Research on Evolution of Chinese Telecom Industry System Based on Dissipative Structure Theory

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***Abstract*—In this paper, the self-organization evolution mechanism of the telecom industry which is regarded as a complex system is studied based on dissipative structure theory by taking into account the telecom industry's characteristics and practical problems. First, the characteristic of the dissipative structure of the telecom industry system is proposed through qualitative analysis. Second, the Brusselator model of the telecom industry system is built, and the dynamic condition needed for the telecom industry system to evolve into a dissipative structure is summarized by quantitative analysis of the evolution equation. Finally, the self-organization evolution mechanism of the telecom industry system is illustrated with the China telecom industry. Different from traditional qualitative analysis, the dynamic and quantitative method adopted by this study gives a deep insight for the evolution mechanism of the telecom industry's system, and guides the telecom market towards rational development.**

***Index Terms*—telecom industry system, evolution, dissipative structure, Brusselator model**

I. INTRODUCTION

Telecom industry is the fundamental industry to the development of the national economy and information. Because of technology development and the globalization of world economy, China's telecom industry is facing intensive competitive challenges. Although China's telecom industry has made great achievements, it cannot meet the requirements of the national economy development. There are many problems, such as low degree of opening to other countries the poor coordination of the sub-systems, the low capability of independent innovation, the weak international competitiveness. China's telecom industry needs adjustment and transformation. Therefore, a research on the evolution of the telecom industry has an important theoretical value and practical significance.

With the many problems that the telecom industry reform and development faces to reform and develop, many scholars analyzed and studied the characteristics and the hot spots of the telecom industry and the hot spots from the following different points of view, such as the research on regulations and industrial policies of the telecom industry[1-3], the study on the transformation of the telecom industry[4,5], the research on the impact which of the development of the telecom industry onto the national economy[6], etc. Moreover, some scholars studied the structure of the telecom industry is researched from industry ecosystem perspective. [7] These studies provide an effective reference for the industry analysis of industry.

The telecom industry is a non-optimized and non-balanceable, complicated industrial and economic system. The development of the industry depends on the balanced growth rate, the rise and decline of the industry, and the mechanism of the internal changes within the industry. Due to the limitations of the traditional economic theory of the industry, we need to study systematically the evolution of the telecom industry so as to adjust and control the evolution of the telecom industry utilizing the principles of industrial evolution, to optimize resource allocation, and make the telecom industry develop along the correct path.

Self-organization theory known as complexity science, has been widely used in the nature and social fields [8-10]. At present, the applications of self-organization theory in economic research include the evolution of the economic system [11-12], the close relationship between economic system and the self-organization [13-14], and research on innovation network [15-16]. As the self-organization theory itself provides an evolutionary mechanism, it provides a broader field of vision to study the evolution of industrial system. Nelson [17] pointed out that the external manifestations of the evolution of the industrial system shall be a economic phenomenon of the industry. The open, non-equilibrium, nonlinear characteristics of the industrial system are the source of

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the complexity and diversity of the economic phenomenon of the industry.

Self-organization theory is not an independent theory, but is a group of theories. It includes: dissipative structure theory, synergetics, catastrophe theory, super-cycle theory, fractal theory and chaos theory. The above mentioned theories interrelate and unify and form the self-organization theory. These theories don't have any logic conflicts. Dissipative structure theory [11] plays the role of the needed conditions of forming a self-organizing system. According to the theory of dissipative structure, we can determine whether a system has the prerequisite to evolve into a self-organization system, and whether it can spontaneously and independently evolve from a state of disorder to an ordered structure.

II. The Definition of Telecom Industry System

Telecom industry has two different classifications depending on whether it is in broad sense or narrow sense. From the narrow sense [19], "the telecom industry generally refers to operating telephone, telegraph, radio paging, data transmission, fax, satellite communications and other telecom services and telecom transmission activities. In other words, it refers to the activities which offer final products to users". Thus it refers to telecom operation industry. From the broad sense, telecom industry refers to the relations of the upstream and downstream industry which are formed by industrial organizations related to production and telecom services and equipments provided. It involves a number of related industries which are from the raw material provides for the telecom equipment, to equipment manufacturing, telecom network construction, telecom network operations, telecom service generation and services, telecom sales.

The development of communication technology brings diverse communication methods and convergence of these methods, which greatly expanded the connotation of the telecom industry. Modern telecom industry includes not only the land phone communications but also the mobile communications. Furthermore, with the development of communication technology and merge of the telecom, computer and cable TV network, the scope of the telecom industry is continually expanding, more and more of main subjects join into the telecom industry. Telecom industry is becoming more and more closely linked with other industries such as electronics manufacturing industry, software industry, information content services industry.

Therefore, a broad definition of telecom industry is chosen in this paper, which can reflect the real range of the telecom industry from the perspective of vertical integration. The telecom industry system studied is the system which consists of the subjects involved in the activities from forming products to providing services for end users, with the telecom services as the core. The telecom industry system is an overall system composed of natural, economic and social environment in which telecom companies and consumers exist in a certain time and space. Within the system, activities are exchanged through the market, activities including material cycles, energy flow, capital flow, information transfer, knowledge sharing and technology proliferation among enterprises and between businesses and consumers.

All enterprises in the telecom industry system are gathered together based on delivering value or interests to the end-users. Industrial model diagram of the telecom industry system is shown in Fig. 1, corresponding map indicating the main functions of the main subjects.

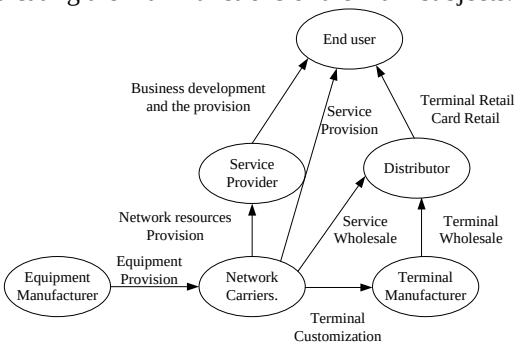

Figure 1. Industrial model diagram of telecom industry system

III. Dissipative Structure Criteria of Thelecom Industry System

Dissipative structure theory states that: when an open system arrives at the nonlinear zone that is far from the equilibrium state, once a system's parameters change to a certain threshold value, the system may be transferred from a stable state to an unstable state, which leads to mutation through fluctuation. That is a non-equilibrium phase transition. As a result, the system transits from the old chaotic and disordered state to a new ordered state. This ordered state needs to exchange material and energy with the outside world to maintain a certain degree of stability, and does not disappear due to external minor disturbance. This new ordered structure which is formed when the system in nonlinear zone and away from equilibrium, and which to maintain its own stability through the dissipation of the energy, is called dissipative structure by Prigogine.

A. *Opening Feature*

As a nation's economical and foundational industrial, telecom industry is in a complex environment and is interdependent with the external environment. On the one hand, the environment provides a variety of factors required by the system to survive and develop, such as materials, technology, information, capital elements. On the other hand, telecom companies export to the environment products and services and dynamically improve the environment through efforts, to create a more favorable environment for the development. Only by opening to the outside world, can it bring in adequate flow of negative entropy, make the dissipation occur between telecom industry and the environment, and ultimately evolve to the dissipative structure. The open feature of telecom industry system is the prerequisite and essential condition of self-organized industrial system.

Telecom industry system is closely linked with other industries. Telecom industry system not only obtains the necessary resources (such as capital and market) from its relevant industries, but also expand the scope of telecom services, enhance product value and improve the competitiveness of the industry through combination of those industries. Under the impetus of the merge of the networks of telecom, computer, and cable TV, the newly formed business is generated in the converged network, such as mobile TV, IPTV and internet radio / TV. These services have become a new point of growth for broadcasting operators and telecom operator.

B. Far from equilibrium

In the telecom industry system, the equilibrium and near-equilibrium refer a single service and a single state of industry chain structure. The characteristics of being far from equilibrium mainly refer varieties and complicity of the industry chain structure.

In the evolution process of telecom industry system, the development of technology drives telecom industry structure away from equilibrium state which has single service and low earning power. In the traditional telecom industry, telecom's voice traffic had been the most important business. However with the development of technology, this situation has significantly changed. Data traffic has become the fastest growing services. In particular, the explosive growth of IP services, the delivery of multimedia services and the rise of download services have made the data service develop rapidly in both services size and volume. It is gradually becoming the main characters of telecom services. The traditionally dominating voice business has begun to shift gradually to the supporting role to the telecom services.

The development of technology and the diversity of operations essentially are to reduce the network cost, improve the utilization of the network, and make the network away from the inefficient, slow growing equilibrium state. The expand of the innovation of network services makes the industrial chain structure even further from equilibrium and promotes telecom services to develop in a professional and personalized way. It will eventually lead to fission of the industrial chain and meet the needs of individual users. With telecom industry system further away from the equilibrium state, after breaking a certain threshold, telecom industry system can have periodical mutation upgrade, improving the system order degree. In recent years, the global telecom operators are trying to obtain the capabilities of providing multi services and transform to be an integrated information service provider in order to improve enterprises' anti-risk capability and achieve high returns. That is a characteristic of the telecom industry system being far from equilibrium state. The evolution of the telecom system towards net generation network (NGN) can save more costs in construction, operation and maintenance. More importantly, since NGN is an open network with separated operations and control and providing multi-services, it can cause network convergence, which greatly expands the types of telecom services, enhances the innovation ability of network technology, produces more diversified network value, and further promotes the telecom industry structure to be further away from equilibrium state.

C. Nonlinear

As a self-organized complex system, telecom industry system has nonlinear characteristic. In the process of evolution, telecom industry system introduces the factors of policy, technology, capital and demand from the environment as negative entropies. Through the amplification of the nonlinear interaction in the inside and outside of the system, a chain reaction of the telecom system and even the socio-economic system is caused. The telecom industry is driven further from equilibrium and into a nonlinear zone. The growth rate of network value begins to have nonlinear variations, showing a nonlinear increase in the number of users. Ultimately, a tremendous influence and impact on the evolution of the telecom industry is caused. For example, telecom network operators generally invest a lot in the construction of network at the beginning, but user requirements often begin to grow after the telecom network and the industry chain grow to a certain stage. The value of new telecom services begins to form a scale only after user demands have a certain degree of maturity. It does not grow simultaneously with the scale of the network construction and development of industry chain.

D. The impact of fluctuations

Fluctuations in the telecom industry system run through every stage and space of the development. The function and structure are constantly adjusted through the fluctuation. And the development of the telecom industry system is further promoted. Fluctuations cause innovative activities, form ordered system structure at a higher level in the telecom system. For example, the impact of the converged services such as IP phones on traditional services and the emergence of 3G foam are the results of fluctuations.

Most fluctuations of the telecom industry system occurred near equilibrium are in the quantitative phase. When the external input reaches a certain threshold condition, telecom industry system may break the original equilibrium and drive the system far from equilibrium to enter into a nonlinear zone. If the system can keep exchanging material, energy and information with the environment, when the entropy input from the external environment into the system is greater than that generated by the system, the fluctuation caused by internal or external factors may be magnified into a giant fluctuation under the nonlinear effect, causing the industrial system to evolve towards a new order. For example, the invention of the web browsers led to the popularity of web surfing and e-mail, the rise of many new internet sites and creation of many kinds of web services. It produced a huge snowball effect. The invention of 3G communications technology brought a qualitative change to the telecom industry.

As a summary, from the irreversible evolution process of the telecom industry, the action of internal nonlinear force, the phenomena of fluctuations far from equilibrium,

and the requirements of "negative entropy" input from the outside environment, we can conclude that if the telecom industry system wants to get the healthy, stable and sustainable development, the necessary precondition is that the system must be a "dissipative structure".

III. DISSIPATIVE STRUCTURE MODEL

The system evolution goal of the telecom industry, is that the whole system evolves proceed systematically from the low-order to the high-order. From the view of dissipative structure theory, the evolution of the telecom industry is the collaborative order process with the environment through dissipation. But it required a certain conditions which led to this process be occurred. Whether the system could be eventually formed a dissipative structure, depends on the system has unstable conditions and the mechanism. From a system point of view, any evolution from an old state to a new state is the results of the old state of instability. It is a necessary condition of the emergence of new state that the old state loses stability. Therefore, the study whether the system has the unstable conditions and the mechanism, is an important accordance determining whether the system form a dissipative structure. According to the dissipative structure theory, the Brusselator model [17] is the expression of dissipative structures, i.e.

$$\begin{cases} (a)\ A \xrightarrow{k_1} X \\ (b)\ B + X \xrightarrow{k_2} Y + D \\ (c)\ 2X + Y \xrightarrow{k_3} 3X \\ (d)\ X \xrightarrow{k_4} E \end{cases} . \tag{1}$$

Where A and B are the reactants, and their consumption are supplied constantly by the outside world; D and E are the products, and once they are generated, they are removed immediately; X and Y are the intermediate resultants, and their concentration change over time. All of the above four groups of reactions are related to X: the first and the third reactions make X to increase; the second and the fourth reactions make X to decrease. Two groups of reactions are related to Y: the second reaction makes X to increase and the third reactions make X to decrease.

Now this "Brusselator model" model is given a new practical meaning. The meanings of A, B, D, E, X, and Y are transferred into factors of the self-organization process of the telecom industrial system.

A— innovation level of telecom industry system.

B— external environment of the telecom industrial system (Accord with the preceding analysis, it includes socio-economic development levels, degree of market competition and the policy environment of telecom industry.).

D— profits of telecom services.

E— competitiveness of telecom industry.

X— service level of telecom industry.

Y— telecom consumption level.

X and Y are the state variables of the system. A, B, D and E are the adjustable parameters or control parameters of the system. Then the model can be interpreted as shown in Fig.2.

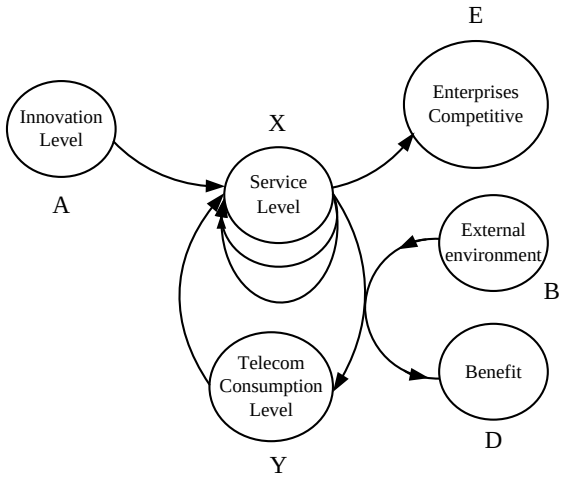

Figure 2. The Brusselator model of the telecom industry system

According to Brusselator reaction model, the evolution of the telecom industry system depends on the level of technological development and the external environment. Under these two conditions, through the constantly increasing level of the telecom services and consumption needs, the two intermediate products， the competitiveness of the telecom enterprises has increased, and that has further enhanced the effectiveness of the telecom industry, finally formed the orderly evolution of the telecom industry.

VI. ANALYSIS OF EVOLUTION MECHANISM

To further analyze the specific evolution trend of the telecom industry system theoretically, we need to analyze the reaction of the system state variables X and Y, i.e. the diffusion kinetics equation:

$$\begin{cases} \dfrac{dx}{dt} = k_1 A - k_2 BX - k_4 X + k_3 XY + D\dfrac{d^2 x}{dt^2} \\ \dfrac{dy}{dt} = k_2 BX - k_3 X^2 Y + D\dfrac{d^2 Y}{dt^2} \end{cases} . \tag{2}$$

Omit the diffusion items and transform the variables, take the variables as $\tau = k_4 t$, $x = \sqrt{k_3 / k_4}X$, $y = \sqrt{k_3 / k_4}Y$, $a = \sqrt{k_1^2 k_3 / k_4^3}A$, $b = (k_2 / k_4)B$, (2) is converted to

$$\begin{cases} \dfrac{dx}{dt} = a - bx - x + x^2 y \\ \dfrac{dy}{dt} = bx - x^2 y \end{cases} . \tag{3}$$

The steady-state solution of (3) is

$$x_0 = a,\ y_0 = b / a . \tag{4}$$

This nonzero solution shows that the reaction is in steady reaction state near equilibrium zone. Whether the system can move toward an orderly dissipative structure depends on whether the steady-state solution can become

unstable, and which one condition can cause instability. (Because the nonstability is more difficult to analyze, the unstable point or region of the system can often be identified by the stability analysis, then determine whether the system evolves from the disorder into an order state.).

The characteristic equation of this model which has a linear stability analysis around the near steady state ($x_0 = a,\ y_0 = b/a$) as follows:

$$\lambda^2 - (b-1-a^2)\lambda + a^2 = 0\,. \qquad (5)$$

In (5), λ is the eigenvalue of the system. Take

$$\omega = b-1-a^2 \qquad (6)$$

Eigenvalues of the system is

$$\lambda_{1,2} = \frac{1}{2}(\omega \pm \sqrt{\omega^2 - 4a^2}) \qquad (7)$$

The stability of the system depends on ω, which is determined by two factors (*a* and *b*). The solution of the characteristic equation is discussed below:

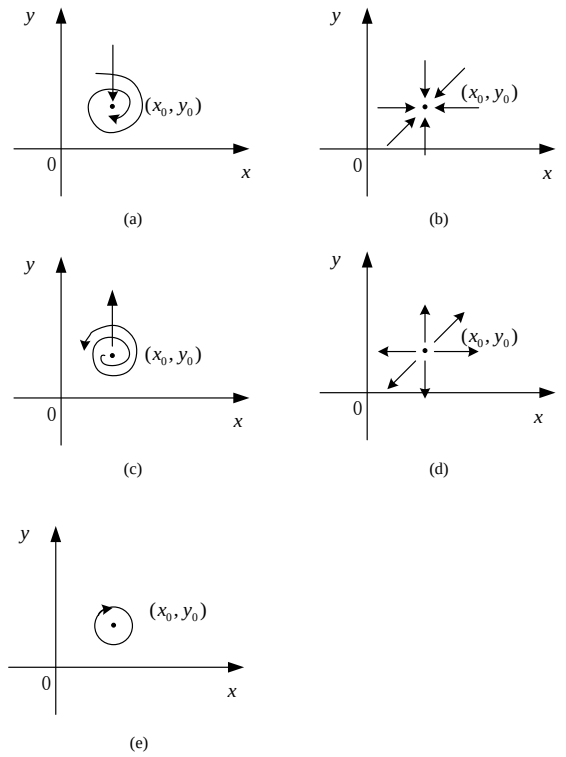

Figure 3. The stable state solution of equation (5)

When $\omega < 0$ and $|\omega| < |2a|$, (5) has two negative real part of complex conjugate roots as shown in Fig. 3-(a). With growth of time, the increment near the steady-state point (x_0, y_0) convergence and limit to the vicinity of 0. Therefore, the steady state point is a stable focus. The system always returns back to an orderly state from the initial chaotic state.

When $\omega < 0$ and $|\omega| > |2a|$, (5) has two negative real roots as shown in Fig. 3-(b). For large disturbances, steady-state point is always stable. At this point, the steady state point is a stable node.

When $\omega > 0$ and $|\omega| < |2a|$, (5) has two positive real part of complex conjugate roots as shown in Fig. 3-(c). The steady state point is the instable focus. With growth of time, the increment near the steady-state point (x_0, y_0) is divergent. Eventually it generates a limit cycle with a steady-state point center. The system cannot be stable and keep vibrating in a certain range.

When $\omega > 0$ and $|\omega| > |2a|$, (5) has two positive real roots as shown in Fig. 3-(d). Any perturbations to steady-state solution will led to steady-state point (x_0, y_0) to be away from the equilibrium point. At this point, the steady state point is an unstable node.

When $\omega = 0$, (5) has two purely imaginary roots as shown in Fig. 3-(e). Therefore, steady-state point is a stable center. The rail line near the central point is neither unlimited nor infinitely far away from it. The central point is Lyapunov stable, rather than the progressive stable.

From the above analysis, it can be included that as follow: When $b<1+a^2$, i.e. ω<0, the steady-state solution is stable. The trajectory line starting from different initial states eventually return to this attractor which is the steady-state point. When $b>1+a^2$, i.e. ω>0 , the steady-state solution is not stable. The trajectory line starting from different initial states will eventually enter into the same periodic orbit (limit cycle). With the growth of time, the concentration of X and Y also changes periodically. To make the system evolve to a stable and orderly state, the reaction concentration must meet $b>1+a^2$. In this way, it is possible for the system to evolve towards dissipative structure. In the system, factor "*a*" parabolically varies with the factor ω. So the factor "*a*" is a crucial factor. That means that the level of technical development of the telecom industry system plays a more important role in the orderly evolution of the system than others.

- When ω<0, i.e. $b<1+a^2$

The system is stable. It shows that when the requirements for the development of the external environment of the telecom industry system are low, the system is in a steady state which lacks motivation to evolve to an orderly system. There are three reasons. Firstly, it is because the level of the development of socio-economic is low. For example, in the early stage of development of China's telecom industry, government investment was tremendously short and the supply capacity of telecom network was insufficient. Secondly, it is because demand from customers is small and the requirements for telecom services are low. Customers are only satisfied with the needs of making phone calls. Thirdly, it is because the regulation of entering the telecom market is strict, which results in lacks of effective competition. Before the China's telecom industry reform in 1994, government monopolized telecom operation. Telecom enterprises lacked creativity

because of the monopoly of China's telecom. Therefore, the investment in telecom companies was mainly for network construction, rather than services innovation to enhance the level of telecom services.

- When $\omega>0$, i.e. $b>1+a^2$,

It shows that when the development of external environment of the telecom industry system requires a higher level of innovation of the system, it will promote instability of the system. The system may appear to evolve to a higher level of steady-state of dissipative structures. At this time, new opportunities such as increased competition, diversified customer demands, and deregulation emerge. The system is in unstable state. In the competition of products and services, telecom companies increase their investment in technical and services innovation, constantly develop new services and new technologies to meet users' requirements, optimize product structure, improve service quality, and lower product prices.

For example, in China's 2G era, the establishment of China Unicom in 1994 broke the exclusive monopoly of China telecom and promoted competition in the China telecom market. The government adopted asymmetric tariff control policy to promote competition in the market, creating the pressure of competition on China's telecom. Telecom charges have been falling since then. However, in the early development stage of 2G, a truly effective competition in the market wasn't formed, and market share of China Unicom was relatively low. It couldn't compete with China's telecom. With the development of communication technology, China's telecom industry was restructured in 2000. There were more competitions and more co-existing networks and effective competition began to take shape. As a result, the number of telecom users has been growing rapidly and operators have increased the types of services and improved the quality of services. The operating companies have substantially increased the level of services. The mobile operators developed from the second-generation to the second-generation enhanced. The fixed network operators compete for customers by using wireless local telephones.

With the drive of market requirements and development of the information technology, the convergence of telecom networks, cable TV and computer networks emerges, which further promotes the telecom operators to upgrade the basic network, re-integrate and coordinate the structure of industrial chains, develop new services and new business models, including voice, data, video and multimedia, to meet the needs of individuals, families and communities for the comprehensive information services. It also promotes the transition of the telecom industry to information services and makes the telecom industry system to evolve constantly towards a new and orderly direction.

V. CONCLUSION

The above analysis shows that the telecoms industry system has four characteristics of dissipative structure. They are the characteristics of being open, far from equilibrium, nonlinear, and fluctuation. It is proven to be a "dissipative structure". However whether the system could eventually form a dissipative structure depends on whether the system has unstable conditions. Based on the analysis of Brusselator model of the telecom industry system, it can be concluded that by adjusting and controlling of the concentration of reactants (A and B) and intermediate resultants (X and Y), i.e. by greatly improving the socio-economic level, actively cultivating customer requirements, developing a reasonable industrial regulation policy of the system, and changing the external environment to benefit the development of the telecom industry system's technical level, the level of innovation and services of telecom enterprises can be promoted to increase. As a result, the system will become unstable and far from equilibrium, and transfer to the dissipative structure, making the whole system evolve from the low-order to higher order, ensuring the healthy and sustainable development of the telecom industry system.

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REFERENCES

[1] J.J Laffont, J. Tirole, "Competition in telecommunications", the MIT press, 2001.

[2] M. Michalis, "Local competition and the role of regulation: the EU debate and Britain's experience", *Telecommunications Policy*, vol.25, No.11, 2001, pp. 759-776.

[3] C.R. Knittel, "Regulatory Restructuring and Incumbent Price Dynamics: The Case of U.S. Local Telephone Markets", *The Review of Economics and Statistics*, vol. 86, No.2, 2004, pp. 614-625.

[4] W. B.Rouse, "Enterprises as Systems: Essential Challenges and Approaches to Transformation", *Engineering Management Review*, IEEE, vol.33, No.3, 2005, pp.138-150.

[5] P. Gao, K. Lyytinen, "Transformation of China's telecom-munications sector: a macro perspective", *Telecommunications Policy*, vol.24, 2000 pp. 719-730.

[6] G.Madden, Scott J. Savage, "CEE telecommunication investment and economic growth" *Information Economics and Policy*, vol. 10, pp.173-195, June, 1998.

[7] Kong Wen, "Evolution of Mobile Communication Ecosystem", *World Telecommunication*, No.1, 2002, pp.25-29.

[8] P.M. Auger, "Self-organization in hierarchically organized systems", *Systems Research*, No. 4, 1990, pp221-236.

[9] W.G.Schieve, P.M Allen, Self-organization and dissipative structures: applications in the physical and social sciences: based upon the proceedings, Austin, TX: University of Texas Press, 1982.

[10] R. H. Day, P. Chen. Nonlinear Dynamics and Evolutionary Economics. Oxford University Press, Oxford, U.K., 1993.

[11] M. Rinne, "Technology Roadmaps: Infrastructure for innovation", Technological Forecasting & Social Change, vol.71, No.1, 2004, pp67-80.

[12] R.N. Kostoff, R.R. Schaller, "Science technology roadmaps", IEEE Transactions on Engineering. Management, vol.48, No.2, 2001, pp132-143.

[13] U.Witt, "Self-organization and economics—what is new?", *Structural Change and Economics Dynamics*, No.8, 1997, pp489-507.
[14] J. Foster, "Economics and the Self-Organization Approach: Alfred Marshall Revisited", *Economic Journal*, vol.103, 1993, pp975-991.
[15] R.W. Rycroft, D.E. Kash., "Self-Organization Innovation Networks: Implications for Globalization", *Technovation*, vol.24, No.7, 2004, pp187-197.
[16] G. Silverberg, G. Dosi, L.Orsenigol, "Innovation, Diversity, and Diffusion: A Self Organizing Model", *Economic Journal*, vol.98, No.393, 1988, pp1032-1054.
[17] R R. Nelson, "Recent evolutionary theorizing about economic change" *Journal of Economic Literature*, vol.33, No. 1, 1995, 48-90
[18] G. Nicolis, I. Prigogine, "Self-organization in Nonequilibrium Systems: from dissipative structures to order through fluctuations", Wiley, New York, 1977.
[19] Hong Wu, Xiou qing Huang,Yuan Chunhui, "Communications Economics", 2nd ed., Beijing University of Posts and Telecommunications Press, 2007.

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