Future Internet of Things Architecture: Like Mankind Neural System or Social Organization Framework?

Huansheng Ning and Ziou Wang

***Abstract*—Internet of things (IoT) is fascinating; its future architecture is still under construction. Based on the analysis on the basic and essential characters of IoT, this paper deals with Future IoT architecture in two aspects: Unit IoT and Ubiquitous IoT. Focusing on a special application, the architecture of the Unit IoT is built from man like neural network (MLN) model and its modified model. Ubiquitous IoT refers to the global IoT or the integration of multiple Unit IoTs with "ubiquitous" characters, and its architecture employs social organization framework (SOF) model. The models for Future IoT are not only helpful to interpret the relationship between IoT and reality world, but also beneficial to the implementation of IoT in its current development milieu.**

***Index Terms*—Networks, architecture, Internet, Internet of things.**

I. Introduction

INTERNET of things (IoT) was first proposed in 1999 by Auto-ID Center and has become a spotlight after U.S. President made a positive statement to encourage the development of IoT, praising it as a future strategic newly-emerged industry.

IoT involves many technologies including architecture, sensor/identification, coding, transmission, data processing, network, discovery, etc. IoT development depends not only on the progress and standardization of technologies, but also on the improvement of our social perception, knowledge, rules and laws. For example, in the future IoT era, the way we live like components or nodes of the network and the exposition of our activities to the public may bring forth many serious security and privacy problems. The standard, reliability, and robustness are also key concerns for IoT development.

Architecture is the cornerstone for all technologies. Therefore, architecture is not only a key issue but also a foundation for future IoT development. Without a definite architecture, many important contents cannot be determined. Henceforth, this paper will focus on establishing basic models for Future IoT architecture.

As a representative of the earlier scheme for IoT, the EPC (Electronic Product Code) [1] system is a vision world that all physical objects can be connected by RFID transponder through a global unique EPC code carried by the RFID tag. And Japan also proposed its earlier IoT prototype, UID solution. With the changes of application requirements and the development of technologies, the concept for IoT is extended [2]–[4] rapidly. Different IoT definitions have been proposed depending on different perspectives and application scenarios, e.g. CASAGRAS [5], CERP-IoT [6], [7], Smart Planet [8]. Some researchers come up with solutions based on RIFD technology or EPC mechanism, e.g. Thiesse [9]; Broll et al gives the Pervasive Service Interaction with things [10], and Vazquez et al shows an integration solution between mobile services and smart objects [11]; Most researches are focusing on specific application or special function [12], such as security [13], network management [14] and others. The Future Internet Assembly (FIA) has been founded by the European Commission to support fundamental and systematic innovation in Europe for realization of the Future Internet [15].

In summary, the architecture for future IoT is not determined. However, rapid development of IoT around the globe has triggered a wave of unreasonable expectation. For example, some governments and their industries have launched massive projects despite that the key technologies including the basic architecture of IoT are still waiting to be determined. If the determination is still on its way, it will be disadvantageous to IoT development and cause great loss. Therefore, it is very urgent to study and determine the future IoT architecture.

Though different from the current Internet, the future IoT architecture shall be compatible with its succession and development. When it comes to smaller scale of application, the IoT architecture and the work processing model shall be relatively centralized. When it comes to a larger scale of system, for example, multiple applications or ubiquitous system, the distributed model shall be adopted. On one hand, technically speaking, it is observed that centralized management exists in distributed system architecture just as distributed management exists in centralized system architecture. On the other hand, different from Internet in its development course and the management model, Future IoT architecture must deliberate factors of nations, regions and even industries since it has become an international concern for many nations to lead in this field and have priority to allocate and manipulate the resources. Unlike the uniformly global Internet, future IoT architecture shall be a kind of flexible, compromising and ubiquitous model, under which every nation or its industry is allowed an easy access to choose suitable partial IoT architecture or exclusive IoT architecture and to communicate with other IoTs.

This paper focuses on the basic and essential requirements of Future IoT based on its intrinsic characters in the 2nd section. Then models for IoT architecture are proposed in the 3rd and 4th section. Some important issues about IoT architecture are also discussed in the last section. The target is trying to describe a new complex future issue with some existing models or knowledge.

Manuscript received January 19, 2011. The associate editor coordinating the review of this letter and approving it for publication was G. Lazarou.

H. Ning is with the School of Electronic and Information Engineering, Beihang University, Beijing, 100191, China (e-mail: ninghuansheng@buaa.edu.cn).

Z. Wang is with the School of Electronics and Information Engineering, Soochow University, Suzhou, 215006, China (e-mail: wziou@suda.edu.cn).

Digital Object Identifier 10.1109/LCOMM.2011.022411.110120

II. IoT Intrinsic Characters and Basic Requirements for its Architecture

Nowadays, internet and the real world are relatively separated and the communication between them mostly depends on the human-computer interface. In addition, some intelligent applications have realized automatic monitor or control the environment and objects in a special range in the real world. We can name these intelligent applications as the early stage IoT applications.

The intrinsic characters of Future IoT are internet of everything, internet of services and internet of networks. It can identify, trace and control trillions of objects over networks. Future IoT is highly unified with networks, services and the reality world. Everything is connected or sensed by ubiquitous sensors. Then the requirement for Future IoT architecture shall be ubiquitous. Meanwhile, the architecture shall help existing intelligent applications immigrate to IoT and meet the requirements for the insufficient developing infrastructure in the underdeveloped regions around the globe.

Based on the analysis above, a good example can be found in human body and the social organization consisting of individuals. In a human body, the nervous system is a kind of complicated intelligent system which can see, taste, feel and control things, or even make decisions. Though different individuals' nervous systems have common physical components and operating law, individual body possesses its own sophisticated and unique consciousness and behaviors. Individuals constitute family, group, industry, nation or other organizations according to some certain rules in a harmonious manner. Each nation has sovereignty and different operating system but it can cooperate, compete and communicate with others.

Now we have ideas concerning the architecture for the future IoT which will be introduced with two aspects: Unit IoT and Ubiquitous IoT. Unit IoT refers to the basic IoT unit with focus on providing solutions for special applications, and its architecture is a man-like nervous (MLN) model. Meanwhile, the vision for future internet in our mind, especially the global IoT, is ubiquitous as "everything connected, intelligently controlled, and anywhere covered". We name it Ubiquitous IoT, which refers to the global IoT, national IoT, industrial IoT or local IoT which is integration of multiple Unit IoTs with "ubiquitous" characters. The Ubiquitous IoT architecture resembles the social organization framework (SOF) model.

III. Unit IoT Architecture: Man Like Nervous System

Some people have the vision that the next generation internet works like mankind nervous system which can see, smell, listen, act, and so on. This is the typical ideal vision for Unit IoT. Unit IoT is the component of Ubiquitous IoT. Therefore, this paper emphasizes more on the Unit IoT than on the Ubiquitous IoT in the discussion of the MLN model.

The architecture of Unit IoT can be classified into two types as shown in Fig.1. One type works like man's nervous system with a centralized data center (Fig.1A). It has three main parts: brain (management and centralized data center: M&DC), spinal cord (distributed control nodes), and a network of nerves (IoT network and sensors). In general, the IoT network transmits the message from sensors to the corresponding control nodes and M&DC, which receives, translates, and sends back message to sensors to control the "things" or to fix the problem it initially has. M&DC is a centralized data center for processing and storing data and managing the whole network. Although the working flow is similar to mankind nervous system, there still remains an important difference that the distributed control nodes are more capable to control or respond to external or internal stimulations in some cases.

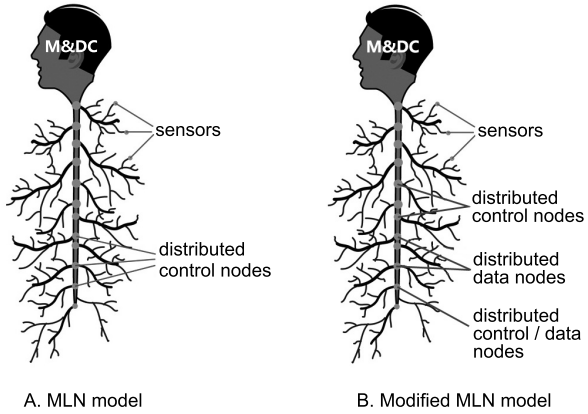

Fig. 1. Two models for Unit IoT architecture.

The other type of Unit IoT is a modified MLN model. Its distributed data center lies not only in the M&DC but also in some distributed cord nodes. In this model, whether a distributed control node works as a distributed data node or not is determined by the requirements (Fig.1B).

One important issue is how the existing intelligent system prototypes can be integrated or immigrated to the future IoT. In general, these intelligent systems can keep their own business structures by adding proper M&DCs as Unit IoTs to access the future IoT. In some occasions, revising or reorganizing is required. This point is like how a relatively separated tribe goes out of its dwelling and gets along with modern society.

IV. Ubiquitous IoT Architecture: Social Organization Framework

Ubiquitous IoT, as defined, not only refers to the global IoT, but also includes national IoT, industrial IoT or local IoT which are integration of multiple Unit IoTs.

As required, we define other three management and data centers: national management and data center (nM&DC) for national IoT, industry management and data center (iM&DC) for industry IoT, and Local management and data center (lM&DC) for regional IoT. They are heads of the national, industrial and local ubiquitous IoT respectively in terms of policy, monitoring, security, and backup of important data. Their relationship is shown in Fig.2.

iM&DC is authorized by a special industrial authority. It manages the corresponding nation-wide Unit IoTs in this industry, such as agriculture, electric power, bank, medical etc. lM&DC manages local Unit IoTs. nM&DC is the national IoT

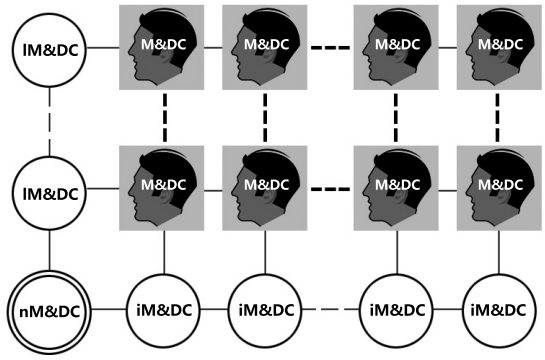

Fig. 2. SOF model: working and management architecture for ubiquitous IoT.

header and controls the connectivity of IoTs and interoperability with international IoT. Together with nM&DCs distributed in other nations, distributed management nodes for global IoT are built. By now the SOF for Ubiquitous IoT architecture has been built.

V. Discussion for IoT Architecture

Based on Future IoT requirements, Unit IoT and Ubiquitous IoT definitions are introduced above. The MLN and SOF models are built respectively to describe the architectures. Similar to the relation between the organization of human society and human individual, future IoTs characterize in highly combination and compatibility. In these models, the most significant issues are the interconnection & intra-connection, and the compatibility:

1) Interconnection & intra-connection. Some global industry IoTs will unite first to build standards, e.g. global logistics. Different IoTs will communicate with or manage each other according to specific rules based on different applications, but some IoTs will be forever limited interconnected considering national advantages, religions, field sensitive, etc.
2) Compatibility. As the basic component of Ubiquitous IoT, the Unit IoT may be completely different in structure, function, and rules, which will requires more for compatibility than uniformity. Some existing intelligent systems can be fused into Ubiquitous IoT as specific Unit IoTs.

Another key issue is the standard for IoT architecture. Like the existing mankind and the social organization, some influential global, industrial, or regional standards can be built based on the interconnection & intra-connection and compatibility requirements.

Acknowledgment

This work is jointly funded by National Natural Science Foundation of China (NSFC) and Civil Aviation Administration of China (CAAC) (61079019), and supported by the National High-Tech Research and Development Program of China (2008AA04A101).

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