ship Owner changes in a large range, which indicates that there exists big gap of strength in Ship Owner.

- Cumulative Distribution: It can be analyzed that FF-SO Network and SA-SO Network approximately obey power-law distribution with an obvious long-tail character, and the power exponent of approximate power law curve is equal to 2.11 and 3 respectively. It indicates that most Freight Forwarders and Ship Agencies cooperate with limited Ship Owners, while someone with strength or fund can cooperate with more. Comparatively speaking, SO-FF and SO-SA Network have no obvious power-law character as a wide range and smooth power-law head. It indicates that Ship Owners tend to cooperate with more Freight Forwarders and Ship Agencies.

Meanwhile, comparative analysis with other collaboration networks is presented in Table 2 [22].

Table 2 Comparative Analysis of Network

<table>
<thead>
<tr>
<th>Network</th>
<th>Indicator</th>
<th>Nodes</th>
<th>MD</th>
<th>PE</th>
<th>MSPL</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movie Actors</td>
<td>449913</td>
<td>113</td>
<td>2.3</td>
<td>3.48</td>
<td>0.78</td>
<td></td>
</tr>
<tr>
<td>Company Directors</td>
<td>7673</td>
<td>14.4</td>
<td></td>
<td>4.6</td>
<td>0.88</td>
<td></td>
</tr>
<tr>
<td>Mathematician</td>
<td>253339</td>
<td>3.92</td>
<td></td>
<td>7.57</td>
<td>0.34</td>
<td></td>
</tr>
<tr>
<td>Physicist</td>
<td>52909</td>
<td>9.27</td>
<td></td>
<td>6.19</td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td>Technology Innovation</td>
<td>1689</td>
<td>3.17</td>
<td>2.02</td>
<td>4.09</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>FF-SO</td>
<td>4815</td>
<td>5.2</td>
<td>3</td>
<td>1.37</td>
<td>0.73</td>
<td></td>
</tr>
<tr>
<td>SA-SO</td>
<td>1640</td>
<td>4.5</td>
<td>2.11</td>
<td>1.61</td>
<td>0.65</td>
<td></td>
</tr>
</tbody>
</table>

MD*: Mean Degree. MSPL: Mean Shortest Path Length. PE*: Power Exponent. CC*: Clustering Coefficient.

Data Analysis:

Comparing with other collaboration networks [22], FF-SO and SA-SO have a moderate mean degree, minimum mean shortest path length and moderate clustering coefficient. It indicates that most freight forwarders and ship agencies cooperate with limited ship owners, but as the smallest amount of ship owners (As Table 1 shown, Ship Owner, Ship Agency and Freight Forwarder have a number of 143, 4913, 32626 respectively), FF-SO and SA-SO have an extremely small MSPL, i.e., Freight Forwards not exceed two (exactly 1.37) would have a common cooperative Ship Owner. Ship Agencies not exceed two (exactly 1.61) would have a common cooperative Ship Owner.

(2) Concentration Rate

The statistics of HHI and PI in four networks are respectively presented in Table 3.

Table 3 Concentration Rate Measurement

<table>
<thead>
<tr>
<th>Nodes</th>
<th>HHI</th>
<th>I/N</th>
<th>PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF-SO</td>
<td>4815</td>
<td>0.1120</td>
<td>0.0002</td>
</tr>
<tr>
<td>SA-SO</td>
<td>1640</td>
<td>0.1732</td>
<td>0.0006</td>
</tr>
<tr>
<td>SO-FF</td>
<td>75</td>
<td>0.0638</td>
<td>0.0133</td>
</tr>
<tr>
<td>SO-SA</td>
<td>114</td>
<td>0.0382</td>
<td>0.0087</td>
</tr>
</tbody>
</table>
Data Analysis:

For $HHI$, $HHI$ value is far more than $1/N$ for FF-SO and SA-SO Network, it indicates that there is a heterogeneous distribution of strength and great competition among them, comparatively speaking, competition among FFs and SAs is more fierce than SOs. For $PI$, $PI$ value in SO-FF and SO-SA Network is more than $80\%$, it indicated that $20\%$ SOs occupy more than $80\%$ of the resource or the market share; while for FF-SO and SA-SO Network, as the huge amount, resource uneven occupancy of FF and SA is relative lower.

(3) Individual Influence

Through calculating on the basis of Section III, for Freight Forwarder, the first three of the most influential individuals are Tianjin International Logistic Co.Ltd, Shanghai Fancheng International Logistic Co.Ltd, and Shenzhen Huayun International Logistic Co.Ltd; for Ship Owner, the first three of the most influential individuals are Maersk (MSK), Mediterranean Shipping (MSC), and China Ocean Shipping Company (COSCO). The result just conforms to the same as the official statistic data of this platform from interaction history record [21].

Through calculating and analysis on the indicator system, an integrated and overall insight of MLS is obtained, which reflects the topology structure and evolution mechanism of MLS.

V. CONCLUSIONS

Business Service Ecosystem (BSE) has many key features different from traditional business model and web service system. This paper focuses on the basic analysis framework and concrete methods to discern BSE’s topology structure and evolution mechanism.

First, business correlation model of BSE reveals the key structure considering correlations; then, a Complex Network-oriented Analysis Framework (CNOAF) for BSE provides a Time-Based Correlation Bipartite Graph (TBCBG) to analysis correlation, and a indicator system to assess BSE; finally, an typical business system about Marine Logistic Service (MLS) is introduced for the empirical study. With application of CNOAF on MLS, it indicates the effectiveness of CNOAF, and some insights are obtained to promote the development of MLS.

This is just the beginning of business service’s research. On the basis of analysis framework, on one hand, the cause of business correlation and its evolution rule can be investigated deeply in the future, on the other hand, for the feature “Sensitive Trust and Security” proposed in Section II, trustworthy and security mechanism in BSE can be studied further to ensure BSE running steadily and healthily.

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