INTERNATIONAL JOURNAL OF COMMUNICATION SYSTEMS
Int. J. Commun. Syst. 2012; **25**:1230–1241
Published online 17 May 2012 in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/dac.2373

Technology classification, industry, and education for Future Internet of Things

Huansheng Ning*,† and Sha Hu

School of Electronic and Information Engineering, Beihang University, Beijing, China

SUMMARY

The Internet of Things (IoT) is developing rapidly and becoming a hot topic around the world. On the basis of the reorganized Unit IoT and Ubiquitous IoT, two models for Future IoT are proposed in this paper. A dimension model is established to classify the complicated IoT technologies and a layer model is built for Future IoT system architecture. Then, the IoT vision and its development phases prediction are presented. Furthermore, the thought of regarding IoT as an emerging industry is explained to be inappropriate because IoT is a new stage of intelligentization and informatization development. Meanwhile, the necessity of training qualified personnel in colleges is introduced. Then, the relation between IoT and the science and technology system and IoT relevant subjects is analyzed. At the end, this paper raises the problem of setting IoT as a major in college and proposes some suggestions. Copyright © 2012 John Wiley & Sons, Ltd.

Received 28 August 2011; Revised 13 April 2012; Accepted 22 April 2012

KEY WORDS: Internet of Things; U2IoT; technology classification; industry; education

1. INTRODUCTION

The Internet of Things (IoT) has attracted worldwide attention rapidly, especially in China, where IoT is upgraded to a significant position and attached great importance to.

Many IoT architectures have been proposed and their fitness for Future IoT is under consideration. Because IoT technologies are very complicated and need classification, the dimension model and layer model for the system architecture should be studied. To guide IoT development appropriately, the IoT vision and its development phases prediction should also be considered.

Along with the increment of commercial interests brought by IoT, it is taken for granted as an emerging industry by some people because they feel industries engaging in related businesses such as sensor network, radio frequency identification (RFID) and logistics all belong to the IoT industry. However, we should recognize that the ‘emerging industry’ is based on many traditional industries that have existed already.

Internet of Things relevant technologies and subjects are miscellaneous so that we cannot set the IoT as a major in college like other majors for undergraduate students. Although the current situation is not suitable to set IoT as a major because of the lack of a systematic curriculum, training materials and teachers for IoT major currently, IoT major is encouraged and supported because the demands of IoT qualified personnel are urgent in many places and industries. To this end, we explore some ways for setting IoT as a major in college.

This paper is organized as follows: Section 2 shows the related work about IoT architectures, industry, and education. Section 3 reorganizes the structure for Unit IoT and Ubiquitous IoT

*Correspondence to: Huansheng Ning, School of Electronic and Information Engineering, Beihang University, Beijing.
†E-mail: ninghuansheng@buaa.edu.cn

(U2IoT), and proposes a dimension model, a layer model, IoT vision and its development phases prediction. Section 4 clarifies that IoT should not be regarded as an independent industry and explains the interplay between IoT and society. Section 5 raises the problem of setting as IoT a major in China and explores ways to resolve it for colleges.

2. RELATED WORK AND OUR WORK

In this section, we will introduce the related work mainly from the following three aspects: IoT architectures, industry, and education.

Various IoT architectures have been proposed by researchers. For Internet of Things (fusion of the physical world and information world), Pujolle [1] proposed an autonomic-oriented architecture for IoT; and Castellani *et al.* [2] described a practical realization of an IoT architecture at the University of Padova. For Internet of Service (connection of the physical world and Internet to provide services for things), Mathew *et al.* [3] proposed a system architecture for the Web of Things; and Christophe *et al.* [4] gave an implementation of the Web of Things vision. For Internet of Brain Informatics (cyber world meets brain informatics), Ma *et al.* built the foundation in this field and the novel work can be referenced in [5] Furthermore, the European Commission founded the Future Internet Assembly for Future IoT realization [6]; Atzori *et al.* [7] proposed a new architecture for the Social IoT etc. The man-like nervous (MNL) and social organization framework (SOF) models have been launched for Future IoT [8]. The models incorporate the social character in IoT, in which the MNL model is the architecture of Unit IoT and the SOF model is the architecture of Ubiquitous IoT. Because Future IoT architecture is composed of Unit IoT and Ubiquitous IoT, this paper reorganizes the structure of U2IoT by combining the MNL and SOF models. For IoT vision and its development phases, there are also various related work conducted, for example, IoT is thought to be a technical revolution that represents the future of computing and communications [9]; Tan and Wang [10] defined three steps for the IoT development trend and three IoT development phases are also indicated in [11] etc. In this paper, we give thr IoT vision and its development phases prediction based on U2IoT to satisfy the IoT development path.

Unlike the Internet with the standard specification IoT has no unified architectures and technologies currently. IoT technologies are miscellaneous and complicated, such as networks, information service, identification, coding, security, etc. Under this situation, technology classification shall be studied to help view IoT and its technologies more clearly, and guide the technology research for practitioners and researchers. Therefore, we propose a dimension model for IoT technology classification.

People usually divide information system into different layers to help understand the system architecture and technology. The existing IoT layer models include three-layer model, four-layer model, IBM eight-story reference architecture, the five-layer model proposed by Wu *et al.* [9], the six-layer model by Tan and Wang [10] etc. After analyzing the most accepted models, we propose a new layer model after considering the social character based on U2IoT.

IoT has been adopted into the national strategy by many countries. In the US, the *2025 Key Technologies with Potential Impact on U.S. Interests* by the National Intelligence Council lists IoT as one of the six key technologies. In Europe, the *Internet of Things-An action plan for Europe* was submitted as a guideline, which regards IoT as a technology vision. Besides, the u-Japan plan and u-Korea plan were also proposed. Researchers and institutions study the technology and application aspects of IoT. Neither in the international community nor in the academic field is IoT declared as an industry. In China, IoT is regarded as a new industry by some people, such as in [12–15]. We shall view IoT reasonably to lead IoT development in the appropriate direction. Therefore, whether or not IoT is a new industry and the interplay of IoT and society is discussed in this paper.

The IoT education can be traced back to 1999, when the Auto-ID Center of Massachusetts Institute of Technology (MIT) first proposed the IoT concept. In the US, research results from college institutions are transferred into practical productive forces by combining with leading enterprises. In Europe, the *Internet of Things-An action plan for Europe* has incorporated IoT research and education. Other countries like Japan, Korea and Singapore are also launching IoT research programs

DOI: 10.1002/dac

to seize the opportunity brought by IoT. In China, the Minister of Education (MOE) has announced a list of newly launched undergraduate majors including IoT major [16]. Many colleges have begun to set IoT and its relevant majors. Researches on IoT education are being conducted including the major setting method and curricular system. Gui [17] analyzed the necessity and feasibility of setting IoT as a major, and studied the curricular system for IoT major to provide reference for colleges. Hu [18] proposed a knowledge hierarchy and curricular system for IoT engineering major. Chen and Shi [19] think that IoT major characteristic resources construction includes five aspects. Xie and Huang [20] studied the mode and key problems of IoT professional personnel training while the curricular system for IoT is proposed. Zhang and Yu [21] analyzed the requirements of IoT qualified personnel in society and pointed out the training qualities and objectives of IoT personnel. In this paper, based on the analysis of the science and technology system and subjects related to IoT, we propose some ways of setting IoT major for undergraduate students.

3. SOME MODELS AND DEVELOPMENT VISION FOR FUTURE IOT

3.1. Reorganized U2IoT architecture for Future IoT

Unit IoT refers to solutions for special applications. Ubiquitous IoT refers to the global IoT, national IoT, industrial IoT, or local IoT, which is an integration of multiple Unit IoT with 'ubiquitous' characteristics [8, 22].

Future IoT architecture is the combination of Unit IoT and Ubiquitous IoT, which is reorganized as shown in Figure 1.

In Figure 1, I and L represent industry and local management data center respectively. The rectangle area denotes the local region managed by the connected L. The line connected to I denotes industry, on which small solid dots are Unit IoT as the figure shows.

Global IoT is composed of national IoT while national IoT manages I and L. I manages the Unit IoT in the corresponding industry. L manages the Unit IoT in its corresponding region. We can see

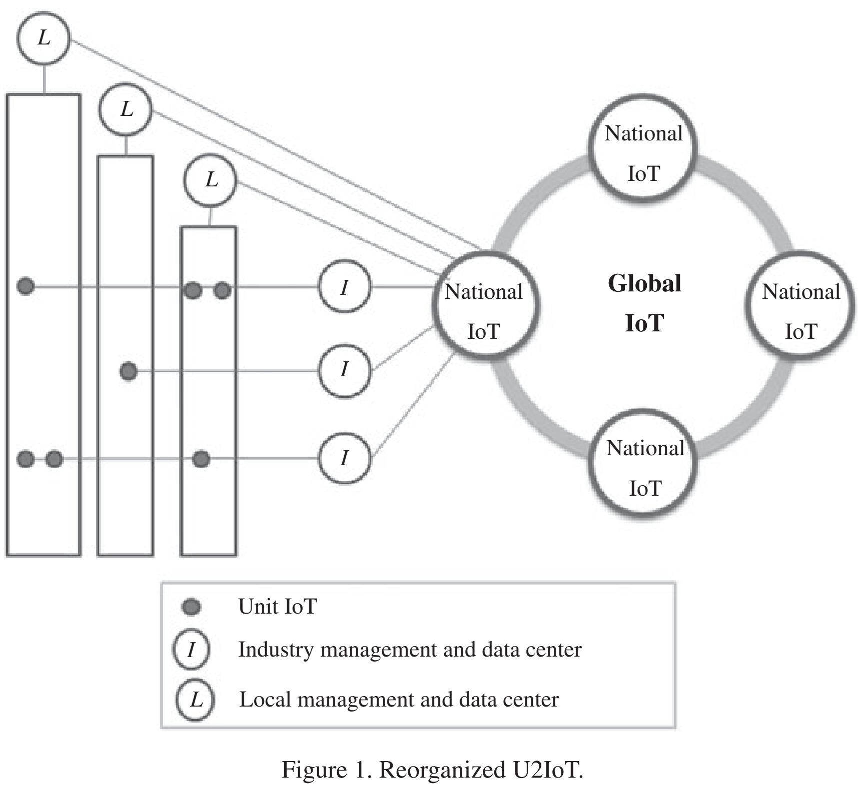

Figure 1. Reorganized U2IoT.

DOI: 10.1002/dac

that industry IoT and local IoT overlap and the three regions involve different Unit IoT. All of Unit IoT in different regions and industries construct the national IoT.

3.2. Dimension model for Future IoT technology classification based on U2IoT

Because many complex technologies are involved in IoT, here we conclude four dimensions (4D) for the technologies as shown in Figure 2.

(1) First Dimension: Body
The IoT body, like hardware engineering, includes all kinds of sensors, networks, and data centers. Besides the physical devices, the main feature is to address device performance, network access, interoperability, flexibility, and reliability. What is more, meeting the developing infrastructure demand in the underdeveloped regions around the globe is a must.
(2) Second Dimension: Processing
Processing means software engineering. Many functions are included, such as identifying, coding, resolving, transmitting, storage, searching, security, etc. IoT processing shall focus on the requirements from thing's intrinsic existing and mankind's will, not devices.
(3) Third Dimension: Intelligence
Intelligence includes advanced network management, intelligent control, automatic decision making, manlike perception, and others. 'Self-' is its characteristic, such as self-recovery, self-organization, self-discovery, self-management, etc.
(4) Fourth Dimension: Sociality
Sociality includes: government and public management, moral action restraint, and IoT relevant laws etc. It is the social regulation for Future IoT to make cyber space meet the social world well This dimension is one of the fundamental requirements of IoT.

3.3. Layer model for Future IoT system architecture based on U2IoT

In this part, we will discuss the common three-layer and four-layer models and propose a new four-layer model for Future IoT system architecture based on U2IoT.

From the aspect of system architecture, IoT is generally divided into three layers: perception layer, network layer, and application layer as shown in Figure 3(a). The four-layer model is similar

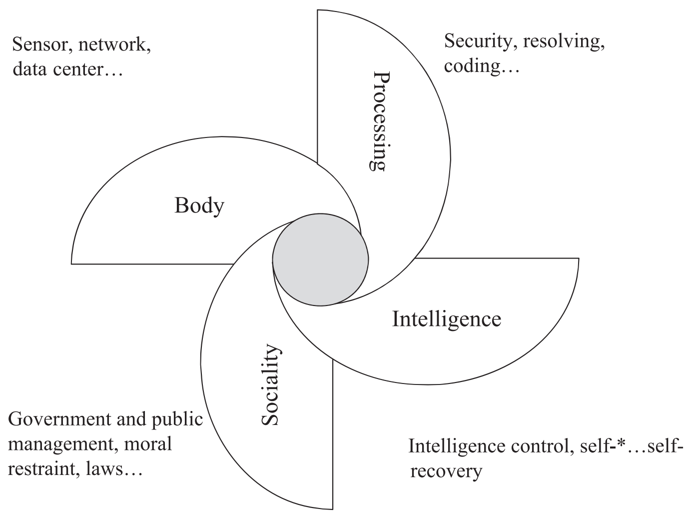

Figure 2. The dimension model for Future IoT technology classification (in the model, self-* means any intelligent activities made by IoT itself, such as self-configuration, self-organization, self-management, etc.).

DOI: 10.1002/dac

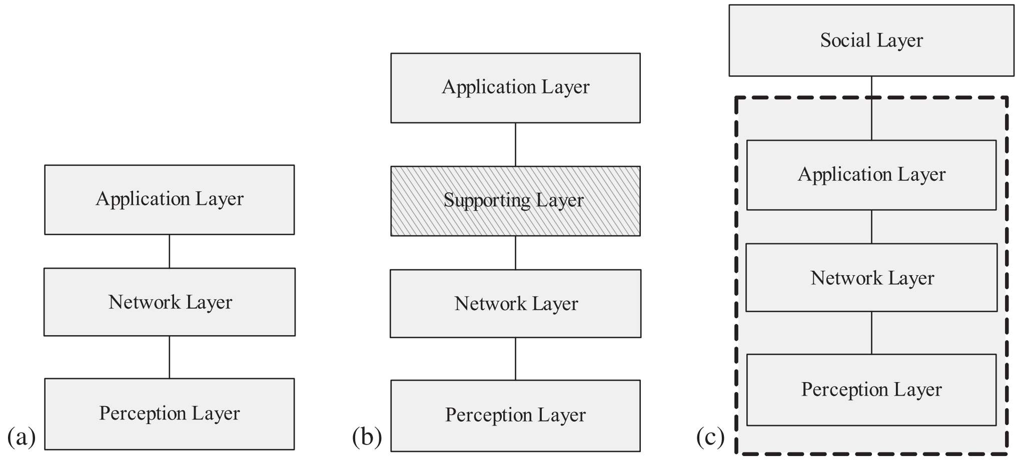

Figure 3. Different layer models: (a) three-layer model; (b) four-layer model; and (c) layer model for Future IoT system architecture based on U2IoT.

to the three-layer model. The difference is an additional supporting layer, shown in Figure 3(b). The supporting layer integrates many common technologies.

In the three-layer model, perception layer is the integration of different sensor systems; network layer is the integration of various communication networks; and application layer is the integration of application systems. The layers of this model are different from those of the Open Systems Interconnection seven-layer model. In the latter model, layers are divided according to functions in the communication operation and corresponding network details are included in each layer. In the former model, each layer covers the whole operation of its systems. The three layers integrate different systems and play their own special roles in IoT. Constructed by the three layers, IoT is the network of networks.

However, in the four-layer model, the added supporting layer is not similar to other layers. It is the integration of IoT common technologies that are involved in other layers. The contents of this layer can be incorporated in other layers. Segregating the common technologies as one layer is not necessary and inappropriate. Therefore, the three-layer model is more suitable. On the basis of the three-layer model and U2IoT, this paper proposes a new layer model that adds an additional social layer to the three-layer model shown in Figure 3(c).

The three-layer model is the architecture for Unit IoT. For Ubiquitous IoT, its architecture is social organization framework, similar to family, group, industry, nation or other organizations consisting of individuals. Because Future IoT is composed of Ubiquitous IoT and Unit IoT, we add a social layer for Future IoT to manage the Unit IoT. It is responsible for the regulation of IoT applications.

To help understand the model easier, Unit IoT is compared with the human individual in society. Ubiquitous IoT is compared with the social organization consisting of individuals. Because human relations are built by organizations, they should obey some certain rules in specified organizations. The society needs social management for organizations to handle individuals and public activities. Similarly, in Future IoT, the model should incorporate the social layer to manage Unit IoT. This social layer is added over the three layers.

3.4. Internet of Things vision and its development phases prediction

A perfect IoT vision in the future may be an era of ‘harmony of man with nature’, which means harmony, coordination, and coexistence of the physical world, human society and cyber world. When that era comes, human development will witness emancipation from mental labor and information overload, achieving a second substantial leap since the first one — industrial revolution, which emancipated humanity from manual labor. Admittedly, threats upon security and privacy issues will become unprecedentedly serious because of the fragility of human society. We believe, however, that solutions to those problems will be worked out in the future.

Here, we divide IoT development into three stages before reaching the perfect IoT vision era: Early stage, Unit IoT stage, Ubiquitous IoT stage, as shown in Figure 4.

Early stage: The beginning of IoT early development stage. A typical scheme for early prototypal IoT is the Electronic Product Code [23] system, which is a vision world that all physical objects can be connected by an RFID transponder through a globally unique Electronic Product Code carried by the RFID tag [24]. Japan also proposed its earlier IoT prototype, the Ubiquitous IDentifications (UID) solution. The main characteristic at this stage is using RFID technology to identify objects uniquely and trace them globally [25].

Unit IoT stage: Focusing on specific IoT application. This can be dated back to 2005 with its milestone — the publishing of the IoT report by the International Telecommunication Union (ITU) [26], followed by some important events: US government made a positive statement to develop IoT in 2008; European Union launched a cluster research on IoT and announced some reports [27, 28]; China also announced that sensor network will be developed as an important industry in China in 2009. One of the stage characteristics is the sensing method in IoT, which not only breaks through the RFID identification, but also involves varieties of sensing methods (all contact, contactless, and remote sensing methods including sound, light, and electricity sensing). Another characteristic is the application of intelligence to IoT. Smart Planet [29] proposed by IBM, for example, has already gained increasing popularity. Despite the IoT's development, it is still a blurred concept for the public. This is the result of a disconnection of the academe and industries. While the academic experts have not established a distinct scientific and technological framework for Future IoT, the industrialists have already taken hasty moves for IoT applications. Therefore, it is difficult to establish IoT standards in the real sense at this stage. Compared with the early stage, one of the significant differences is that various sensing methods involved in IoT include not only RFID [30], but also wireless sensor networks [31], Wi-Fi etc.

So far, IoT development has experienced two stages: early development stage and Unit IoT stage. The Unit IoT development will go on, but IoT will be gradually steered to industry orientation, nation orientation, and global orientation, which constitute the third stage: Ubiquitous IoT stage.

Ubiquitous IoT stage: From now on, Ubiquitous IoT stage may last for 30–50 years and it can be divided into three steps: Industrial IoT, National IoT, and Global IoT.

Step 1: Industrial IoT. The beginning of 2011 saw a milestone when China announced to push IoT development in 10 important application fields, such as industrial IoT. Although IBM has developed solutions such as Smart Bank in 2008, it is, after all, a corporation aiming at the Unit IoT rather than establishing and operating an industrial IoT led by a country. Speaking of policy making, China strides ahead of other countries and has become one of the leaders of IoT development. As a pioneer, China will not be daunted by the obstacles at this stage but will probe the way steadily. Meanwhile,

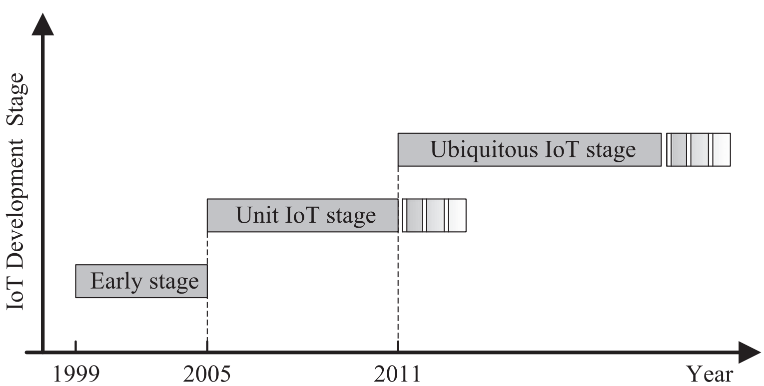

Figure 4. IoT development stages.

DOI: 10.1002/dac

scientific problems concerning IoT will be resolved at this stage. Some national standards for industrial IoT will be formulated and cross-field cooperation mechanism will be established. Also, some global industrial standards concerning cross-nation communication, such as global logistics, will emerge at this stage. Furthermore, local IoT will also be generated at this stage to coordinate and manage the local industry and Unit IoT.

Step 2: National IoT. At this step, national IoT that manages all industries in the country will be formed with relatively mature technologies, laws and regulations, security and user consciousness and cultivation. Nations can independently control their information network and resources. Cross-disciplinary subjects upon science, technology, and engineering associated with IoT will be introduced, and IoT relevant subjects and humanities and social science such as economics, management, sociology, legal and philosophy, etc., will also be considered in IoT. The standards for national IoT will be established.

Step 3: Global IoT. When this step commences, IoT covering different countries will be connective and cross-national cooperation mechanism will also be founded. Under the new information network, changes will occur in people's life styles, ideals, social organization structures, and government functions. After a relatively long period of development, global IoT and the related cooperation will achieve ripeness, realizing interconnection, transparency, and resource-sharing around the globe. When a more advanced life philosophy and nation organizational structure show up, the global IoT standard will come to its perfection.

4. INTERNET OF THINGS: A NEW INDUSTRY?

The IoT involves many kinds of industries. After IoT technologies and applications are analyzed, this section studies whether IoT is suitable to be regarded as a new industry. Also, the interplay of IoT and society is discussed.

4.1. Internet of Things: a new industrial or not?

A wide range of IoT-related technologies are involved, such as coding, identification, resolving, information service, wireless transmission, security, standards, and middleware technologies etc. IoT can be applied for intelligent building, smart grid, smart home, intelligent hospital, environment monitoring, mine safety management, and ticket management, etc. In fact, almost all intelligent systems can be referred to as IoT applications. The broad scope of industries involved in IoT is obvious.

In the future most industries may build their corresponding industry IoT. Cross-regional IoT are countless, while national IoT and global IoT arise. These Unit IoT and Ubiquitous IoT will cover all fields in our life.

For one thing, regarding IoT as an independent emerging industry seems improper. We cannot count all increment of communications, electronics, and control industry as IoT industries. For example, future smart grid is an important application area, and we cannot consider the development achievements of smart grid all to be the benefits of IoT. In the 12th 5-year-plan, China will focus on the development of IoT applications in 10 fields [32]. If achievements of the 10 fields including smart home, fine agricultural, and so on are pooled together to make up a new IoT industry, it is inappropriate that even part of the increment is regarded to be the benefit of IoT.

For another thing, 'developing IoT will bring huge economic benefits in the near future' seems unreasonable. Presently, people are used to referring industries engaging in sensor network, RFID, logistics, and intelligent monitor business to the IoT industry, covering many IT industries, especially communication and Internet industries. If so many existing industry businesses related IoT are counted to IoT, many IoT contents exist already, with just a change of wording. Hence, current considerable economic benefits and future optimistic prediction around this emerging industry are inappropriate.

Not regarding IoT as one industry seems to be more reasonable. In fact, intelligentization and informatization are the inexorable trend for every industry development. Without the IoT concept, these industries will also develop towards the high intelligence direction.

DOI: 10.1002/dac

4.2. Interplay of Internet of Things and society

Because IoT involves so many industries, new jobs will be generated and additional value will be increased, which bring chances to social development, including promoting employment and economic development. Society also affects IoT development. For instance, the Chinese government creates a favorable policy environment for IoT development. The *Twelfth Five-Year-Plan Outline for National Economic and Social Development of China* points out 10 fields of IoT applications that need huge investment The fields cover smart grid, intelligent transportation, intelligent logistics, smart home, environment and safety testing, industry and automation control, health care, fine agricultural, finance and services, and military defense [32]. In these fields, Unit IoT and corresponding industry IoT are greatly supported to be built and developed. IoT and society promote the development of each other.

5. INTERNET OF THINGS: A NEW MAJOR?

Internet of Things development cannot be separated from personnel training. In the current situation, an important factor affecting IoT development is the shortage of qualified personnel. An IoT qualified personnel is becoming a kind of a scarce personnel. In China, it is urgent to train IoT qualified personnel to participate in its development. In this section, science and technology system is introduced and IoT relevant subjects are also presented. Meanwhile, the problem of setting IoT as a major is analyzed and some solutions are proposed subsequently.

5.1. Science and technology system

In Figure 5, the structure of science and technology system from Ma's lecture [33] embraces three dimensions. The first dimension is composed of natural science, social science, and humanities and aesthetics. Obviously, the sensing function in IoT depends on the things' natural attributions. From the study of Section 4, it is known that IoT covers each field in this dimension. The three scientific fields are important for IoT.

The second dimension includes human, geographical, building, and military sciences. IoT development is bound up with humans. Building and military are import application areas of IoT. Because geographical information belongs to things' basic characteristics in the physical world,

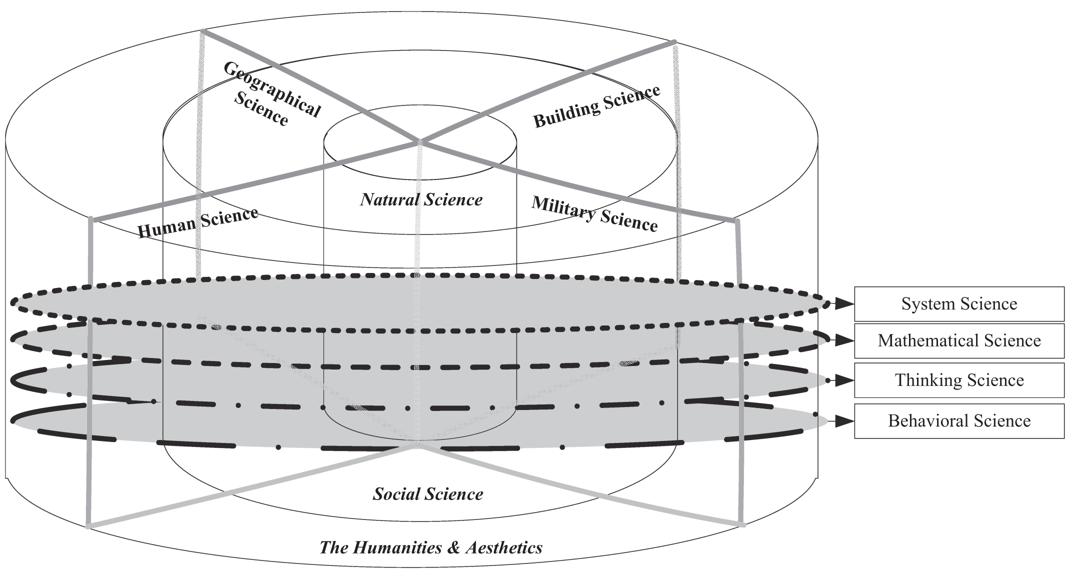

Figure 5. Science and technology system structure.

DOI: 10.1002/dac

geographical science is significant for positioning in IoT. From these aspects we can see that all the four sciences in this dimension are related to IoT.

The third dimension comprises system, mathematical, thinking, and behavioral sciences. Undoubtedly, IoT is a complicated system. It needs system science and mathematical foundations. Moreover, human thinking and behavioral sciences are necessary for Future IoT realization because they are needed for intelligentization and automation.

Overall, IoT is related to all the fields in the science and technology system. The detailed relevant first-level disciplines (called subjects here) are discussed as follows.

5.2. *Subjects related to Internet of Things*

Modern knowledge systems can be divided into many subjects. Table I lists some relative IoT subjects and their corresponding relevance to IoT development.

For Unit IoT, it requires the connection of the physical world and information world. Information and communication engineering is the basis for IoT construction and is assigned to the highest degree. Instrument science and technology is needed to manufacture physical devices for IoT implementation so it is assigned to a very high degree. Meanwhile, chemistry is assigned to a high degree as sensors of identifying things' chemical characteristics are used.

For Ubiquitous IoT, new laws should be formulated to regulate IoT and public activities. It is necessary for developing Ubiquitous IoT, therefore law is assigned to a middle degree.

Other subjects like artistic theory make little change with IoT development. They are assigned to a low degree. In the future, many subjects of modern science will need adjustment to fit the new paradigm.

5.3. *New-emerging problem of setting Internet of Things major in China*

Because the Chinese government has decided to vigorously develop IoT, the MOE also wants to contribute to IoT development as the education authority, for which the most direct approach is to set an IoT major in college to train professional personnel. Accordingly, in 2010, MOE announced a list of newly launched 140 undergraduate majors. The first 42 colleges in the list are key colleges and 31 of them have been authorized to set IoT major. Again in 2011, the MOE announced 2010 major setting record and approval results of colleges, in which 27 colleges have been authorized to set IoT relevant majors. Moreover, more colleges managed by local governments and vocational schools will also set IoT courses and major.

Therefore, the main problem is: on one hand, the number of enrolled students majoring in IoT is growing rapidly in the following years; on the other hand, we currently lack a mature systematic curriculum, training materials, and teachers for IoT major. The contradiction will soon become noticeable. Therefore, it is significant to find some appropriate ways to solve the problem.

Table I. Subjects examples related to IoT.

Relevance	Subjects examples
Highest	Information and communication engineering, electronic science and technology, control science and engineering, computer science and technology
Very high	Instrument science and technology, mechanical engineering, optical engineering
High	Chemistry, biology, physics, mathematic, transportation engineering, aviation aerospace science and technology, architecture, agricultural engineering, medical technology, pedagogy
Middle	Law, public management, applied economics
Low	Artistic theory, archeology…

5.4. Some ways for setting Internet of Things major

Although core technologies of IoT are yet unclear, one point for sure is that plenty of contents are the outcome of new development stage.

For graduate students, considering the demand of more professional research personnel, setting the IoT major is relative easy and appropriate, because graduate students can follow the research direction of supervisors and concentrate on one aspect of IoT. However, it is not easy to set IoT major independently like other majors for undergraduate students at present, because they still need a wide range of common basic courses. New training methods shall be explored for undergraduate students. Here two methods are proposed to train IoT qualified personnel at the undergraduate level:

(1) **Public optional course:** This method is to set public optional courses on IoT theory and technologies in schools. Students will be taught application examples from different aspects including IoT technologies, solutions, design, and operation to inspire their ideas. Also, they can have IoT relevant graduation projects. Students in different traditional schools can choose these optional courses according to their interests.

(2) **IoT school/major:** This method is to build an IoT school or IoT major. Basic courses such as mathematics, physics, chemistry, computer, and communications will be given in the beginning. Then specific IoT courses are systematically taught by the IoT school. Afterwards, instances and methods of building IoT applications are provided by IoT or other schools. Moreover, the practice and graduation design are also managed by the IoT school. The IoT school may combine the resources from corresponding traditional schools or cooperate with industries. In China, colleges can further explore the method by combining the 'Excellence Engineering Program' [34].

Different colleges should explore the proper approach according to their own characteristics. For example, North China Electric Power University can focus on the smart grid field because it has advantages on the research of electric power. Another case is Beijing Jiaotong University, for which intelligent transportation field is the best choice to set IoT major in. For the comprehensive colleges, such as Tsinghua University and Peking University, they can choose one of the modes mentioned above to set the major according to their own situation. We should recognize that there seems to be no unified IoT syllabus for colleges at present.

In terms of curriculum development, many scientific issues on IoT are still to be studied. Textbook content and curricular system need to be gradually established and improved. Because the core of IoT is achieving the unity of the physical world and information world, many cross-cutting areas and the corresponding training will be generated in the future. The curriculum system will be comparatively complicated, which may also appear in the future vocational skills training. IoT personnel training shall be circumspect and needs joint efforts of academia and industries.

6. CONCLUSION

In summary, this paper reorganizes U2IoT architecture for Future IoT, based on which a dimension model is proposed to classify the complicated IoT technologies and a layer model is built for system presentation. After analyzing relevant issues on the industry and education, we conclude that IoT is not a specific industry but a new stage of intelligentization and informatization development. IoT involves every field in the science and technology system and its technologies cover most subjects. It is a challenge for colleges to set IoT major for undergraduate students. Ways to solve the problem are also proposed.

REFERENCES

1. Pujolle G. An Autonomic-oriented architecture for the internet of things. *IEEE John Vincent Atanasoff 2006 International Symposium on Modern Computing (JVA'06)*, Sofia, 2006; 163–168, DOI: 10.1109/JVA.2006.6.
2. Castellani AP, Bui N, Casari P, Rossi M, Shelby Z, Zorzi M. Architecture and protocols for the internet of things: A case study. *2010 8th IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM Workshops)*, Mannheim, 2010; 678–683, DOI: 10.1109/PERCOMW.2010.5470520.

3. Mathew SS, Atif Y, Sheng Z, Zakaria M. Web of things: Description, discovery and integration. *2011 IEEE International Conferences on Internet of Things, and Cyber, Physical and Social Computing*, Dalian, 2011; 9–15, DOI: 10.1109/iThings/CPSCom.2011.165.
4. Christophe B, Boussard M, Lu M, Pastor A, Toubiana V. The web of things vision: Things as a service and interaction patterns. *Bell Labs Technical Journal* 2011; **16**:55–62.
5. Ma J, Wen J, Huang R, Huang B. Cyber-Individual meets brain informatics. *IEEE Intelligent Systems* 2011; **26**:30–37.
6. Future Internet Assembly (FIA). Available from: http://www.future-internet.eu/home/future-internet-assembly.html.
7. Atzori L, Iera A, Morabito G. SIoT: Giving a social structure to the internet of things. *IEEE Communications Letters* 2011; **15**:1193–1195.
8. Ning H, Wang Z. Future internet of things architecture: Like mankind neural system or social organization framework? *IEEE Communications Letters* 2011; **15**:461–463.
9. Wu M, Lu T, Ling F, Du H. Research on the architecture of internet of things. *2010 3rd International Conference on Advanced Computer Theory and Engineering (ICACTE)*, Chengdu, 2010; 484–487.
10. Tan L, Wang N. Future internet: The internet of things. *2010 3rd International Conference on Advanced Computer Theory and Engineering(ICACTE)*, Chengdu, 2010; 376–380.
11. 2010 Internet of Things Industry Development Research Report Summary, 2010. Available from: http://www.cww.net.cn/news/html/2010/4/12/20104121045171311.htm.
12. Dong A, He S, Yi M. Internet of things industry development status and framework system exploration. *Science & Technology Progress and Policy* 2011; **28**:61–65.
13. Lv J, Ma R. Opportunities and challenges of the development of the internet of things industry. *Journal of Xi'an University of Post and Telecom* 2010; **15**:81–84.
14. Chen Y, Zhang H, Zhang Y. Research on the development of internet of things industry in China. *Science and Technology Management Research* 2010; **30**:103–106.
15. Sheng L, Zhang Y, Wang G. The SWOT analysis on industrial cluster development of Chinese internet of things and duggestions. *Journal of University of Science and Technology* 2010; **26**:138–141.
16. Ministry of Education announced a list of new launching undergraduate majors related to future strategic newly-emerged technologies, 2010. Available from: http://www.moe.edu.cn/edoas/website18/71/info1280198962196771.htm.
17. Gui X. Research on the courses program and educational mission for the specialty in the internet of things. *Computer Education* 2010; **16**:1–3.
18. Hu Z. "Internet of things program" New major curricular system design. *China Electric Power Education* 2010; **22**:109–111.
19. Chen Z, Shi L. Internet of things specialty resources database construction practice of higher vocational colleges. *China Education Info* 2011; **5**:29–31.
20. Xie Q, Huang G. Personnel training and teaching practice study based on internet of things. *Journal of Education Technology* 2011; **10**:44–46.
21. Zhang G, Yu H. On the personnel quality and training objectives of internet of things engineering speciality. *Science & Technology Information* 2011; **11**:216–217.
22. Ning H, Hu S. Internet of things: An emerging industrial or a new major? *2011 IEEE International Conferences on Internet of Things, and Cyber, Physical and Social Computing*, 2011; 178–183.
23. EPCglobal. "The EPCglobal Architecture Framework"(Final Version 1.3, 2009).
24. Ning H. *RFID Major Projects and National Internet of Things*, (3rd edn). China Machine Press: Beijing, 2012.
25. Lu Y, Zhang Y, Yang LT, Ning H (eds). *The Internet of Things: From RFID to the Next-Generation Pervasive Networked Systems (Wireless Networks and Mobile Communications)*. Auerbach Publications: New York, 2008.
26. ITU. The Internet of Things. ITU International Reports (2005).
27. Cluster of European Research Projects on the Internet of Things (CERP-IoT), CERP-IoT Research Roadmap, 2009.
28. Cluster of European Research Projects on the Internet of Things (CERP-IoT), Vision and Challenges for Realising the Internet of things, 2010.
29. IBM Institute for Business Value. A Smart Planet [EB/OL].
30. Cho K, Pack S, Kwon T, Choi Y. An extensible and ubiquitous RFID management framework over next-generation network. *International Journal of Communication Systems* 2010; **23**:1093–1110.
31. Bai F, Munasinghe KS, Jamalipour A. Accuracy, latency, and energy cross-optimization in wireless sensor networks through infection spreading. *International Journal of Communication Systems* 2011; **24**:628–646.
32. The 12th five-year plan pushes Internet of Things and tera-scale industry will form in the future, 2011. Available from: http://www.rfidchina.org/news/readinfos-50802-177.html.
33. Ma A. Meet the second renaissance and learn the scientific thinking of Qian Xuesen. Available from: http://graduate.buaa.edu.cn/GetPubFile.aspx?ID=1310.
34. Several opinions of Ministry of Education about implementing Excellence Engineer Education Training Program, 2011. Available from: http://www.moe.gov.cn/publicfiles/business/htmlfiles/moe/s3860/201102/115066.html.

AUTHORS' BIOGRAPHIES

Huansheng Ning was born in 1975 in Anhui province, China. He received the BS degree from Anhui University in 1996 and Ph.D. degree in Beihang University in 2001. From 2002 to 2003, he worked at Aisino Ltd Co. From 2004 to 2005, he was a post-PhD in Beihang University. From 2006, he worked as an associate professor at the School of Electronic and Information Engineering, Beihang University. He has presided over several research projects of the Natural Science Foundation of China (NSFC), National High Technology Research and Development Program of China (863 Project), etc. He serves as an editor of Advances in Internet of Things (2012), Guest Editor for the Journal of Universal Computer Science Special Issue on Internet of Things (2011), and a Co-Editor for <The Internet of Things: From RFID to the Next-Generation Pervasive Networked Systems> (Taylor and Francis Group, 2006–2007). He serves as chair for international conferences, including Program Chair (iThings 2012), CPS and Internet of Things Track Chair (CIT 2012), and Workshop Chair (iThings 2011). His current research focuses on Internet of Things and its application and aviation security.

Sha Hu received the B.Eng. degree from the International School, Beijing University of Posts and Telecommunications. She is currently a master's candidate at the School of Electronic and Information Engineering, Beihang University, China. Her research interests are things' modeling and Internet of Things.