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Research on the Internet of Things (IoT)

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Abstract: The Internet of things (IoT) has become a research hotspot in computer science. The fact it will lead to a new information revolution is considered by most researchers. The main idea of IoT is that all objects are connected to the Internet and thus to be managed and controlled remotely, even interact with each other by receiving and sending information as well as sense their surroundings and have a certain reaction through intelligent technologies. In this paper, we firstly introduce the definition and connotation of IoT briefly. Secondly, we present the enabling technologies of IoT such as RFID (Radio Frequency Identification) systems, WSN (wireless sensor networks), intelligent technologies, NT (nanotechnology), addressing schemes, data storage and analysis and visualization. Thirdly, we give a brief introduce of the applications of IoT. It includes individuals and families, enterprise, public utilities and mobile. Fourthly, some open issues and research directions are introduced. Finally, we give the conclusion. *Copyright © 2013 IFSA.*

Keywords: Internet of Things, RFID, WSN, Intelligent Technologies, Addressing Schemes.

1. Introduction

With the development of mobile computing and wireless telecommunication, a novel paradigm called the Internet of Things is rapidly gaining ground in the field of computer science. The basic idea of this concept is the pervasive presence around us of a variety of things or objects such as Radio-Frequency Identification (RFID) tags, sensors, mobile phones, etc. which are able to interact with each other and cooperate with their neighbors to reach common goals through unique addressing schemes. All objects are connected to the Internet and thus to be managed and controlled remotely, even interact with each other by receiving and sending information as well as sense their surroundings and have the corresponding reactions through intelligent technologies. No doubt that the main strength of the idea of IoT idea is that it will have impact on all aspects of daily life and behavior of all users. From the point of view of a private user, the most obvious effects of the IoT will be visible in both working and home. IoT will play a leading role in the near future. Similarly, from the perspective of business users, the most apparent effects will be equally visible.

The emergence of a new paradigm always produces manifold understandings and definitions. IoT is no exception. It is a real difficulty for researchers to understand which basic ideas are standing behind this concept and what IoT really means. The fuzziness around the term ‘Internet of Things’ firstly derives from the name itself. It syntactically is composed of two terms ‘Internet’ and ‘Things’. The former shows that IoT is network-oriented architecture while the latter shows that the focus of IoT is on universal objects which are to be integrated into a generic framework. Researchers have begun to study this issue from either an Internet-oriented or a Things-oriented perspective according to their specific interests and backgrounds. When

Internet and Things are put together, many challenging problems are generated such as the unique addressing of objects and the representation and storing of the exchanged information. This brings to a third perspective of IoT directly, namely a Semantic-oriented vision of IoT. It isn't hard to understand that the IoT shall be the result of the convergence of the three main visions.

From the perspective of Things-oriented vision of IoT, there are two main elements to support the development of IoT. They are RFID (Radio Frequency Identification) tags and WSN (wireless sensor networks). As a matter of fact, it is a Things-oriented perspective that the first definition of IoT derives from. At that time, it is the RFID tags that the considered things were. WSN will also play a crucial role in the IoT. It can cooperate with RFID systems to better track the status of things. As such, they can augment the awareness of a certain environment and, thus, act as a further bridge between physical and digital world. From the perspective of Internet-oriented vision of IoT, it is necessary that all things can be connected to the common network framework. Thus, some research problems arise from the Internet-oriented vision such as addressing schemes and communication protocols etc. To some extent, the well-known IPv6 technology is developed for the future IoT and, as said, makes every grain of sand have a network address. It is for the deployment of the IoT that what makes all things have network addresses is prepared. From the perspective of Semantic-oriented vision, the IoT is facing some notable problems of semantic technologies. Since the number of objects involved in the future IoT is destined to be quite large, the representation, store, interconnection, search and organization of generated information by the IoT will be very challenging. In this context, semantic technologies could play a key role. In fact, these can exploit appropriate modeling solutions for things description, reasoning over data generated by IoT, semantic execution environments and architectures that accommodate IoT requirements and scalable storing and communication infrastructure [1].

2. Enabling Technologies of the IoT

In this section, we discuss some enabling technologies which are essential to actualize the IoT idea into the real world by their integration. As said above, the IoT has three visions of Things oriented, Internet oriented and Semantic oriented. In the Things-oriented vision of the IoT, we will discuss the enabling technologies of RFID systems, WSN systems and NT (Nanotechnology). In the Internet-oriented vision of IoT, we will discuss the enabling technologies of addressing schemes. In the Semantic-oriented vision of the IoT, we will discuss the enabling technologies of intelligent technologies, data storage and analytics and visualization. Note that we don't put the seven enabling technologies into three categories. In fact, each enabling technology has the attributes of the three visions. It is just related to the perspective from which we see them. The purpose of this section is to provide a picture of the roles which these enabling technologies will likely play in the IoT.

2.1. Radio-Frequency Identification Technology

Radio Frequency Identification (RFID) is a technology used for automated identification of objects and people. People are good at identifying objects under lots of challenge circumstances. Computer vision, though, performs such tasks poorly. RFID may be viewed as a means of explicitly labeling objects to facilitate their 'perception' by computing devices [2]. A typical RFID system consists of tags and readers, application software, computing hardware and middleware. An RFID device is just called an RFID tag as shown in Fig. 1 (a).

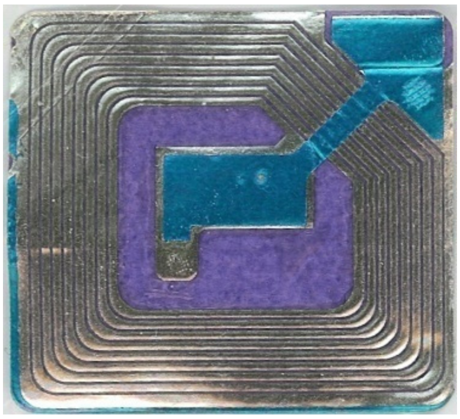

Fig. 1 (a). An instance of RFID – RFID tag.

It is a small microchip designed for wireless data transmission. It is generally attached to an antenna in a package that resembles an ordinary adhesive sticker. The microchip itself can be as small as a grain of sand [3]. An RFID tag transmits data over the air in response to interrogation by an RFID reader as shown in Fig. 1(b).

The embedded communication paradigm enables design of microchips for wireless data communication. It is RFID technology that is a major breakthrough in it. They have abilities in the automatic identification of anything which they are attached to acting as an electronic barcode [2, 4]. The passive RFID tags need not to be powered by batteries and they use the power of the reader's interrogation signal to communicate the ID to the RFID reader. This has resulted in many applications particularly in retail and supply chain management. The applications can be found in transportation (replacement of tickets, registration stickers) and access control applications as well. The passive tags are currently being used in many bank cards and road toll tags which are among the first global deployments. Active RFID readers have their own battery supply and can instantiate the communication. Of the several applications, the main application of active RFID tags is in port containers [2] for monitoring cargo.

Fig. 1 (b). An instance of RFID – RFID reader.

We have often talked about anytime and anywhere connection by anyone [5]. But it can go further still through radio technology: by anything. Wireless technologies have played an important role and today the ratio of radios to humans is nearing 1 to 1. The reduction of size, weight, energy consumption and cost of the radio increases of orders of magnitude and it can take us to a new era. That is, it will allow us to integrate radios in almost all things and thus to add anything of the world to the above vision, which leads to the IoT concept. So it is obvious that RFID systems will be key components of the IoT [6].

2.2. Wireless Sensor Networks

Wireless sensor networks consist of large numbers of sensing nodes communicating in a wireless multi-hop fashion. Wireless sensor networks (WSN) together with RFID are considered to be the basic components which have abilities in linking the digital world with the real world. Wireless sensor networks will also play a crucial role in the IoT. In fact, they can cooperate with RFID systems to better track the status of things such as their location, temperature, movements etc. Thus, the awareness of a certain environment can be augmented. It can act as a further bridge between physical and digital world. The utilization of wireless sensor networks has been proposed in several application scenarios, such as environmental monitoring, e-health, intelligent transportation systems, military and industrial plant monitoring. Generally, nodes report the results of their sensing to a small number (usually only one) of special nodes called sinks as shown in Fig. 2. A large scientific literature has been produced on sensor networks in the recent past, addressing several problems at all layers of the protocol stack [7]. Design objectives of the proposed solutions are energy efficiency, scalability, reliability and robustness. To take full advantage of the available Internet technology, there is a need to deploy large-scale and platform independent wireless sensor network infrastructure that includes data management and processing, actuation and analytics.

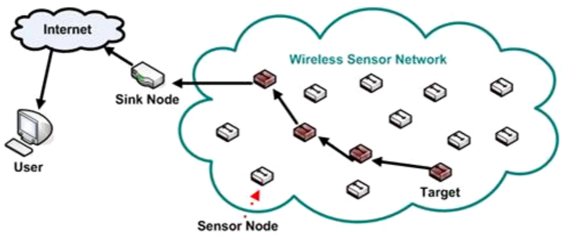

Fig. 2. An example of wireless sensor network.

Recent technological advances in low power integrated circuits and wireless communications have made available efficient, low cost, low power miniature devices for use in remote sensing applications. The combination of these factors has improved the viability of utilizing a sensor network consisting of a large number of intelligent sensors, enabling the collection, processing, analysis and dissemination of valuable information, gathered in a variety of environments [7]. Active RFID is nearly the same as the lower end WSN nodes with limited processing capability and storage. The scientific challenges that must be overcome in order to realize the enormous potential of WSNs are substantial and multidisciplinary in nature [7]. Sensor data are shared among sensor nodes and sent to a distributed or centralized system for analytics.

Typically a node (WSN core hardware) consists of sensor interfaces, processing units, transceiver units and power supply. Almost always, they comprise of multiple A/D converters for sensor interfacing and more modern sensor nodes have the ability to communicate using one frequency band making them more versatile [7]. The nodes are expected to be deployed in an ad-hoc manner for most applications. It is critical for the scalability and longevity of the deployed network to design a suitable topology, routing and MAC layer. The nodes need to communicate with each other to transmit data in single or multi-hop to a base station in a WSN. The communication stack at the sink node should be able to interact with the outside world through the Internet to act as a gateway to the WSN subnet and the Internet [8]. These features of WSN have made it become the indispensable application technology of the IoT. Its groundbreaking advance will promote the development of the IoT and the extensive utilization of all industries.

2.3. Intelligent Technologies

Intelligent technologies are referring to various methods and means which are aiming to achieve some intended goals by utilizing the knowledge. Embedding intelligent systems into the objects has enabled these objects have a certain intelligence and achieve the interaction with users actively or passively. It is also one of the key technologies of the IoT. It has many research content and directions. Intelligent control technology and system is one of them. The IoT is to give all objects intelligence and make the objects' communication and dialogue with people carried out as well as even to achieve the communication and dialogue between objects. In order to reach such a goal, the intelligent control technology and its system implementation must be researched. For instance, research how to control an intelligent service robot to complete tasks, trajectory control, accurate positioning and tracking target etc.

2.4. Nanotechnology

NA is a technology for studying the properties and applications of the materials whose construction dimensions are within the range of 0.1~100 nm. It mainly includes Physics of Nano-systems, Nanochemistry, Nanomaterials, Nanobiology, Nanoelectronics, Science of Nano-processing and Nanomechanics etc. The seven disciplines are mutually independent and interpenetrative. Nanometer materials, nanometer devices and nanometer dimension are three research fields of NA on their Detection and characterization. The preparation and research of nanometer materials are the basis of the whole NA. And Nanophysics and Nanochemistry are the theoretical basis of NA while Nanoelectronics is the most important content of NA. The RFID and WSN technologies can be used to detecting the physical states of objects. The embedded intelligence of objects have abilities in transmitting information and processing data through the network boundary and thus to strengthen the power of the IoT. And the emergence of NA means that smaller and smaller objects are able to connect and interact in the IoT. Therefore, the importance of NA for the IoT is self-evident.

2.5. Addressing Schemes

It is evidently critical for successfully implementing the IoT to have abilities in uniquely identify all 'Thing'. It involves that billions of objects and devices need to be uniquely identified while they can be remotely controlled and communicate with each other through the Internet. Simplification, uniqueness, reliability, persistence and scalability are the most important characteristics of creating a unique address. Each device or object which not only is already connected to the Internet but also is being connected to the Internet and is going to the Internet should be identified uniquely by their unique identification. To some extent, the current IPv4 may support that a group of sensor devices can be identified geographically. But it does not have ability in identify each individual. The Internet Mobility attributes in the IPv6 may alleviate some of the device identification problems; however, the heterogeneous nature of wireless nodes, variable data types, concurrent operations and confluence of data from devices exacerbates the problem further [9]. In addition, the IoT needs to channel the data traffic ubiquitously and relentlessly by implementing the persistent network function. In the existing Internet, we have the TCP/IP. But for the IoT, it can't deal with the bottleneck between the current gateway and wireless sensor devices. What is more, the problem of the scalability of devices address in the current Internet has been yet addressed let alone in the IoT world. Not to mention that the performance of the network and the functioning of devices as well as the reliability of data through the network need be kept at the same time. With large amounts of spatial data being gathered, it is often quite important to take advantage of the benefits of metadata for transferring the information from a database to the user via the Internet [10]. Aiming to address these problems, URN (the uniform resource name) system which creates a copy for each resource which may be accessed through the URL address and the development of the lightweight and extended IPv6 are considered to be essential for the development of the IoT.

2.6. Data Storage and Analysis

The emerging of the IoT will produce large numbers of data which must be stored and analyzed to obtain valuable information and make the corresponding objects have the corresponding interactions and responses by analyzing these data. The ownership and expiry of the data have also become critical problems. To address these problems, the data has to be stored, analyzed and utilized in an intelligent cloud data center for smart actuating and monitoring. Developing heuristic approaches and some centralized or distributed artificial intelligent algorithms in terms of requirements are very necessary for reach these goals. Based on evolutionary algorithms (such as genetic algorithms, simulated annealing algorithm and swarm intelligence algorithms etc.), neural networks and other artificial intelligent approaches, the most advanced non-linear machine learning approaches should be developed for achieve making automated decision while the novel self-adaptive algorithms for making sense of the obtained data also need be developed. These intelligent approaches have many features such as integration, adaptive communications and interoperability. They are suitable for applications of the IoT. It is to be observed that the research on cloud data centers for data storage and analysis the IoT are foreseen and necessary.

2.7. Visualization

The IoT is designed and developed ultimately to serve the users. The 'Things' need interact and dialogue with the users. Thus, for the whole IoT environment, visualization is crucial for each element since it is the interface between 'Things' and users. In the current mobile information era, smart mobile devices and tablets are widely used and the touch screen technologies have been popular and advanced. For both the ordinary users and professional users who will benefit from the IoT era, the visual interface must be created explicitly. It conforms to the trend of the development of human civilization. That is, any scientific and technological achievements should be with ease of use. The 2D and 3D screens technologies have made large amounts of useful information provided for the users in varieties of meaningful ways. The visualization technologies are more advanced and the obtained knowledge and useful information which the collected data are converted into will be much more. And thus it is also the key to making fast decision for the smart devices in the IoT. As a matter of fact, raw data acquisition is not easy and meaningful information extraction is more difficult from it. The systems not only consider how to detect events, how to model the obtained data and how to visualize the original data etc. but also achieve the representation of information and knowledge in terms of the requirements of the consumers.

3. Applications of the IoT

The reason for the emergence of the IoT concept is that people have such requirements as well as people have seen its application prospects and its development space. Too many application scenarios will be affected by the emerging IoT. The applications of the IoT can be categorized into four application fields according to user involvement and impact, network availability, scale, coverage, heterogeneity and repeatability [11]. The four application fields are Individuals and Families, Enterprise, Public Utilities and Mobile. Several typical applications in each application field are given.

3.1. Individuals and Families

Remote human motion tracking and gait analysis over wireless networks can be used for various e-healthcare systems for fast medical prognosis and diagnosis. In [12], the authors propose a new accurate and cost-effective e-healthcare system for fast human gait tracking over wireless networks, where gait data can be collected by using advanced video content analysis techniques with low-cost cameras in a general clinic environment. The aim of home automation is to control home devices from a central control point. In [13], the design and implementation of a low cost but yet flexible and secure internet based home automation system is presented. The communication between the devices is wireless. The protocol between the units in the design is enhanced to be suitable for most of the appliances. The system is designed to be low cost and flexible with the increasing variety of devices to be controlled. Based on the analysis of the basic and essential characters of IoT, in [14] the authors deal 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. Smart homes can apply the IoT concepts along with RFID technologies for creating ubiquitous services. Mohsen Darianian et al. in [15] introduces a novel read-out method for a hierarchical wireless master-slave RFID reader architecture of multi standard NFC (Near Field Communication) and UHF (Ultra High Frequency) technologies to build a smart home service system that benefits in terms of cost, energy consumption and complexity. Various smart home service use cases such as washing programs, cooking, shopping and elderly health care are described as examples that make use of this system.

3.2. Enterprise

The Mobile Sales Assistant (MSA) is a mobile product information system for retailers based on a combination of Near Field Communication (NFC) and the Electronic Product Code (EPC). The MSA aims at optimizing the sales process in retail stores.

It enables shop assistants to check the availability and stock information of products directly at the Point of Sale (PoS) with an NFC enabled mobile phone. Thus, shop assistants can inform their customers without letting them wait, which might increase customer satisfaction and sales. In [16], the authors present a prototype, which has been implemented for a clothing department store, and evaluates its acceptance with a focus group of shop assistants. Miniaturization and price decline are increasingly allowing for the use of RFID tags and sensors in inter-organizational supply chain applications. This contribution aims at investigating the potential of sensor-based issuing policies on product quality in the perishables supply chain. In [17], the authors develop a simple simulation model that allows us to study the quality of perishable goods at a retailer under different issuing policies at the distributor. The results show that policies that rely on automatically collected expiry dates and product quality bear the potential to improve the quality of items in stores with regard to mean quality and standard deviation.

3.3. Public Utilities

In [18], the author present the vision for an open, urban-scale wireless networking testbed, called CitySense, with the goal of supporting the development and evaluation of novel wireless systems that span an entire city. CitySense is currently under development and will consist of about 100 Linux-based embedded PCs outfitted with dual 802.11a/b/g radios and various sensors, mounted on buildings and streetlights across the city of Cambridge as shown in Fig. 3.

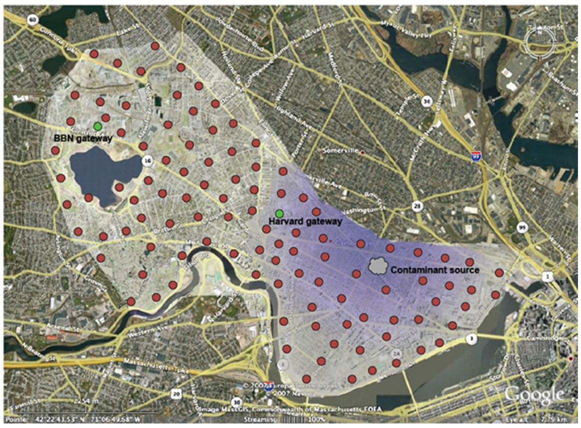

Fig. 3. Conceptual deployment of sensor nodes in Cambridge, MA.

CitySense takes its cue from citywide urban mesh networking projects, but will differ substantially in that nodes will be directly programmable by end users. The goal of CitySense is explicitly not to provide public Internet access, but rather to serve as a new kind of experimental apparatus for urban-scale distributed systems and networking research efforts. In [19], the authors introduce an IoT application, smart community as shown in Fig. 4, which refers to a paradigmatic class of cyber-physical systems with cooperating objects (i.e., networked smart homes). They then define the smart community architecture, and describe how to realize secure and robust networking among individual homes. Two smart community applications, Neighborhood Watch and Pervasive Healthcare are presented, with supporting techniques and associated challenges, and envision a few value added smart community services.

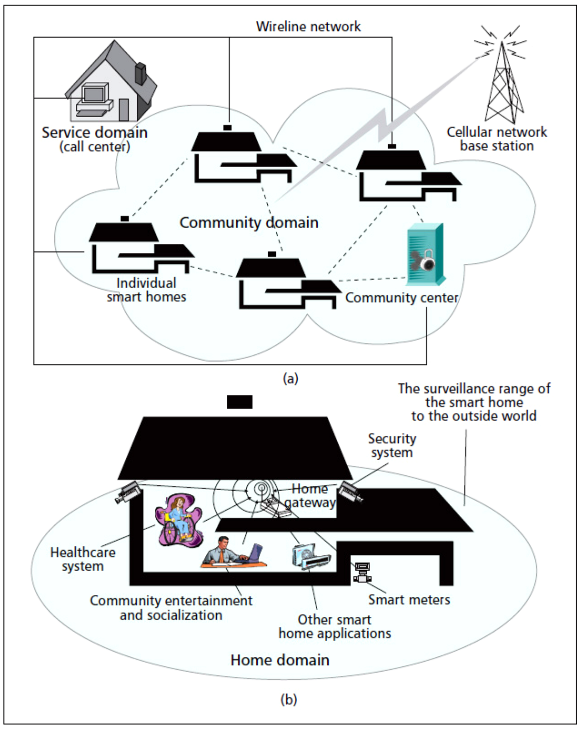

Fig. 4. The smart community architecture:
a) community and service domains; b) home domain.

3.4. Mobile

The advancement of ubiquitous computing technologies has greatly improved the availability of digital resources in the real world. In [20], the authors investigate mobile interaction with tagged, everyday objects and associated information that's based on the IoT and its technologies. Their framework for integrating Web services and mobile interaction with physical objects relies on information typing to increase interoperability. Two prototypes for mobile interaction with smart posters build upon this framework to realize multi-tag interaction with physical user interfaces. The authors' evaluation identifies usability issues regarding the design of physical mobile interactions, interfaces, and applications. Another important application in mobile

IoT domain is efficient logistics management [21]. It includes monitoring the items being transported as well as efficient transportation planning. The monitoring of items is achieved more locally, say, within a truck replicating enterprise domain but transport planning is achieved using a large scale IoT network.

4. Some Open Issues and Research Directions

In this section, we will discuss some open issues and future research directions of the IoT. There are still many problems needing a large research effort in spite of that the enabling technologies discussed above are able to make the IoT concept feasible. We firstly review the standardization of the IoT concept. Secondly, we discuss the problems related to security and privacy of the IoT. Thirdly, the quality of service of the IoT is discussed. Finally, the integration of Cloud computing and the IoT is discussed.

4.1. Standardization

There are several standardization efforts by many scientific communities such as the European Commission [22] and European Standards Organizations (ETSI, CEN, CENELEC, etc.), the International Standardization Institutions (ISO, ITU) and other standards bodies and consortia (IETF, EPCglobal etc.) but they are not integrated in a comprehensive framework. Efforts towards standardization have focused on several principal areas: RFID frequency, protocols of communication between readers and tags, and data formats placed on tags and labels [23]. The major standardization bodies dealing with RFID systems are EPCglobal, European Commission and ISO. EPCglobal mainly aims at supporting the global adoption of an EPC for each tag and related industry-driven standards [24]. European Commission has made coordinated efforts aiming at defining RFID technologies and supporting the transition from localized RFID applications to the IoT [22]. Differently from these, ISO deals with how to modulate, utilize frequencies and prevent collision technically [25]. The Machine-to-Machine (M2M) Technical Committee has been launched to conduct standardization relevant to M2M systems and define cost-effective solutions for M2M communications by the European Telecommunications Standards Institute (ETSI). Since the standardization of this main paradigm of the IoT is absent, the standard Internet, mobile devices and web technologies have been utilized for solving the Standardization. Thus, the ETSI M2M committee is aiming at developing and maintaining an end-to-end architecture for M2M and strengthening the standardization efforts on M2M [26].

4.2. Security and Privacy

In the IoT, the problems of security mainly are related to authentication and data integrity. Authentication is difficult in IoT scenarios. Objects don’t enough resources to carry out complex computing. In [2], some approaches for authentication have been presented. However, they all have serious problems and can’t deal with the man-in-the-middle scenarios [27]. In the IoT environment, the maintaining of data integrity requires that the data can’t be modified during the transactions in the case that no systems are detecting the change. In the field of traditional network security, it has been widely researched. But in the IoT due to the accession of RFID systems and WSN systems, some new problems have been generated. In the IoT environment, large numbers of WSN nodes and RFID tags are spread in a wide area and most of them are unattended within most of the time. Data can be modified by adversaries while it is stored in the node or when it traverses the network [28]. To protect data against the first type of attack, memory is protected in most tag technologies and solutions have been proposed for wireless sensor networks as well [29]. To protect data against the second type of attack, messages may be protected according to the Keyed-Hash Message Authentication Code (HMAC) scheme [30].

The right to privacy can be considered as either a basic and inalienable human right, or as a personal right or possession [31]. In the IoT, the privacy problems of people mainly refer to data collection, the use of collected data and recently begun data forgetting [27]. In RFID systems of the IoT, there are two problems concerning data collection. On the one hand, RFID tags are generally passive and reply to readers queries regardless of the desire of their proprietary [2]. Thereby, individuals’ data could be collected without them even knowing about it [31]. On the other hand the reply from a tag to another authorized reader can be eavesdropped on by an attacker. A new system based on preferences set by the user has been proposed in [32] to negotiate privacy on the individual’s behalf. Aiming at addressing the problem of un-authorized utilization of personal data collected, approaches have been proposed that usually rely on a system called privacy broker [33]. Digital forgetting has become an important issue recognized recently, it is still studied at the beginning phase [34]. Since the cost for storing has been decreasing, the amount of recordable data has rapidly increased. Thus, once information is generated, it will most probably be retained indefinitely [27]. It is necessary to create methods for periodically deleting information of no use.

4.3. Quality of Service

The IoT environment is in heterogeneous networks and thus it is multi-service. That is, it provides more than one distinct application or service. The fact means that there are multiple traffic types in the network of the IoT. Besides, it is the ability of a single network to support all applications without QoS compromise [35]. A controlled, optimal approach to serve different network traffics, each with its own application QoS needs is required [36]. To provide QoS guarantees in wireless networks is very hard since large numbers of segments usually constitute gaps in resource guarantee because of the constraints of resource allocation and management ability in shared wireless media. With the appearance of high capacity applications and the IoT developing, this could become a bottleneck.

4.4. Cloud Computing and the Internet of Things

Cloud computing is the development of parallel computing, distributed computing and grid computing. It distributes the computation tasks into a resource pool composed by great amounts of computing resources, and makes users on-demand obtain computing power, storage space and information service. Compared to cluster computing and grid computing, cloud computing is a commercial computing model which is more suitable for providing services to users. “Cloud” is large amounts of virtual computing resources which have abilities to maintain and manage themselves in the system. Generally, these resources include computing servers, storage servers and bandwidth resources etc. Cloud computing system pools the computing resources into a resource pool and achieves their automatic management by using specialized software. Users can dynamically utilize and reserve some of the resources to support varieties of applications. It benefits improving efficiency, reducing costs and makes users more focus on their own business. The development of cloud computing is not limited to PC [37]. The integration of cloud computing and the IoT can enable the creation of smart environments. It is necessary for the integration of cloud computing and the IoT to have abilities in operating in both wired and wireless network environments. With the vigorous development of the mobile Internet, the cloud computing services based on mobile devices such as mobile phones, tablet PC etc. have emerged and been widely used for the field of information sharing, mobile learning, e-commerce, home monitoring and mobile health etc. Mobile cloud computing is a kind of IT resources, while it is also a delivery and utilization mode of information as well as services. It obtains the required infrastructures, platforms and software (applications) etc. in an on-demand and scalable way through the mobile Internet [37]. The integration of mobile cloud computing and the IoT can do with many constraints (access devices and data sources etc.) with limited energy and relatively unreliable connectivity.

5. Conclusion

In this paper, we briefly survey the development of the IoT, including the definitions from various visions, some enabling technologies, already or soon available applications and open research issues. The main purpose of this paper isn’t aiming to provide a comprehensive review of the relevant technologies’ details in the IoT but provide a picture of the role these elements likely play in the IoT. As believed by all researcher, the vision of ‘from anytime, anyplace connectivity for anyone’ will surely come to pass in the near future and should be achieved depend on cooperative efforts in all related field. RFID and WSN systems have become the background technologies of the IoT. It is their developments that have made people see a promising future and broad space of the IoT concept in advance. The development of intelligent technologies has made the IoT concept have a soul and provided a foundation of implementation to the IoT. The contribution of the Nanotechnology to the IoT is that it have extended the ‘Things’ concept in the IoT to a much greater range and given the IoT a chance of implementing the Internet of all things. Not only addressing schemes and visualization but also data storage and analysis, all of these technologies and elements are supporting the implementation of the IoT concept while proving that the IoT concept can be achieved. As mentioned above, many IoT applications of individuals, families, enterprise, public utilities and mobile life have emerged and been providing service to people. In the respect of scientific research, the field of the IoT has many open issues and research directions. It has become a research hotspot. The IoT has wide research prospects in both theory and practice.

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