GREEN INTERNET OF THINGS IN HEALTHCARE APPLICATIONS AND AGRICULTURE: A SURVEY

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ABSTRACT

The presentation of the two trending and popular technologies, Cloud Computing (CC) and the Internet of Things (IoT) are current hot discussions in the field of agriculture and healthcare applications. Driven by achieving a sustainable world, this paper discusses various technologies and problems regarding green cloud computing and green Internet of Things, further improves the discussion with the reduction in energy consumption of the two techniques (CC and IoT) combination in agriculture and healthcare systems. Green computing introduction first and later focuses on the recent works done regarding the two emerging technologies in both agriculture and healthcare cases. Moreover, this paper contributes by presenting Green IoT Agriculture and Healthcare Application using sensor-cloud integration model. At Outset, lists out the advantages, challenges, and future research directions related to green application design. Our research aims to make green area broad and contribution to sustainable application world.

Keyword: Green, IoT (Internet of Things), Cloud Computing, Agriculture application, Healthcare application, Sensor-Cloud, RFID.

1. INTRODUCTION

Today's world comprises of several "things/objects". As the internet of things (IoT) one of the smart world enabler, targets to connect various objects (*e.g.*, mobile phones, computers, cars, and appliances) with unique addresses, to enable them interacts with each other and with the world. An increasing number of physical objects are being connected to the Internet at an extraordinary rate realizing the idea of the Internet of Things (IoT). The applications include transportation, agriculture, healthcare, industrial automation, and emergency response to natural and man-made disasters where human decision making is difficult. Among the package of applications enabled by the Internet of Things (IoT), agriculture and healthcare are cases for this research. Networked sensors, either worn on the body or embedded in our living environments, make possible the gathering of rich information indicative of our physical and mental health. The IoT enables physical objects to see, hear, think and perform jobs by having them "talk" together, to share information and to coordinate decisions. Eventually, all aspects regarding people's cyber, physical, social and mental world will be interconnected and intelligent in smart world.

Cloud Computing is one of the very popular developing technologies, a new and promising pattern which delivers computing as a utility. It provides software usage, data access, data storage services and other computation through the Internet. The customers are charged only for as much as they have used. So it is cost effective. The main advantage of Cloud Computing is that users can get their computing and data storage services on demand without much investment in the computing infrastructure.

Sensor-cloud architecture theoretically integrates cloud infrastructure with sensor networks, thereby enabling real-time monitoring of data-intensive applications that are typically spread over geographically distributed locations. Sensor networks are used for set up health-related applications such as monitoring patients with blood sugar, blood pressure, and sleep-activity pattern monitoring. In such application, the health center takes necessary decisions according to the sensed data from patients. It is a difficult task to follow the health-status remotely, when a patient moves randomly. So, an efficient computing mechanism is necessary to monitor the health-status of patients when they are mobile. The data-intensive, time-varying requirements of the sensor networks can benefit from the intricate integration of the computational and storage resources offered by the cloud computing applications for big-data processing. Thus, sensor-cloud platforms are increasingly become popular. This paper presents a green IoT agriculture and healthcare system using sensor-cloud integration model.

The IoT transforms these objects from being outdated too smart by exploiting its underlying technologies such as ubiquitous and pervasive computing, embedded devices, communication technologies, sensor networks, Internet protocols and applications. Although the Internet of Things (IoT) and the cloud computing are two very different technologies that are both already part of our life. IoT is generally characterized by real world small things, widely distributed, with limited storage and processing capacity, which involve concerns regarding reliability, performance, security, and privacy. On the other hand, cloud computing has virtually unlimited capabilities in terms of storage and processing power, is a much more mature technology, and has most of the IoT issues partially solved. Thus, any application in which cloud and IoT are two complementary technologies merged together is expected to disrupt both current and future internet.

This paper organised into sections such as: In Section 3, we present proposed architecture, requirements, green IoT application to proposed architecture, and also ICT enabled green components such as green RFID, green WSN, green CC, green M2M, and green DC infrastructure. Finally conclusion, future directions are presented in section 4.

2. FRAMEWORKS FOR GREEN IOT AGRICULTURE AND HEALTHCARE APPLICATIONS

In this section, we discuss the basic concepts of ICT enabled green IoT technologies components and also present the architecture using sensor-cloud integration concept.

2.1 Architecture

Sensor-cloud computing is proposed as one of the enabling technologies for agriculture and healthcare monitoring system. Sensor-Cloud is a new model for CC that uses the physical sensors to gather its data and communicate all the sensor data into a CC infrastructure. It also controls sensor data efficiently, which is used for many monitoring applications. First we will see sensor-cloud definitions as below,

According to IntelliSys, “An infrastructure that allows truly pervasive computation using sensors as an interface between physical and cyber worlds, the data- compute clusters as the cyber backbone and the internet as the communication medium”.

According to MicroStrains’s Sensor-Cloud definition “it is a unique sensor data storage, visualization and remote management platform that leverage powerful cloud computing technologies to provide excellent data scalability, rapid visualization, and user programmable analysis. It is originally designed to support long-term deployments of MicroStrain wireless sensors, Sensor-Cloud now supports any web connected third party device, sensor, or sensor network through a simple OpenData API”.

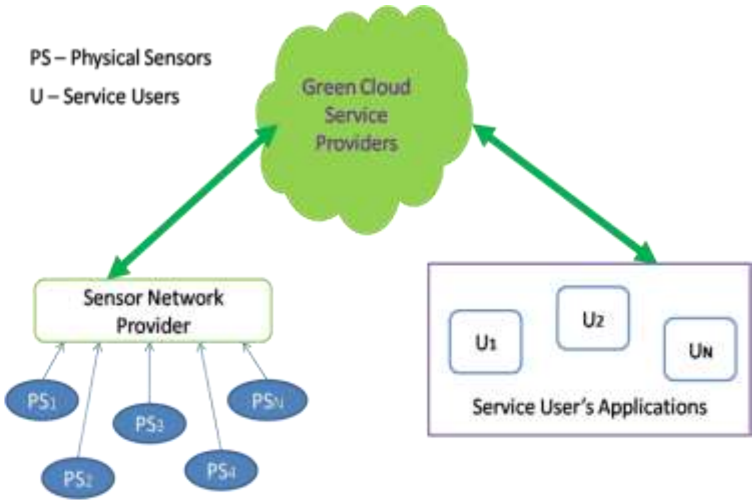

Figure 1. Green IoT Agriculture and Healthcare Applications Architecture

Attracting increasing interest from both academic and industrial communities, sensor- cloud is actually a new paradigm, motivated by complementing 1) the ubiquitous datasensing and data gathering capabilities of WSNs as well as 2) the powerful data storage and data processing abilities of CC. Precisely, the basic application model of sensor-cloud is to use the ubiquitous sensors or physical sensors, a number of easily available and most often wearable sensors like accelerometer sensors, proximity, ambient light and temperature sensors offered by the sensor network provider to collect different monitoring sensory data. The raw sensory data is further communicated to the cloud provided by the cloud service provider for storage and further data processing. After the cloud stores and processes that raw sensory data with data centers, the processed or valued sensory data are delivered to the service user’s applications on demand. In this full consequence, sensor network providers act as the data sources for cloud service providers. Service users are the data requesters for cloud service providers.

2.2 Applying Green Internet of Things (IoT)

Before discussing about green IoT, first we have to see various definitions related to IoT, and it is considered as the next wave in the era of computing is predicted to be outside the realm of traditional desktop. In line with this observation, a novel paradigm called Internet of Things rapidly gained ground in the last few years. IoT refers to “a world-wide network of interconnected objects uniquely addressable based on standard communication protocols" whose point of meeting is the Internet. The basic idea behind it is the pervasive presence around people of things, able to measure, infer, understand, and even modify the environment. IoT is fuelled by the recent advances of a variety of devices and communication technologies, but things included in IoT are not only complex devices such as mobile phones, but they also comprise everyday objects. These objects, acting as sensors or actuators, are able to interact with each other in order to reach a common goal.

Figure 2. Building Blocks of IoT

Identification plays a crucial role in naming and matching services with their demand. Examples of identification methods used for the IoT are electronic product codes (EPC), ubiquitous codes (uCode), *etc*. Sensing is for collecting various data from related objects and sending it to a database, data warehouse, data center, *etc*. The gathered data is further analysed to perform specifications based on required services. The sensors can be humidity sensors, temperature sensors, wearable sensing devices, mobile phones, *etc*. Communication technologies connect heterogeneous objects together to offer specific services. The communication protocols available for the IoT are: Wi-Fi, Bluetooth, IEEE 802.15.4, Z-wave, LTE-Advanced, Near Field Communication (NFC), ultra-wide bandwidth (UWB), *etc*.

About computation, the hardware processing units (*e.g.* microcontrollers, microprocessors, system on chips (SoCs), field programmable gate arrays (FPGAs)) and software applications perform this task. The services in IoT can be categorized into four classes: identity-related services, information aggregation services, collaborative-aware services and ubiquitous services. Identity related services lay the foundation for other types of services, since every application mapping real world objects into the virtual world needs to identify the objects first. Semantic means the ability to extract knowledge intelligently so as to provide the required services. This process usually includes: discovering resources, utilizing resources, modelling information, recognizing and analysing data. The commonly used semantic technologies are: resource description frameworks (RDF), web ontology language (OWL), *etc*.

- **Green IoT**

To enable a green IoT, the IoT should be distinguished by energy efficiency. Especially, since all devices in the agriculture and healthcare application world are supposed to be equipped with additional sensory and communication add-ons so that they can sense and communicate with each other, they will require more energy. In addition, driven by a rising interest and support from various organizations, the energy demand will further greatly increase. All these make green IoT which focuses on reducing the energy consumption of IoT a necessity, in terms of fulfilling the smart world with sustainability. Considering the energy efficiency as the key during the design and development of IoT, green IoT can be defined as below.

"The energy efficient procedures (hardware or software) adopted by IoT either to facilitate reducing the greenhouse effect of existing applications and services or to reduce the impact of greenhouse effect of IoT itself. In the earlier case, the use of IoT will help reduce the greenhouse effect, where as in the next case further optimization of IoT greenhouse footprint will be taken care. The entire life cycle of green IoT should focus on green design, green production, green utilization and finally green disposal/recycling to have no or very small impact on the environment."

3. COMPONENTS

In this section, we first see outline of ICT and enabling green technologies are discussed. ICT is an umbrella term that relates to any facility, technology, application regarding information and communication, enabling users to access, store, transmit, and manipulate a variety of information. We have listed them below, regarding identification, sensing, communication and computation which are IoT elements introduced in Section 3.

RFID (radio-frequency identification): A small electronic device that consists of a small chip and an antenna, automatically identifying and tracking tags attached to objects. **WSN (wireless sensor network)**: A network consisting of spatially distributed autonomous sensors that cooperatively monitor the physical or environmental conditions (*e.g.* temperature, sound, vibration, pressure, motion, *etc.*).

WPAN (wireless personal area network): A low-range wireless network for interconnecting devices centered on an individual person's workspace.

WBAN (wireless body area network): A wireless network consisting of wearable or portable computing devices (*e.g.* sensors, actuators) situated on or in the body.

HAN (home area network): A type of local area networks (LANs), connecting digital devices present inside or within the close vicinity of a home.

NAN (neighborhood area network): An offshoot of Wi-Fi hotspots and wireless local area networks (WLANs), enabling users to connect to the internet quickly and at very little expense.

M2M (machine-to-machine): A technology that allows both wireless and wired devices to communicate with other devices of the same type.

CC (cloud computing): A novel computing model for enabling convenient, on- demand network access to a shared pool of configurable resources (*e.g.* networks, servers, storage, applications, services). Integrating CC into a mobile environment, mobile cloud computing (MCC) can further offload much of the data processing and storage tasks from mobile devices (*e.g.* smartphones, tablets, *etc.*) to the cloud.

DC (data center): a repository (physical or virtual) for the storage, management, and dissemination of data and information.

Green RFID: RFID includes several RFID tags and a very small subset of tag readers. Enclosed in an adhesive sticker, the RFID tag is a small microchip attached to a radio (utilized for receiving and transmitting the signal), with a unique identifier. The purpose of RFID tags is storing information regarding the objects to which they are attached. The basic process is that the information flow is triggered by RFID tag readers through transmitting a query signal, followed with the responses of nearby RFID tags. Generally, the transmission range of RFID systems is very low (*i.e.* a few meters). Two kinds of RFID tags (*i.e.* active tags and passive tags) exist. Active tags have batteries powering the signal transmissions and increasing the transmission ranges, while the passive tags are without onboard batteries and need to harvest energy from the reader signal with the principle of induction.

Green Wireless Sensor Networks (WSN): A WSN usually consists of a certain number of sensor nodes and a base station (*i.e.* sink node). The sensor nodes are with low processing, limited power, and storage capacity, while the base station is very powerful. Sensor nodes equipped with multiple on-board sensors, take readings (*e.g.* temperature, humidity, acceleration, *etc.*) from the surroundings first. Then they cooperate with each other and deliver the sensory data to the base station in an ad hoc manner generally.

Green Cloud Computing (CC) : In CC, resources are treated as services, *i.e.*IaaS (Infrastructure as a Service), PaaS (Platform as a Service) and SaaS (Software as a Service). Based on users' demands, CC elastically offers various resources (*e.g.* high- performance computing resources and high-capacity storage) to users. Rather than owning and managing their own resources, users share a large and managed pool of resources, with convenient access. With growing applications moved to cloud, more resources need to be deployed and more power are consumed, resulting in more environmental issues and $CO2$ emissions.

Green Machine to Machine (M2M): In terms of M2M communications, massive M2M nodes which intelligently gather the monitored data are deployed in M2M domain. In network domain, the wired/wireless network relays the gathered data to the base station. The base station further supports various M2M applications over network in the application domain. Concerning green M2M, with the massive machines involved in M2M communications, it will consume a lot of energy, particularly in M2M domain. The following methods might be used to increase energy efficiency

Green Data Center (DC): The main job of DCs is to store, manage, process and disseminate various data and applications, created by users, things, systems, *etc*. Generally, dealing with various data and applications, DCs consume huge amounts of energy with high operational costs and large *CO*2 footprints. Furthermore, with the increasing generation of huge amounts of data by various pervasive and ubiquitous things or objects (*e.g*. mobile phones, sensors, *etc*.) on the way to smart world, the energy efficiency for DCs becomes more pressing.

4. CONCLUSION

In this paper, we had discussed about ubiquitous computing, requirements of truly ubiquitous applications and green computing. Later headed over with reviewing the technologies such as green ICT's enabling technologies, and then presented architecture using sensor-cloud computing integration along with listed out advantages of sensor-cloud integration. Sensor networks alone have some native challenges which can be undertaken by sensor-cloud infrastructures: 1) Data management 2) Resource utilization 3) High utility cost. The sensor-cloud infrastructure is a cost-effective approach, where the existing cloud platform can be used.

Finally, future directions observed related to architecture with the sensor-cloud convergence is featured such as: 1. Application designing should be approached from an overall system energy consumption perspective, concerning about satisfying service, good quality and performance; 2. Characteristics and usage requirements of different applications needs better understanding; 3. Cost issues, Sensor-Cloud service access requires both the sensor service provider and cloud service provider. Although, they have independent user's management, services management, modes and methods of payments and pricing.

References

1. L. Atzori, A. Iera and G. Morabito, "The Internet of Things: A survey", Comput. Netw., vol. 54, no. 15, **(2010)**, pp. 2787-2805.
2. C. Perera, C. H. Liu, S. Jayawardena and M. Chen, "A survey on Internet of Things from industrial market perspective", *IEEE Access*, vol. 2, **(2014)**, pp. 1660-1679.
3. L. Da Xu, W. He and S. Li, "Internet of Things in industries: A survey", *IEEE Trans. Ind. Informat*., vol. 10, no. 4, **(2014)**, pp. 2233-2243.
4. A. Al-Fuqaha, M.Guizani, M. Mohammadi, M. Aledhari and M. Ayyash, "Internet of things: A survey on enabling technologies, protocols, and applications", *Communications Surveys & Tutorials, IEEE*, vol. 17, no. 4, **(2015)**, pp.2347-2376.
5. C.Zhu, V.Leung,L.Shu andE. C. H Ngai, "Green Internet of Things for smart world", *Access, IEEE*, vol. 3, **(2015)**, pp.2151-2162.

6. M.Hassanalieragh, A.Page, T.Soyata, G.Sharma, M.Aktas, G.Mateos and S.Andreescu, "Health monitoring and management using internet-of-things (IoT) sensing with cloud-based processing: Opportunities and challenges", *In Services Computing (SCC), 2015 IEEE International Conference* on **(2015)**, pp. 285-292.
7. J.Zhou, T.Leppanen, E.Harjula, M. Ylianttila, T.Ojala, C.Yu andH.Jin, "Cloudthings: A common architecture for integrating the internet of things with cloud computing",in: CSCWD, *IEEE*, **(2013)**.
8. M.Weiser, "The computer for the 21st century. Pervasive Computing", *IEEE*, vol. 1, no.1, **(2002)**, pp.19-25.
9. http://www.koreaittimes.com/story/defining-perfect-ubiquitous-healthcare-information-system.
10. S.Murugesan, "Harnessing green IT: principles and practices", *IEEE IT Professional*, **(2008)**, pp. 24–33.
11. J.Gubbi, R.Buyya, S.Marusic andM.Palaniswami, "Internet of Things (IoT): A vision, architectural elements, and future directions", *Future Generation Computer Systems*, vol. 29, no.7, **(2013)**, pp.1645- 1660.
12. A, K.Evangelos,D. T.Nikolaos andC. B.Anthony, "Integrating RFIDs and Smart Objects into a Unified Internet of Things Architecture", *Advances in Internet of Things*, **(2011)**.
13. A.Botta, W.de Donato, V. Persico and A.Pescapé, "Integration of cloud computing and internet of things: a survey", *Future Generation Computer Systems*, vol. 56, **(2016)**, pp.684-700.
14. F. K.Shaikh, S. Zeadally and E.Exposito, "Enabling Technologies for Green Internet of Things", **(2015)**.
15. A. Juels, "RFID security and privacy: A research survey", IEEE J. Sel.Areas Commun., vol. 24, no. 2, Feb. **(2006)**, pp. 381-394.
16. C. Zhu, L. Shu, T. Hara, L.Wang, S. Nishio and L. T. Yang, "A survey on communication and data management issues in mobile sensor networks", *Wireless Commun. Mobile Comput*., vol. 14, no. 1, Jan. **(2014)**, pp. 19-36.
17. J. A. Gutierrez, M. Naeve, E. Callaway, M. Bourgeois, V. Mitter and B. Heile, IEEE 802.15.4: "A developing standard for low-power low-cost wireless personal area networks", IEEE Netw., vol. 15, no. 5, Sep./Oct. **(2001)**, pp. 12-19.
18. S.-H. Han and S. K. Park, "Performance analysis of wireless body area network in indoor off-body communication", IEEE Trans. Consum.Electron. vol. 57, no. 2, May **(2011)**, pp. 335-338.
19. U. Saif, D. Gordon and D. J. Greaves, "Internet access to a home area network", IEEE Internet Comput., vol. 5, no. 1, Jan./Feb. **(2001)**, pp. 54-63.
20. C. P. Mediwaththe, E. R. Stephens, D. B. Smith and A. Mahanti, "A dynamic game for electricity load management in neighborhood area networks," IEEE Trans. Smart Grid.
21. M. Weyrich, J.-P. Schmidt and C. Ebert, ``Machine-to-machine communication," IEEE Softw., vol. 31, no. 4, Jul./Aug. **(2014)**, pp. 19-23.
22. M.Dayarathna, Y. Wen and R.Fan, "Data Center Energy Consumption Modeling: A Survey".
23. V. Namboodiri, and L.Gao,"Energy-aware tag anticollision protocols for RFID systems. Mobile Computing", IEEE Transactions on vol. 9, no.1, **(2010)**, pp.44-59.
24. T. Li, S. S.Wu, S. Chen and M. C. K. Yang, "Generalized energy-efficient algorithms for the RFID estimation problem," IEEE/ACM Trans. Netw., vol. 20, no. 6, **(2012)**, pp. 1978-1990.
25. D. K. Klair, K.-W. Chin and R. Raad, "A survey and tutorial of RFID anti-collision protocols," IEEE Commun. Surveys Tuts., vol. 12, no. 3, **(2010)**, pp. 400-421.
26. G. Anastasi, M. Conti, M. Di Francesco and A. Passarella, "Energy conservation in wireless sensor networks: A survey," Ad Hoc Netw., vol. 7, no. 3, **(2009)**, pp. 537-568.
27. T. Rault, A. Bouabdallah, and Y. Challal, "Energy efficiency in wireless sensor networks: A top-down survey," Comput. Netw., vol. 67, **(2014)**, pp. 104-122.
28. F. Farahnakian"Using ant colony system to consolidate VMs for green cloud computing," IEEE Trans. Services Comput., vol. 8, no. 2, **(2015)**,pp. 187-198,.
29. C.H. Chang, R. Y. Chang and H.-Y. Hsieh, "High-fidelity energy-efficient machine-to-machine communication", in Proc. IEEE 25th Annu.Int. Symp. Pers., Indoor, Mobile Radio Commun., **(2014)**, pp. 91-96.
30. J. Shuja, "Survey of techniques and architectures for designing energy-efficient data centers", IEEE Syst. J. **(2014)**.
31. W. Song, Z. Xiao, Q. Chen and H. Luo, "Adaptive resource provisioning for the cloud using online bin packing", IEEE Trans. Comput., vol. 63, no. 11, **(2014)**, pp. 2647-2660.