

# *Internet of Things and Geography*

## Review and Prospect

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**Abstract**—Due to the development of Internet of Things, which is closely related to a series of geographical questions, this paper explores such new phenomenon of Human Geography, especially the change from Internet era to Internet of Things era. The aim of the geographical research on the new information technology in the near future is: to solve geographical problems in application, such as spatial attributes, space organizations, geographical distribution of elements and function, geographical types of service, spatial regularity; to re-examine Geography under Internet of Things, including new man-land relationship, new spatial structure, new business model and Commercial Geography, new urban spatial structure, new Industrial Geography, new Behavioral Geography, and new Information Geography.

**Keywords**—Internet of Things; information technology; Geography; review

### I. INTRODUCTION

The development and application of computer, Internet and other information and communication technologies (ICTs) brought about a great impact on the people's economic management, production operation, social management and even personal life. Recently, the new generation of information technology - Internet of Things set off a huge boom all over world and is highly valued by the United States, China, European Union and other countries or regions, which is a huge network combined by the Internet and sensing devices including radio frequency identification devices (RFID), infrared sensors, global positioning systems, and laser scanners [1-2]. The system can identify, locate, track, monitor object and trigger the corresponding event automatically and real-timely.

Computer, Internet and other information and communication technologies have profoundly changed space-time view. As the core of geography - man-land relationship and the content of geographical environment have undergone great change [3]. With the appearance of Internet of Things, there are changes again. First, in the theoretical level, distance extinction view [4], geography extinction view [5-6], slightly influence view [7], and moderate influence view become a hot spot again. The content [8, 3], composition, type, space form [9], space effect [10-11], economic geography [12-13], social and cultural geography [14] of information space need to be re-examined. Especially as intermediary between information space and

geography space, Internet of Things leads to changes in relationship between the two and brings about further evolution of man-land relationship [15-16]. Second, the content, composition, and spatial organization of the geographical environment change again under Internet of Things, reflected in the regional space [17], urban space [18-19], industrial space [20-23], and behavior space [24-26]. Third, the focus of the geographical research on phenomenon related to and derived from information technology shifts from Internet to Internet of Things, including regional proliferation [27], type of development, regional structure and regional spatial differences [28-29], location choice [30], analysis of the spatial distribution and guidance of user behavior [31], competition model of information flow [32], etc.

Based on the above three changes, geographical research on Internet of Things is necessary, not only for guidance value for application in the economic, cultural and other aspects, but also for reference value for information industry and policy-making department.

### II. GEOGRAPHICAL STUDIES ON DERIVATIVE PHENOMENON OF INTERNET OF THINGS

#### A. Space Organizations

In order to create an information source for different levels of decision-making, Internet of Things must get rid of single-point pattern of application and need spatial orientation of each sensor and dynamic information of geographical location. The formation of smart planet and smart city depends on the spatial layout of Internet of Things, so what need to study include: space coverage requirements of Internet of Things in different industries; the association patterns between spatial layout of Internet of Things and smart planet or city; programs and mechanisms for coordination of the spatial distribution of infrastructure when Internet of Things used in high-speed rail, smart grid, transport logistics, electricity, public safety and other fields.

#### B. Geographical Distribution of Elements and Function

ITU (International Telecommunication Union) reports there are four key technologies in Internet of Things: Radio Frequency Identification, Sensor, Smart technologies, and Nanotechnology [33]. The combination of RFID, Internet and telecommunications technology can achieve global tracking and information sharing [34]. What need to study:

the geographical distribution of different element; interaction between the geographical distribution of Internet of Things elements and the geographical distribution of the Internet and mobile communications technology; space network model combining multi-point distribution of Internet of Things elements and the relative concentration of Internet; components space form-based evaluation system for infrastructures.

### C. Spatial Attributes of Function

Internet of Things is itself a cross-functional space, joining physical space and information space together as one. Research on spatial attributes of Internet of Things function include: spatial accessibility and openness, the space participatory, spatial dimensions and information statistical approach, complex relationship between the two spaces, geographical background of the information technology space, differences of spatial attributes among different types of geographic space.

### D. The Geographical Types of Service Process

Objects sending message can be classified into "action" and "static" according to their state. For static objects, we should mainly study the impact of information providing on the state of people, vehicles, ships and other moving subjects, route selection, and spatial behavior regularity; For dynamic objects, the main research include: real-time information processing and behavior pattern recognition, spatial information integration, and data warehouse mining and spatial decision. Based on combination of Internet and Internet of Things, characteristics of spatial agglomeration and formation mechanism of information port should be studied.

### E. Geographical Distribution of Covering Space

Study on mutual influence among regional diffusion, regional differences and regional development of Internet of Things, can begin from three perspectives: Internet penetration rate, the abundance of network information resources, and Internet business applications. Further, we need study evolution of regional differences, relationship among geographical distribution of mobile communication network, Internet, and Internet of Things.

### F. Spatial Regularity

Although in its infancy, Internet of Things has become nowadays the most popular words in information industry, reflected in capital markets and construction plan all over the world. On the road of industrialization of Internet of Things, there are several geographical issues to study: geographical division and space competition of industry research, target market, and application industry to avoid duplication of research and development or excessive competition; analysis of factors affecting geographical division of industry and building mathematical model; maximizing the overall efficiency-based research on industrial location layouts, spatial regularity, and mathematical model; regional differences-based research on industrial development strategy, development model, and spatial transference.

### G. Geographic Issues Derived from Technology Standard-Setting

To fight for the high ground, game for different countries and regions in developing technical standards of Internet of Things is obvious. If to play key role, we should consider the problem from geographic angle at national level. In addition to taking a more proactive approach to participate in the process, more importantly, the reality of industrial scale and development can protect a country's right. Therefore, construction of industrial clusters, momentum, spatial structure, development pattern and such a series of geography questions are important research topics. From domestic perspective, the study on regional distribution of existing standards, the geographical path of unification, gradient transfer of the standards and other issues can help unify technical standards.

## III. THE NEW GEOGRAPHY RESEARCH UNDER INTERNET OF THINGS

### A. New Man-Land Relationship

Geography has studied man-land relationship for long time, which is regarded as the core of Geography [35]. Man-land relationship is dynamic, and with the development of the times, "land" and "human" content are constantly changing, expanding and innovating [36]. Based on the extensive application of Internet of Things, "Land" content changes substantially as well as environmental factors become more informational and intelligent, so its existence dimensionality and manifestation morphology are important research fields.

In the man-land system, besides natural environment, technical (showing as building of man-made environment) and social factors constitute main means of human adaptation to the environment and become key factors which constrain man-land system state [37]. Revealing driven mechanism of man-land system influenced by Internet of Things, and revealing interactions and feedback mechanisms of natural environment, human environment, and social environment are important research tasks, which core is to clarify the role of each component of new man-land system in the balance of resources (natural environment) - production (artificial environment) - consumer (human).

### B. New Spatial Structure

Spatial structure refers to interaction and mutual relationship of each object (population, materials, energy, capital, information, etc.) in the geographical space and it is bound to change under Internet of Things. Study focuses on location configurations of socio-economic activities, for example, how will the number, quality, and species composition of facilities change? How will the combination relation such as the proportion in the number of facilities, using conditions for each other, and coordination of supporting change? How will the distribution and spatial patterns of facilities change in the geographical space?

Some models explaining spatial interaction and dynamic mechanism of socio-economic object, such as gravity

models, vector models, and distance decay principle, are required to be re-examined and amended.

Internet of Things can be applied to various aspects from macro level to micro level and it provides a new tool for studying the spatial distribution, regional differentiations, spatial agglomeration and diffusion.

#### C. *New Business Model and Commercial Geography*

E-commerce is emerging as a business model co-existing with the traditional business model and it will be affected by Internet of Things. Research topics such as E-commerce business model innovation, individual consumption, solution of the bottleneck of e-commerce, consumers information accessing and spending habits, e-commerce security and consumer perception are valuable.

Internet of Things will further affect the Commercial Geography, bringing about a number of issues: In macro level, huge information source provided by Internet of Things benefit the study of resource distribution and transportation condition, the study of international, domestic commodity circulation pattern and interregional links, the study of regional difference in business activities and market differentiation, and the study of hierarchy of commercial centers and business network; In micro level, study focuses on the impact on the organization of commercial outlets and retail, location of commercial and warehousing facilities, spatial structure of point - line - network of business in specific regional, and spatial behavior of consumers.

#### D. *New Urban Spatial Structure*

Information technology has brought significant effect on spatial structure [38] and urban space which show trends of overall dispersion and dominant concentration [39]. What kind of impact will Internet of Things bring on the changes of functions of transport, housing, work, and leisure? What kind of impact will Internet of Things bring on the interaction of urban space, location flexibility, and city spatial substitution? Further, study should focus on the trends of urban space development and urban spatial structure optimization.

#### E. *New Industrial Geography*

Based on Internet of Things, the information transmission technology will acquire revolutionary development, economic globalization will get unprecedented strengthening correspondingly, and regional boundaries will become blurred, so the effectiveness and applicability of traditional location theory need to do in-depth study [40], including: the changes of production, distribution and sales methods; empirical analyzing how traditional location factors (transportation, gathering, marketing, and raw materials) and knowledge-based factors (knowledge, technology, and intelligence) affect industrial distribution; small quantities of flexible production; appropriate scale, geographical dispersion of space, and international production; network, information technology, and virtualization of economic activity.

#### F. *New Behavioral Geography*

Behavioral Geography is to study individual or group behavior and decision-making in different geographical environments [41]. Internet of Things will affect the two most critical aspects - environmental sensing and environmental perception. Environmental sensing: geographical influence on the individual behavior; geographical mechanism of human observing and sensing, including interference in induction process caused by the barriers of limiting factors. Environmental perception: factors; formation of environmental image; geographic images and cognitive maps; cognitive differences formed by different behavior of the individual characteristics. In addition, course of conduct, behavior space, location selection, changes in preferences and patterns of space, and Time Geography will be new emphasis of Behavioral Geography.

#### G. *New Information Geography*

Computer network information space is an extension of the traditional geo-space, when its formation, distribution, internal characteristics, and impact are closely related to traditional geospatial and become the new objects of modern Geography [3]. As the intermediary between computer network information space and real geographical space, Internet of Things makes the relations closer and brings about new geography propositions, including: analysis of dimensions, composition and new type of space; comparative study of new space with the traditional geographical space and network space; space flow (information, logistics, et al.) about direction, power, spatial structure, gathering, and regularity; the concept and characteristics of urban network information space; the formation mechanism of network space; the interaction of network space; information space of small cities and rural areas; city network information space planning; new urban information space [42].

### IV. CONCLUSION

After the advent of computers and the Internet, Information Geography transferred from the geographical studies of the traditional communication mode (post, telephone, and telegraph) [43] to studies of computer applications [44] and Internet information space [45]. The objects of Information Geography research changed from real space to virtual space. Traditional concept of space changed from realism to relationship theory, meanwhile, spatial scale narrowed infinitely and space developed multi-dimension [46]. Geography is space science [47], so the changes of space concepts make the Information Geography present a completely new look.

After the advent of Internet of Things, Information Geography is facing another transition. Internet of Things makes seamless docking between information space and physical space, which bring changes in the study: ① Concepts of space return, which means combination of virtual space and real space. The traditional space is still the basis of the world, but there are many new research

propositions after the information is mapped to virtual space. ② Because of acquisition of subtle information of things, research will be more in-depth and detailed. Micro-Geography will acquire large development. ③ Due to the involvement of a large number of real spatial data, mere information space research may lose their significance. New information space research will be more empirical, research content will be closer to reality of production and living, and practical guidance of research will be more significant. ④ Based on uninterrupted acquirement of objects information, information in the time dimension will enrich greatly, so the corresponding study will receive attention in Information Geography and even it will bring breakthrough impact on Time Geography. ⑤ Rich and comprehensive information obtained from the real world help the computer's virtual computing, meanwhile, process and the results show of Information Geography maybe head for three-dimension and digital virtualization.

# REFERENCES

- [1] R.G. Gustavo, M.O. Mario, D.K. Carlos, "Early infrastructure of an Internet of Things in spaces for learning," Eighth IEEE International Conference on Advanced Learning Technologies (ICALT 08), July.2008, pp.381-383, doi:10.1109/ICALT.2008.210.
- [2] A.C. Sarma, J. Girão, "Identities in the future Internet of Things," Wireless Personal Communications, Vol. 49, 2009, pp.353-363, doi:10.1007/s11277-009-9697-0.
- [3] Jie Zhang, Chaolin Gu, Jinkang Du, "Geographical approach to Cyberspace: review and prospect," Scientia Geographica Sinica, Vol. 20, 2000, pp. 368-372, doi:CNKI:SUN:DLKX.0.2000-04-012.
- [4] E.J. Malecki, S.P. Gorman, "Maybe the death of distance, but not the end of geography: the Internet as a network," The Worlds of Electronic Commerce (New York: John Wiley), in SD Brunn, TR Leinbach, (eds.), 2001, pp. 87-105.
- [5] P. Gordon, H.W. Richardson, "Beyond polycentricity: the dispersed metropolis, Los Angeles 1970-1990," American Planning Association Journal, Vol. 62, 1996, pp.289-295, doi:10.1080/01944369608975695.
- [6] S. Graham, "The end of geography or the explosion of place? Conceptualizing space, place and information technology," Progress in Human Geography, Vo. 22, 1998, pp.165-185, doi:10.1002/9780470755716.ch21.
- [7] I. Salomon, E. Razin, "Geographical variations in telecommunications systems: the case of Israel's telephone system," Transportation, Vol. 14, 1988, pp.311-327, doi:10.1007/BF00145754.
- [8] Nigel. Thrift, K. Olds, "Refiguring the economics in Economic Geography," Progress in Human Geography, Vol.20, 1996, pp.311-317, doi:10.1002/9780470755716.ch4
- [9] Zi Lu, "Spatial morphology of the communication network: about the barrier effect of the distance and borders," Economic Geography, Vol. 20, Mar.2000, pp.18-22, doi:CNKI:SUN:JJDL.0.2000-02-004.
- [10] A. Kellerman, The Internet on earth: a Geography of Information, WS: John Wiley and Sons Ltd, 2002, pp.12-82.
- [11] B. Warf, "Geographies of the tropical Internet: an overview," Singapore Journal of Tropical Geography, Vol.28, Jul.2007, pp.219-238, doi: DOI: 10.1111/j.1467-9493.2007.00292.x.
- [12] E. Malecik, "The Economic geography of the Internet's infrastructure," Economic Geography, Vol. 78, Oct.2002, pp.399-424, doi:10.1111/j.1944-8287.2002.tb00193.x.
- [13] J. Weltevreden, O. Atzema, "Cyberspace meets high street: Adoption of click-and-mortar strategies by retail outlets in city centers," Urban Geography, Vol.27, 2006, pp.628-650, doi:10.2747/0272-3638.27.7.628.
- [14] M. Moss, A. Townsend, "The Internet backbone and the American metropolis," The Information society, Vol.16, Mar.2000, pp.35-47, doi:10.1080/019722400128310.
- [15] H. Bakis, Zi Lu, "The change from the geographical space to Geo-cyberspace: review on the western scholars on regional effects by Telecommunication," Acta Geographica Sinica, Vol.55, Jan.2000, pp.104-111, doi:CNKI:SUN:DLXB.0.2000-01-011.
- [16] Zi Lu, Chi Fang, "Comparison of realistic geo-space and virtual cyberspace in China," Scientia Geographica Sinica, Vol.28, Oct.2008, pp.601-606, doi: CNKI:SUN:DLKX.0.2008-05-003.
- [17] Feng Zhen, Xiaoshu Cao, Yifeng Yao, "New component factors of regional spatial structure in information era," Human Geography, Vol.19, Oct.2004, pp.40-45, doi:CNKI:SUN:RWDL.0.2004-05-009
- [18] E.J. Malecki, "The Internet: A preliminary analysis of its evolving economic geography," Economic Geography, Vol.12, 2002, pp.76-84
- [19] A.M. Townsend, "Networked cities and the global structure of the Internet," American Behavioral Scientist, Vol.44, 2001, pp.1697-1716, doi:10.1177/00027640121957998.
- [20] Mingfeng Wang, Jian Li, "Internet, industry clusters and global production networks: the new ICTs' effects on industrial space organization," Human Geography, 2009, pp.17-22, doi:CNKI:SUN:RWDL.0.2009-02-006
- [21] Jianghui Ding, Zhouying Song, Weidong Liu, "An empirical study on the spatial organization variation with the application of Information and Communication Technologies (ICTs): a case study of textile and apparel enterprises in China," Geographical Research, Vol.28, Jul.2009, pp.883-892, doi:CNKI:SUN:DLYJ.0.2009-04-003.
- [22] Jie Zhang, Minghua Wen, Zehua Liu, Jinhe Zhang, "Research trends on ICTs and tourism," Tourism Tribune, Vol.19, 2004, pp.93-94, doi: CNKI:SUN:LYXK.0.2004-03-023.
- [23] Jie Zhang, Minghua Wen, Shufei Lu, "Knowledge economy and the tourism and leisure industry in the 21st century," Tourism Tribune, 1998, pp.45-47, doi: CNKI:SUN:LYXK.0.1998-04-011.
- [24] Zongcai Wei, Feng Zhen, "The evolution characteristics of personal communication network of economically developed regions under the influence of infomationization: a Case Study of Suzhou-Wuxi-Changzhou Area," Progress in Geography, Vol.27, Jul.2008, pp.82-88, doi:CNKI:SUN:DLKJ.0.2008-04-012.
- [25] Feng Zhen, Zongcai Wei, "The impact of information technology on the characteristics of urban resident travel: case of Nanjing," Geographical Research, Vol.28, Sep.2009, pp.1307-1317, doi:CNKI:SUN:DLYJ.0.2009-05-016.
- [26] Zi Lu, Na Liu, Z.Zui, "The guiding effect of information flow of Australian tourism website on tourist flow: process, intensity and mechanism," Human Geography, 2007, pp.88-93, doi: CNKI:SUN:RWDL.0.2007-05-019.
- [27] C. Antonellia, "Induced adoption and externalities in the regional diffusion of in formation technology," Regional Studies, Vol.24, 1990, pp.31-40, doi: 10.1080/00343409012331345764.
- [28] Jie Zhang, Zehua Liu, "On types of the spacial distribution of Chinese tourist website," Scientia Geographica Sinica, Vol.24, Aug.2004, pp.493-499, doi:CNKI:SUN:DLKX.0.2004-04-018.
- [29] Wenxin Liu, Pingyu Zhang, "Analysis on the regional differential of the Internet diffusion in China," Scientia Geographica Sinica, Vol.23, Aug.2003, pp.398-407, doi:CNKI:SUN:DLKX.0.2003-04-002.
- [30] M. E. O'Kellya, D. L. Bryanb, "Hub location with flow economies of scale," Transportation Research Part B: Methodological, Vol.32, Nov.1998, pp.605-616, doi: doi:10.1016/S0191-2615(98)00021-6.
- [31] Zi Lu, Yahong Zhao, "The time distribution and guide analysis of visiting behavior of tourism website users," Acta Geographica Sinica, Voi.62, Jan.2007, pp. 621-630, doi:CNKI:SUN:DLXB.0.2007-06-006
- [32] R. L. Mitchelsona; J. O. Wheelerb, "The flow of in formation in a global economy: the role of the American urban system in 1990," Annals of the Association of American Geographers, Vol.84, Mar.1994, pp.87-107, doi:10.1111/j.1467-8306.1994.tb01730.x.

- [33] International Telecommunication Union UIT, ITU Internet Reports 2005: The Internet of Things, 2005.
- [34] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, "Wireless sensor networks: A survey," *Computer Networks*, Vol.38, Mar.2002, pp.393-422, doi:10.1016/S1389-1286(01)00302-4.
- [35] Chuanjun Wu, "The core of study of geography: regional system of man-land relationship," *Economic Geography*, Vol.11, Mar.1991, pp.1-6, doi:CNKI:SUN:JJDL.0.1991-03-002.
- [36] Meie Ren, "Geography: great prospects for the development of science," *Acta Geographica Sinica*, Vol.58, Jan.2003, doi:CNKI:SUN:DLXB.0.2003-01-000.
- [37] Xiuqi Fang, Lansheng Zhang, "Alienation of man earth relationship and the research on man-earth system," *Human Geography*, Vol.11, Dec.1996, pp.4-9, doi:CNKI:SUN:RWDL.0.1996-04-001.
- [38] Dadao Lu, *Regional Development and Spatial Structure*, Beijing: Science Press, 1998.
- [39] Shiliang Jiang, Jianfu Cui, "Discussion on the evolutionary tendency of urban spatial structure in the information age," Vol.22, 2006, pp.94-96, doi:CNKI:SUN:GHSL.0.2006-07-040.
- [40] Jianhua Xu, "On the geography in the era of knowledge economy," *Scientia Geographica Sinica*, Vol.19, Aug.1999, pp.349-352, doi:CNKI:SUN:DLKX.0.1999-04-010.
- [41] Qimin Jin, Xin Dong, *Introduction to Human Geography*, Jiangsu: Jiangsu Education Publishing House, 1986, pp.367.
- [42] Mingfeng Wang, Yuemin Ning, "The urban geography of cyberspace: review and prospect," *Advance In Earth Sciences*, Vol.17, 2002, pp.855-862, Doi:CNKI:SUN:DXJZ.0.2002-06-009.
- [43] Zengming Ji, "Preliminary study on Information Geography," *Human Geography*, 1989, pp.17-22, doi:CNKI:SUN:RWDL.0.1989-03-004.
- [44] Jiaan Ye, "Microcomputers in geographical teaching and research: applications and constraints," *Acta Geographica Sinica*, Vol.43, Mar.1988, pp.67-77, doi:CNKI:SUN:DLXB.0.1988-01-008.
- [45] Shupeng Chen, "Information and modernization of Geography," *Scientia Geographica Sinica*, Vol.21, Jul.2001, pp.193-197, doi:CNKI:SUN:DLKX.0.2001-03-000.
- [46] Lizhen Shen, Min Zhang, Feng Zhen, "An overview of space and the development of its research with the influence of information technology," *Human Geography*, 2010, pp.20-23, doi:CNKI:SUN:RWDL.0.2010-02-006.
- [47] R. Hartshorne, "The concept of geography as a science of space, from Kant and Humboldt to Hettner," *Annals of the Association of American Geographers*, Vol.48, Jun.1958, pp.97-108, doi:10.1111/j.1467-8306.1958.tb01562.x.