RFID Technology and Its Applications in Internet of Things (IOT)

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***Abstract*—Radio frequency identification system (RFID) is an automatic technology and aids machines or computers to identify objects, record metadata or control individual target through radio waves. Connecting RFID reader to the terminal of Internet, the readers can identify, track and monitor the objects attached with tags globally, automatically, and in real time, if needed. This is the so-called Internet of Things (IOT). RFID is often seen as a prerequisite for the IOT. This paper introduces the technologies of RFID and IOT, discusses the applications and challenges of RFID technology used in IOT.**

Keywords-RFID technology; application; Internet of Things

I. INTRODUCTION

Radio frequency identification system (RFID) is an automatic technology and aids machines or computers to identify objects, record metadata or control individual target through radio waves [1]. The RFID technology was first appeared in 1945, as an espionage tool for the Soviet Union, which retransmitted incident radio waves with audio information. Similarly, the IFF (Identification Friend or Foe) transponder developed in the United Kingdom was routinely used by the allies in World War II to identify aircraft as friend or foe.

A typically RFID system is consisted of tags (transmitters/ responders) and readers (transmitters/receivers) [2]. The tag is a microchip connected with an antenna, which can be attached to an object as the identifier of the object. The RFID reader communicates with the RFID tag using radio waves. The main advantage of RFID technology is the automated identification and data capture that promises wholesale changes across a broad spectrum of business activities and aims to reduce the cost of the already used systems such as bar codes. Although RFID technology was discovered many years ago, it has advanced and evolved only during the last decade since cost has been the main limitation in all implementations.

As predicted in [3], RFID is one of the big opportunities in information technology, which will change the world broadly and deeply. When the RFID readers abided by appropriate communication protocols are connected to the terminal of Internet, the readers distributed throughout the world can identify, track and monitor the objects attached with tags globally, automatically, and in real time, if needed. This is the so-called Internet of Things (IOT).

The IOT refers to uniquely identifiable objects (things) and their virtual representations in an Internet-like structure. The IOT first became popular through the Auto-ID Center and related market analysts publications. RFID is often seen as a prerequisite for the IOT. If all objects of daily life were equipped with radio tags, they could be identified and inventoried by computers. This paper introduces the primary concepts and technologies of RFID and IOT, discusses the applications and challenges of RFID technology used in IOT.

II. IOT AND RFID TECHNOLOGY

A. *Internet of Things*

Internet of Things (IOT) is a global network infrastructure, linking physical and virtual objects through the exploitation of data capture and communication capabilities. It will offer specific object identification, sensor and connection capability as the basis for the development of independent cooperative services and applications. These will be characterized by a high degree of autonomous data capture, event transfer, network connectivity and interoperability.

The IOT system architecture is generally divided into three layers: the perception layer, the network layer, and the service layer (or application layer), as shown in Fig.1.

Perception layer: It is the information origin and the core layer of IOT. All kinds of information of the physical world used in IOT are perceived and collected in this layer, by the technologies of sensors, wireless sensors network (WSN), tags

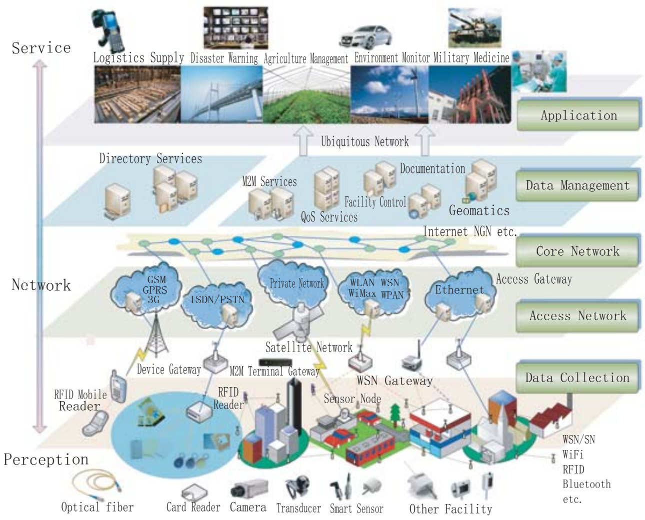

Fig.1 The system architecture of Internet of Things (IOT)

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and reader-writers, RFID system, camera, global position system (GPS), intelligent terminals, electronic data interface (EDI), objects, and so like.

Network layer: This layer, also called transport layer, including access network and core network, provides transparent data transmission capability. By the existing mobile communication network, radio access network, wireless sensor network (WSN) and other communications equipment, such as global system for mobile communications (GSM), general packet radio service (GPRS), worldwide interoperability for microwave access (WiMax), wireless fidelity (WiFi), Ethernet, etc., the information form perception layer can be sent to the upper layer. At the same time, this layer provides an efficient, reliable, trusted network infrastructure platform to upper layer and large scale industry application [4].

Service layer: This layer, also called application layer, includes data management sub-layer and application service sub-layer. The data management sub-layer provides processing complex data and uncertain information, such as restructuring, cleaning and combining, and provides directory service, market to market (M2M) service, Quality of Service (QoS), facility management, geomatics, etc. by service oriented architecture (SOA), cloud computing technologies, and so on. The application service sub-layer transforms information to content and provides good user interface for upper level enterprise application and end users, such as logistics and supply, disaster warning, environmental monitoring, agricultural management, production management, and so forth.

B. RFID System

RFID systems are composed of three main components: RFID tags, reader, application system [2][5], as shown in Fig.2.

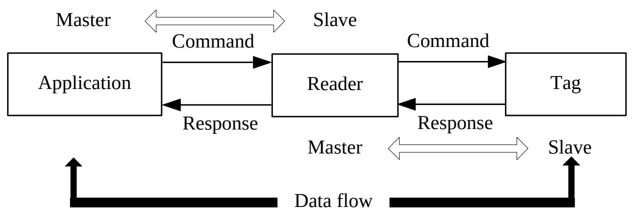

Fig.2 The components of a RFID system

RFID tags: also known as transponders (transmitter/ responder), are attached to the objects to count or identify. Tags could be either active or passive. Active tags are those that have partly or fully battery powered, have the capability to communicate with other tags, and can initiate a dialogue of their own with the tag reader. Passive tags, on the other hand, do not need any internal power source but are powered up by the tag reader. Tags consist mainly of a coiled antenna and a microchip, with the main purpose of storing data.

Reader: also known as transceiver (transmitter/receiver) made up of a radio frequency interface (RFI) module and control unit. Its main functions are to activate the tags, structure the communication sequence with the tag, and transfer data between the application software and tags.

Application system: also called data processing system, which can be an application or database, depending on the application. The application software initiates all readers and tags activities. RFID provides a quick, flexible, and reliable way for electronically detecting, tracking and controlling a variety of items. RFID systems use radio transmissions to send energy to a RFID tag while the tag emits a unique identification code back to a data collection reader linked to an information management system. The data collected from the tag can then be sent either directly to a host computer, or stored in a portable reader and up-loaded later to the host computer.

C. RFID Tags

RFID tags come in many different shapes, sizes, and capabilities. When an RFID solution is designed, the solution's architect must take into account both business and technology requirements before choosing the type of RFID tag to use [6]. All RFID tags have the following essential components in common: antenna, integrated circuit, printed circuit board (or substrate).

The main responsibility of antenna of RFID tag is to transmit and receive radio waves for the purpose of communication. The antenna is also known as the coupling mechanism, which can transform the energy in the form of electromagnetic radiation. This is the way the tag and reader communicating each other. In a suitable environment and proximity to an RFID reader, the antenna can collect enough energy to power the tag's other components without a battery.

The integrated circuit (IC) is a packaged collection of discrete components that provide the brains for the tag. The IC in a RFID tag is much like a microprocessor found in any cellular phone or computer, but it is usually not very sophisticated. For many RFID tags, the IC component has only a single purpose, to transmit the tag's unique identifier (ID). If the tag has any peripheral components, the IC is also the master controller that is responsible for gathering any extra information and transmitting it along with the tag's ID.

The printed circuit board (PCB) is the material that holds the tag together. The circuit board may be rigid or flexible, and is composed of many different types of materials, depending on the type and purpose of the tag. For example, tags that are used for tracking components on an assembly line where extremely high temperatures may be encountered would tend to be much more rigid and are usually placed inside a protective enclosure.

Tags are built to comply with a categorization called a class. Classes progressively have greater capability. EPCglobal has defined six classifications for RFID tags (0 to 5). A general description of functionality that each class is required to comply is as follows.

- **Class 0/class 1:** These classes provide the basic radio frequency (RF) passive capability. Class 0 is factory-programmed. Beyond class 0, including class 1, the tags are user-programmable.
- **Class 2:** Additional functionality is added, which includes encryption and read-write RF memory

- **Class 3:** Batteries are found on board that will power logic in the computer circuit. Class 3 provides longer range and broadband communications
- **Class 4:** Active tags are part of the definition of class 4 tags. Peer-to-peer communications and additional sensing are also included.
- **Class 5:** Class 5 tags contain enough power to activate other tags and could be effectively classified as a reader.

Passive tags, which have no built-in power source and the power is provided by the radio frequency wave created by the reader, are usually classified in the class 0 to 3 range. Class 4 describes active tags, which have an internal power source (a battery), that provides the necessary power for the operation of the tag over a period of time. Class 5 is reserved for tag readers and active tags that can read data from other tags.

D. RFID Reader

RFID readers are also referred to as interrogators because they query tags as the tags enter their read range. The reader is responsible for orchestrating the communication with any tags in its read range and then presenting the tags' data to an application that can make use of the data.

Readers in all systems can be reduced to two fundamental functional blocks: the control system and the high frequency (HF) interface, consisting of a transmitter and receiver, as shown in Fig.3. The entire system is controlled by an external

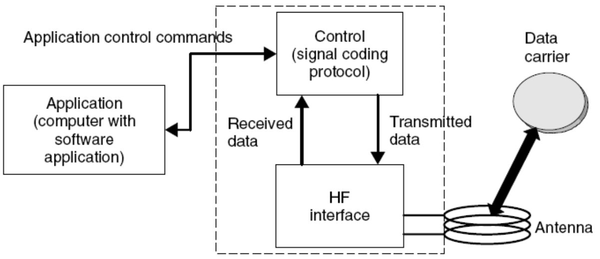

Fig.3 RFID reader consisting of control system and HF interface [2]

application via control commands.

The reader's HF interface performs the following functions: (a) generation of high frequency transmission power to activate the transponder and supply it with power; (b) modulation of the transmission signal to send data to the transponder; (c) reception and demodulation of HF signals transmitted by a transponder.

The reader's control unit performs the following functions: (a) communication with the application software and the execution of commands from the application software; (b) control of the communication with a transponder (master–slave principle, as shown in Fig.2); (c) signal coding and decoding. In more complex systems the following additional functions are available: (d) execution of an anti-collision algorithm; (e) encryption and decryption of the data to be transferred between transponder and reader; (f) performance of authentication between transponder and reader.

The control unit is usually based upon a microprocessor to perform these complex functions. Cryptological procedures, such as stream ciphering between transponder and reader, and also signal coding, are often performed in an additional ASIC (application specific integrated circuit) module to relieve the processor of calculation intensive processes.

III. APPLICATIONS OF RFID TECHNOLOGY

The functions of RFID system generally include three aspects: monitoring, tracking, and supervising. Monitoring generally means to be aware of the state of a system, by repeated observing the particular conditions, especially to detect them and give warning of change. Tracking is the observing of persons or objects on the move and supplying a timely ordered sequence of respective location data to a model. Supervising is the monitoring of the behaviors, activities, or other changing information, usually of people. It is sometimes done in a secret or inconspicuous manner.

The RFID applications are numerous and far reaching. The most interesting and successful applications include those for supply chain management, production process control, and objects tracking management. Now RFID has been gradually and broadly used in the following fields.

- Logistics and Supply
- Manufacturing
- Agriculture Management
- Health Care and Medicine
- Marine Terminal Operation
- Military and Defense
- Payment Transactions
- Environment Monitor and Disaster Warning
- Transportation and Retailing
- Warehousing and Distribution Systems
- Other applications in many walks of life businesses

For instance, in Manufacturing, RFID technology offers a number of applications in the automotive industry. A RFID-based antitheft vehicle immobilizer is a protective device installed in many cars. RFID also holds great promise for the assembly and manufacturing processes of automobiles, in particular, for flexible and agile production planning, spare parts, and inventory management. RFID technology not only helps to automate the whole assembly process in which a significant reduction in cost and shrinkage can be achieved, but it also offers improved services to automobile users that include more efficient replacement part ordering and automated generation of maintenance reminders. The benefits that RFID offers to the automotive industry, both to the production process as well as to end users, are visibility, traceability, flexibility, and added security.

As illustrated in Fig.4, the evolution of IOT is coinciding with that of RFID and sensor technologies. Form supply-chain helper to vertical-market applications to ubiquitous positioning,

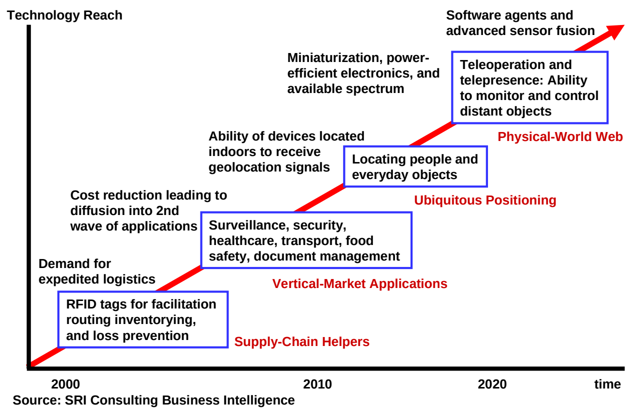

Fig.4 Technology roadmap of Internet of Things (IOT)

and so on, the RFID technology is a very important and fundamental groundwork for IOT.

IV. Challenges of RFID Technology

Although promising, RFID is not without its challenges, which arise from both a technological and usage point of view.

A. Collision Problems

Communication between tags and readers are inherently susceptible to electromagnetic interference. Simultaneous transmissions in RFID lead to collisions as readers and tags typically operate on a same wireless channel. Therefore, efficient anti-collision protocols for identifying multi-tags simultaneously are of great importance for the development of large-scale RFID applications [1].

Many anti-collision protocols for RFID tag identification have been proposed, such as query tree protocol (QT), binary tree protocol (BT), frame slotted ALOHA protocol (FSA), etc., but almost all known protocols exhibit an overall identification efficiency small than 50%. Besides, uniform IDs distribution has always been assumed in the past. Furthermore, it is very useful for pointing out the best performing features of RFID tag identification protocols, and for designing new and better protocols. In [1], we present a novel and efficient anti-collision protocol for RFID tag identification, i.e., collision tree protocol (CT), which outperforms all the other anti-collision protocols proposed so far.

B. Security and Privacy Concerns

Security and privacy issues [7] of RFID tags can effect both organizations and individuals. Unprotected tags may be vulnerable to eavesdropping, traffic analysis, spoofing or denial of service and many more. Even unauthorized readers can affect the privacy by accessing tags without enough access control. Even if the tag content is secure then also it can be tracked by the predictable tag responses; “location privacy” can be affected by a traffic analysis attack. Attacker can also threaten the security of systems, which depends on RFID technology through the denial of service attack.

Due to its cost and resource constraint limitations, RFID system does not have a sufficient security and privacy support. Many researcher and scientist work to implement low cost security and privacy protocol to increase the applicability. Lots of lightweight solutions have been proposed for RFID, but they are still expensive and vulnerable to the security and do not fully resolve the security issues. So there is a good research scope in the field of designing an efficient ultra-lightweight cryptographic protocol for low-cost RFID system.

C. Other Challenges

Three other issues also are mainly holding back RFID’s widespread adoption. The first one is the cost. The RFID tags are still more expensive than printed labels. The second issue is design. It is still needed to engineer tags and readers so that they guarantee highly reliable identification. Another challenge to RFID is its integration into existing systems. It is significant to develop effective RFID middleware which used to link new RFID systems into existing back-end infrastructures.

Despite these challenges, it’s only a matter of time before these issues could be solved. RFID’s potential benefits are large, and many novel applications will be see in the future, even some of which can not begin to imagine.

V. Conclusion

The IOT uses a variety of information sensing identification device and information processing equipment, such as RFID, WSN, GPRS, etc. combining with the Internet to form an extensive network in order to informationize and intelligentize the entities or objects. This paper analyzes the applications and challenges of RFID technology, which is the important and foundational component of IOT.

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