Internet of Things: an Emerging Industrial or a New Major?

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***Abstract*—Internet of Things (IoT) develops rapidly and becomes a hot topic around the world now. After analyzing and comparing the current IoT layer models, a three-dimension (3D) technology model is proposed to classify the complicated IoT technologies logically for the existing IoT. Furthermore, U2IoT (Unit IoT and Ubiquitous IoT) model is summarized and the layer model is updated by adding social layer for the future IoT. Based on this, whether IoT can be regarded as an emerging industrial or a new major is answered. After studying the related issues, this paper argues that IoT is inappropriate to be an independent industry while it should be regarded as a new thing at the stage of intelligentization and informatization development for all walks of life. Meanwhile, how to train talents in colleges is also a problem to be explored. After analyzing how IoT relates to the science system and why setting IoT major for undergraduate is different with other majors setting, this paper proposes two modes to set IoT major and gives some suggestions for universities on the related IoT major problem in China as well.**

Keywords-Internet of Things; model; U2IoT; education; major; industry

I. INTRODUCTION

Internet of Things (IoT) has attracted worldwide attention rapidly [1-3]. China attaches importance to IoT development as well.

Recently, various architecture models for the existing IoT have been built. The general models are three-layer model and four-layer model, and there are still arguments that IoT should be divided into three layers or four layers. To help view the existing IoT structure and technologies clearly, Section II of this paper analyzes each layer and the difference of additional layer compared with other layers. Three-layer model is thought to be more appropriate in this paper. And then against the technologies, a three-dimension (3D) technology model is proposed to summarize IoT technologies. In Section III, based on the U2IoT (Unit IoT and Ubiquitous IoT) model [4] for the future IoT, we re-organize the structure for U2IoT and re-construct the layer model by analyzing IoT intrinsic characteristics.

Along with the increment of commercial interests brought by IoT, It is thought to be an emerging industry by some people as they feel industries engaging in related business such as sensor network, RFID, logistics, all belong to IoT industry. However, we should recognize many contents exist already and the "emerging industry" is based on such many traditional industries if so. Section IV of this paper discusses IoT related technologies, applications, social effects and the experience of IoT development, and then expounds drawbacks of regarding IoT as an emerging industry from the aspect of involved industries and technology range, and further clarifies that IoT is not suitable to be an independent industry while a new thing in the phases of development.

Sciences in each dimension of science system are related to IoT and the subjects and specialties involved in IoT are so many that we cannot set IoT major as other majors for undergraduate students. Although the current situation is not suitable to set IoT major as the lack of systematic curriculum, training materials and teachers for IoT major now, IoT major is encouraged and supported to set by the government currently as the demands of IoT talents are enormous and urgent. To solve the problems in setting IoT major, we explore the training modes for universities. The details are given in Section V.

II. ESTABLISH A 3D TECHNOLOGY MODEL TO SUMMARIZE IOT TECHNOLOGIES

For the existing IoT, various architecture models are raised, including three-layer model, four-layer model and IBM eight-story reference architecture etc. Even for the same layer number model, different concepts are given. In this part, common three-layer and four-layer models are chosen to be discussed. Subsequently, a 3D technology model is proposed subsequently to classify so many complicated technologies involved in IoT.

A. General description on IoT structure & technologies

IoT is generally divided into three layers from the aspect of technology architecture, which are perception layer, network layer and application layer, shown in Fig.1 (a). The perception layer consists of various sensors and sensor gateways. Its function is like ophthalmology, otolaryngology, skin and other nerve endings used to identify objects and collect information. The network layer includes a variety of private networks, Internet, communication network, network management system, which is like nerve center and brain used to transmit and process information from perception layer. And application layer is the interface of IOT and users

978-0-7695-4580-6/11 $26.00 © 2011 IEEE
DOI 10.1109/iThings/CPSCom.2011.115

(including human, organizations and other systems etc.). It combines with the demands of industries to realize intelligent applications.

The four-layer model is similar to the three-layer model. The difference is an additional supporting layer, shown in Fig.1 (b). The supporting layer integrates the common technologies overall. It adopts unified coding, data security and privacy, data fusion, data management, and data storage cloud computing and cloud storage technology to obtain information classification [5].

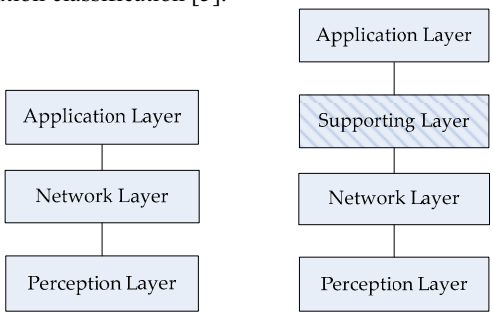

Figure 1. (a) three-layer model (b) four-layer model

B. *Comments on above layers for IoT*

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 integration of all kinds of application systems. This model is different with OSI (Open Systems Interconnection model) seven-layer model. In the later model, layers are functional divided of 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.

However, in the four-layer model, the added supporting layer is not similar to other layers. It is the integration of the common technologies 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, three-layer model is more suitable for the existing IoT.

C. *3D technology model*

For so many technologies involved in IoT, here we divide technologies into three dimensions (3D). Fig.2 shows the detail in each dimension.

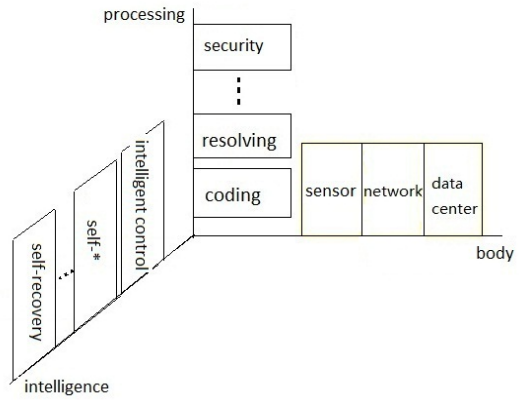

Figure 2. The IoT characters and technologies in three dimensions.

Self-* means any intelligent activities made by the IoT itself, such as self -configuration, self-organization, self-management, and so on.

1) First Dimension: Body

IoT body, like hardware engineering, includes all kinds of sensors, networks and data centers. Besides the physical devices, the character of this dimension also addresses device performance, network access, interoperability, flexibility and reliability. What's more, meeting the insufficient developing infrastructure in the underdeveloped regions around the globe is a must.

2）Second Dimension: Processing

Processing means software engineering. Many functions are included here: identifying, coding, resolving, transmitting, storage, searching, security, and so on. IoT processing shall focus on 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, and so on.

The above models are against the existing IoT, while for the future IoT some adjustments shall be done. Next section gives the re-organized structure and its updated layer model for the future IoT.

III. EXTEND THE STRUCTURE AND TECHNOLOGIES FOR FUTURE IOT

Reference [4] has proposed U2IoT model for the future IoT. This model is composed of Unit IoT and Ubiquitous IoT. Unit IoT refers to the basic IoT unit with focus on providing solutions for special applications. Ubiquitous IoT refers to the global IoT, national IoT, industrial IoT, or local IoT, which is integration of multiple Unit IoT with "ubiquitous" characters. Unit IoT includes management and centralized data center (M&DC), distributed control nodes, and IoT network and sensors. And Ubiquitous IoT architecture model is social organization framework. nM&DC, iM&DC, and lM&DC are corresponding to national, industry, and local management data center. Global IoT can be built together with nM&DCs distributed in all nations.

A. *Re-organize the structure for U2IoT*

For better description of U2IoT model, this paper re-organizes the structure shown in Figure 3.

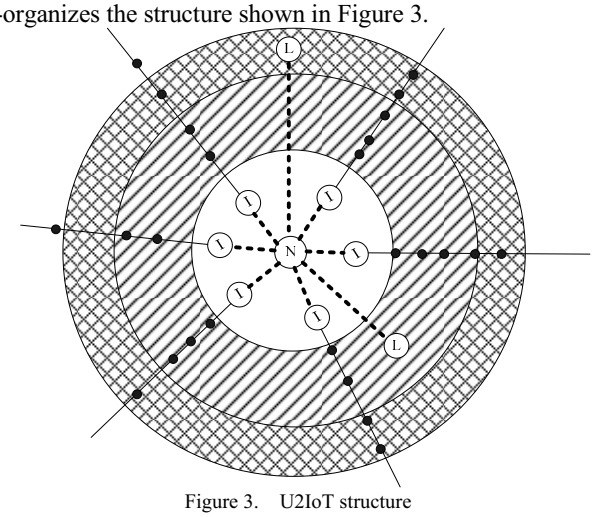

Figure 3. U2IoT structure

In Fig.3, the N, I, L represent nM&DC, iM&DC, and lM&DC respectively. The radial solid line denotes industry, on which small solid dots are Unit IoT. The girdle regions with different patterns indicate different regions, in which L is lM&DC of the regional IoT.

As the figure shows, N controls I and L. I manages the Unit IoT in the corresponding industry. And L manages the Unit IoT in its corresponding region. We can see from the figure, industry IoT and local IoT overlap and two regions involve different Unit IoT. In various regions, different unit IoT in each industry may be included. For some cases, even none of Unit IoT in certain industries exist in some regions.

B. *Re-construct the layers for Future IoT based on U2IoT model*

Based on the U2IoT structure, this part further re-constructs the layer model for future IoT. The three-layer model introduced in Fig.1 (b) is the architecture for unit IoT. It is composed of Application Layer, Network Layer, and Perception Layer. For ubiquitous IoT, its architecture is social organization framework, similar to family, group, industry, nation or other organizations consisting of individuals [4]. As the future IoT is composed of Ubiquitous IoT as well as Unit IoT, we add social layer for future IoT to manage these unit IoT. The reconstructed structure is shown in Fig.4.

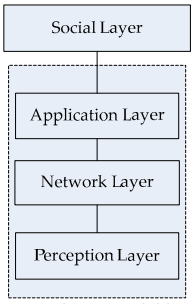

Figure 4. Future IoT layer Model based on U2IoT

To help understand the model easier, here we compare the Unit IoT to the human body in the society. Ubiquitous IoT is compared to the social organization consisting of individuals. As we know the relations of humans are built by organizations, they should obey some certain rules in specified organizations. The society needs social management for organizations to handle individuals. Similarly, in the future IoT, the model should incorporate Social Layer to manage the Unit IoT. This social layer is added over the three layers. It includes the ubiquitous IoT except Unit IoT and manages Unit IoT.

IV. IOT: A NEW INDUSTRIAL?

IoT involves too many kinds of industries. After analyzing these industries involved and introducing IoT development experience, this section studies whether IoT is suitable to be regarded as a new industrial or not.

A. *Technologies, applications and social effects*

In IoT layer model, perception layer involves sensors, identification, RFID, wireless transmission, time and space consistency, positioning system technologies, etc. Network layer includes all kinds of communication networks, including 4G, mobile communication network, and Internet etc. Application layer includes some middleware, information open platform, service supporting platform and all kinds of specific applications. The key technologies of these layers include coding, identification, resolving, information service, security and middleware technologies. From the technologies involved in the layers, we can see IoT related technologies are too wide.

In the aspect of application, IoT can be used for intelligent building, street light control, smart home, intelligent hospital, water quality monitoring, mine safety management, and ticket management, etc. In fact, almost all intelligent systems in the whole industries can be referred to be IoT applications. The broad of industries involved in IoT is obvious.

B. *The development phases*

According to the U2IoT model, this paper divides the phases to reach future IoT into Unit IoT phase and Ubiquitous IoT phase. Since Ubiquitous IoT should be built based on the Unit IoT, IoT will develop from Unit IoT phase to Ubiquitous IoT phase.

1) Unit IoT

As the IoT system is complicated, constructing the system costs too much and affects interests from many aspects. The step should be taken from special applications, and then expended to various kinds of applications till all objects are connected to reach Ubiquitous IoT. Only after constructing enough Unit IoT can Ubiquitous IoT be realized. Therefore, realizing Unit IoT is an important phase for future IoT development and the scale has to be extended gradually.

2) Ubiquitous IoT

The intrinsic characters of future IoT are internet of everything, internet of services and internet of networks. After completing the Unit IoT, a larger scale of system shall be adopted. Ubiquitous IoT integrates all of the built Unit

IoT that may be used in global IoT, national IoT, industrial IoT and local IoT. In this phase, the physical world and information world are unified and human is freed from the mental labor. Reaching this phase means realizing the future IoT truly.

C. *Experience in China*

In China, IoT is put on a significant position to develop and paid great attention. Development experience in China is introduced here. To seize the opportunity timely, almost all kinds of applications, IoT technologies are supported to develop in various regions. Recently Ministry of Industry and Information Technology releases the development guide of IoT related key common technologies, including highly reliable and secure computer system design, highly reliable real-time communications network, IoT sensing, cloud computing software, virtual security, Internet software and new sensors technologies, etc.

China government creates a favorable policy environment for IoT development. The twelfth five-year-plan outline for national economic and social development of China also points out ten fields of IoT application that needs key investment clearly, the related 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 [6]. In these fields, Unit IoT are supported largely to be built. Then Unit IoT in each industry will form industry IoT.

Against areas with different features, Unit IoT shall be constructed correspondingly. Then all the Unit IoT in this region will form local IoT. For example, In Guangdong Province, Some Unit IoT focus on the intelligentization of production operations, warehouse management, logistics tracking, and customs supervision in ports. In Guangxi Province, as the foundation of China-Association of South East Asian Nations Free Trade Zone, intelligent logistics can be developed with the unique regional advantages.

D. *IoT: a new industrial or not?*

In the future most industries may build their corresponding industry IoT. Cross-regional IoT are countless, national IoT may emerge and even global IoT may arise. All these Unit IoT and Ubiquitous IoT will cover all fields in our life [4]. Therefore:

For one thing, regarding IoT as an emerging industry seems to be 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 can neither take the development achievements of smart grid all to be the benefit of IoT. The similar examples are many. In the twelfth five-year-plan, China will focus on the development of IoT applications in the ten fields [6]. If achievements of the ten fields including smart home, fine agricultural and so on are pooled together to make up a new IoT industry, it is also inappropriate that even part of increment is regarded to be the benefit of IoT industry.

For another thing, “developing IoT will bring huge economic benefits in the near future” seems unreasonable. Presently, people get used to referring industries engaging in sensor network, RFID, logistics and intelligent monitor business to IoT industry, covering many IT industries, especially communication and Internet industry. If so many existing industry businesses related IoT are counted to IoT, many contents in IoT exist already, only 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 concept of IoT, these industries will also develop in the highly intelligent direction.

V. IOT: A NEW MAJOR?

Development of IoT cannot be separated from the personnel training. In the current situation, factors affecting IoT development are various, and one of the most important factors is the lack of talents. IoT talents become one kind of the scarcest talents now in China. It is urgent to train talents in IoT to participate in its development. In this section, science system is first introduced and IoT related subjects and specialties are shown. Lastly, problems of setting IoT major in China are analyzed and solutions are proposed.

A. *Science system*

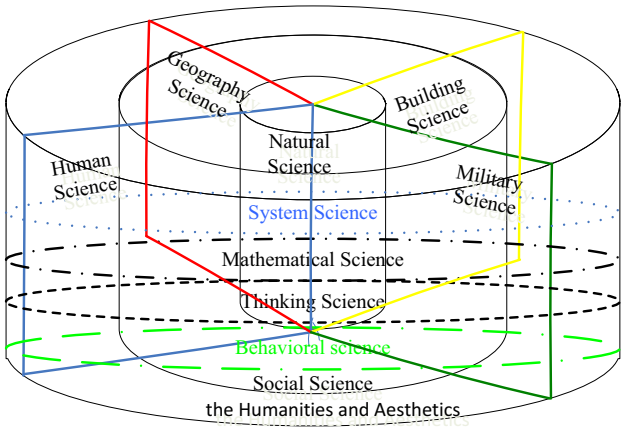

Figure 5. Science System Structure

In Fig. 5, we can see the structure of science system from Ma’s lecture [7] embraces three dimensions. One is composed of natural science, social science, and humanities and aesthetics. Obviously, the sensors of IoT depend on the things’ natural characteristics, so IoT relates to natural science for sure. To construct Ubiquitous IoT with social organization framework architecture, social science has to be considered as well. As the development of IoT involves almost all industries, the organization structure in the society will be changed. All of the three sciences are related to IoT.

Another dimension includes human science, geography science, building science and military science. We have known IoT is aimed to free human from mental labor and human characteristics are also needed to do identification in IoT. Human science is related to IoT closely. Geography science is also concerned as geography information is significant to be used for positioning in IoT. And one of the application areas of IoT is intelligent building, so building science is essential. From these aspects we can see all of the four sciences in this dimension are also related to IoT.

Last dimension comprises system, mathematical, thinking and behavioral sciences. IoT is a complicated system and needs system science to help construct. The most essential construction for one thing is mathematical modeling so that mathematical science is necessary. Thinking and behavioral sciences are related to IoT as they are needed for the intelligentization and automation.

From each dimension we can see IoT is related to all the sciences. Then next we will discuss the detail related subjects (First Level Discipline) and specialties (Second Level Discipline).

B. Subjects and specialties related to IoT

Modern knowledge architecture is divided into many subjects, and each subject is divided into many specialties. IoT penetrates into most of the subjects and specialties. This part gives the relation analysis of subjects and specialties with IoT.

Science is the base of the IoT, as IoT is the cyber and physical world fusion system, and the implementation and designation of IoT need to make full use of the physical discipline and mathematic modeling. Various kinds of sensors are used in IoT, including chemical sensors, biological sensors and so on. So physics, chemistry, biology and mathematic is related to IoT to a high degree. And other subjects of science are also related to IoT to a middle degree as they are involved in the applications of IoT.

Electronic Science and Technology, Information and Communication Engineering, Control science and engineering, Computer science constitute the modern IOT knowledge and theory. So these subjects are related to IoT to the highest degree. Mechanical engineering, Optical engineering, Instrument science and technology are related to IoT to a very high degree. Other subjects of engineering like transportation engineering, aero space science and technology, architecture, hydraulic engineering and others are related to IoT to comparatively high degree. With the potential to be widely used in agriculture, the coefficient of planting process controlling is also related to IoT to comparatively high degree, which is the same to medical subject.

Many subjects and specialties of modern science need some adjustment to fit the new paradigm, including social science. New laws should be made to regulate IoT and its users' action. The law and management are related to IoT to a middle degree. With the development of IoT, new economic models should be made based on the changed world's paradigm. The economics is also related to IoT at middle degree. Military science may be a big beneficiary of the IoT technology and is related to IoT to a comparatively high degree.

In other fields like art, history, they change little with the IoT developing, so they are the related to IoT to a low degree.

C. How to set IoT major in universities

From the above relations anlysis we can see IoT involves extremely wide technology fields and covers so many disciplines. Although core technologies of IoT are yet unclear, one point for sure is that plenty contents are the outcome of new development stage in traditional fields. For instance, the core network architecture for Ubiquitous IoT is the key issue that needs considerations in the Internet development.

Hence, it is not easy to set IoT major independently as other majors for undergraduate at the present stage, otherwise talents are hard to meet standards in basic capabilities and expertise. New modes shall be explored for undergraduate students. For students at the graduate level, taking the demand of more professional research talents into account, setting IoT major is appropriate, since graduate student can study one aspect of IoT deeply, instead of setting a wide range of common basic courses like undergraduate education. They can follow the research direction of supervisor. Here we propose two modes to train IoT talents at the undergraduate lever:

Publical optional course mode: This is to set publical optional courses related to IoT in schools. For the school and major setting in university, there is no change in this mode. Then all the students including students in other schools can choose the new optional courses according to their interests. And they can have graduation project related to IoT as well.

IoT school/major mode: This is to build a IoT major or IoT school. For students in the first studying phase, basic courses such as mathematic, computer, communications and some IoT couseds are given in the school. Then more specific courses are given gradually by different professional instructors from corresponding schools. The IoT school may combine the resources from other schools or cooperate with industries. In China, universities can explore the training mode by combining the "Excellence Engineering Program" [8] which is piloting in universities with wide caliber engineers training mode.

D. Problems of setting IoT major in China and how to resolve them?

Since China government has decided to vigorously develop IoT, Chinese Minister of Education (MOE) also wants to contribute to the IoT development as education authority, for which most directly method is to set IoT major in universities to train professional talents. Accordingly, in 2010, MOE has announced a list of new launching 140 undergraduate majors [9]. The first 42 universities in the list are key universities and 31 of them have been authorized to set IoT major. Moreover, more colleges managed by local governments and numerous vocational schools will also set IoT courses and major, as other colleges can set major themselves except that major set of class I and class II

colleges in front rank needs approval from MOE. Therefore, the problem is: on one hand, the number of enrolled students majoring IoT is growing rapidly in the following years. On the other hand, there is a lack of systematic curriculum, training materials and teachers for the IoT major now. The contradiction will soon become noticeable. So we have to find appropriate way to solve problems. For different universities with their own characteristics, they can choose the mode of setting IoT major and explore the most proper way for themselves.

We should recognize that there seems no unified IoT syllabus for universities at present. For some common IoT concepts and technologies common materials can be adopted. And IoT in different fields need its corresponding courses For example, in North China Electric Power University, students can have their courses related to the smart grid while common IoT concepts and technologies can be obtained from common materials. As the university is mainly committed to the research of electric power and has abundant resources on this aspect, students in the university can focus on the smart grid study. Another case is Beijing Jiaotong University, for which intelligent transportation field is the best choice to set IoT major in. For the comprehensive universities, 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.

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. At the present stage, the content that can appropriately reflect the IoT features may lie in the aspect of "More comprehensive sensing and higher intelligence". Meanwhile, as the core of IoT is achieving the unity of physical world and information world[4], many cross-cutting areas and the corresponding training will be generated in the future, and the curriculum system will be comparative complicated, which may be most likely to appear in the future vocational skills training. IoT major setting needs the cooperation with other specialties or industries. It shall be circumspect.

VI. CONCLUSION

In summary, this paper tries to classify the complicated IoT technologies and builds a 3D technology model for the existing IoT. For the future IoT, its structure and layer model are also shown. After further analyzing related issues, we conclude that IoT is not a specific industrial as it develops based on the traditional industries in so wide range, and it relates too many disciplines to be a new major independently.

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