

# Platformization Mechanism and Simulation Analysis of High-tech Service Innovation Network Based on Structural Holes Theory

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## **Abstract**

*Platformization is an important evolutionary trend of the high-tech service innovation network. From the perspective of structural holes theory, this paper studies the platformization evolution mechanism of high-tech service innovation network and the formation of different kinds of platform enterprises in this process with a simulation analysis. Results indicate that, based on the scale-free property of the high-tech service innovation network and the evolution of structural holes and so on, network evolves into platform with an approach of “appearance and differentiation of node enterprises→ modularization→ module embedded→ formation of system platform”; the node with rich structural holes has more advantages to become the platform enterprise, and the node bridging large amount of structural hole is more likely to be the system platform enterprise.*

**Keywords:** *High-Tech Service Innovation Network; Platformization; Platform Enterprise; Structural Holes; Modularization*

## **1. Introduction**

Driven by manufacturing service and global value network restructuring, open innovation model with modules embedded and network integration in high-tech service innovation network is becoming popular and significant. System solutions are offered for customers through the integration of innovative results from various modules [1]. Platform has become an important development trend, and platform industry and platform economy develop rapidly. On April 2, 2014, as the emerging and famous company in mobile Internet industry in China, Xiaomi issued a "MIUI operating system of no root". This was not only a strategic move of its product diversity, but also a deep understanding and response for the advantage of platform leadership that Microsoft has acquired with the Microsoft Windows operating system. Other than Xiaomi, more and more companies in high-tech services industry make use of evolution of the innovation network to transform into a platform enterprise. So, how the high-tech innovation service networks evolve into a platform, platform enterprise how to produce, and what is the inner mechanism and law of platformization development. Those are important scientific research and practical problem, and they will be discussed in this paper.

In recent years, scholars have studied the development of high-tech service innovation network from various perspectives. There are a series of valuable research topics and scientific problems in high-tech service field, such as mechanism of co-opetition and value creation, open integration pattern and evolution structure optimization and so forth [1]. In order to enforce innovation, high-tech service enterprises committed to technology diffusion through network construction.

Industrial integration and transformation and upgrading have driven the explosive growth of modern service industry, and as a new network organization form, platform has become an important evolution carrier of high technology service innovation network. Platform service has its own characteristics, such as network externalities, resource integration, function integration, cooperativity, derivatives and other characteristics. And

platform service under network environment has low access cost, effectively integrates scattered and specialized service resource and creates value together [2]. Now smart phone operating system platform has become the key point of competition in mobile communications industry, which has promoted "the competition between enterprises" to "the competition between operating system platform alliances" [3]. Platform enterprise is the most important behavioral agent in platform ecosystem. It is usually the platform leader, and controls the core factors in platform ecosystem. Under common interface standard, platform enterprises and complementary enterprises depend on each other, implement collaborative innovation activities. SUN and ZHAI show that, as a platform provider, module of operating system couples with complementary modules, such as downstream developers, mobile terminal providers, network operators, network equipment providers, and they form into a complete network platform ecosystem [4]. ROCHET and TIROLE confirm that platform plays a intermediary role in two-sided market, it attracts both parties, and formulate reasonable pricing strategy [5]. CUSUMANO and GAWER suggest that there are four distinct and closely related levers of platform leadership which include scope, product technology, relationships with external complementors, and internal organization, and the four levers are useful for managing innovation [6]. LEE et al. suggest that in the Web 2.0 era platform leadership depends on five interdependent dimensions: innovation ability, connectivity, complementarities, efficiency, and network effects [7]. PON et al. think that it is important for platform enterprise to use the different core competence to establish complementary services to control platform and lock the user [8].

In the research of platformization trend of high-tech service innovation network, LU takes an example of operating system platform and mobile value-added business platform, and suggests that industry value chain has evolved into value network through modularization, and the center module has developed into platform to provide network infrastructure [9]. Based on whether platform pairs are complements, weak substitutes, or functionally unrelated, EISENMANN et al. present a typology of envelopment attacks, and analyze the successful conditions [10]. Bridging differing perspectives on technological platforms, GAWER concludes an integrative framework, and suggests that platforms can be usefully conceptualized as evolving organizations or meta-organizations that: federate and coordinate constitutive agents who can innovate and compete; create value by generating and harnessing economies of scope in supply or/and in demand; and entail a modular technological architecture composed of a core and a periphery [11]. All in all, scholars have conducted study on platform about the evolution motivation and platform formation path, but, from the perspective of the network system structure, there is little research, which focuses on the characteristics of network node, and further reveals the platformization evolution mechanism and platform enterprise formation path of high-tech service enterprise innovation network.

## 2. Methodology

Social network analysis focuses on the study of social phenomenon and social structure from the perspective of "relationship", which includes behavior structure, political structure, social structure and economic structure, etc. [12]. The integration of social network and innovation network makes social network analysis method widely used in the research of innovation network [13]. Social resource and social capital based on the network utility and the strong and weak ties of network, and the average shortest path, cluster coefficient and structural holes based on the network structure both are important research perspectives. Among them, a structural hole is a relationship of nonredundancy between two contacts. The hole is a buffer, like an insulator in an electric circuit [14]. Namely, two actors which have no direct link with each other, but linked by a third party. The network location of the third party is a structural hole, and the third party is called

actor bridging structural hole. This theory focuses on the exploration of network non-redundancy information.

Platformization of the high-tech service innovation network is the fusion sequence of evolution of nodes and elements in the different location of network. From the perspective of structural holes, this paper studies the platformization evolution of network, and gives full consideration to the status of different nodes in the network, as well as the relationship between nodes, which contributes to a more comprehensive and accurate analysis of the platformization mechanism.

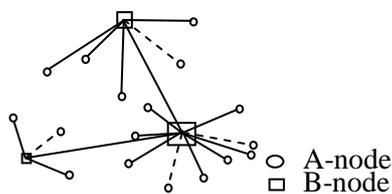
### **3. Platformization Mechanism of High-tech Service Innovation Network based on Structural Holes Theory**

#### **3.1. Structure Properties of High-tech Service Innovation Network and its Structural Holes**

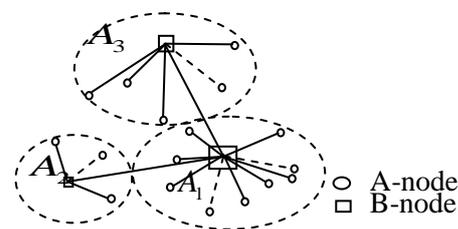
**3.1.1. High-tech Service Innovation Network Features:** (1) Technology complexity. High technology always means the complexity of technology. A single enterprise often cannot accomplish a high technology research and development independently. (2) Open. Because of the complexity of technology, the high-tech service enterprises carry on innovation activities based on the principle of open innovation. Network boundaries are fuzzy and there are still enterprises to join and out. Enterprises in the network transfer knowledge mutually, share resources, and create value together based on open innovation. (3) Functional complementarities. Enterprises in the network provide complementary products/services to each other, based on formal contracts or informal business relationship, they communicate and collaborate mutually, and enterprises forms into different complementary function groups. Enterprises which belong to the same function group are homogeneous in their knowledge, technology, and resource, and they produce similar products or provide similar services. Enterprises which belong to different function groups are of high heterogeneity, and they usually belong to different business field and focus on different modules of the product/service system supplying. (4) Integration. Based on common principles of open innovation, complex technical system requires different network function groups produce complementary module, and provide integrated products/services solution to end users.

**3.1.2 Scale-free Property of High-tech Service Innovation Network:** Based on these features above, a high-tech service innovation network contains rich nodes, and more than one network level. Network knowledge, resources and capabilities also show uneven distribution. Different network nodes have different network position, and network structure presents a scale-free feature. Enterprises in the network have initiative to select partners, and there is high interactivity among them. Enterprises often cooperate with one who has scarce and high quality resources, therefore enterprises with such advantages occupy the central position in the network. Preferential linkage makes several core enterprises in the network become partners of many other enterprises, and those who possess no key resources, and lack core technology have a small amount of partners. Node degree distribution of high-tech service innovation network is nonuniform. Degrees of most nodes are low, and a small number of nodes have a relatively high degree. Degrees satisfy power-law distribution:  $P(k) : k^{-\gamma}$ ,  $P(k)$  is the probability that the degree of randomly selected node is  $k$ , and  $\gamma$  is a constant<sup>[21]</sup>. Software industry cluster and TD industry alliance are a kind of high-tech service innovation network, which have obvious scale-free property<sup>[21, 22]</sup>.

**3.1.3. Structural Holes in High-tech Service Innovation Network:** According to the scale-free property of high-tech service innovation, a large number of nodes of the network have a little direct connections with the others, and a small amount of nodes are directly connected with a large number of nodes. We divide them into two categories. The node with a small amount of ties are called A-node, and the node with great amount of ties are B-node. There are many A-nodes, but only a small amount of B-nodes, as shown in Figure 1. From the perspective of social network, each enterprise in the innovation network corresponds to a node, and the cooperation relationships are the ties in the network. The solid lines represent the formal cooperation relationship, and the dashed lines represent informal relationships. There are less direct ties between A-nodes, and structural holes appear in the network. B-nodes bridge the holes, act as a mediator, provide non redundant information, and control information and resource flow. Further, B-nodes can be divided into two groups, one with rich structural holes and the other with less. And the former is called super actor bridging structural holes, and the latter is called ordinary actor bridging structural holes.



**Figure 1. A Model of High-tech Service Innovation Network of Scale-free**



**Figure 2. Modularization**

### 3.2 Evolution of High-tech Service Innovation Network based on Structural Holes Theory and Formation of Network Platform

#### 3.2.1 Structural Holes and Formation of Module Platform

##### (1) Super actor and formation of core module platform

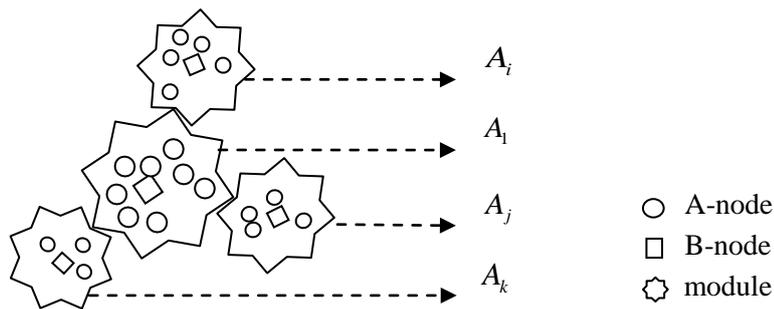
Based on the previous analysis, average shortest path between A-nodes become smaller, and B-nodes around them link them together by bridging the structural holes. At this time, such A-nodes relate to each other, and form a module  $A_i (i = 1, 2, L, s)$  which center on the B nodes, as shown in Figure 2. Super actor bridging structural holes cooperates with surrounding A-nodes which belong to the same function group with it, and they form module  $A_1$ . Super actor links with nodes from the other function group as well, bridges structural holes between multiple functional groups, and controls the resource and information flow between groups. Thus, module  $A_1$  acts as the technology architecture provider in the overall solution, and has become the core module in the network by its network location advantage.

##### (2) Ordinary actor and formation of complementary module platform

Like the super actor bridging structural holes, ordinary actors bridging structural holes also link surrounding A-nodes which belong to the same function group with it, which evolve into complementary module  $A_i (i = 2, L, s)$ , as shown in Figure 2. Enterprises tend to cooperate with the enterprise belonging to the same function groups in order to share basic technology, or internalize external resources. Ordinary actors act as a mediator, integrate different resources and capabilities in their business field, go beyond their original organizational boundaries, reorganize business process. They are committed

to the core business field, reduce the intermediate links of resources transformation, broaden the channels of information transmission, shorten the chain of knowledge transfer, share and integrate value elements within groups, construct field advantage, and co-create value together. In a word, the ordinary actor bridges structural holes in the group of A-nodes around it, and they evolve into a complementary module. Ordinary actor is the core enterprise in this module, which has a strong technical ability, knowledge creation and spillover ability in general. Ordinary actors are located in the communication channel between the enterprises in the module, control the relationships, and take the core position. They become module platform enterprises, and dominate the business development of the module.

**3.2.2. Module Embedded and Formation of System Platform:** With evolution of module, the original cooperation between enterprises in the module and enterprises in the other modules transform into the connection between modules. Modules aggregate together through the connection between them. Linked by core module, complementary modules are embedded, which are formed into system platform, and produces multilateral market. The contracts and the implied agreements between core module and complementary modules, evolve into system interface standards. Core module becomes the system dominator and leader. System platform goes through rapid growth on the basis of concentration of the original connections, as shown in Figure 3. Any complementary module provides a product or service innovation will be under core module control. Because of the super actor bridging structural holes, core module promotes system innovation and leads changes of other modules, have greater network effect.

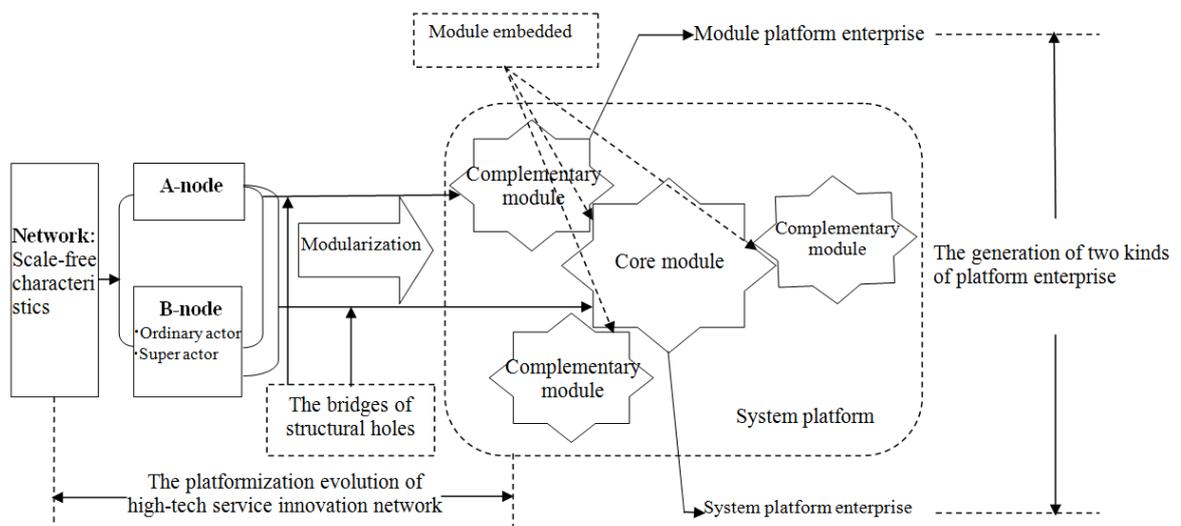


**Figure 3. Modules Embedded**

As shown in Figure 3, the leading enterprise in core module is the super actor bridging structural holes of the whole system. Based on bridges of structural holes, the interconnections with a large number of enterprises evolve into the relationships with various modules, and the super actor controls the only communication route between modules. This core, dominant position and the mediator role of super actor in the network contribute to high visibility, bring it more information, and make it easier to grasp the market opportunity, and obtain the platform technology architecture control ability. Of course, acquisition of such a status must be based on its strong technical strength, the system technology structure with high compatibility as well as strategic resource gathering and integration ability. Then, in the process of information and resources flow, it promotes the formation of network routines, builds platform interface standard, becomes the system platform enterprise, and gets platform leadership. To be specific, it mainly includes three missions. Firstly, system platform enterprise should design platform architecture, absorb the complementary modules to join in the system platform, integrate complementary resources, and make  $A_i (i = 1, 2, \dots, s)$  become multilateral groups around core module. Secondly, it should formulate unified interface standards, normalize

and define the degree of openness. It takes advantages of super actor's network position, selective conveys information to the modules, builds trust and knowledge sharing mechanism, reduces transaction costs, provides customers with the overall solution by enhancing interoperability between modules. Thirdly, system platform enterprise should define and dominate system technology development, attract complementors to increase innovation investment to extend the scope of business, coordinate the relationship between each module, leads the innovation and development of whole system platform.

All in all, based on the structural holes theory, high-tech service innovation network evolves into a platform, which experiences a process of "two types of nodes → appearance and differentiation of nodes → modularization → module embedded → formation of system platform". And module platform enterprise and system platform enterprise are appeared during the process. The main platformization mechanism and platform enterprise generating path are as shown in Figure 4.

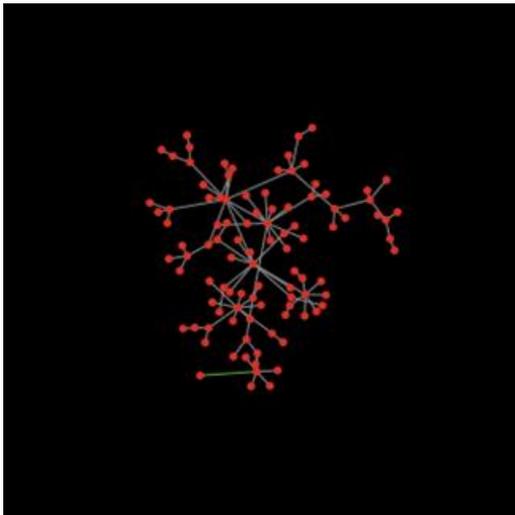


**Figure 4. A Framework of Studying Platformization Evolution**

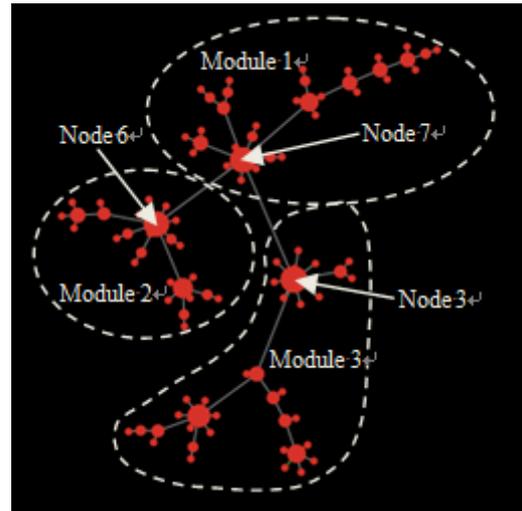
## 4. Simulation and Case Analysis

### 4.1 Simulation

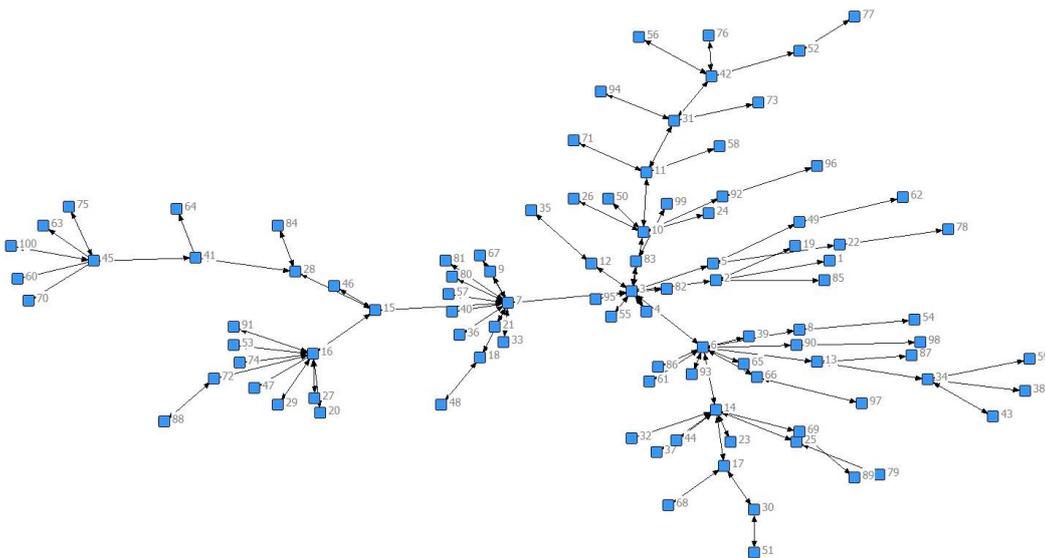
Use preferential attachment model in Netlogo5.0.5 to generate a high-tech service innovation network, and the network is scale-free, as shown in Figure 5. For convenience of analyze network structure, we use Ucinet6.487 to draw Figure 6 which shows connections between each node in Figure 5. In Figure 6, we find that node 7, node 3 and node 6 are B-node which has a large amount of ties, and most of the rest nodes are A-node which has a low degree. Further we use effective size and constraint degree to analyze structural holes of two kinds of nodes, and the results are shown in Table 1.



**Figure 5. Network Topology, Scale Free**



**Figure 7. Network topology, modularization**



**Figure 6. The Connections of the Nodes in Figure 1**

**Table 1. Analysis Results of Network Structural Holes**

Node number	EffSize	Constra
7	12	0.083
3,6	11	0.091
16	9	0.114
14	8	0.125
10	6	0.167
45	6	0.185
2,11,15,31,34,42	4	0.25
5,13,17,28	3	0.333

41	3	0.36
8,12,18,22,25,30,49,52,66,69,72,83,90,9	2	0.5
2		
others	1	1

From Table 1, node 7, node 6 and node 3 all has a relatively large number of structural holes in the network (there are a plurality of nodes spanning structural holes, but the number is relatively small). Their effective size was significantly larger than the other nodes', and their constraint degree are significantly smaller compared to other nodes, indicating they span rich structural holes. Among them, effective size of node 7 is 12, and its constraint degree is 0.083, which indicates it is the super actor bridging structural holes. The effective size of node 6 and node 3 are both 11, and their constraint degree are the same 0.091, and the two nodes are regarded as the ordinary actors bridging structural holes.

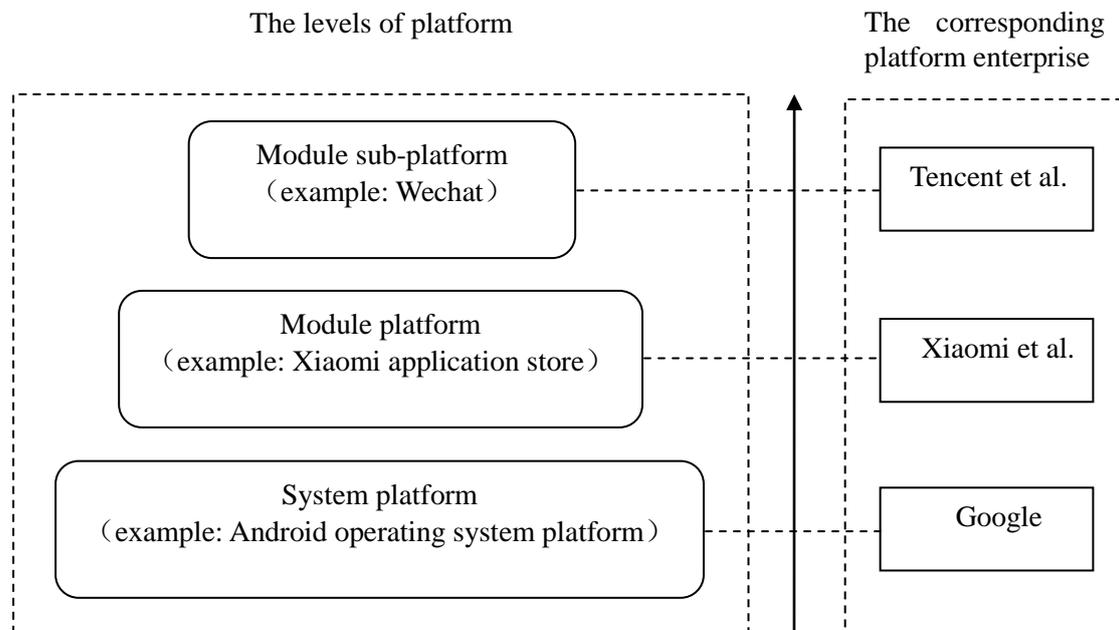
Use Netlog5.0.5 to simulate network evolution, and network in Figure. 5 is re-layout shown in Figure 7. We discover that node 7, node 6 and node 3 have a larger effective size, and control the throat of information and resources flow, due to the rich structural holes they span. These nodes have a high status in the network, easy to attract the other nodes around to cooperate. It is seen from Figure 6, the super actor (Node 7) links with A-node (such as node 9, node 67, etc.) around it, which form core modules 1 in Figure 7, accordingly, node 7 becomes the core module platform enterprise. Node 6 and node 3, as an ordinary actor, link with A- nodes around it (such as node 86, node 55, etc.) respectively, experiencing a "hold together" process (Figure 7), evolve into complementary module 2 and module 3. Node 6, and node 3 bridge the largest amount of structural holes in module 2 and module 3 respectively, which contribute to a leadership position, and they become module platform enterprise. Furthermore, under the bridges of structural holes occupants, modules converge, and they formed a system platform in which Module 1 acts as the core module, and Module 2, Module 3 are the complementary module. Among them, as the super actor bridging structural holes, node 7 have spanned richest structural holes in the core module, and also in the entire network. Node 7 has access to information and information control advantages, and it has maximum individual scale in this module and the entire system platform, so it plays a dominant part in system platform, and it develops into a system platform enterprise.

#### 4.2 Case Study

There is a typical high-tech service innovation network in mobile internet industry. Google's Android and Apple's iOS are two major system platforms in the mobile Internet industry which focuses on operating system as a strategic point currently, and Android market has an absolute advantage (Xiaomi's MIUI, Meizu's Flyme, Huawei's EMUI are all part of the Android operating system, and they are the depth of customization ). Android operating system is mounted on a mobile terminal device, provided by the network operator's network service (network equipment manufacturers provide technical support), interacts with end users through a variety of mobile APP offered by the application provider. In such way, they provide users with a complete solution<sup>[10]</sup>.

As an application in mobile Internet, Wechat integrates a variety of of functional products, such as instant messaging, didi taxi, Wechat Payment, JD selected, movie tickets, meilishuo, lottery tickets, games and so on, and then link the relevant enterprise together. The enterprise who span the richest structural holes leads the network develop into a platform. Furthermore, the super APP Wechat becomes a complementary module sub-platform which belongs to the complementary module consist of application providers, and Tencent becomes the sub-platform enterprise of this module. In the application provider groups, Google's Google play, Xiaomi's application store,

QIHU360's phone assistant are in the form of APP collections to provide application services. These enterprises have a large customer base through the accumulation of the original business, attracting many application providers to release their applications in this store. With the effects of preferential ties, more and more application providers publish applications in the store. Thus, the application store becomes the information transfer bridge in module of application providers, spanning rich structural holes in this module, and becomes modular platform enterprise. From a system perspective, Android operating system integrates several major modules such as mobile terminal providers, application providers, network operators, network equipment providers, and end-users, and they form into a mobile Internet system platform. As the core module, operating system connect multiple modules, and Google becomes the super actor bridging the most abundant structural holes in the network with Android operating system, and holds a dominant position in the core modules of operating system, then it becomes a system platform enterprise. In short, Google led mobile services innovation networks to develop into a system platform, wherein each complementary modules evolved into a modular platform, while a module platform covered a modular sub-platform. Accordingly, because of Android operating system, Google becomes system platform enterprise, Xiaomi and others become the module platform by virtue of the application store, and Tencent and others become module sub-platform enterprises with super APP. Platform level distribution is shown in Figure 8.



**Figure 8. The Distribution of Platform Levels in Mobile Service Innovation Network Google Dominated**

## 5. Conclusion

In this paper, we use social network analysis to explore platformization mechanism of high-tech service platform innovation network based on structural holes theory, and we use Netlogo and Ucinet to conduct a simulation, combined with the mobile Internet industry giants Google and its Android platform as a examples analysis, we get the following conclusions: (1) As the evolution of structural holes in network structure, high-tech innovation service network evolves into a platform with an approach of "two types of nodes → appearance and differentiation of nodes → modularization → module embedded → formation of system platform". (2) The evolution of module platform enterprise and system platform enterprise have a path consistency, both of them are

derived from the node which spans rich structural holes at their own network level. The ordinary actor bridging structural holes evolves into a module platform enterprise, and the super actor develops into a system platform enterprise by virtue of its advantages and leading position in the core module and system platform.

The above-mentioned platformization development mechanism and laws offer some pointers for innovation practitioners and policy makers. First, based on systematic, complexity and openness, high-tech service innovation networks have inherent platformization mechanism and basic path. Nowadays, in the wake of developments of economy, platform economy experience rapid growth, and platform competition intensified. Both the innovation practitioners and policy makers should comprehend and adapt to this trend, changing traditional thoughts of isolated development, and actively participating in the platform or building their own platform, and achieve development in cooperation. Second, spanning network structural holes is actually associating and developing cooperation relationship in the business district. In high-tech service innovation development, large enterprises should focus on industry, cross-link, using their own system capabilities and resources, and taking network advantages of structural holes, build a platform, and lead the development. Middle and small-sized enterprises should take advantage of their unique abilities and professional advantage, actively develop association, to become module platform enterprises, and get access to business dominance. Small and micro enterprises should make full use of information resources, knowledge spillover effects in the Internet age and their own flexible advantages, actively participate in innovation networks, and seek development opportunities for the living space in platform system. And government policy makers should focus on matchmaking for enterprise, helping enterprises to build a platform, promoting industrial clusters and regional innovation systems development. Limitations of this article show lights on the further study. In the future, we should have full access to partnership data between enterprises in the high-tech service industry, and conduct a quantitative analysis of structural holes in the network, and reveal the evolution characteristics of high-tech service innovation network in different areas, and the specific generating path of each platform enterprise.

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