

# The study on the architecture of crowd system supporting platform

Architecture of crowd system

17

Shuangxi Huang

*Department of Automation, Tsinghua University, Beijing, China*

Zhixuan Jia

*School of Software and Microelectronics, Peking University, Beijing, China*

Yushun Fan

*Department of Automation, Tsinghua University, Beijing, China*

Taiwen Feng

*School of Management, Harbin Institute of Technology, Harbin, China*

Ting He

*College of Computer Science and Technology, Huaqiao University, Quanzhou, China*

Shizhen Bai

*School of Management, Harbin University of Commerce, Harbin, China, and*

Zhiyong Wu

*School of Computer Science and Technology, Shandong University of Technology, Zibo, China*

Received 23 November 2019

Revised 26 December 2019

Accepted 26 December 2019

## Abstract

**Purpose** – The purpose of this paper is to better understand and study the architecture and system characteristics of the underlying support platform for crowd system, by recognizing the characteristics of service internet is similar to the coordination characteristics between the massive units in the underlying platform of crowd system and studying the form, nature and guidelines of the service internet.

**Design/methodology/approach** – This paper points out the connection between the underlying support platform of crowd system and service internet, describes the framework and ideas for researching service internet and then proposes key technologies and solutions for service internet architecture and system characteristics.

**Findings** – The research unit in the underlying support platform of crowd system can be regarded as a service unit. Therefore, the platform can also be regarded as service internet to some extent. The ideas and technical approaches for the study of service internet's form, criteria and characteristics are also provided.

© Shuangxi Huang, Zhixuan Jia, Yushun Fan, Taiwen Feng, Ting He, Shizhen Bai and Zhiyong Wu. Published in *International Journal of Crowd Science*. Published by Emerald Publishing Limited. This article is published under the Creative Commons Attribution (CC BY 4.0) licence. Anyone may reproduce, distribute, translate and create derivative works of this article (for both commercial and non-commercial purposes), subject to full attribution to the original publication and authors. The full terms of this licence may be seen at <http://creativecommons.org/licenses/by/4.0/legalcode>

This paper is supported by the National Key R&D Program of China under Grant No. 2018YFB1402902.



**Originality/value** – According to this paper, relevant staff can be guided to better build the underlying support platform of crowd system. And it can provide a highly robust and sustainable platform for research studies of crowd science and engineering in the future.

**Keywords** Crowd system, Underlying support platform, Service internet, Architecture

**Paper type** General review

## 1. Introduction

Crowd science and engineering is a new interdisciplinary direction to study the principles, laws, methods, techniques and related engineering applications of the ternary fusion system about information, physics and society in a large-scale interconnected online environment (Prpic and Shukla, 2017). By making full use of the wisdom of human individuals and groups, it can effectively solve the complex problems that computers or humans cannot solve alone (Franzoni and Sauermann, 2014).

In recent years, advanced information technologies such as cloud computing (Singh *et al.*, 2013), artificial intelligence (Acemoglu and Restrepo, 2018), big data (Walker, 2014), Internet of Things (IoT) (Atzori *et al.*, 2010) and mobile internet (JayeW, 2015) have been rapidly developed and applied to all walks of life. This has led to the trend of “everything is service” (Banerjee *et al.*, 2011). The services available in various fields are becoming more and more prosperous, and the interconnection between mass services has formed the service internet (Maamar *et al.*, 2011). It forms an innovative value chain by layer-by-layer aggregation of heterogeneous cross-domain services, fully realizes the domain service business that meets user needs and values and creates value for the internet-related stakeholders with high efficiency and accuracy. And it becomes a huge driving force for the development of industries, for example, crowd science (Schroth and Janner, 2007; Cardoso *et al.*, 2008; Bouguettaya *et al.*, 2017).

The crowd system is a kind of crowd science research system based on the connection and composition of several units. And every unit can be regarded as a single service unit. The networked structure formed by the cooperation of a large number of service units is the service internet (Soriano *et al.*, 2013). To be precise, the service internet is a network space composed of many service entities interconnected and coordinated in the internet environment. It is a complex service networked application form in the internet, which is implemented as integrated services across domains/networks/world. And it also provides various business services. In the multi-service cross-domain interconnection integration and collaboration, to meet user needs, realize user expectations, improve service provider value, and continuously optimize and improve service quality, the support platform like the service internet is necessary (Moreno-Vozmediano *et al.*, 2013).

Therefore, the establishment and continuous operation of the crowd system, and to complete the work of exploring and researching group intelligence activities in a large, connected online environment, all of them are inseparable from the support of its business operation platform, that is, the support of the service internet. At the same time, to provide high-level protection of technology, quality and value for the public intelligence system, the service internet also needs high reliability, adaptive ability and sustainable evolution. Therefore, research on the form, nature and norms of the service internet is critical to the crowd system.

However, at present, there is still a lack of basic theory and systematic research on the essential law cognition, architecture structure and modelce, engineering design method and operation mechanism, platform construction and evolution technology of the service internet. It makes the practice of service internet applications somewhat blind. Compared to traditional service application technologies, the service internet has theoretical and technical challenges in

terms of ecological integration, cross-domain service aggregation, value perception, precise matching of demand and service resources, platform system operation guarantee, and service intelligent interaction. Consequently, further research is urgently needed.

## 2. Research status

Most research focus of traditional service computing is to conduct research from the perspective of a single service provider or a third-party service platform, and to optimize the quality of service provision and service quality (Mora *et al.*, 2017). However, these traditional methods fail to aggregate services at the service ecosystem level and satisfy customer needs. And they also have the disadvantages of high cost of constructing service systems, low construction efficiency, and difficulty in ensuring system performance. Compared with the traditional service system, the service internet needs to solve the problems of service ecological integration, cross-domain aggregation, value perception, precise matching of demand and service resources, and intelligent interaction of services.

For the service internet and service system, the current research status is summarized from three different perspectives:

- (1) *Service internet architecture*: In this part, it mainly focused on the modeling, analysis, evolution and other research studies of the service internet structure and its behavior. In terms of architecture, it mainly explores how service individuals aggregate to form complex networks and the impact of individual behavior on the overall network. Tsinghua University has done a lot of research work in the basic theory of service internet, structural model, and behavioral characteristics (Li *et al.*, 2011; Liu *et al.*, 2013; Fan *et al.*, 2015). In terms of basic theory, it mainly studies the characteristics of the openness, dynamics and adaptability of the service internet and analyzes the behavioral characteristics and dynamic evolution characteristics of the service network. At the same time, in the service ecosystem theory, developing service system modeling, management and application platform (Huang *et al.*, 2013). In terms of key technologies, research focuses on service system modeling, service aggregation methods, service resource composition and scheduling. Network of Excellence S-Cube, EU describes the knowledge model and quality reference model for service internet (Metzger and Pohl, 2009), and transfers the technical achievements of all aspects of the internet to more than 400 enterprises through the European technology platform. IBM has described the service computing research framework, service science, management and engineering systems in terms of intelligence and cognitive services (Endrei *et al.*, 2004; Kloeckner *et al.*, 2018), and some of the technical methods have been integrated into IBM cloud computing, business management and other products.
- (2) *Service system construction and optimization*: It mainly studies the methodology based on traditional software engineering methods, model-driven service methodology, service methodology based on domain analysis and business objectives/semantic-driven service methodology. In terms of service composition/aggregation and “demand-service” precision matching, Harbin Institute of Technology and others use the prior knowledge of the fields contained in big data, supplemented by AI, graph search, workflow and other technologies (Xu *et al.*, 2015; Lartigau *et al.*, 2015; Xu *et al.*, 2018). Peking University has achieved good results in demand cognition, domain service modeling and demand acquisition (Jin and Zhu, 2011). North China University of Technology has developed the first IOT big data service cloud platform DeCloud in the IOT data service platform (Zhao

*et al.*, 2014); Zhejiang University has developed “Qiantang” platform and studied complex electronic service key technologies for the modern service industry in terms of service computing for the modern service industry (Lu *et al.*, 2016)”.

- (3) *Service system operation optimization and dynamic reconfiguration*: It mainly studies the on-demand dynamic combination sharing, value sensitive maintenance and continuous performance optimization of services in the continuous iterative process. Zhejiang University and others start from the service management and service platform to study the dynamic selection, reconstruction, error recovery and adaptive self-evolution of services in static and mobile environments (Zhang *et al.*, 2009; Tao and Zhang, 2012; Wang *et al.*, 2016); The Institute of Software, Chinese Academy of Sciences describes the evolution of the internet-based dynamic architecture applied to SOA (Wang *et al.*, 2014). Technical University Wien describes the relevant theoretical methods of service ecosystem, service system enhanced diagnosis and testing in terms of service computing technology in mobile and ubiquitous scenarios (Truong *et al.*, 2016) and some technical methods have achieved initial application in smart cities, transportation services, and e-government. Harbin Institute of Technology conducted research on large service theory, service value and quality management, and developed a cloud service platform and service system for bilateral resource integration (Xiaofei *et al.*, 2012).

In general, domestic and international research on service internet has made certain achievements, but there is still a lack of systematic research on the essential mechanism and value synergy of service internet, design and optimization methods, quality assurance and evolution management. Related engineering methods and supporting carriers are also insufficient.

### 3. framework and thoughts of service internet research

According to the research status of the above-mentioned service internet, in the current complex business and service environment, it is important to conduct research in the service internet architecture, the aggregation model, the service internet business integration model for multilateral resource integration, and the service-value-based service value chain collaborative optimization theory system. At the same time, it is necessary to give the architecture and formation mechanism of such complex service systems at the basic theory and method level.

This section describes the overall research framework and research ideas of the service internet architecture and its value chain synergy theory.

#### 3.1 Overall research framework

According to the characteristics of heterogeneity, autonomy, ecological ecology and self-evolution of service internet, this research studies the mechanism of formation and evolution of service internet community from the characteristics of service internet structure and dynamic evolution mechanism. The emerging theory is used to construct the service internet convergence model, and the form, nature, behavior principle and effect mechanism of the service internet are systematically analyzed. Studying the unified expression of heterogeneous, multi-source massive service resources/data/content/domain knowledge, intelligent search, active awareness, collaborative management technology and service resource virtualization method.

Studying collaborative mechanism and service model of business process and service Resources in Service internet Environment, service aggregation coordination mechanism. Researching service internet business integration model for multilateral resource integration and

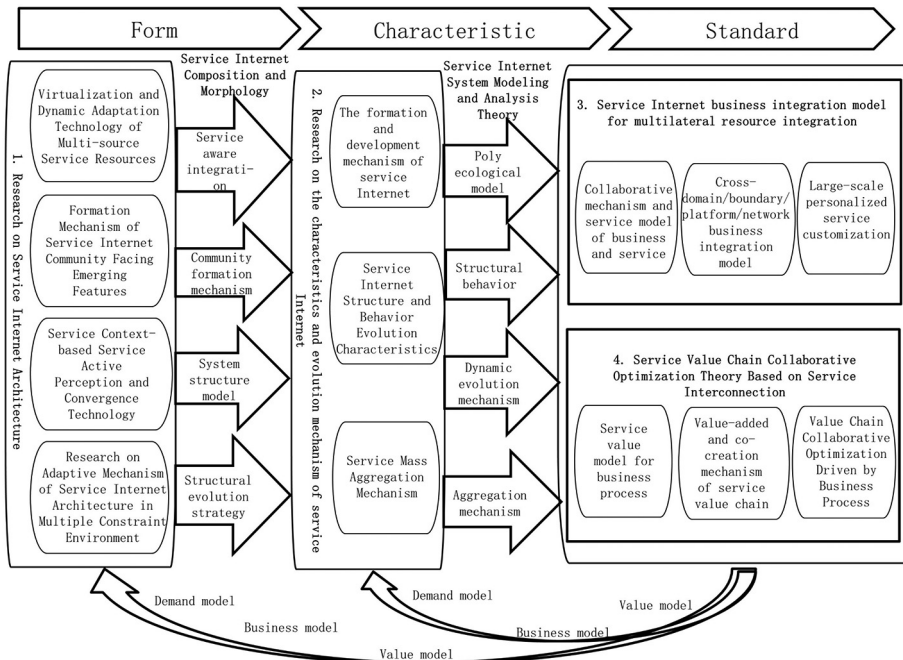
large-scale/personalized service customization technology approach. Constructing a service value-chain collaborative optimization theory system based on service interconnection. Studying the service value model for business operation management. Researching the value creation and value-added mechanism of the service value chain based on service interconnection and the value chain collaborative optimization model and method based on business process.

The overall research framework is shown in Figure 1.

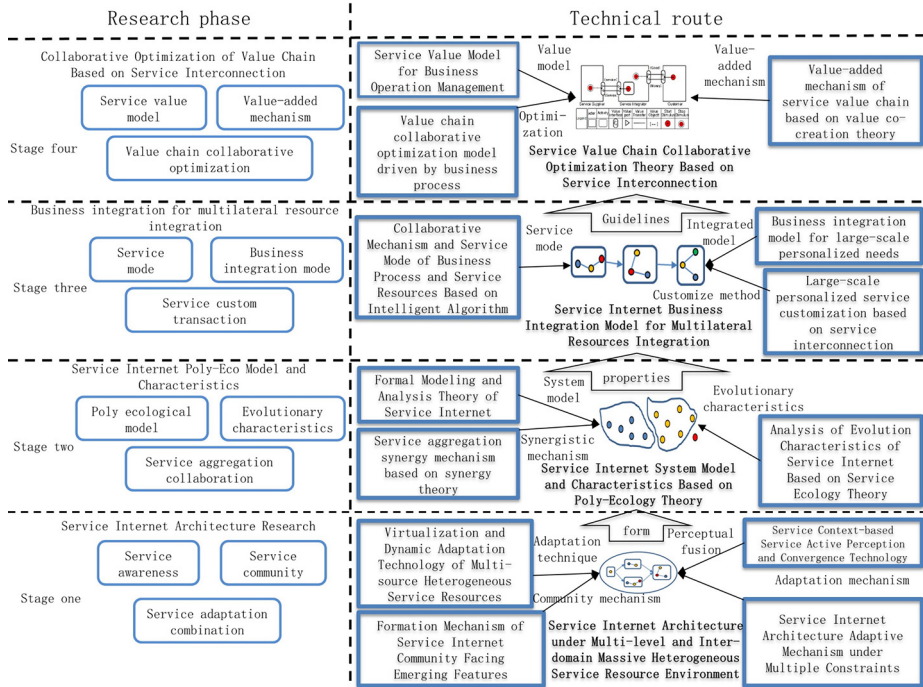
### 3.2 Research ideas and technical routes

The research ideas and technical routes of the service internet architecture can be divided into four stages, as shown in Figure 2. The specific explanation is as follows:

- (1) *Phase 1:* Do research studies on the service internet form and architecture. Establishing a service internet architecture under a multi-level and multi-domain massive heterogeneous service resource environment. Supporting virtualization and dynamic adaptation of service resources in multi-source heterogeneous environments, the formation and evolution of service internet communities for emerging features, the active awareness and convergence of services based on business context and the adaptive evolution of service internet architecture in a multi-constrained environment.
- (2) *Phase 2:* Research service internet convergence model and system characteristics. Analysis of the phenomenon of poly-ecology through the complex business behavior of services and the dynamic relationship between services. And on this basis, do research studies on the structural characteristics, scale characteristics, community characteristics, business aggregation characteristics and distribution characteristics of the service internet. Discussing the formation and evolution



**Figure 1.**  
Service internet architecture and its value chain synergy theory research framework



**Figure 2.**  
Service internet  
architecture and  
value chain synergy  
theory research ideas

mechanism of service network, the emergence mechanism of aggregation service, the detectability and controllability of system status, etc.

- (3) *Phase 3:* Studying the service internet business integration model for multilateral resource integration. Analyzing the composite characteristics of user requirements and the related characteristics of service services, and proposing a service integration model for multilateral resources. Establishing a business integration model and multi-domain service recommendation algorithm in a multilateral resource environment for composite needs, and forming a large-scale personalized service customization and trading strategy.
- (4) *Phase 4:* Do research studies on Service Value Chain Collaboration Theory and Optimization Method Based on Service Interconnection. Based on service value theory, supply and demand theory and dynamic evolution game theory, studying the service value collaborative co-creation mechanism and optimization method for business operation management. How service value is created, delivered, accumulated, decomposed, exchanged, and consumed across different service resources and how the service value chain and service business processes are mutually constrained and work together are described from a business process perspective.

#### 4. Key technologies and solutions for service internet research

This section mainly discusses the key technologies and solutions for the service internet's form and architecture, the aggregation ecological model and the dynamic evolution mechanism.



#### 4.1 Research on service internet form and architecture

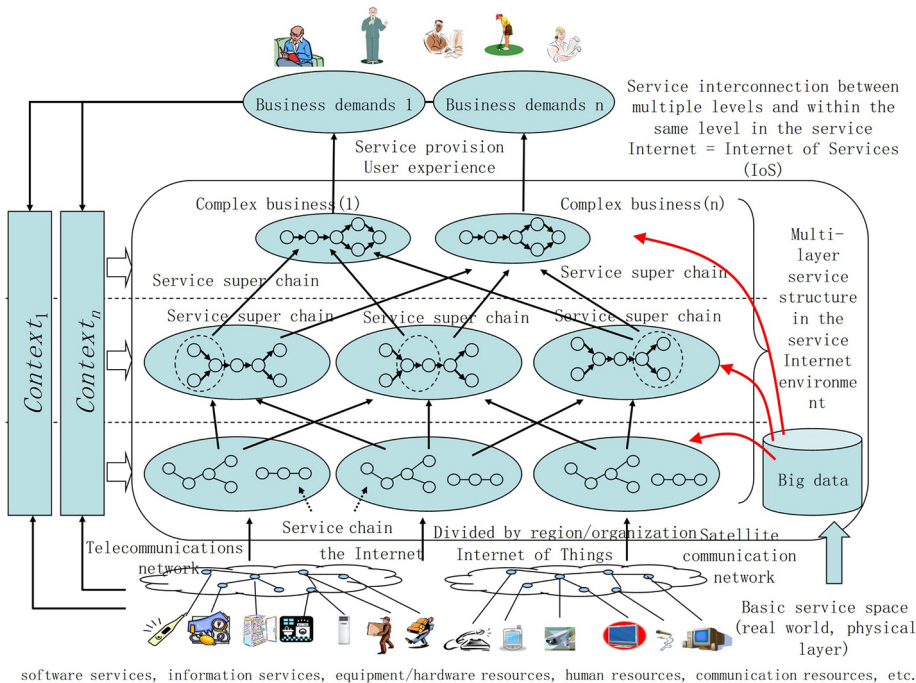
First, the service internet architecture in a multi-level and cross-domain massive heterogeneous service resource environment is shown in Figure 3.

How to effectively aggregate decentralized services into an integrated and orderly complex service network in a complex business and service environment, it is necessary to study the composition and growth rules of service communities and service networks, how to form aggregates to form service communities, the symbiosis and competition between services in service communities, and the synergistic mechanism of connection and aggregation between different service communities.

This part of the research can be further broken down into two phased tasks:

- (1) Cross-domain massive heterogeneous service resource modeling/expression/search/perception/management and virtualization methods; and
- (2) Service aggregation and collaboration mechanisms and multi-level service internet architecture in complex business and service environments.

**4.1.1 Cross-domain massive heterogeneous service resource modeling/expression/search/perception/management and virtualization methods.** It mainly studies the virtualization model of network service resources virtualization, proposes a resource virtualization encapsulation method, hierarchically abstracts the functions, interfaces and capability features of resources, establishes the mapping of virtual resources to physical resources, and realizes the registration, management, maintenance, and dynamic allocation of virtual resources. Service internet resources are massive, cross-domain, and heterogeneous. The survey method is used to analyze the application of different industry fields. At the same



**Figure 3.**  
Service internet  
architecture

time, the basic data of the typical internet open service interface is collected, and the inductive method is used to form the service internet resource pool.

Service resource virtualization is the infrastructure provided by third-party service providers. To accurately and efficiently obtain the required service resources, it is necessary to abstractly model the service internet physical resources and virtual service resources. The mathematical model and the similarity calculation principle are used to establish an effective virtualization service resource mapping mechanism and strategy.

The reality of the service internet is a complex network. Combining network characteristics not only needs to define participating entities, but also abstracts entity attributes and parameter information that can provide intelligent high-reputation service perception and recommendation capabilities, and research service models and scene model construction methods. Finally, it provides support for users to provide active services.

The combination of services usually corresponds to a specific application scenario. Therefore, it is necessary to better realize the mining and organization of service composition scenario information, and accordingly establish an efficient service recommendation algorithm to assist users in creating service combinations. Then, in order to build a high-quality service portfolio, it is necessary to select a higher-reputation service candidate in the selected scenario, and select or construct an optimal service chain to form a service composition structure.

*4.1.2 Service aggregation coordination mechanism and multi-level service internet architecture in complex business service environment.* The service internet is characterized by heterogeneity, autonomy, and self-evolution. The structural characteristics, aggregation mechanism, and coordination mechanism of the service internet are the key issues in the research of service internet architecture. Through the two methods of empirical and model analysis, the self-organization, self-adaptation and dynamic evolution of complex service networks in inter-network, heterogeneous, ubiquitous and open environments will be analyzed. On this basis, the service internet system architecture model is constructed to study its behavior and structural characteristics (scale characteristics, community characteristics, service relationship characteristics, aggregation characteristics and distribution characteristics, etc.).

Through the analysis of the interaction between service internet structure, behavior and service resources, the evolutionary game theory is used to establish the evolution model of service internet architecture. Then, it analyzes the competitive cooperation mechanism in the process of resource game, identifies the multi-level and multi-service domain cores existing in the service internet architecture, discusses the synchronization and evolution mechanism of the service internet, and studies the induction mechanism and generalized control strategy of the service internet.

In the aspect of service internet architecture analysis and modeling, through empirical analysis of the cross-network convergence nature and evolution law of service-oriented internet, and constructing the structural model of service internet. Based on this, a complex network analysis method is applied to study the small world characteristics, scale-free characteristics, correlation, co-evolution characteristics, community structure characteristics, and service aggregation characteristics of the service internet. Based on ECA rules, logical reasoning and other technologies, the adaptive evolution strategy and network synchronization mechanism are constructed to realize the dynamic evolution and adaptive migration of the service internet, and then the evolution model of the system structure is built on the basis of the network behavior model. It analyzes the evolutionary trend of the service internet, and then analyzes the complex characteristics of the system's self-organization, self-adaptation, dynamic evolution, and emergence. Then, a computer-



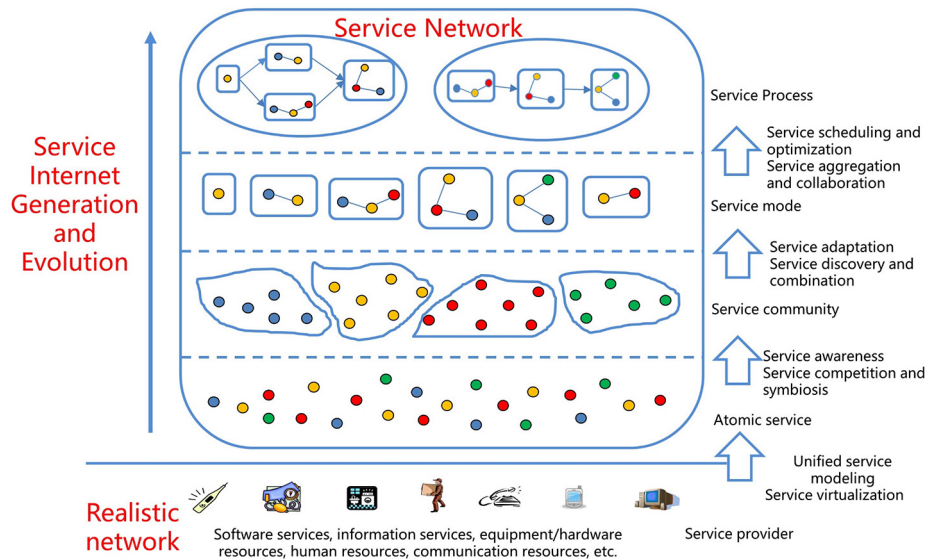
understandable specification description is needed to define and describe the identified new structure or function. The focus is on their features, boundaries, and emergent characteristics.

The service internet architecture generation and evolution technology route based on service aggregation and collaboration is shown in Figure 4.

#### 4.2 Research on the characteristics and evolution mechanism of service internet poly-ecosystem

The ecological characteristics of the service internet need to be studied. And it needs to reveal the laws governing the development of the internet. Through the analysis and research of the dynamic behavior of the service internet, the dynamic service perception mechanism of the service internet is described. Researching the formal modeling and analysis theory of the service internet, establishing a model of the service internet ecosystem, and revealing the basic characteristics of the service internet; Based on the theory of service ecology, under the consideration of time dimension and ecological transformation, the deep learning technology is used to mine the internal factors, external environmental factors and their influencing mechanisms that affect the evolution of the service internet system. The dynamic evolution model of nonlinear service internet based on complex system theory is constructed.

Through the model analysis, the purpose of discovering the evolution direction and evolution characteristics of the system is achieved. Researching different levels (cross-domain services, business function services), different granularity (large-grained business process services, medium-sized business function services, small-grained IT services), mapping methods for heterogeneous services and the aggregation mode, integration mechanism and principle of convergence and communication of the service network. Establishing negotiation mechanisms and interaction models between different services, and explore collaboration and competition modes between services. Therefore, the



**Figure 4.** Service internet architecture generation and evolution technology route based on aggregation and collaboration

schematic diagram of the characteristics and evolution mechanism of the service internet system based on the poly-ecological model is shown in Figure 5.

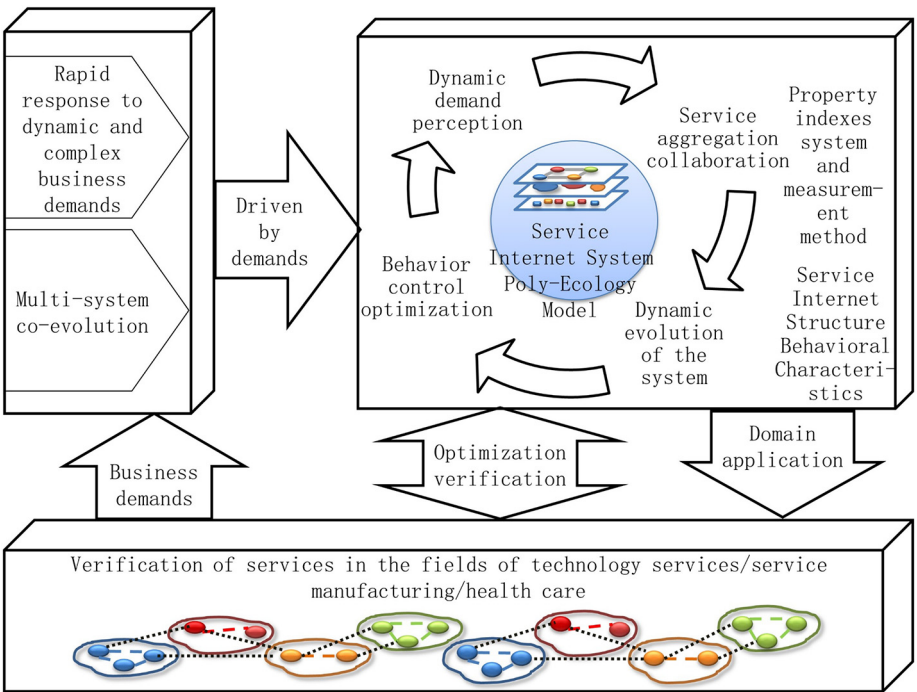
Similarly, the research content can be further divided into two tasks:

- (1) The service internet community based on the service ecosystem theory; and
- (2) The research on the ecological model.

The evolution mechanism and system characteristics analysis method of service internet based on poly-ecological model.

4.2.1 *Research on service internet community and ecological model based on service ecosystem theory.* The heterogeneity, autonomy, self-evolution, intricate relationship and emergent characteristics of the service internet make its composition and cooperation similar to the characteristics of individual species and communities in the ecosystem. Therefore, it is necessary to study the characteristics of the ecosystem-oriented ecosystem of the service-oriented internet for the dynamic and complex business environment, and establish an ecosystem-like model of the internet from the perspective of the overall system. The service internet aims to provide business solutions that meet the needs of large-scale personalized users, and its operations need to span multiple networks such as the internet, organization networks, social networks, and business networks.

Therefore, the service internet is formed by aggregating services provided by multiple service networks, and is also a poly-ecological network that provides users with integrated service solutions. It breaks through the boundaries of a single service system, and the relationship between its services and service subnets is complex and has obvious ecological



**Figure 5.**  
Schematic of the  
characteristics and  
evolution mechanism  
of service internet  
system based on  
poly-ecological model

characteristics. There are a lot of nonlinear mechanisms and self-organizing phenomena in the poly-ecological network, which can constantly change and adapt to adjust its functions and performance in use. It also has a complex network open architecture. Therefore, the ecological service network is the service of the service, the network of the network.

Based on the ecology and service ecology theory, it is necessary to analyze the dynamic relationship between the complex business behaviors and services that serve the internet. At the same time, it analyzes the self-organization, self-adaptation, dynamic evolution and emergence of the service internet, and establishes an ecosystem model of complex service networks. Then, it analyzes the dynamic characteristics of service communities, service hyperlinks and service networks that emerged during the evolution of the service internet.

In the research of the service internet poly-ecological model, the ecological characteristics of the service internet will be studied to reveal the development law of the service internet. Through the analysis and research of the dynamic behavior of the service internet, the dynamic service perception mechanism of the service internet is described. The formal modeling and analysis theory of the service internet is proposed, and the service internet aggregation ecosystem model is established to reveal the basic characteristics of the service internet.

The technical route of service internet ecosystem model and service community formation mechanism is shown in Figure 6.

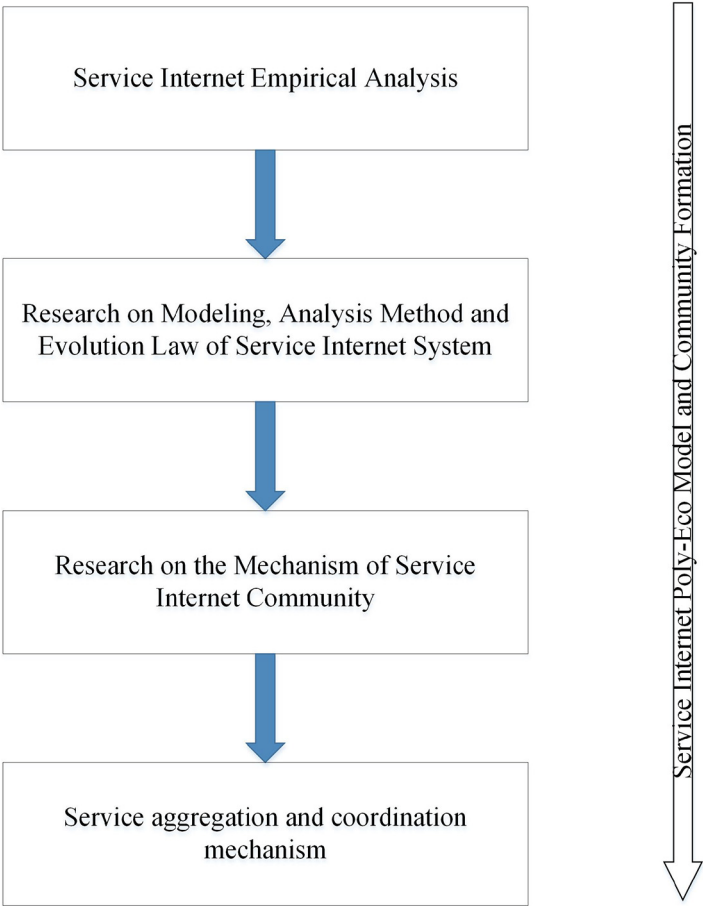
*4.2.2 Research on evolution mechanism and system characteristic analysis method of service internet based on poly-ecological model.* Collecting basic data of the typical service internet industry by using survey methods, case studies, and network structure analysis methods. Then, information about the basic form, architecture, and state characteristic parameters of the service internet can be obtained.

The reality service internet network is a complex adaptive system. The interaction behavior of system members is highly self-organizing and non-linear. The corresponding individual relationships are intertwined and different network patterns emerge. Analyzing the ecological phenomenon of the service internet from two perspectives: network behavior and dynamic relationship between services. Using ecological theory, emerging theory, and complex network theory to construct a poly-ecological model that describes the service internet.

In the process of researching the evolution mechanism of service internet network, the evolution process is analyzed and studied by using robust control, evolutionary game theory and small world theory for the changes of state, structure and operation mode. The adaptive integrated learning algorithm is used to study the structural characteristics, scale characteristics, community characteristics, business aggregation characteristics and distribution characteristics of the service internet. Then, we need to explore the interaction mechanism between different properties. Combined with the evolutionary system dynamics theory, the detectability and controllability of the system state are studied. Based on the above research, the inductive analysis method is used to form the research conclusions of the service internet, including the formation mechanism, evolution mechanism, aggregation mechanism and control mechanism of the service internet.

## 5. Conclusion

As one of the hottest professional and research fields, crowd science and engineering has attracted more and more academic and industrial people to continuously research and develop it. This paper expounds the indispensable underlying support platform in the research and design of crowd system, its relationship with the crowd system, development and research status. This paper introduces the research on the architecture, form, norms and



**Figure 6.**  
Service internet  
ecosystem model and  
service community  
formation mechanism  
technical route

nature of the service internet to better support the construction and development of the crowd system and the crowd science.

Service internet is an important support for improving the service quality of modern service industry and the level of scientific research on group intelligence in the era of scientific and technological revolution. It is also a powerful driving force for promoting industrial agglomeration and service industry productivity. The good construction and development of the service internet can provide basic theoretical support for multiple service application areas and has important scientific and theoretical value. It will also provide theoretical and technical support for the development of information society and the development of modern service industry. It has broad application scenarios in the fields of education, medical care, health, pension, culture, e-commerce, social governance and smart city.

In summary, this paper describes a series of research contents, key technologies and solutions for the research of service internet architecture. Combined with a series of methods, related platforms and tools for the design, development and operation of the

service internet, it provides an overall underlying support solution for the future research and application of crowd science. For the future research, we will further study and understand the morphological guidelines and characteristics of the service internet, build a service internet platform, and prepare to build a facility platform for the next research of the crowd system.

## References

- Acemoglu, D. and Restrepo, P. (2018), "Artificial intelligence, automation and work", NBER Working Papers.
- Atzori, L., Iera, A. and Morabito, G. (2010), "The internet of things: a survey", *Computer Networks*, Vol. 54 No. 15, pp. 2787-2805.
- Banerjee, P., Friedrich, R., Bash, C., Goldsack, P., Huberman, B.A. and Manley, J. (2011), "Everything as a service: powering the new information economy", *Computer*, Vol. 44 No. 3, pp. 36-43.
- Bouguetaya, A., Singh, M., Huhns, M., Sheng, Q.Z., Dong, H., Yu, Q. and Ouzzani, M. (2017), "A service computing manifesto: the next 10 years", *Communications of the Acm*, Vol. 60 No. 4, pp. 64-72.
- Cardoso, J., Voigt, K. and Winkler, M. (2008), "Service engineering for the internet of services. Enterprise information systems", *10th International Conference, ICEIS*, Barcelona, 12-16 June, Revised Selected Papers, Springer, Berlin Heidelberg.
- Endrei, M., Ang, J., Arsanjani, A., Chua, S., Comte, P., Kroghdahl, P. and Newling, T. (2004), *Patterns: service-Oriented Architecture and Web Services*, IBM Corporation, International Technical Support Organization, New York, NY, pp. 17-44.
- Fan, Y., Huang, K., Tan, W., Zhong, Y. and Chen, S. (2015), "Domain-aware reputable service recommendation in heterogeneous manufacturing service ecosystem", *International Journal of Computer Integrated Manufacturing*, Vol. 28 No. 11, pp. 1178-1195.
- Franzoni, C. and Sauermann, H. (2014), "Crowd science: the organization of scientific research in open collaborative projects", *Research Policy*, Vol. 43 No. 1, pp. 1-20.
- Huang, K., Fan, Y., Tan, W. and Qian, M. (2013), "Bsnet: a network-based framework for service-oriented business ecosystem management", *Concurrency and Computation: Practice and Experience*, Vol. 25 No. 13, pp. 1861-1878.
- JayeW (2015), "internet society global internet report 2015: mobile evolution and development of the internet".
- Jin, Z. and Zhu, H. (2011), "Unifying domain ontology with agent-oriented modelling of services".
- Kloekner, K., Adam, C.M., Anerousis, N., Ayachitula, N., Bulut, M.F. and Dasgupta, G. (2018), "Building a cognitive platform for the managed it services lifecycle", *IBM Journal of Research and Development*, Vol. 62 No. 1, pp. 8:1-8:11.
- Lartigau, J., Xu, X., Nie, L. and Zhan, D. (2015), "Cloud manufacturing service composition based on qos with geo-perspective transportation using an improved artificial bee colony optimisation algorithm", *International Journal of Production Research*, Vol. 53 No. 14, pp. 4380-4404.
- Li, X., Fan, Y., Sheng, Q.Z., Maamar, Z. and Zhu, H. (2011), "A petri net approach to analyzing behavioral compatibility and similarity of web services", *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans*, Vol. 41 No. 3, pp. 510-521.
- Liu, Y., Fan, Y. and Huang, K. (2013), "Service ecosystem evolution and controlling: a research framework for the effects of dynamic services", *Journal of Applied Polymer Science*, Vol. 127 No. 3, pp. 28-33.
- Lu, X., Yin, J., Xiong, N.N., Deng, S., He, G. and Yu, H. (2016), "Jtangcms: an efficient monitoring system for cloud platforms", *Information Sciences*, Vol. 370-371, pp. 402-423.
- Maamar, Z., Hacid, H. and Huhns, M.N. (2011), "Why web services need social networks", *IEEE internet Computing*, Vol. 15 No. 2, pp. 90-94.



- Metzger, A. and Pohl, K. (2009), "Towards the next generation of service-based systems: the S-Cube research framework", *Advanced Information Systems Engineering, 21st International Conference, CAiSE*, Springer-Verlag, Amsterdam, 8-12 June.
- Mora, M., O'Connor, R.V., Tsui, F. and Marx Gómez, J. (2017), "Design methods for software architectures in the service-oriented computing and cloud paradigms", *Software: Practice and Experience*, Vol. 1
- Moreno-Vozmediano, R., Montero, R.S. and Llorente, I.M. (2013), "Key challenges in cloud computing: enabling the future internet of services", *IEEE Internet Computing*, Vol. 17 No. 4, pp. 18-25.
- Prpic, J. and Shukla, A. (2017), *Crowd Science: measurements, Models, and Methods*, Social Science Electronic Publishing, New York, NY.
- Schroth, C. and Janner, T. (2007), "Web 2.0 and soa: converging concepts enabling the internet of services", *IT Professional*, Vol. 9 No. 3, pp. 36-41.
- Singh, B., Dhawan, S., Arora, A. and Patail, A. (2013), "A, view of cloud computing", *International Journal of Computers and Technology*, Vol. 4 No. 2b1, pp. 50-58.
- Soriano, J. Heitz, C. Hutter, H.P. Fernández, R. and Bohnert, T.M. (2013), "Internet of services", Evolution of Telecommunication Services.
- Tao, W. and Zhang, G. (2012), "Trusted interaction approach for dynamic service selection using multi-criteria decision making technique", *Knowledge-Based Systems*, Vol. 32, pp. 116-122.
- Truong, H.L., Copil, G., Dustdar, S., Le, D.H., Moldovan, D. and Nastic, S. (2016), "On engineering analytics for elastic IoT cloud platforms", *International Conference on Service-Oriented Computing*, Springer, Cham, pp. 267-281.
- Walker, S.J. (2014), "Big data: a revolution that will transform how we live, work, and think", *Mathematics and Computer Education*, Vol. 47 No. 17, pp. 181-183.
- Wang, X., Cao, J. and Wang, J. (2016), "A dynamic cloud service selection strategy using adaptive learning agents", *International Journal of High Performance Computing and Networking*, Vol. 9 Nos 1/2, pp. 70-81.
- Wang, J., Peng, Q. and Hu, X. (2014), "A modeling: internetware-based dynamic architecture evolution applying to soa", *Proceedings of the 2014 IEEE 18th international conference on computer supported cooperative work in design (CSCWD)*, IEEE, pp. 100-105.
- Xiaofei, X., Lanshun, N., Dechen, Z. and Lartigau, J. (2012), "Services for cloud manufacturing", *Enterprise Interoperability: I-ESA'12 Proceedings*, 39-45.
- Xu, X., Sheng, Q.Z., Zhang, L.J., Fan, Y. and Dustdar, S. (2015), "From big data to big service", *Computer*, Vol. 48 No. 7, pp. 80-83.
- Xu, X., Motta, G., Tu, Z., Xu, H., Wang, Z. and Wang, X. (2018), "A new paradigm of software service engineering in big data and big service era", *Computing*, Vol. 1.
- Zhang, Y., Zhang, S.S. and Han, S.Q. (2009), "Adaptive service configuration approach for quality of service management in ubiquitous computing environments", *Journal of Zhejiang University-SCIENCE A*, Vol. 10 No. 7, pp. 964-975.
- Zhao, Z. Fang, J. Ding, W. and Wang, J. (2014), "An integrated processing platform for traffic sensor data and its applications in intelligent transportation systems, services", *IEEE*.

**Corresponding author**

Zhixuan Jia can be contacted at: [jjazz@pku.edu.cn](mailto:jjazz@pku.edu.cn)

---

For instructions on how to order reprints of this article, please visit our website:

[www.emeraldgroupublishing.com/licensing/reprints.htm](http://www.emeraldgroupublishing.com/licensing/reprints.htm)

Or contact us for further details: [permissions@emeraldinsight.com](mailto:permissions@emeraldinsight.com)