INTERNET OF THINGS FOR SMART OBJECTS – UBIQUITOUS NETWORKING BETWEEN HUMANS AND OBJECTS

Gyu Myoung Lee, Noel Crespi

Institut Telecom, Telecom SudParis
9 rue Charles Fourier, Evry-Cedex, France
{gm.lee, noel.crespi}@it-sudparis.eu

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Abstract

As many new types of devices will be connected to networks, it is very important to provide ubiquitous networking capabilities for "connecting to anything" between humans and objects. In this paper, we introduce ubiquitous networking capabilities for the Internet of Things (IoT) and present our vision related to this topic with the basic concept. In addition, we clearly identify key technologies to be used for the IoT. For various services using ubiquitous networking of IoT, we propose object identification and identity processing for "connecting to anything" to smart objects. This mechanism will be essential for realization of IoT.

1 Introduction

The "ubiquitous" refers to the method of enhancing computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user. Through this computing, it is predicted that computing devices with intuitive, intelligent interfaces will become embedded in all of devices and communications networks which will connect these devices together which will extend to become available anywhere and anytime [1].
In this context, the ubiquitous networking is used for naming the networking capabilities which are needed to provide the support of various classes of applications/services which require "Any Services, Any Time, Any Where and Any Objects" type of operation [2].
Ubiquitous networking supports three types of communications:

- Human-to-Human Communication: humans communicate with each other using attached devices (e.g. mobile phone, PC);
- Human-to-Object Communication: humans communicate with a device in order to get specific information (e.g. IPTV content, file transfer);
- Object-to-Object Communication: an object delivers information (e.g. sensor related information) to another object with or without involvement of humans.

Ubiquitous networking for Internet of Things (IoT) [3] aims to provide seamless communications between humans, between objects as well as between humans and objects while they move from one location to another. With the help of ubiquitous networking, an object can aware of its characteristics, context, and situation. The smart object shares and processes information, such as its identity, current location, physical properties and the information it senses from its surroundings while using the Internet as communication infrastructure.
Ubiquitous networking requires key capabilities for the support of IoT as follows: connecting to anything, open web-based service environment, context-awareness, seamlessness, multi-networking, end-to-end connectivity, etc [4]. These capabilities are built upon capabilities of current Internet with necessary extensions and/or modifications of capabilities required for the support of ubiquitous networking services and communications.
In this paper, we describe the visions of ubiquitous networking for IoT. Based on perceived future features of networking, we explain the importance of interdisciplinary fusion technologies in terms of services expanding other industries beyond the information technology (IT) industry. In addition, we identify key technologies in the ubiquitous networking environment. For various services using ubiquitous networking, we propose object identification and identity processing for "connecting to anything" to smart objects.
The remainder of the paper is organized as follows. In Section 2, we explain the visions of ubiquitous networking for IoT. Then, in Section 3, we propose a technical solution for providing connectivity to smart objects and illustrate several services using ubiquitous networking. Finally in Section 4, we summarize and discuss future work.

2 The Visions of Ubiquitous Networking for the Internet of Things

This section provides further information regarding the potential directions for network evolution and a vision of ubiquitous networking services, applications and capabilities.
One of the ultimate objectives of ubiquitous networking is to meet the challenge of seamless communications of "anything" (e.g. humans and objects).

As a result, ubiquitous networking will also enable innovative services involving the use of technologies such as bio-technologies (BT), nano-technologies (NT) and content technologies (CT), thus allowing the provision of services that go beyond traditional telecommunication and IT services. These innovative services will require extensions in terms of networking capabilities as well as the availability of any types of objects.
The concept of "5C+5Any" illustrated in Figure 1 represents key features of ubiquitous networking for IoT.

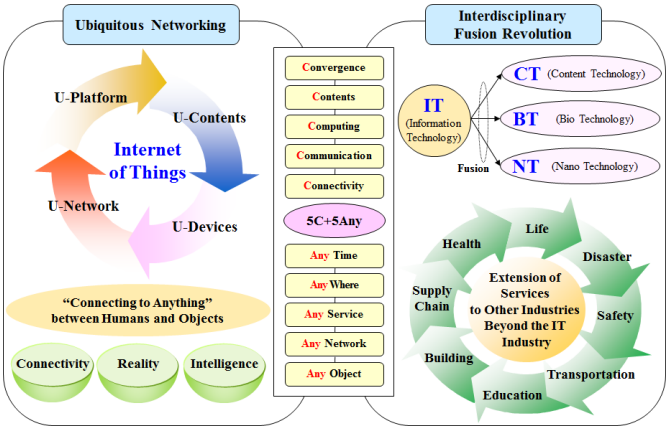

Figure 1. The visions of ubiquitous networking for IoT

New businesses using ubiquitous networking require multiple technologies to operate together such as radio frequency identification (RFID)/sensors, protocols, security, and data processing. In order to communicate with related technical parties accommodated in new business relationships, one of the most urgent needs consists in the integration and combination of technologies such as BT, NT or CT. In particular attention needs to be paid to "interdisciplinary fusion" technologies which combine BT, NT, CT as well as IT using ubiquitous networking capabilities. Thus, integrated engineering for new "Interdisciplinary Fusion Revolution" will emerge allowing for extension of services to other industries beyond the IT industry and constituting the vision of ubiquitous networking.
Communication networks have been mainly supporting the evolution of information processing and service capabilities within IT industries. However, the capabilities of networks benefiting from ubiquitous networking should impact other industries such as medical industry, education industry, finance industry or transportation/distribution industry resulting in new requirements for medical or education networks and services taking into consideration of IT technologies. There are several examples of interdisciplinary fusion services using ubiquitous networking: remote medical services, intelligent transport systems (ITS), supply chain management (SCM), U-Building or U-City. Providing "fusion services" in future Internet will require that the following capabilities be supported: location tracking, sensing, surveillance and management capabilities.
Businesses using ubiquitous networking will impact on many other industries. Thus, technologies related to architectural functions and enhanced capabilities for the support interdisciplinary fusion services using ubiquitous networking capabilities need to be developed once the basic concept and principles will be ready. Case studies for each service area are also required for helping future developments of future Internet technologies.

3 Providing Connectivity and Services for Smart Objects

In order to realize object to object communications, so-called IoT using ubiquitous networking, it is very essential to provide connectivity to smart objects. For this, there are specific technical considerations for connecting to anything in the following points:
- Identification of fixed/mobile object(s);
- Finding/tracking the location of object(s);
- Provide seamless connectivity to the network in cooperation with naming and addressing.

All of devices (i.e., objects) should be reachable to the other users/devices. Since managing a large number of different identification codes to use IP network infrastructure will become vital, it is very important to use both location information of IP address and uniqueness information of identification codes [5,6].
As shown in Figure 2, the types of objects in end-user side include the following: personal devices, information devices, RFID/sensors, contents, appliances, vehicles, etc. We can provide the global connectivity with future Internet to objects through gateway and/or ad-hoc networks in heterogeneous networking environments with different protocols and physical access mediums.

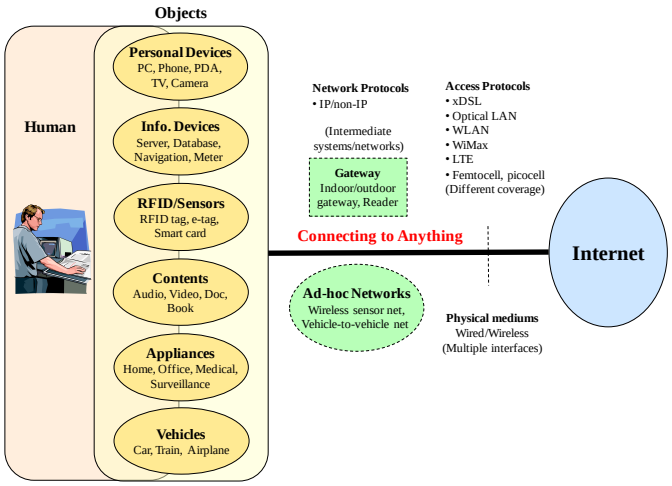

Figure 2. Basic concept for "connecting to anything" of IoT

Identification of smart objects for providing end-to-end connectivity in ubiquitous networking environment is crucial. Identifier(s) in ubiquitous networking is capable enough of identifying all relevant objects and facilitating object-to-object communications. In particular, the globally unique identifier(s) will enable a great many applications including tracking, access control, and protection of objects, etc [7].
There are other kinds of identifiers such as E.164 number code, extended unique identifier (EUI)-64, media access control (MAC) address, uniform resource identifier (URI)/

uniform resource locator (URL), etc. Recently, the most important technology used to provide identity is the RFID tags. The code for the identifier used in RFID is an electronic product code (EPC) [8]. It is simply a number assigned to an RFID tag representative of an actual electronic product code. Using these identifiers, all of devices using RFID tags should be reachable to the other users and/or devices such as RFID tag reader.

As shown in our proposed diagram (see Figure 3), the layered architecture of network requires specific processing capabilities at each layer. Each user/object in applications identifies by identity like name with a set of attributes of an entity. An attribute can be thought of as metadata that belongs to a specific entity in a specific context, some of which could to be highly private or sensitive [9]. The identity should be associated with object IDs (RFID, content ID, URI/URL, etc) through identification and authorization. Each object ID also should be associated with communication IDs (session/protocol ID, IP address, MAC address, etc) through mapping/binding. We call these procedures "Ubiquitous Identity Processing".

An ID resolution server such as domain name system (DNS) can provide a function to translate the identifier of object into object/communication ID to access ubiquitous networking services provided by database/application servers. From the IoT perspective, how to map/bind IP address with other identifiers for providing end-to-end IP connectivity is challenging issue for further study.

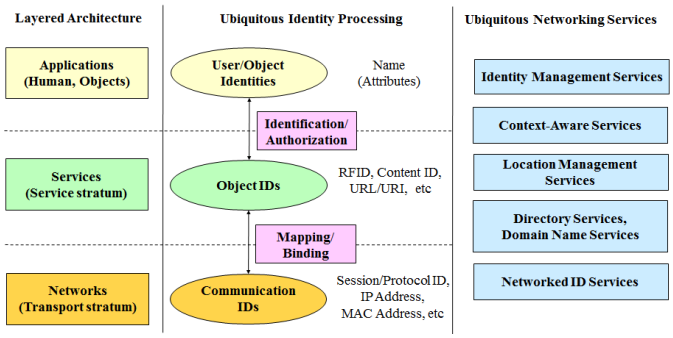

Figure 3. Identity processing for ubiquitous networking services

Using the proposed ubiquitous identity processing, the future Internet can provide an integrated solution for personal location and management through identification/naming/ addressing including ID registration, location tracking, dynamic mobility control, and security using the following ubiquitous networking services:

- Identity management (IdM) services for the management of the identity life cycle of objects including managing unique IDs, attributes, credentials, entitlements to consistently enforce business and security policies.
- Context-aware services for improving the usability and providing personalized services based on context recognition through adapting the service to the context.
- Location management services for real-time location tracking, monitoring, and information processing of moving objects similar with SCM.
- Directory services for searching and retrieving information from a catalogue of well-defined objects, and domain name services for translating human-readable names into the IP addresses that network equipment needs to deliver information.
- Networked ID (N-ID) services for providing communication service which is triggered by an identification process started via reading an identifier from identifier storage such as RFID tag, barcode label, smartcard, etc.

4 Conclusion

This paper has presented the issues to support ubiquitous networking for IoT. We have provided the visions of ubiquitous networking and clearly identified key technologies essential to the ubiquitous networking in the IoT environment. For developing the relevant technical solutions, we have proposed key capabilities and ubiquitous networking services using object identification for further enhancement of current Internet. We hope that our proposals will provide some key inputs for realization of IoT.

As future work, we plan to focus on objects-to-objects communications for various use cases using ubiquitous networking in the IoT environment and business aspects. For this, it would be helpful if the relevant research efforts for realization of the ubiquitous networking are accelerated with special consideration of their commercial viability.

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