Future Internet: The Internet of Things

Lu Tan
Computer Science and Technology Department
East China Normal University
Shanghai, China
Email: jackytan217@gmail.com

Neng Wang
Computer Science and Technology Department
East China Normal University
Shanghai, China
Email: nwang@cs.ecnu.edu.cn

Abstract. **Nowadays, the main communication form on the Internet is human-human. But it is foreseeable that in a near soon that any object will have a unique way of identification and can be addressed so that every object can be connected. The Internet will become to the Internet of Things. The communicate forms will expand from human-human to human-human, human-thing and thing-thing (also called M2M).This will bring a new ubiquitous computing and communication era and change people's life extremely. Radio Frequency Identification techniques (RFID) and related identification technologies will be the cornerstones of the upcoming Internet of Things (IOT).This paper aims to show a skeleton of the Internet of Things and we try to address some essential issues of the Internet of Things like its architecture and the interoperability, etc. At the beginning we describe an overview of the Internet of Things. Then we give our architecture design proposal of the Internet of Things and then we design a specific the Internet of Things application model which can apply to automatic facilities management in the smart campus. At last, we discuss some open questions about the Internet of Things.**

Keywords-Internet of Things; M2M; RFID; ubiqutious computing; smart campus; automatic facilities management.

I. INTRODUCTION

To date, the vast majority of Internet connections worldwide are devices used directly by humans, such as computers and mobile handsets. The main communication form is human-human. In a not distant future, every object can be connected. Things can exchange information by themselves and the number of "things" connected to the internet will be much larger than the number of "people" and humans may become the minority of generators and receivers of traffic [1]. We mix the physical world and information world together. The future is not going to be people talking to people; it's not going to be people accessing information. It's going to be about using machines to talk to other machines on behalf of people. We are entering a new era of ubiquity, we are entering the Internet of Things era in which new forms of communication between human and things, and between things themselves will be realized. A new dimension has been added to the world of information and communication technologies: from anytime, any place connectivity for anyone, we will have connectivity for anything [2]. Fig.1 shows this new dimension.

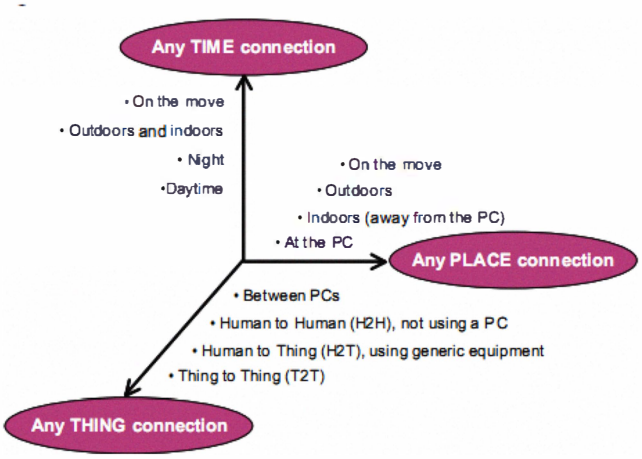

Figure 1. A new dimension

There is no standard identification of "Internet of Things". Considering the functionality and identity as central it is reasonable to define the IoT as "Things have identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environment, and user contexts". A different definition that puts the focus on the seamless integration could be formulated as "Interconnected objects having an active role in what might be called Future Internet" [3].

A. *Main Technologies for the Internet of Things*

The Internet of Things is a technological revolution that represents the future of computing and communications, and its development needs the support from some innovational technologies.

Radio frequency identification (RFID) is seen as one of the pivotal enablers of the Internet of Things. Objects should be indentified so that they could be connected. RFID, which use radio waves to identify items, can provide this function [4]. Sometimes RFID has been labeled as a replacement of bar code, but RFID system can do much more than that. In addition to identify items it also can track items in real-time to get important information about their location and status. RFID has already had some valuable applications in retail, health-care, facilities management [5], etc. A mature RFID

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technology provides a strong support for the Internet of Things.

One of the biggest breakthroughs of the Internet of Things is making the physical world and information world together. Sensors play a very important role to bridge the gap between the physical world and information world. Sensors collect data from their environment, generating information raising awareness about context. So the changes of their environment can be monitored and the corresponding things can make some responses if needed [6].

Nanotechnology and miniaturization can make embedded intelligence in things themselves which called smart devices. They can process information, self-configure, make decision independently, just until then there will be a real thing-thing communication.

B. Trends

From a long perspective, the development trend of the Internet of Things includes three steps: embedded intelligence, connectivity, interaction.

Firstly, we have embedded intelligences which can do actions automatically. There already have been many applications, for example: the RFID tag embedded in food can record the information about the food and we can get the information by using a RFID reader; the washing machine controller can make washing machine complete its work automatically; engine controllers and antilock brake controllers for automobiles; inertial guidance system, flight control hardware/software and other integrated systems in aircraft and missiles; artificial arms with semi-functional hands, etc[7]. Though all of those devices are intelligent, we can see that they only work alone and locally, there's nothing to do with "network".

So the next step is making every smart device can be connected. From the smart connected devices viewpoint, smart devices are not smart because they are just endowed with agent capabilities and all the actions are pre-designed by human, they are smart because they are connected. Things can be connected wired or wirelessly. In the Internet of Things wireless connection will to be the main way. Base on the existed infrastructure, there are many ways to connect a thing: RFID, ZigBee, WPAN, WSN, DSL, UMTS, GPRS, WiFi, WiMax, LAN, WAN, 3G, etc. Connect smart things makes interaction possible.

Even though we can connect anything does not mean things can communicate by themselves. So new smart things should be created which can process information, self-configure, self-maintain, self-repair, make independent decision, eventually even play an active role in their own disposal. Things can interact, they exchange information by themselves. So the form of communication will change from human-human to human-thing to thing-thing. As the Internet of Things is application driven, new business applications should be created which can improve the innovation and development of the Internet of Things [8].

Fig.2 shows a rough development trend of the Internet of Things [9].

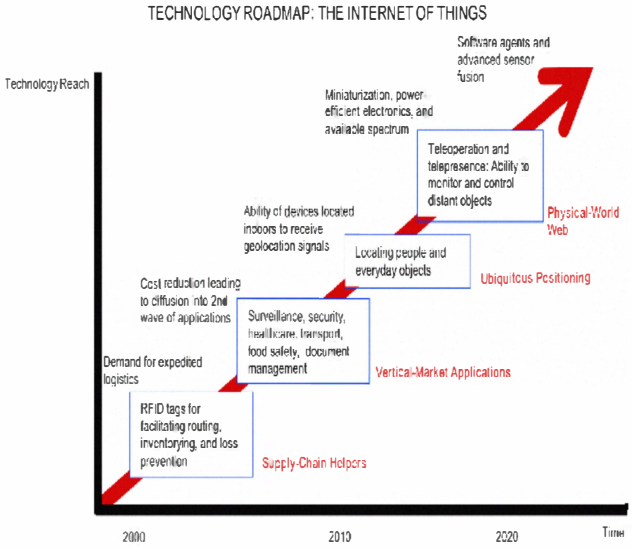

Figure 2. Trend of the Internet of Things

II. ARCHITECTURE

Current Internet has a five-layered architecture, running with TCP/IP protocols, which has worked well for a long time. However, in the Internet of Things billions of objects are connected which will create much larger traffic and need much more data storages. In addition to these, there still have some other challenges like security, governance, etc. But today's Internet was designed in the 1970s for purposes that bear little resemblance to today's usage scenarios and related traffic patterns. Mismatches between original design and current utilization are now beginning to hamper the Internet's potential. In the BLED Declaration [10] and other supporting statements, they all point out this point. So it is reasonable and essential to design a new architecture for the Internet of Things.

Redesign a new architecture is a very complex project, which needs consider many factors like reliability, scalability, modularity, interoperability, interface, QoS, etc. About the architecture design of the Internet of Things, service-oriented architecture (SOA), exploiting integration with Internet and interfacing with wide ranging edge technologies and associated networks is a key objective. For this objective, we should consider embracing a fully inclusive range of "edge" technologies, including RFID for interfacing with the physical world; exploiting evolving object-connected data capture technologies and networking capabilities—sensory, location, local communication and security; integration with the evolving Internet and some other technique issues. In addition to these, we should also view the needs for governance, QoS, security, privacy and other socio-economic issues.

Anthony Furness gives us a proposal about the Internet of Things' architecture [11]. Fig.3, Fig.4 are from this proposal and they show us the Internet of Things with different level of edge technologies.

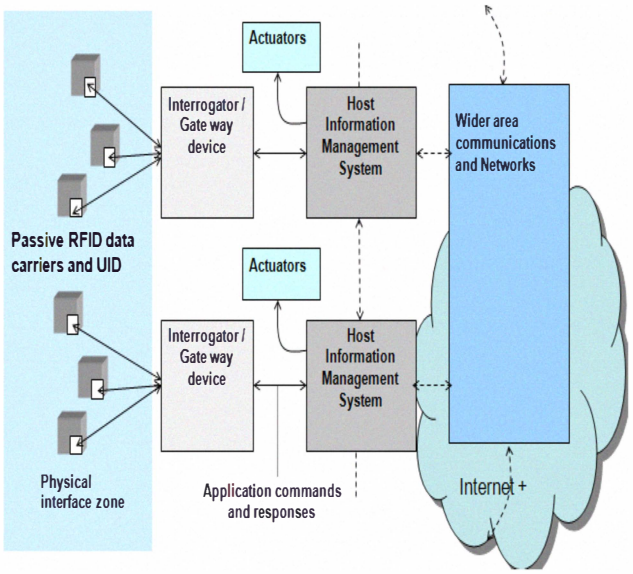

Figure 3. Internet of Things—at its most basic level

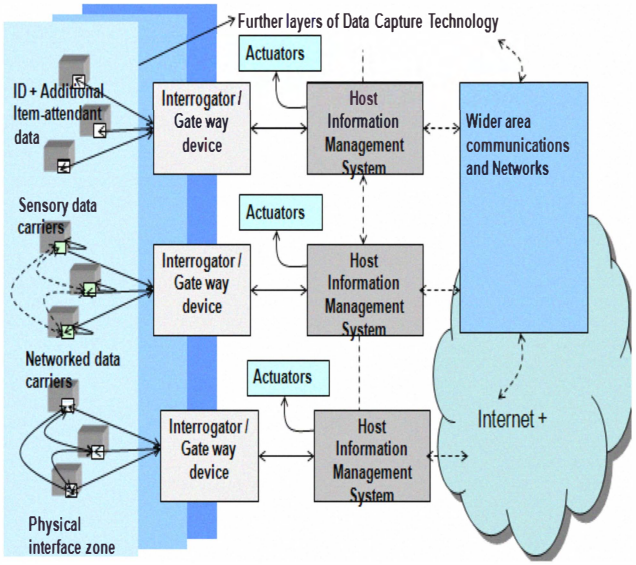

Figure 4. Internet of Things—including RFID and other edge technologies

Then he gives the architecture of the Internet of Things he has designed. Fig.5

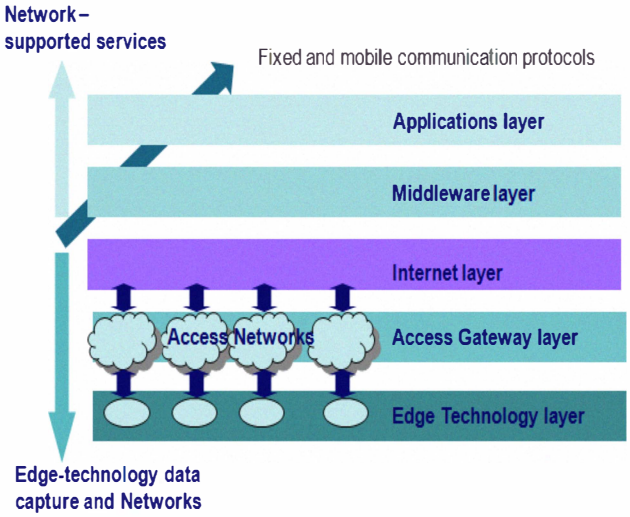

Figure 5. Architecture of the Internet of Things

This is a good proposal which has given us a rough solution of the Internet of Things' architecture. But there still are some further important issues we should think about carefully. The first is if every object is connected and things can exchange information by themselves, then the traffic and storages in the network will increase very rapidly with an exponential way. Does today's Internet really can bear this? Do we need a new backbone? Connecting every object and make them can communicate independently is a very attractive vision, and yes we can imagine many cases in future that a thing needs to "talk" to another thing, but is it real necessary that an object "talks" to all the other objects? Why a toothbrush needs to "talk" to a fridge? In fact, the main connections of an object are with those objects which are in the same the Internet of Things application system as it. And it is could be seen that the Internet of Things is made up of many the Internet of Things application systems. From this point of view, we can have a new seeing of the Internet of Things. Fig.6 shows us this new viewpoint.

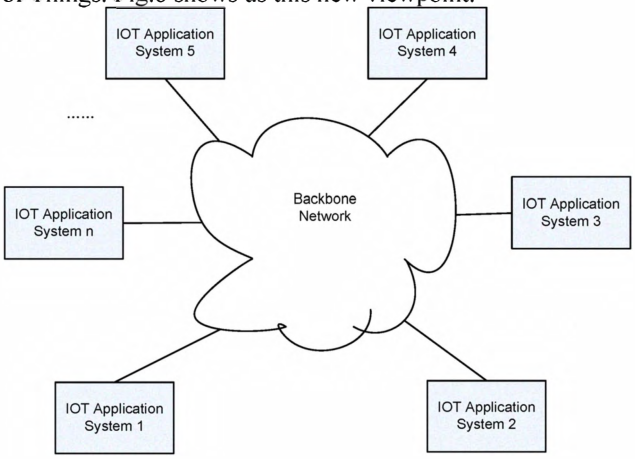

Figure 6. Internet of Things

The Backbone Network may be today's Internet, may be not or may be its expansion.

Now the Internet of Things' application situation is there already have been many applications like EPC Global, smart hospital and so on which seem work well. But the problem is these application systems work alone, and even though I mentioned before that today an object mainly communicate with another object who is in the same application system, but there's no doubt that the technical future is connecting every application system and with the growth of the Internet of Things the communication between different application systems will become more and more frequently for their collaboration. But as the lack of global standards, they may have used different standards and technologies, so the interoperability is a problem. Only if we can solve the interoperability problem we can have a real the Internet of Things. The authors come up with a solution that adding a Coordination Layer into the Internet of Things' architecture design. The coordination layer responses to process the structure of packages from different application systems and reassemble them to an unified structure which can be identified and processed by every application system. Of course if the standards of the Internet of Things are completed then the systems which based on the standards will have no problem in interoperability, this problem exists between the existed application systems and the new deployed systems, and between the existed application systems themselves. Based on all above, we give our architecture design proposal of the Internet of Things.Fig.7 shows our design.

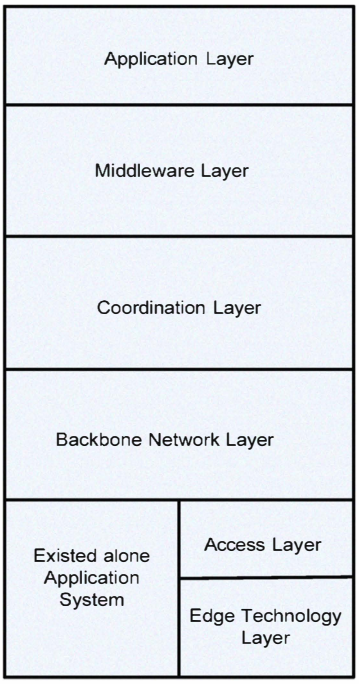

Figure 7. The Internet of Things' Architecture

III. A THE INTERNET OF THINGS APPLICATION IN COLLEGE

The Internet of Things is not a theory, it's an application technology which our life can benefit from. In fact, in a long term the value of the internet of things exists in some specific application. Specific application solutions will be one of the most important engines of the innovation and development of the Internet of Things. It's application driven.

Currently, there already have some successful applications in different fields like retail, food, logistics, transportation, etc. So far, we have mentioned so many stuffs about the Internet of Things, but what a real the Internet of Things application system like? Here the authors design an application model for the college campus facilities management using the Internet of Things technology and take it as an example to show what a real the Internet of Things like and how it can benefit our life.

In the college campus, there are many buildings, e.g. teaching buildings, office buildings, library, dinning halls, etc. Almost every building has its own heating, ventilating, air condition systems (HVAC) and elevator system, those devices should be managed and maintained but it's not easy to make this job well done. Now we can use the Internet of Things technology in campus facilities management. Fig.8 is the architecture of this pilot project we have designed for this kind of facilities management.

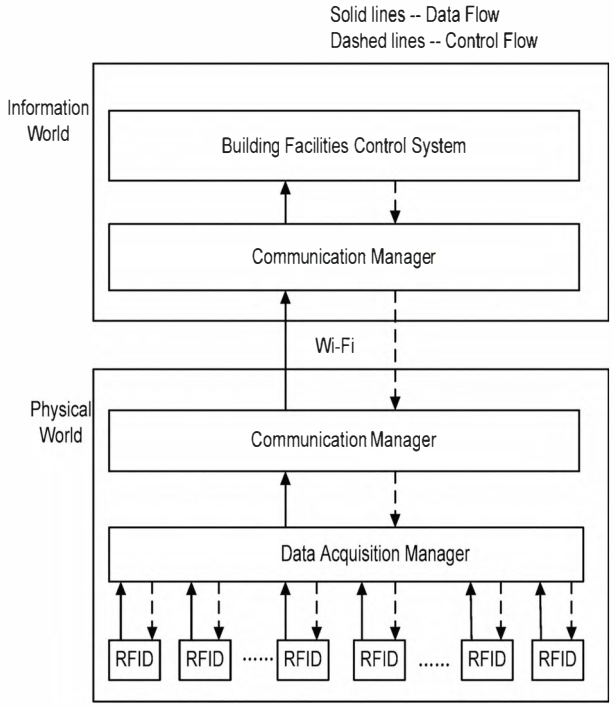

Figure 8. Architecture for Facilities Management

We deploy enough number of RFID tags in the building which can monitor the HVAC and elevators' behavior, collect information, sense the change of their environment

and also could be located. As the entire college is covered by WiFi signal, each building's data acquisition manager can transmit the data it has acquired to the building facilities control system via WiFi. Communication manager has a function of interfacing the physical world and information world, so it exists in both physical and information worlds. Then the building control system processes these data and makes decisions based on the process result, e.g. sending configure information back to the RFID tags or turning off some air conditions. We can see that all actions can be done automatically without human intervention. And we can use energy more efficiently by this method. In addition, by analyzing the data we can know the maintenance situation of facilities and if there is potential problems we could do some particular actions in advance to avoid damage happening.

IV. DISCUSSION

The Internet of Things is ongoing, but there are many issues need to be addressed. In this part we discuss two crucial issues: standardization, security and privacy.

There's no doubt that for any kind of communication technology an open standard is one of the most important enablers to make it successful, including the Internet of Things. Without clear and recognized standards such as the TCP/IP in the Internet world, the expansion of the Internet of Things cannot reach a global scale. In another words, there will no real the Internet of Things without a global standard. But the fact is technological standardization of the Internet of Things in most areas is still in its infancy, or remain fragmented. So efforts are needed, collaboration among ISO, ETSI, IETF, ITU and other related organizations is very important and urgent.

Security and privacy is always one of the most concerned issues by the public. There is a need to have a technically sound solution to guarantee security and privacy of the customers in order to have a widespread adoption of the Internet of Things. Looking back to the history, since at the very beginning of the Internet there's no need for security and privacy so there's no design for the security and privacy. As the growth of the Internet many security and privacy problems came out, then we could do nothing but build patches, it seems that the security and privacy is an add-on feature. But it is feeling that the public acceptance for the Internet of Things will happen only when the strong security and privacy solutions are in place. So we should take security and privacy a very important role from the beginning design and build an integrated approach to security and privacy in the Internet of Things. In addition, looking at security and privacy only from the technical perspective is not enough. Besides technology, the regulation, marketing and socio-ethic are also should be considered. Fig.9 shows the facets which need to be considered about the security and privacy issue.

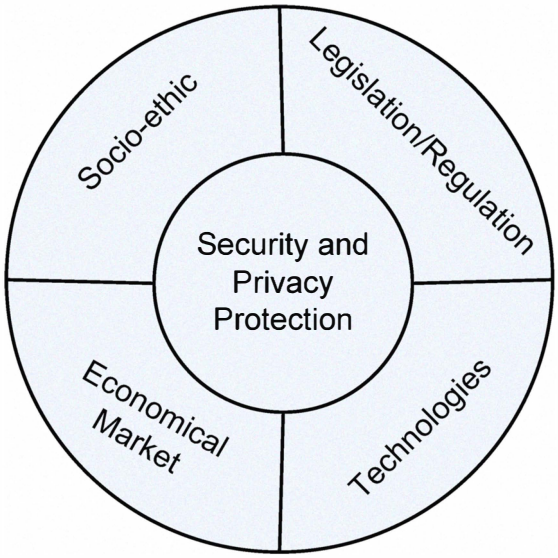

Figure 9. The facets of Security and Privacy

V. CONCLUSIONS

The Internet of Things is coming which brings us into a new era in which everything from tires to toothbrushes can be identified and connected and things can exchange information and make decisions by themselves. The communication forms will be human-human, human-thing, thing-thing. Things will be the main traffic makers. People's life can benefit from the Internet of Things. The future is bright but the way is hard. There still are many technical issues need to be addressed and a long way to go to make a real global the Internet of Things.

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