Green IoT Agriculture and Healthcare Application (GAHA)

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Abstract

The application 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. Motivated by achieving a sustainable world, this paper discusses various technologies and issues 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. The history and concept of the hot green information and communications technologies (ICT's) which are enabling green IoT will be discussed. Green computing introduction first and later focuses on the recent works done regarding the two emerging technologies in both agriculture and healthcare cases. Furthermore, this paper contributes by presenting Green IoT Agriculture and Healthcare Application (GAHA) using sensor-cloud integration model. Finally, 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

1. Introduction

Today's world consists of several "things/objects". As the internet of things (IoT) [1]-[4], 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. A growing number of physical objects are being connected to the Internet at an unprecedented 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 bundle 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 [6]. 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. As the later stage in human history, smart world is receiving numerous attentions from academia, industry, government *etc.* Further, green IoT targets at a sustainable smart world, by reducing the energy consumption of IoT[5].

Cloud Computing is one of the very popular emerging technologies, a new and promising paradigm which delivers computing as a utility [1]. It provides software usage, data access, data storage services and other computation through the Internet and facilitates customers to rent resources based on the pay-as-you-go model. The customers

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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. According to statistics given by Mark Hachman [46], all data centers of world consumed 30 billion watts of electricity in 2012 that is equivalent to the output of 30 nuclear power plants. The electricity that can power 5 million households for 1 year is required for cooling of these servers and data center in 1 year. So we have to search new ways to optimize the power requirement of these data centers (cloud). Green Computing is defined as the environmentally sustainable computing. It refers to the attempts to maximize the use of power consumption and energy efficiency and to minimize the cost and CO_2 emission.

Sensor-cloud architecture conceptually integrates cloud infrastructure with sensor networks, thereby enabling real-time monitoring of data-intensive applications that are typically spread over geographically distributed locations [47]. Sensor networks are popularly used for deploying health-related applications such as monitoring patients with blood sugar, blood pressure, and sleep-activity pattern monitoring [44],[48]. In such application, the health center takes necessary decisions according to the sensed data from patients. It is a difficult task to monitor 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 traditional too smart by exploiting its underlying technologies such as ubiquitous and pervasive computing, embedded devices, communication technologies, sensor networks, Internet protocols and applications [4]. 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 [7].

This paper organised into sections such as: Section 2 provides an introduction to ubiquitous computing, requirements for truly ubiquitous application and green computing brief introduction. In Section 3, we present proposed architecture, requirements, green IoT application to proposed architecture, andalso ICT enabled green components such as green RFID, green WSN, green CC, green M2M, and green DC for GAHA infrastructure. Finally conclusion, future directions are presented in section 4.

2. Related Work and Research Motivation

2.1 Ubiquitous Computing

Mark D. Weiser [8], the father of ubiquitous computing, stated it as "it represents a powerful shift in computation, where people live, work, and play in a seamlessly interweaving computing environment. Ubiquitous computing postulates a world where people are surrounded by computing devices and a computing infrastructure that supports us in everything we do."

In ubiquitous computing, individuals will be surrounded by many networked, spontaneously yet tightly cooperating computers, some of them worn or carried, some of them encountered on the move, many of them serving dedicated purposes as part of

physical objects, all of them used in an intuitive, hardly noticeable way with limited attention. In other words, ubiquitous computing will truly bring about the era of many computers surrounding a single user and become a transparent part of the physical environment, and its components will be distributed at all scales throughout everyday life and can generally be turned to distinctly quotidian ends. There are four essential components to ubiquitous computing: wearable devices, customizable sensor nodes, networked appliances, smart labels. To achieve ubiquitous service, there are so-called five goals of ubiquity as Availability, Transparency, Seamlessness, Awareness, and Trustworthiness. Viewing a ubiquitous service from the viewpoint of ubiquitous computing, we shall need the following five criteria (S.C.A.L.E.); Scalability, Connectivity, Adaptability, Liability, Ease-of-use [8-9].

2.2 Truly Ubiquitous Agriculture and Healthcare Application Requirements

According to [9], the Ubiquitous application has three objectives, which are to reduce time loss due to lag, reduce the medium cost, and reduce inaccuracy in traditional medical flow. Lag is the time required for printing and sending paper or for human-based transmission of information which causes delays that may represent a major reason for revenue loss. A reduction in lag would reduce the gap between when data is recorded in a system and when it is available for information processing.

In addition, ubiquitous agriculture and healthcare consumers will send out data from various sources receive real-time information, knowledge, and relevant expertise and search out relevant and useful information. If the above-mentioned criteria are satisfied, the application will become truly ubiquitous. It will be a system that is embedded, performing one or a few dedicated functions. It will be pervasive, connecting devices, and embedded in such a way that the connectivity is unobtrusive and always available. It will be context-aware, linking changes in the environment with computer systems. It will be mobile, using technology while moving. It will be wearable, using devices while the user's hands, voice, eyes or attention are actively engaged with the physical environment. It will be sentient, perceiving its environment and reacting accordingly. And it will be ambient, working in concert to support people in carrying out everyday life activities, tasks and rituals in an easy, natural way using information and intelligence that is hidden in the network connecting these devices.

2.3 Green Computing:

Green computing, Green ICTas per IFG International Federation of Green ICT and IFG Standard, green IT, or ICT sustainability, is the study and practice of environmentally sustainable computing or IT. In [10], Murugesan defines the Green IT "is the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated sub systems such as monitors, printers, storage devices, and networking and communications systems efficiently and effectively with minimal or no impact on the environment". Also, lists out the following four complementary paths along to comprehensively and effectively address the environmental effects of computing should be addressed for green computing road:

1. **Green Use**: Reducing the energy consumption of computers and other information systems as well as using them in an environmentally sound manner.
2. **Green Disposal**: Refurbishing and reusing old computers and recycling unwanted computers and other electronic equipment.
3. **Green Design**: Designing energy efficient and environmentally sound components, computers, and servers and cooling equipment's.
4. **Green Manufacturing**: Manufacturing electronic components, computers and other associated sub systems with minimal impact or no impact on the environment.

Green computing spans a number of focus areas and activities, including design for environmental sustainability, energy-efficient computing, power management, data center design, layout, and location, server virtualization, responsible disposal and recycling, regulatory compliance, green metrics, assessment tools, and methodology, environment-related risk mitigation, use of renewable energy sources and eco-labelling of it products.

3. Frameworks for Green IoT Agriculture and Healthcare Applications (GAHA)

Till here, we had our set focus on discussing ubiquitous computing, requirements to achieve truly ubiquitous application and green computing fundamentals in order to relate them to GAHA. In this section, we discuss the basic concepts of ICT enabled green IoT technologies components related to GAHA and also present the architecture of GAHA using sensor-cloud integration concept.

3.1 GAHA Architecture

Sensor-cloud computing is envisioned 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 [42], "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"[44].

According to MicroStrains's Sensor-Cloud definition "it is a unique sensor data storage, visualization and remote management platform that leverage [sic] 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" [43].
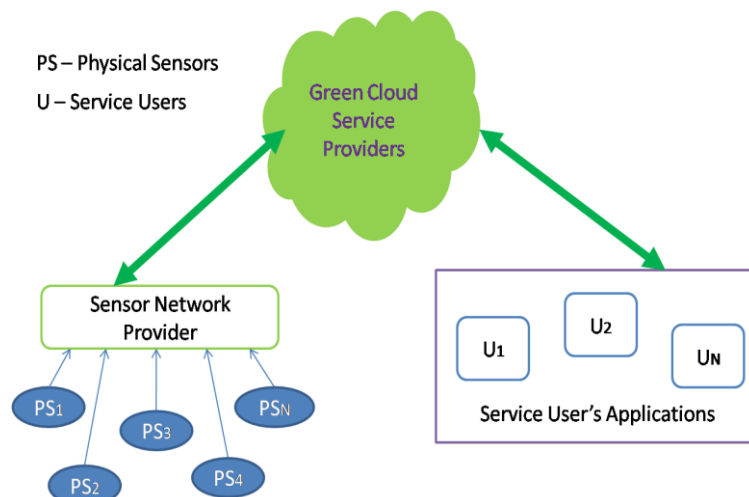

Figure 2. Green IoT Agriculture and Healthcare Applications (GAHA) Architecture

Attracting increasing interest from both academic and industrial communities, sensor-cloud[44] is actually a new paradigm, motivated by complementing 1) the ubiquitous data

sensing 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 [45] 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 scenario, sensor network providers act as the data sources for cloud service providers. Service users are the data requesters for cloud service providers.

With sensor-cloud integration, there are many favorable advantages [44], benefiting the users and the WSN as well as the cloud such as: Users can have access to their required sensory data from cloud anytime and anywhere if there is network connection, instead of being stick to their desks. The utility of WSN can be increased, by enabling it to serve multiple applications. The services cloud provides can be greatly enriched, by being able to offer the services that WSN provides (e.g., agriculture and healthcare monitoring in this case). Specifically, enhancing the performance (e.g., data processing speed, response time, visualization) of WSN with immense storage and processing capability of cloud, analytical results have shown that sensor-cloud could out perform a traditional WSN, by increasing the sensor's lifetime by 3.25% and decreasing the energy consumption by 36.68%. All these are very desirable for smart world and green GUHS.

3.2 GAHA Requirements

We listed the below general green ICT requirements for GAHA architecture and briefly summarizes them as following:

1) **Turn off facilities that are not needed:** If the facilities are always working, it will consume much energy. However, if the facilities are only turned on when necessary, the energy consumption will be reduced. For example, sleep scheduling [35] is one of the widely used techniques for saving the energy consumption in WSNs, by making sensor nodes dynamically awake and asleep.
2) **Send only data that are needed:** Data (*e.g.* large sized multimedia data) transmission consumes quite a lot of energy consumption. Sending the data that are only needed by users, can significantly save the energy consumption. Predictive data delivery based on user behavior analysis, is one possible method to provide only required data to users.
3) **Minimize length of data path:** This is also a straight forward method to reduce energy consumption. Routing schemes (*e.g.* [36]) considering the length of chosen data path could be energy-efficient. In addition, network working mechanisms (*e.g.* [37]) which cater to the routing requirement are also potential ways to achieve much shorter data path.
4) **Minimize length of wireless data path:** Regarding minimizing length of wireless data path, energy-efficient architectural designs (*e.g.* [38]) for wireless communication systems could be considered. Moreover, cooperative relaying [39] for wireless communications is also promising in energy efficiency, by using relay nodes to overhear the transmission and relay the signal to the destination node, resulting in significant diversity gains.
5) **Trade off processing for communications:** As a new way of sensing the signal with a much lower number of linear measurements provided that the underlying signal is sparse, compressive sensing [40] is also able to enhance energy efficiency.
6) **Advanced communication techniques:** Towards green communications, advanced communication techniques are emerging. For example, a cognitive-radio (CR) system [41] which is aware of its environment and can change its modes of operation (operating frequency, modulation scheme, waveform, transmitting power, *etc.*) via software and

hardware manipulation is able to improve spectrum-usage efficiency and minimize the problem of spectrum over-crowdedness.

7) **Renewable green power sources:** Different from traditional resources, a renewable resource (*e.g.* oxygen, fresh water, solar energy, timber, and biomass) is a resource which is replaced naturally and can be utilized again. Therefore, utilizing renewable green power sources will have a fundamental impact on minimizing the dependence on oil and the emission of CO2 [5].

3.3. Applying Green Internet of Things (IoT) to GAHA

Before discussing about green IoT, first we have 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 [11]. 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" [1] whose point of convergence 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 [12]. These objects, acting as sensors or actuators, are able to interact with each other in order to reach a common goal[13].

The key feature in IoT is, without doubt, its impact on every-day life of potential users. IoT has remarkable effects both in work and home scenarios, where it can play a leading role in the next future (assisted living, health, agriculture, smart transportation, *etc*). Important consequences are also expected for business (*e.g.* logistic, industrial automation, transportation of goods, Agriculture monitoring, security, healthcare monitoring *etc.*). The elements in IoT [4-5] environment are presented in Figure1. Specifically, there are six building blocks in IoT such as identification, sensing, communication technologies, computation, services and semantics.

Figure 1. Building Blocks of IoT for GAHA

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. Many hardware platforms (*e.g.*Arduino, UDOO, Friendly ARM, Intel Galileo, Raspberry PI, Gadgeteer) are developed and various software platforms (*e.g.*TinyOS, LiteOS, Riot OS) are utilized. Cloud platform is a particular important computational part of IoT, since it is very powerful in processing various data in real-time and extracting all kinds of valuable information from the gathered data. 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. Information aggregation services gather and summarize the raw information which needs to be processed and reported. The obtained data are further utilized by the collaborative-aware services to make decisions and react accordingly. Ubiquitous services are for offering the collaborative-aware services to anyone on demand, anytime and anywhere. 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), efficient XML interchange (EXI), *etc*.

3.3.1   Green IoT for GAHA

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 [5-14].

"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."

3.4 GAHA Components

In this section, we first see outline of ICT and enabling green technologies for GAHA 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)[15]: 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)[16]: 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)[17]: A low-range wireless network for interconnecting devices centered on an individual person's workspace.

WBAN (wireless body area network)[5-18]: A wireless network consisting of wearable or portable computing devices (*e.g.* sensors, actuators) situated on or in the body.

HAN (home area network)[19]: A type of local area networks (LANs), connecting digital devices present inside or within the close vicinity of a home.

NAN (neighborhood area network)[20]: 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) [21]: A technology that allows both wireless and wired devices to communicate with other devices of the same type.

CC (cloud computing)[7-13]: 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)[22]: a repository (physical or virtual) for the storage, management, and dissemination of data and information.

3.4.1 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). Furthermore, various bands (*i.e.* from low frequencies at 124-135 kHz up to ultrahigh frequencies at 860-960 MHz) are used to perform transmission. 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 [5].

For green RFID [14], [23]-[25], a) Reducing the sizes of RFID tags should be considered to decrease the amount of non-degradable material used in their manufacturing (*e.g.* bio degradable RFID tags, printable RFID tags, paper based RFID tags), because the tags themselves are difficult to recycle generally; b.) Energy-efficient algorithms and protocols should be used to optimize tag estimation, adjust transmission power level dynamically, avoid tag collision, avoid overhearing, *etc.*

3.4.2 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. A commonly used commercial WSN solution is based on the IEEE 802.15.4 standard, which covers the physical and medium access control (MAC) layers for low-power and low-bit-rate communications [5].

Regarding green WSN, the following techniques should be adopted [14], [26-27]:

a. Make sensor nodes only work when necessary, while spending the rest of their lifetime in a *sleep mode* to save energy consumption;

b. Energy depletion (*e.g.* wireless charging, utilizing energy harvesting mechanisms which generate power from the environment (*e.g.* sun, kinetic energy, vibration, temperature differentials, *etc.*));

c. Radio optimization techniques (*e.g.* transmission power control, modulation optimization, cooperative communication, directional antennas, energy-efficient cognitive radio (CR));

d. Data reduction mechanisms (*e.g.* aggregation, adaptive sampling, compression, network coding);

e. Energy-efficient routing techniques (*e.g.* cluster architectures, energy as a routing metric, multipath routing, relay node placement, node mobility).

f.

3.4.3 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 CO_2 emissions [5].

With respect to green CC, potential solutions are shown as follows [14], [28], [31-32].

1) Adoption of hardware and software that decrease energy consumption. In this regard, hardware solutions should target at designing and manufacturing devices which consume less energy. Software solutions should try to offer efficient software designs consuming less energy with minimum resource utilization;

2) Power-saving virtual machine (VM) techniques (*e.g.* VM consolidation, VM migration, VM placement, VM allocation);

3) Various energy-efficient resource allocation mechanisms (*e.g.* auction-based resource allocation, gossip-based resource allocation) and related task scheduling mechanisms;

4) Effective and accurate models and evaluation approaches regarding energy-saving policies;

5) Green CC schemes based on cloud supporting technologies (*e.g.* networks, communications, *etc*.).

3.4.4 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 [29], [33-34]:

1) Intelligently adjust the transmission power (*e.g.* to the minimal necessary level);

2) Design efficient communication protocols (*e.g.* routing protocols) with the application of algorithmic and distributed computing techniques;

3) Activity scheduling, in which the objective is to switch some nodes to low-power operation/sleeping mode so that only a subset of connected nodes remain active while keeping the functionality (*e.g.* data gathering) of the original network;

4) Joint energy-saving mechanisms (*e.g.* with overload protection and resources allocation);

5) Employ energy harvesting and the advantages (*e.g.* spectrum sensing, spectrum management, interference mitigation, power optimization) of CR.

3.4.5 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[5].

About green DC, possible techniques to improve energy efficiency can be achieved from the following aspects [10], [22], [30].

1) Use renewable or green sources of energy (*e.g.*, wind, water, solar energy, heat pumps, *etc.*);

2) Utilize efficient dynamic power-management technologies (*e.g.*Turbo boost, sphere);

3) Design more energy-efficient hardware (*e.g.* exploiting the advantages of DVFS (dynamic voltage and frequency scaling) techniques and VOVO (vary-on/vary-off) techniques);

4) Design novel energy-efficient data center architectures (*e.g.* nano data centers) to achieve power conservation;

5) Design energy-aware routing algorithms to consolidate traffic flows to a subset of the network and power off the idle devices;

6) Construct effective and accurate data center power models;

7) Draw support from communication and computing techniques (*e.g.* optical communication, virtual machine migration, placement optimization, *etc.*).

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 GAHA architecture using sensor-cloud computing integration along with listed out advantages of sensor-cloud integration to GAHA. 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 GAHA 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. Realistic energy consumption models of various components of GAHA are needed; 4. 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.

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