Research Article

Constructing the Green Campus within the Internet of Things Architecture

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The “Internet of Things” radically changes the view of the “Internet” by embracing every physical object into network. The vision of “IoT” promises to enhance the capabilities of objects and forms a smart environment so that people will benefit from the IoT revolution. As the global population grows, the resources on earth are depleted quickly. In order to have a sustainable earth, governments around the world put a lot of efforts to advocate the reduction of carbon production as well as to emphasize the benefits of reducing the consumption of energy. The proposition has been promoted on campus of educational institutions as well. Smart campus is a trendy application in the paradigm of the IoT. This research adopts the concept of the “Internet of Things” to construct a green campus environment which will realize the idea of energy saving. The architecture of the construction of green campus is established and three application systems have been developed as well. The efforts of this work allow the campus to manage the computer labs and the air conditioners more efficiently. The sensor network will save more energy since data are reported periodically and the analysis will be carried out in time to locate the problems.

1. Introduction

The advances of emerging technologies have broadened the meaning as well as the applications of the Internet. In other words, almost every “object” can be part of a network. With smart connectivity, physical objects are networked and will gain the ability to communicate with each other. The vision of “The Internet of Things (IoT)” promises to enhance the capabilities of objects and forms a smart environment so that people can benefit from the IoT revolution [1, 2]. The IoT applications cover the building of smart cities, the setup of smart environment, the provision of smart public services, the plan of eHealth, and the building of smart home/office, and so forth [1, 3].

As the global population grows, the resources on earth are depleted quickly. In order to have a sustainable earth, governments around the world put a lot of efforts to advocate the importance of the reduction of carbon production as well as to emphasize the benefits of reducing the consumption of energy. The proposition has been promoted on campuses of educational institutions as well. Smart campus is a trendy application in the paradigm of the IoT. The concept of constructing a “Smart campus” implies that the institution will adopt advanced ICTs (Information Communication Technologies) to automatically monitor and control every facility on campus. To use the facilities more efficiently and to minimize the energy consumed are believed the most important advantages of building a smart campus. Such efforts are also recognized as constructing a “green campus.”

Two major ICTs which make the realization of IoT possible are the emergence of cloud computing and the network of wireless sensors. In fact, cloud computing and wireless-sensor network together can provide the most reliable, scalable, dynamic, and composable resources that the IoTs required [4–7]. Wireless sensor networks are, particularly, adopted in many urban cities to provide smarter and advanced lives [8].

In order to construct a green campus with the utilization of the Internet of Things, this research reviews the cores of IoT, cloud computing, and wireless sensors network. Thereafter, the definition, the architecture, and the steps for the development of green campus are proposed. This paper also demonstrates our work toward constructing a green campus and the system we have developed. The ultimate goal of this work is the implementation of a cloud-based monitoring
system built upon wireless sensor network architecture so that data are gathered and stored on cloud database and the analysis can be carried out periodically.

The paper is organized as follows. In Section 2, this paper discusses the development of green campus in depth. Some well-known green campus projects will be introduced. Cloud computing as well as the definition, the architecture, and the applications of the Internet of Things are reviewed in Section 2 as well. This paper then discusses the construction of green campus within the IoT architecture. In Section 4, this paper shows the lab management system that we have developed within the IoT architecture. And finally, the conclusion and further works are given in Section 5.

2. Literature Review

2.1. The Development of Green Campus. New emerging technologies have changed human life styles dramatically. As people enjoy advanced and smart lives, ironically, our earth is facing a major crisis that may bring disasters to human lives as well. Figure 1 shows the carbon emission records from January 1955 to January 2013. The concentration of atmospheric CO$_2$ was below 320 ppm in 1955. By June 2013, the number has increased by 25%. The data indicate how serious the earth has been polluted. In addition, more environmental crises such as global warming and climate disturbance; acid rain and soil erosion; ecosystem damage have got the attention across the world [9, 10].

Information technologies have been introduced to campus to, hopefully, yield new levels of institutional and instructional "productivity" and to reduce instructional costs at the same time [12]. However, the research revealed that educational institutions might have benefited from information technologies in the areas of content, curriculum, and pedagogy; the costs saved had not shown obvious achievement [12]. On the contrary, the budgets for the investments on information technologies have been increased. More computers, printers, and ICT equipment have been purchased. More environmental pollution issues have been raised as a consequence of the use of information technologies on campus. In other words, instead of investing more on physical facilities, the universities should search for other inexpensive solutions.

Scholars and experts have agreed that the knowledge of protecting the earth should be cultivated by educations. Universities should provide leadership for broader society [9] and institutions of higher learning have a special responsibility to address the continuing environmental crisis [9, 10]. In [9], the author specifically points out that one of the greatest opportunities and abilities to conserve energy was through facilities management on campus.

Educational institutions across the world, especially the higher education, have recognized that they are in a unique position to prevent the crisis from getting worse. Not only are the faculties realizing that they possess the intellectual capacity to address these issues, but also the institutions are putting a lot of efforts in the integration of all resources and effectively adopting new technologies to their missions to create a green environment.

2.2. Some Well-Known Examples. There are a number of well-known "green campus" examples.

Harvard University also believes universities should play the environmental stewardship. The way Harvard University contributes to protect the earth is by including the commitment to a greenhouse gas (GHG) reduction goal of a 30 percent by 2016. In addition, Harvard University also established green building standard to ensure all sustainable design [13].

The mission that the University of Pennsylvania promises is to develop plans to reduce the emissions of greenhouse gases. The climate action plan was launched in 2009. In the 2011 progress report, the record showed that total energy usage decreased by 9.5%. The overall carbon emissions per capita on campus remained the same despite the growth of campus [14].

Macquarie University in Australia is another example. Macquarie University was one of the greenest universities in Australia. In order to make Macquarie University greener, the goals are set to reduce the total energy consumption per year per EFTP (Equivalent Full Time Persons) by 15% from 2005 by 2014 and to reduce the total GHG emissions produced per year for campus operations per EFTP by 30% of 2005 emissions, and so forth [15]. The goals for green campus at the university of Copenhagen are to reduce energy consumption to a level in 2013 that is 20% below that of 2006; and the CO$_2$ emissions from energy consumption shall be reduced in 2013 to a level that is 20% below that of 2006; and at least 75% of all purchases via purchase agreements shall require sustainability [16].

In Taiwan, Y. S. Sun Green Building Research Center Located at the NCKU Li-Hsing Campus is Taiwan's first zero-carbon, energy-saving building. The building is very famous to people in Taiwan as "The Magic School of Green Technology." Embedded within The Magic School is the hope that its design principles can eventually be scaled to Taiwan's metropolitan centers [17]. The building was designed to use
“adequate techniques,” instead of “expensive techniques,” to achieve “quadruple benefit.” The aims are estimated to save 50% energy, to conserve 30% water, and to reduce 30% carbon emission. It is also expected that the building will be utilized for one hundred years [18]. The building started operation in January 2011, and in six months, the accumulated Energy Usage Intensity (EUI) was 19.3 kWh/m². The figure was far less than Taiwan’s medium and low intensity office buildings, which consume 125 kWh/m² per year in average [18]. The existence of “The Magic School of Green Technology” will be a model for all other universities in Taiwan.

However, in the review of the outstanding green campus examples, we noticed that most action plans that the universities initiated focused on the design of green buildings, environment, or the purchase of energy-saving facilities. Information technologies were rarely, if not entirely, applied or considered in the plans. In fact, contemporary information technologies may contribute a lot in energy saving or in the protection of the environment if they are used smartly. The IoT is one of the smart solutions.

2.3. The Internet of Things. The concept and the realization of the “Internet of Things” make the world truly ubiquitous since the IoT radically changes the view of the “Internet” by embracing every physical object into network [4, 19]. The communications could take place not only between things but also between people and their environment in the IoT [6]. With the combination of the Internet, the cloud services, the near-field communications, real time localization, and embedded sensors, we can transform all objects into smart objects so that all components can understand and react to their environment [5]. The new concept of IoT will tie the Internet of information and services together [6] and as a result, more data, more information, and the knowledge will be generated and used.

The term “Internet of Things” has become very popular in recent years. There are books to teach or to discuss various subjects about the IoT. International conferences open up sessions for scholars and specialists to exchange their ideas, opinions, and experiences regarding the development or the applications of the IoTs. And finally in 2009, even the EU Commission realized the importance of the revolution of the Internet and initiated an IoT action plan [20].

In [21], it is suggested that an IoT must be Internet-oriented (middleware), things oriented (sensors), and semantic oriented (knowledge). Based on the assertions, [4] proposed that the architecture of an IoT actually contains three segments which are the hardware segment, the middleware segment, and the presentation segment. The hardware segment mainly refers to the connection of sensors or any embedded communication hardware. The middleware segment usually refers to cloud environment which is responsible for data storage, computation, and data analytics. The presentation segment, on the other hand, visualizes the result of data analytics or interprets the data in an easy and understandable format. Moreover, an IoT must possess the capabilities of communication and cooperation, addressability, identification, sensing, actuation, embedded information processing, localization, and user interfaces [19].

At the hardware segment, wireless sensor network is expected to be a key technology for various IoT applications such as home automation [22] and energy saving [23]. The sensor devices in the wireless sensor network work as the communicate node and will communicate to other devices wirelessly [24]. The sensor device also carries out its designated duty to collect data and send data to data center. Therefore, communication and measurement are the two major functions of a wireless sensor network [24]. Sensors can be deployed randomly and densely with much less costs in a wireless sensor network environment. All the conditions are monitored at all times. Therefore, it is believed that the construction of a green campus based on the IoT concept is more advanced than merely purchasing the energy-saving facilities.

ZigBee is the name of a standard that specifies the application layer of a wireless network in a small area with a low communication rate [25]. Previous researches and projects have shown that ZigBee sensor networks are suitable for applications in many different areas.

2.4. Cloud Computing. Earlier sensing network applications for environmental monitoring were mostly event-driven [26]. The data were collected upon the occurrence of the instance. Wireless sensor network provides real time monitoring opportunities. As a result, more space is required to store the data and smart tools are mandatory in order to analyze the data. Cloud computing is recognized as the best solution [27].

The major function of cloud computing is the delivery of services. It is not new to consider the pursuit of “service” as the entire and sole philosophy in the adoption of new technology. Clustering computing, grid computing, and service oriented architectures are the three famous examples that have seamlessly combined technologies with business flow. Cloud computing is similar to the aforementioned concepts but with three unique characteristics, which include virtual, dynamic provision on demand, and negotiation. Therefore, in the literature, cloud computing is defined as “offering hardware and software resources as services across a parallel and distributed system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned” [28, 29].

Cloud services are classified into four categories.

(i) Infrastructure as a service (IaaS): main services include the provision of virtual hardware, network, storage, computing power, and so forth. The clients include IT managers or software developers. Amazon S3 (simple storage service) and EC2 (elastic compute) are the two well-known services in the category.

(ii) Software as a service (SaaS): SaaS represents a new concept of “software on demand.” The software refers to application systems that can be activated directly on the internet. For example, the customer relationship management system provided by Salesforce.com is commonly adopted by businesses.

(iii) Platform as a service (PaaS): PaaS delivers a service oriented platform. The whole process in the software development life cycle (i.e., design, test, execution,
and deployment) would be provisioned as an integrated service over the Internet. Services in this category include the APP engine from Google and Azure from Microsoft. The software developers are possibly the major clients in this category.

(iv) Database as a service (DaaS): DaaS, such as the SSDS of Amazon, moves the traditional database features, including the definition of data and the storage and retrieving of data, over to the network. The services protect clients from tracking long timing transactions or assist with the maintenance of the integrity of the data. Software developers may be the major clients.

Cloud services promise users no longer being confined to limited space, time, or the compatibility of computers [30]. To adopt existing services from the Internet will minimize the expenditures spent on the information facilities and management. The pay-by-use mechanism will rationalize the market of intelligent property. Furthermore, with all services in cyber space, businesses or users will have more flexibility and options in search of the best alternatives and hence save more preprocess time. The new technology may guarantee the leverage of acceptance of users and smooth the introduction of new systems to the users as well. The users will always be updated with the new version and will not be bothered by copyright issues. For the enterprises, the management of documents, the cooperation, and the coordination within the organization will be easier.

According to the definition, in the cloud paradigm, there are many distributed systems. In many cases, the distributed architecture consists of wireless sensor networks which are responsible for sensing data. Cloud computing usually plays an important role in this kind of architecture since wireless sensor networks are limited in their processing power, battery life, and communication speed, while cloud computing is known for having powerful computational and processing capacity and the communication speed is much faster as well [31]. Cloud computing is also believed the paradigm for delivering services in the realization of IoT environment [4].

Previous researches have proved that the merits and the performances of wireless sensor networks will be doubled when the architecture is combined with cloud environment [27, 32, 33]. Cloud environment is also more flexible to be migrated once the university wants to expand the object network and move toward building a smart campus with more smart applications.

3. Constructing Green Campus within IoT Architecture

To construct green campus within IoT architecture is exactly the same as running a business. The goals must be clear and a set of objectives should be established. The missions that will be achieved toward the vision are then to be carried out. Figure 2 shows the procedures of the construction of green campus within IoT architecture.

In addition to define the vision and objectives, [6] suggested that the issues that need to be addressed in IoT environment also include the transformation of everyday objects into smart objects, the plan of system architecture, the design and development of the systems, the integrated management, and human involvement.

In Figure 2, action plans that are related to the overall campus redesign should be proposed after vision and objectives are determined. For each action plan, all the related objects are transformed into smart objects. The system architecture is drawn and the system within the IoT is developed. All projects should be managed in an integrated view and the entire plan should be supported by all people in the organization. The involvement of the executive administration level is especially essential to sustain the project.

4. The Application of IoT on Campus-Lab Management

This research takes lab management to realize the architecture we have planned (as shown in Figure 2). The details are described below.

4.1. The Architecture. The first phase of our project is to set up an IoT in our computer labs. Following the steps to construct green campus within IoT architecture given in Section 2, the vision of this project is to efficiently control the use of the computers and air conditioners. Although the definite figures were not determined, the objectives of the project were to reduce the idle time of computers and to reduce the electricity costs. During the second step, every air conditioner was assigned an IP; the RFID as well as the ZigBee sensors were installed as well.

Based on the definition and the required elements defined before, Figure 3 shows the proposed architecture of part of our green campus within IoT. The system architecture consists of three major segments which are the hardware segment, the middleware segment, and the presentation segment.

The hardware segment mainly uses RFID to induce the students who are going to enter the computer labs. The system reads and saves the student ID. The IoT is setup to connect the computers and the air conditioners in the lab. Every computer in the lab has its own IP, so does the conditioner.
The temperature sensor module of ZigBee is used to monitor the temperatures in the lab.

In our work, a ZigBee network is constructed with ZB2530-01 devices from Dmatek Limited Taiwan. The specifications of the devices are as follows:

(i) radio frequency: 2.4 GHz band;
(ii) data rate: 38400 bit/s (max to 115200);
(iii) distances: 10 meters;
(iv) number of channels: the device is able to search up to 32 satellite channels;
(v) 10 I/O ports.

The emitter of the temperature sensor is shown in Figure 4. The emitter device is in the lab and connects to the IoT. The emitter senses the temperature of a lab and sends out the signal continuously. The receiver device of the temperature sensor is shown in Figure 5. The receiver connects to a PC via a USB interface. The receiver device will collect all the data sent by the emitter.

There is a cloud server in the middleware segment. The server owns the database, all the applications, and the tools. All the data collected, including the data read by RFID, the status of each of the computers in the lab, and the temperatures of the computer room, are sent to the cloud server. The data then are computed, analyzed, and controlled.

At the presentation segment, two major systems are provided to students and controller of the general affairs office. The students may use computers or any mobile devices to connect to the system and retrieve the usage status of the selected computer lab. This will allow the students to make proper decisions if they still want to go to the labs which might not have seats available.

The second system is at the general affairs office site. The status of the usage of computer labs as well as the changes of the temperatures of each lab are analyzed and updated every 30 minutes. The results on the screen allow the controller to control the air conditioners in the lab. In addition, a network alert system will track the usage of each computer so that
the computer will be shut down once it has been idle for a designated time.

4.2. The Introduction of the System the Internet of Things.
The prototype of the computer labs control system has been developed in this research. Figure 6 through Figure 12 demonstrate how the system operates.

On the lab side, the system tracks the usage of every computer lab at all times (Figure 6). The system gives the information of computers that is occupied, available, or malfunctioning.

Once a student enters a lab, the RFID reader reads his or her ID, the system will assign an available seat to the student (Figure 7), and the status of that seat will be marked with green color to indicate that the seat is “in use” (Figure 8).

Each student is allowed one hour to use the computer. A warning message will be given and the computer will be shut down automatically by the system (Figure 9) if the computer has been occupied for more than one hour or if the system detects that the computer has been idle for some time.

A system control dashboard is provided to the controller in the general affairs office. Four functions are available at the present system. The first tab shows the same labs information as the students can see. The second tab (Figure 10) gives the current temperature of a selected lab. By clicking the on/off button, the controller is able to turn on or turn off the air conditioners in the lab.

The third page shows the real time average temperatures of all computer labs (Figure 11). In every 30 minutes, this system records the average temperatures of all computer labs. The records are shown on the fourth page of the dashboard (Figure 12). The temperatures that are below 26 are marked with green. If the temperatures are higher than 30, red colors appear to show the warning. Yellow colors are shown if the temperatures are in between.

Together with the information of the status of computer labs, air conditioners, and the changes of the temperatures as well as the statistics of the temperatures in the labs, the controller can make decisions easily. The decisions such as how many labs should open to students, when and which air conditioner should be turned on, and finally, the controller can also monitor if the computers are used properly and efficiently.

5. Conclusion

This research appeals to the responsibilities the universities should bear in the issues of environmental protection. The performance that information technologies may contribute to the sustainability of universities is emphasized in the
Figure 10: The status of each of the air conditions in the computer lab.

Figure 11: The average temperature measured by ZigBee temperature sensor in the computer labs.

Figure 12: The changes of the temperatures in the computer labs.

paper. This research also proposes the steps as well as the architecture of how to construct a green campus by utilizing the advanced technologies smartly.

Furthermore, this research adopts the concept of the “Internet of Things” to construct the green campus which will realize the idea of energy saving. The objects of our work include the computers and air conditioners. RFID s and the ZigBee device with temperature module are used to build up the wireless sensor network.

The contributions delivered by the system we have developed include the following.

(i) The computer labs can be managed efficiently. More labs will be open only when the demand is increasing.

(ii) The use of the computers will be monitored at all times. This mechanism decreases the number of idle power-on computers.

(iii) The air conditioners will be turned on only when the temperatures reach a preset level. As a result, more energy will be saved.

(iv) Combing the wireless sensor network and cloud computing, the architecture we proposed will collect real time data from sensor. The results of the analysis of data will be sent to the appropriate party so that proper actions can be taken in time.

(v) The architecture we proposed allows users to connect to the system with any mobile device in any place.

The idea of constructing a green campus is just the first step in our institution. This research shows how to build up the IoT to manage computer labs. The performance of the current project will be examined continuously.

The next phase is to build the IoT around the whole campus and, thereafter, the integration of all the subsystems will be carried out. The energy-saving program has full support from the administration office. However, the idea of “green” and “sustainability” has not yet been planted in everybody’s mind. In other words, more educating programs need to be arranged to broadcast the concept of “green campus.” Hopefully, as a higher educational institution, we can show some leadership and demonstrate our responsibilities to the society.

Conflict of Interests

There is no conflict of interests regarding the publication of this paper.

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References

[1] A. Gluhak, S. Krco, M. Nati, D. Pfisterer, N. Mitton, and T. Razafindralambo, “A survey on facilities for experimental internet of things research,” IEEE Communications Magazine, vol. 49, no. 11, pp. 58–67, 2011.

[2] M. Zorzi, A. Gluhak, S. Lange, and A. Bassi, “From today’s intranet of things to a future internet of things: a wireless- and mobility-related view,” IEEE Wireless Communications, vol. 17, no. 6, pp. 44–51, 2010.

[3] Libelium, “50 Sensor Applications for a Smarter World,” 2013, http://www.libelium.com/top_50_iot_sensor_applications_ranking.
[4] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, “Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions,” FGCS, http://www.cloudbus.org/papers/Internet-of-Things-Vision-Future2012.pdf.

[5] G. Kortuem, F. Kawasar, D. Fition, and V. Sundramoorthy, “Smart objects as building blocks for the internet of things,” IEEE Internet Computing, vol. 14, no. 1, pp. 44–51, 2010.

[6] O. Vermesan, P. Friess, P. Guillemin et al., “Internet of things strategic research roadmap,” in IoT Cluster Strategic Research Agenda, chapter 2, pp. 10–52, 2011.

[7] B. Singh and D. K. Lobiya, “A novel energy-aware cluster head selection based on particle swarm optimization for wireless sensor networks,” Human-Centric Computing and Information Sciences, vol. 2, no. 13, 18 pages, 2012.

[8] M. S. Obaidat, S. K. Dhurander, D. Gupta, N. Gupta, and A. Asthana, “Dynamic energy efficient and secure routing protocol for wireless sensor networks in urban environments,” Journal of Information Processing Systems, vol. 6, no. 3, pp. 269–294, 2010.

[9] L. Sharp, “Green campuses: the road from little victories to systemic transformation,” International Journal of Sustainability in Higher Education, vol. 3, no. 2, pp. 128–145, 2002.

[10] W. Simpson, “Energy sustainability and the green campus,” Planning for Higher Education, vol. 31, no. 3, pp. 150–158, 2003.

[11] Earth’s, 2013, http://co2now.org/.

[12] K. C. Green and S. W. Gilbert, “Great expectations,” Change, vol. 27, no. 2, pp. 8–19, 1995.

[13] Sustainability at Harvard, “Harvard’s Commitments to Sustainability,” 2013, http://www.green.harvard.edu/commitments.

[14] University of Pennsylvania, "Climate Action Plan Progress Report 2011," http://www.upenn.edu/sustainability/sites/default/files/PENN_2011_Climate_Action_Plan_Progress_Report.pdf.

[15] Macquarie University, “Sustainability strategy, target 2014,” 2013, http://www.mq.edu.au/about_us/strategic_initiatives/sustainability.

[16] Green Campus at the University of Copenhagen, 2013, http://climate.ku.dk/green_campus/goals/.

[17] B. Fox and J. D’Angola, Taiwan’s Magic School, 2011, http://thediplomat.com/china-power/taiwans-magic-green-school/.

[18] The Magic School of Green Technologies, 2009, http://www.msgt.org.tw/about.php?Type=1&menu=about_class&pic=1&list=1.

[19] F. Mattern and C. Floerkemeier, "From the internet of computers to the internet of things," in From Active Data Management to Event-Based Systems and More, K. Sachs, I. Petrov, and P. Guerrero, Eds., vol. 6462 of Lecture Notes in Computer Science, pp. 242–259, Buchmann Festschrift, 2010.

[20] European Commission, "Internet of Things An action plan for Europe," COM, 278, 2009, http://eur-lex.europa.eu/LexUriServ/site/en/com/2009/com2009_0278en01.pdf.

[21] L. Atzori, A. Iera, and G. Morabito, "The internet of things: a survey," Computer Networks, vol. 54, no. 15, pp. 2787–2805, 2010.

[22] ZigBee Alliance, "ZigBee Home Automation Public Application Profile," 2007, http://www.zigbee.org/Products/TechnicalDocumentsDownload/tabid/237/Default.aspx.

[23] ZigBee Alliance, "The Choice for Energy Management and Efficiency,” ZigBee White Paper, 2007, http://www.zigbee.org/Products/TechnicalDocumentsDownload/tabid/237/Default.aspx.

[24] M. Terada, “Application of zigbee sensor network to data acquisition and monitoring,” Measurement Science Review, vol. 9, no. 6, pp. 183–186, 2009.

[25] ZigBee Alliance, ZigBee Specification, 2006, http://www.zigbee.org/Products/TechnicalDocumentsDownload/tabid/237/Default.aspx.

[26] P. Morreale, F. Qi, and P. Croft, "A green wireless sensor network for environmental monitoring and risk identification," International Journal of Sensor Networks, vol. 10, no. 1-2, pp. 73–82, 2011.

[27] S. K. Dash, S. Mohapatra, and P. K. Pattanaik, "A survey on applications of wireless sensor networking using cloud computing," International Journal of Computer Science & Emerging Technologies, vol. 1, no. 4, pp. 50–55, 2010.

[28] S. Yang, "The Issues to Think about Before Entering the Cloud Services Market," 2009, http://www.zdnet.com.tw.

[29] H. R. Motahari Nezhad, B. Stephenson, S. Singhal, and M. Castellanos, "Virtual business operating environment in the cloud: conceptual architecture and challenges," Lecture Notes in Computer Science, vol. 5829, pp. 501–514, 2009.

[30] Y. Pan and J. Zhang, “Parallel programming on cloud computing platforms—challenges and solutions,” Journal of Convergence, vol. 3, no. 4, pp. 23–28, 2012.

[31] W. Kurschel and W. Beer, “Combining cloud computing and wireless sensor networks,” in Proceedings of the 11th International Conference on Information Integration and Web-based Applications & Services (iiWAS ’09), pp. 512–518, 2009.

[32] R. Piyare, P. Sun, M. Se Yeong et al., “Integrating wireless sensor network into cloud services for real-time data collection,” in Proceedings of the International Conference on ICT Convergence (ICTC ’13), pp. 752–756, Jeju, Republic of Korea, 2013.

[33] P. Zhang, Z. Yan, and H. Sun, “A novel architecture based on cloud computing for wireless sensor network,” in Proceedings of the 2nd International Conference on Computer Science and Electronics Engineering (ICCSEE ’13), pp. 0472–0475, Hangzhou, China, 2013.
