SUSTAINABLE AGRI-MED IOT NETWORK (SAMIN)

Dr. Anil L. Wanare
Professor, JSPM's BSIOTR, Pune
Dept. of Electrnics & Telecommunication Enginering
Savitribai Phule Pune University, Pune

Abstract: The upcoming trends in development encompass two admired technologies: Cloud Computing Application (CCA) and the Green Internet of Things (GIoT). These technologies are currently the focal point of discussions in both the agriculture and healthcare industries. Driven by the pursuit of a sustainable world, this chapter delves into a comprehensive exploration of green cloud computing (CCA) and the Green Internet of Things (G-IoT). Moreover, it enhances this discourse by investigating the potential energy reduction achievable through the synergistic implementation of these two techniques (CCA and G-IoT) in agriculture and healthcare systemsKeyword: Green Internet of Things (GIoT), Cloud Computing applications, GIoT based Agriculture application, Healthcare industry application, Sensor-Cloud, GIoT-AHAS.

1. Introduction

In today's world, a multitude of objects and entities coexist. The emergence of the Internet of Things (IoT)[2], a remarkable technological advancement, aims to interconnect diverse entities and objects via the internet. This includes smart devices like mobile phones, advanced computers, vehicles, and various appliances, each possessing unique IP addresses. This connectivity facilitates seamless interactions between them on a global scale. The proliferation of interconnected physical entities is rapidly increasing, embodying the concept of the IoT [2]. IoT-driven applications span sectors such as transportation, agriculture, healthcare, industrial automation, and responses to different types of disasters, whether natural, man-made, or a combination of both, situations where human decision-making complexity is heightened. This chapter primarily focuses on two pivotal applications stemming from the IoT: agriculture and healthcare. A myriad of networked sensors, integrated into either the human body or our living environments, enable the collection of valuable data indicative of both physical and mental human health [2][3].

The Internet of Things empowers physical entities to observe, listen, process information, and carry out tasks collaboratively. This fosters the exchange of information and coordinated decision-making among these entities. Ultimately, every facet of human existence, encompassing the realms of cyber, physicality, social interactions, and cognition, will become interconnected and intelligent on a global scale, constituting the smart world. This paradigm marks a significant milestone in human history and has garnered considerable attention from academia, business, industries, governments, and various organizations. Additionally, the concept of the Green Internet of Things (G-IoT) strives for a sustainable smart world by curbing the energy consumption of IoT-based applications [4][5].

Cloud Computing stands as a prominent and transformative emerging technology, a promising paradigm that renders computing as a utility [1][2]. This framework enables seamless utilization of cutting-edge software, extensive data access, substantial data storage, and intricate statistical computations through the Internet. It empowers users to procure resources following a pay-as-you-go model [3], ensuring cost-effectiveness by charging only for the resources consumed. A significant benefit of Cloud Computing is its capacity to furnish statistical computing and substantial data storage on demand, eliminating the need for substantial investments in computing infrastructure, such as computational tools. Notably, statistics from Mark Hachman reveal that global data centers collectively consumed an astonishing thirty billion watts of electricity in 2012, a magnitude akin to the output of thirty nuclear power plants [8]. The energy required to cool these servers and substantial data centers for a year is equivalent to the power needed to sustain five million households over the same duration [9]. Consequently, it is imperative to explore innovative approaches to optimize the power consumption of these substantial data centers, namely, the cloud [9]. Basic agriculture trends and network has been shown below in figure1.

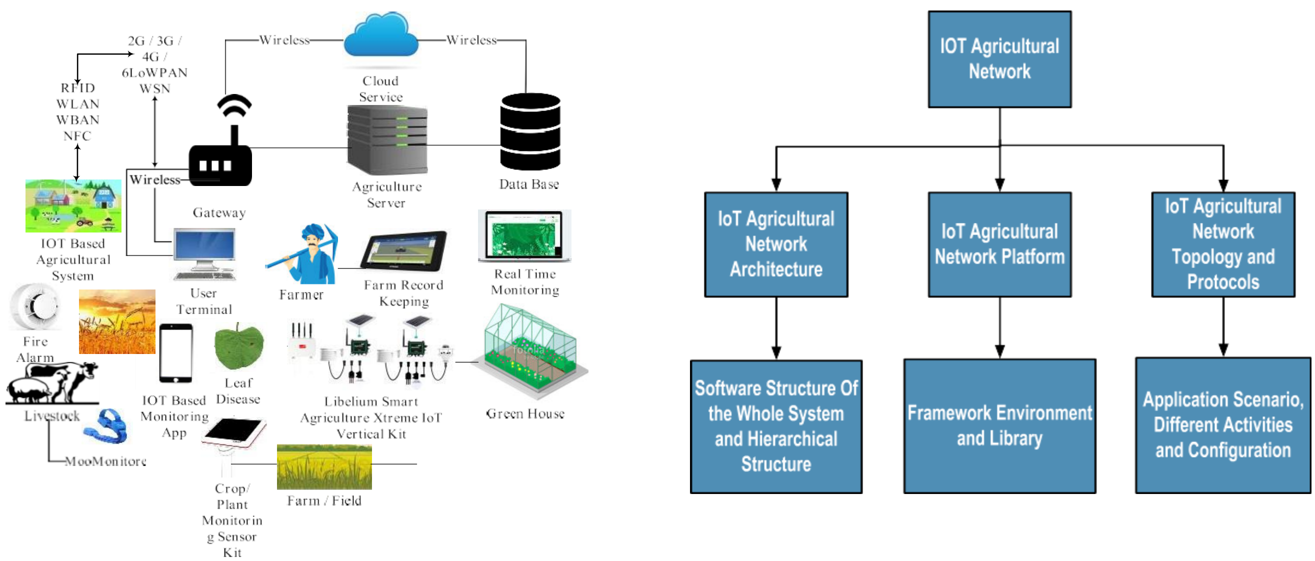

Figure1. Agricultural trends and basic IoT agricultural network.

Green Internet of Things (G-IoT) driven statistical computing embodies ecologically mindful computing. This concept revolves around endeavors aimed at optimizing power consumption and energy efficiency while concurrently minimizing costs and CO_2 emissions [10]. The sensor integrated approach, exemplified by the sensor-cloud architecture, ingeniously amalgamates cloud infrastructure with sensor networks. This synthesis empowers real-time monitoring of data-intensive applications that span across dispersed geographical domains [11][2].

Sensor networks find widespread utility in the deployment of health-centric applications, encompassing tasks like monitoring patients' blood sugar levels, blood pressure, and sleep activity patterns [12][13]. In these applications, health facilities respond appropriately based on the data acquired from patient sensors. Monitoring the health status of patients in real time, especially as they move unpredictably, poses a considerable challenge. Thus, the establishment of an efficient computational mechanism becomes imperative to track patients' health status during their spontaneous mobility. Addressing the data-intensive and dynamically evolving demands of sensor networks benefits from the intricate fusion of computational and storage capabilities provided by cloud computing applications tailored for extensive data processing [14][15].Consequently, sensor-cloud platforms have garnered escalating popularity in the contemporary landscape. This chapter introduces a sustainable G-IoT Agriculture and Healthcare system employing a sensor-cloud integration model, denoted as GIoT-AHAS. The Internet of Things (IoT) revolutionizes commonplace objects into intelligent entities, harnessing its foundational technologies encompassing ubiquitous and pervasive computing, embedded devices, communication technologies, sensor networks, Internet protocols, and diverse applications [1][4]. Despite their distinct characteristics, both the Internet of Things (IoT) and cloud computing stand as two distinct yet interconnected technologies that have seamlessly woven into the fabric of our global existence [4].

The Internet of Things (IoT) is commonly marked by its association with real-world small-scale entities, widely dispersed, and possessing restricted storage and processing capacities. These characteristics raise crucial considerations encompassing reliability, performance, security, and privacy. On the contrary, cloud computing boasts virtually boundless capabilities concerning storage and processing potency. It stands as a well-established, sophisticated technology, having partially addressed several of the challenges posed by the Internet of Things through the integration of novel IoT-related advancements. Consequently, applications that synergistically blend the strengths of both cloud and IoT technologies have the potential to significantly reshape the present and future digital landscape, ushering in transformative disruptions [13]. This chapter is structured as follows: In Section 'b,' an initiation into ubiquitous statistical computing is offered, accompanied by an exploration of the prerequisites for a genuinely pervasive application and a concise introduction to green computing. Section 'c' delves into a presentation of the proposed architecture, encompassing its requirements and the integration of green IoT applications. Additionally, this section highlights the role of Information and Communication Technologies (G-ICT) in furnishing green components, including green Radio Frequency Identification (G-RFID), green Wireless Sensor Networks (G-WSN), green Cloud Computing (G-CC), green Machine-to-Machine communication (G-M2M), and green Data Centers (G-DC) for the infrastructure of GIoT-AHAS. Ultimately, Section 'd' encompasses the conclusion and offers insights into future directions for this chapter.

2. Relevant Work and Research Motivation for GIoT-AHAS

Ubiquitous Computing:

Ubiquitous computing represents a multifaceted paradigm encompassing lifestyle, engineering, and technological innovation all at once. This concept revolves around technologies that seamlessly infiltrate every facet of a user's life, operating inconspicuously in the background and delivering value without causing disruption. This approach is also known as pervasive computing [17]. The genesis of ubiquitous computing can be traced back to 1988, when Mark D. Weiser introduced this groundbreaking idea to the computing community [17],[18]. Weiser articulated it as a transformative shift in computation, envisioning a world where computing is interwoven into the fabric of human existence—where people inhabit a realm of work, play, and daily life that seamlessly integrates with computing [18], [19]. Ubiquitous computing imagines an environment where individuals are enveloped by a multitude of networked computers, some worn or carried, others encountered while on the move, many of them integrated into physical objects, all functioning harmoniously and inconspicuously. This orchestration occurs with minimal human attention, resulting in an unobtrusive and natural interaction. In essence, this paradigm heralds an era where advanced computers envelop a single user and dissolve into the physical surroundings. Its components span a wide range of scales in daily life, each unobtrusively tailored to common tasks. At the core of ubiquitous computing are four fundamental components: wearable devices, customizable sensor nodes, networked appliances, and intelligent labels that resonate with the concept of the green Internet of Things (G-IoT). The pursuit of ubiquitous computing rests on the foundation of five pivotal goals termed ATSAT: Availability, Transparency, Seamlessness, Awareness, and Trustworthiness. These attributes collectively shape the ideal user experience in a ubiquitous computing landscape. Taking a broader perspective on ubiquitous services within the context of ubiquitous computing, it becomes evident that these services adhere to the SCALE criteria—Scalability, Connectivity, Adaptability, Liability, and Ease-of-use—intertwined with the tenets of the GIoT-AHAS concept [19],[20].

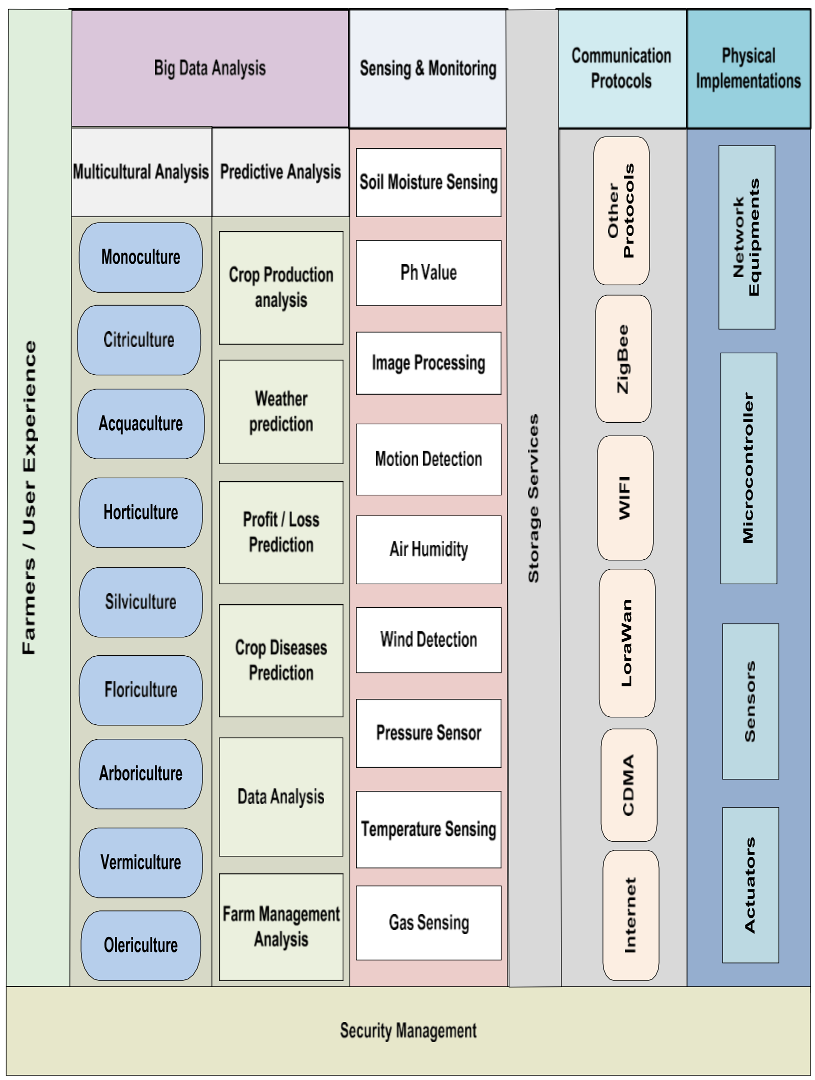

Figure 2: GIoT-AHAS network platform based on big data analysis.

Ubiquitous Agriculture and Healthcare Application Requirements:

The goals of ubiquitous applications are threefold: to mitigate time loss resulting from delays, lower the costs associated with intermediaries, and diminish inaccuracies inherent in conventional medical procedures, as outlined in existing literature [21]. Delays, often referred to as "lag," stem from the time required for manual data entry, paper-based communication, or human-mediated information transmission. These delays can contribute to significant revenue losses within the medical sector. By integrating IoT devices, the time gap between data input into a system and its availability for digital processing can be notably reduced, thereby addressing the challenge of lag and enhancing the efficiency of information processing.

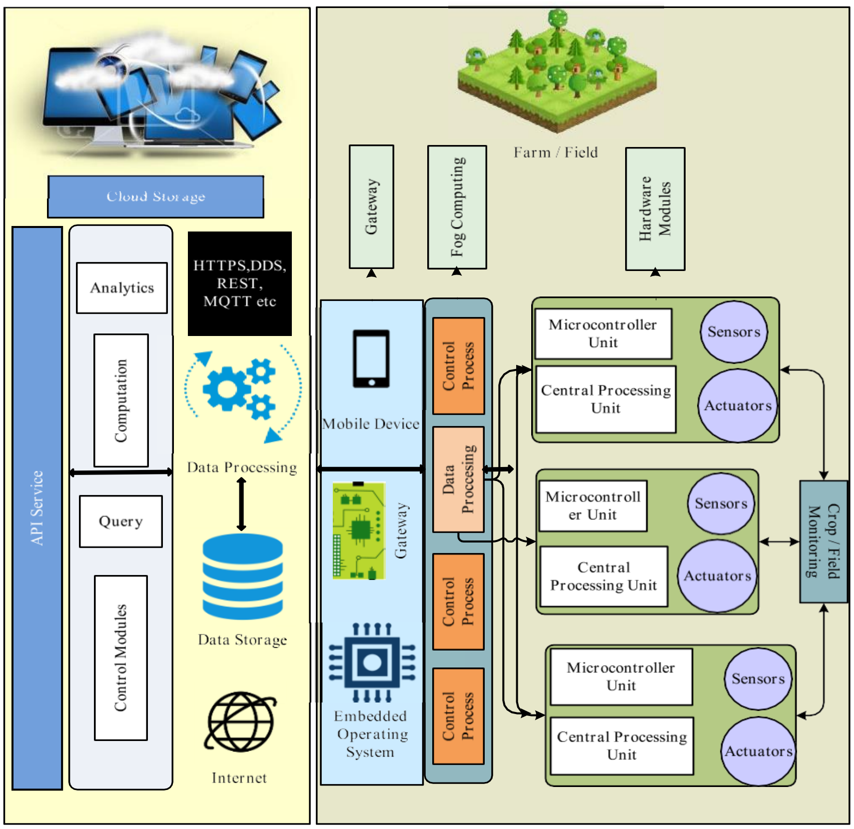

Figure 3. G-IoT agricultural and healthcare network platform based on cloud.

Furthermore, in the realm of ubiquitous agriculture and healthcare, end-users will transmit data from diverse origins and receive immediate access to real-time information, knowledge, and pertinent expertise. They will actively seek out relevant and valuable insights. Once these aforementioned criteria are met, an application can genuinely be considered ubiquitous. Such an application would adopt a linear spatial structure, seamlessly embedded to fulfill specific functions or a limited set of tasks. It would embody pervasiveness, establishing connections between devices that remain inconspicuous yet consistently accessible for real-time interactions. Context-awareness would be its hallmark, enabling it to correlate environmental changes with digital computing systems. The application would demonstrate intelligence in mobility, harnessing advanced technologies while in motion [21],[22]. Furthermore, it would be wearable, harmonizing with the user's hands, voice, eyes, or focus as they engage with the surrounding physical environment. The application's heightened sentience would empower it to perceive its surroundings and respond adaptively. Operating in harmony with its surroundings, it would serve as an ambient companion, facilitating users in their everyday activities, tasks, and routines. This assistance would seamlessly integrate hidden information and intelligence from the interconnected IoT network that binds these devices together [22].

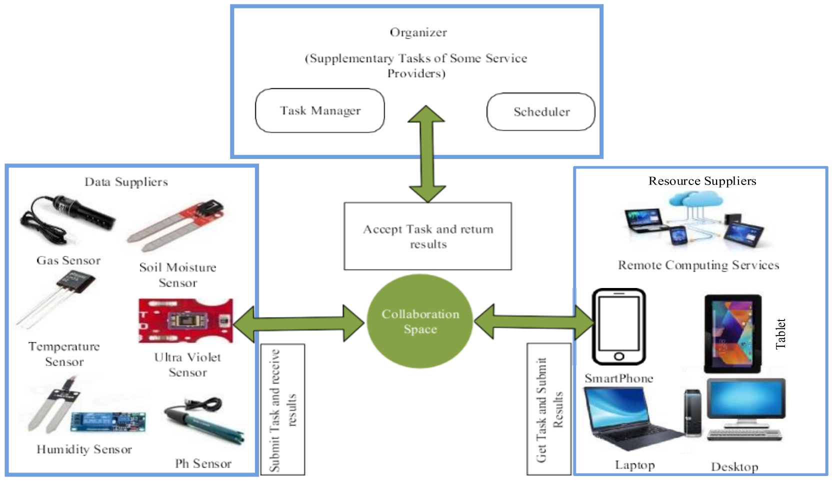

Figure 4. Green IoT Agriculture and Healthcare Applications (GIoT-AHAS)

Green cloud Computing:

The concept of green computing has begun to spread in the last few years, gaining increasing popularity. Besides the widespread sensitivity to environmental issues, such interest also stems from financial needs, since both energy expenses and electrical requirements of IoT industry around the world show a continuously growing trend [23]. Green computing is the environmentally responsible use of digital advanced computers and related resources. Such practices include the implementation of energy-efficient central processing units, Servers and Peripherals as well as reduced resource consumption and proper disposal of e-waste [22],[23]. Green computing is the study and practice of efficient and eco-friendly computing and the principle behind energy efficient coding is to save power by getting advance software to make less use of the more power consumption hardware, rather than continuing to run the same flexibility in code on hardware that uses less power.

Green computing, Green G-ICT as per IFG International Federation of Green G-ICT and IFG Standard, green G-IT, or G-ICT sustainability, is the study and practice of environmentally sustainable computing or IT. In [24], Murugesan V. et. al. 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 [24]. Also, lists out the following major four complementary paths along to comprehensively and effectively address the environmental effects of statistical computing should be addressed for green computing. Some ternimalogies has been used related to our GIoT-AHAS are defined as below:

1. Green Use: Reducing the energy consumption of computers and other information systems as well as using them in an environmentally sound manner (eco-friendly)[25].
2. Green Disposal: Refurbishing and reusing old computers and recycling unwanted computers and other electronic equipment (re-usable).
3. Green Design: Designing energy efficient and environmentally sound components,

computers, peripherals, and servers and cooling equipment's.

4. Green Manufacturing: Manufacturing electronic components, computers and other advanced equipments associated sub systems with minimal impact or negligible impact on the environment.

Green cloud computing (G-CC) spans a number of focus areas and activities, including design for environmental sustainability, energy-efficient computing, power management, big data center design, layout, architecture, 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-labeling of the products GIoT-AHA system.

3. Green IoT Agriculture and Healthcare Applications (GIoT-AHA System)

We focused to discuss ubiquitous computing, requirements to achieve truly ubiquitous application and green cloud computing fundamentals in order to relate them to GIoT-AHA System. In this section, we have explained basic concepts of G-ICT enabled green G-IoT technologies components related to GIoT-AHA System and also present the architecture of GIoT-AHAS using sensor-cloud integration concept.

GIoT-AHAS Architecture

Sensor-cloud computing (SSS) is envisioned as one of the most powerful enabling technologies for agriculture and healthcare monitoring system. Sensor-Cloud computing (SSS) 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,

As per theory presented by IntelliSys et. al., "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"[26].

One more literature available of MicroStrains and el al. 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 reliable deployments of Micro Strain wireless sensors, Sensor-Cloud now supports any web connected third party device, sensor, or sensor network through a simple Open Data application programming interface (API)" [27].

Attracting increasing interest from both academic and industrial communities, sensor- cloud computing (SCC) [28] is actually a new paradigm, motivated by complementing:

1. The ubiquitous data sensing and data gathering capabilities of wireless sensors networks.

2. The powerful data storage and data processing abilities of SCC.

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 [28] offered by the sensor network provider to collect different monitoring sensory data from various locations. The collected 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 and as per requirement. In this full scenario, sensor network providers act as the data sources for cloud service providers (GIoT-AHAS). Service users are the big data requesters for cloud service providers.

With sensor-cloud integration (SCI), there are many favorable advantages [29], benefiting the users and the wireless sensor network as well as the cloud such as: Users can have access to their required data of sensors from cloud anytime and anywhere if there is network connection, instead of being stick to their desks i.e. twenty four by seven service. The utility of wireless sensor network 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 wireless sensor network provides (e.g., agriculture and healthcare monitoring in this system i.e. GIoT-AHAS). Specifically, enhancing the performance (e.g., data processing speed, response time, visualization) of network system with immense storage and processing capability of cloud, analytical results have shown that sensor-cloud could out perform a traditional wireless sensor network, by increasing the sensor's lifetime by 3.35% and decreasing the energy consumption by 37.55%. All these are very desirable for smart world and green HEIs in India if applied in a proper ways.

4. GIoT-AHAS Requirements

We have listed the below general green G-ICT requirements for GIoT-AHAS architecture and briefly summarizes them as follows:

a. *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 [30] is one of the widely used techniques for saving the energy consumption in wireless sensor networks, by making sensor nodes dynamically awake and asleep.
b. *Send only data that are needed: Big-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 [30].
c. *Minimize length of data path:* This is also a straight forward method to reduce energy consumption. Routing schemes [30] considering the length of chosen data path could be very energy-efficient. In addition, network working mechanisms [32] which cater to the routing requirement are also potential optimal ways to achieve much shorter data path.
d. *Minimize length of wireless data path*: Regarding minimizing length of wireless data path in wireless sensors network, energy-efficient architectural designs [32] for wireless communication systems could be considered. Moreover, cooperative relaying system must be there [33] 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 [33].
e. *Trade off processing for communications:* As a new optimal ways of sensing the signal with a much lower number of linear measurements provided that the underlying signal is sparse, compressive sensing [34] is also able to enhance energy efficiency in both the system.

f. *Advanced communication techniques:* Towards green communications, advanced communication techniques are emerging. For example, a cognitive-radio (CRS) system [35] which is aware of its environment and can change its modes of operation (operating frequency, modulation scheme, waveform, transmitting power.) via advanced software and hardware manipulation is able to improve spectrum-usage efficiency and minimize the problem of spectrum over-crowdedness by utilizing the optimal algorithms.

g. *Renewable green power sources:* Different from traditional resources, a renewable energy resource i.e. oxygen, fresh water, solar energy, timber, and biomass, fuel cell, and geothermal energy are resources which are 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 CO_2 carbon dioxide [35], [36].

5. Applying Green Internet of Things (G-IoT) to AHAS

While discussing about green G-IoT, initially we have to see the various definitions related to IoT, and it is considered as the next wave in the era of cloud computing is predicted to be outside the realm of traditional desktop [37]. In line with this observation and by considering literature available, 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] [2] 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 to get the optimum solutions. G-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 smart 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[12][13].

The key feature in IoT is, without doubt, its impact in dat to 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 like assisted living, health, agriculture, smart transportation, and many more applications. 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 Figure2. Specifically, there are six building blocks in IoT such as identification, sensing, communication technologies, computation, services and semantics.

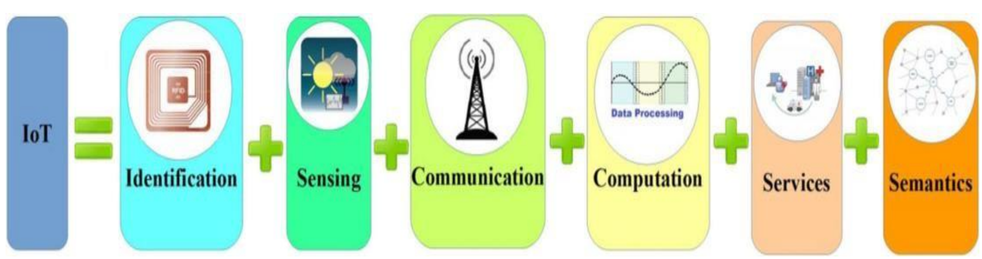

Figure 5. Building Blocks of G-IoT to AHAS

Classification and identification plays a crucial role in naming and matching services with their demand. Examples of identification methods are used for the IoT are electronic product codes, ubiquitous codes. Sensing is for collecting various data from related objects and sending it to a database, data warehouse, and data center. The gathered data is further analyzes to perform specifications based on required services. The sensors can be humidity sensors, temperature sensors, wearable sensing devices, mobile phones, etc.. Advanced communication technologies connect heterogeneous objects together to offer specific services as per requirement. 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 [34]. About cloud computation, the hardware processing units (*e.g.* microcontrollers, microprocessors, system on chips (SoCs, RC, etc.), field programmable gate arrays (FPGAs)) and advanced software applications perform this task. Now days 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 G-IoT, since it is very powerful in processing various big-data in real-time and extracting all kinds of valuable information from the gathered data.

The services in G-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 [1]. This process usually includes: discovering resources, utilizing resources, modelling information, recognizing and analyzing data. The commonly used semantic technologies are: resource description frameworks (RDF), web ontology language (OWL), efficient XML interchange (EXI).

6. Green IoT for AHA System (G-IoT to AHAS)

To facilitate a green G-IoT, the IoT must be distinguished by energy efficiency. Especially, 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 properly within time limit, they will require more energy. In addition, driven by a rising interest and support from various organizations, the energy demand will be further greatly increased. All these make green G-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 point during the design and development of IoT, green IoT can be defined as below [5]. “The energy efficient procedures (hardware or software) adopted by G-IoT either to facilitate reducing the greenhouse effect of existing applications and services or to reduce the impact of greenhouse effect of G-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 G-IoT should focus on green design, green production, green utilization and finally green disposal/recycling to have negligible or very small impact on the environment [15].

7. G-IoT to AHA System Components

In this section, first to see an outline of G-ICT and enabling green technologies for G-AHA system are discussed. G-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. Whatever the components are required are listed them below, regarding identification, sensing, communication and computation which are IoT elements introduced in Section c of the chapter.

1. RFID (radio-frequency identification): A very small electronic device that consists of a small chip and an antenna, automatically identifying and tracking tags attached to objects, operating on specific frequency range [32].
2. WSN (wireless sensor network): A network consisting of spatially distributed autonomous sensors that cooperatively monitor the physical or environmental conditions like temperature, sound, vibration, pressure, motion, etc [31].
3. WPAN (wireless personal area network): A low-range wireless network for interconnecting devices centered on an individual person's workspace [33].
4. WBAN (wireless body area network): A wireless network consisting of wearable or portable computing devices (*e.g.* sensors, actuators, etc.) situated on or in the body [8-10].
5. HAN (home area network): A type of local area networks (LANs), connecting digital devices present inside or within the close vicinity of a home [19].
6. 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 [20].
7. M2M (machine-to-machine): A technology that allows both wireless and wired devices to communicate with other devices of the same type [21].
8. 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.* smart mobile phones, tablets, *etc.*) to the cloud [8][15].
9. Big Data Center (BDC): a repository (physical or virtual) for the storage, management, and dissemination of data and information [22].
10. Green RFID (G-RFID): Radio-frequency identification model includes several Radio-frequency identification tags and a very small subset of tag readers. Enclosed in an adhesive sticker, the Radio-frequency identification tag is a small microchip attached to a radio (utilized for receiving and transmitting the signal), with a unique identifier.

    The purpose of Radio-frequency identification tags is storing information regarding the objects to which they are attached. The basic process is that the information flow is triggered by Radio-frequency identification tag readers through transmitting a query signal, followed with the responses of nearby Radio-frequency identification tags.

    In general, the transmission range of Radio-frequency identification 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 Radio-frequency identification tags (i.e. Active Tags and Passive Tags- ATPT) 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 Radio-frequency identification (G-RFID) [14], [23]-[25],

i) Reducing the sizes of Radio-frequency identification tags should be considered to decrease the amount of non-degradable material used in their manufacturing (e.g. bio degradable Radio-frequency identification tags, printable Radio-frequency identification tags, paper based Radio-frequency identification tags), because the tags themselves are difficult to recycle generally;

ii) Energy-efficient algorithms and protocols should be used to optimize tag estimation, adjust transmission power level dynamically, avoid tag collision, avoid overhearing, etc.

Green Wireless Sensor Networks (G-WSN):

A Wireless Sensor Networks 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].

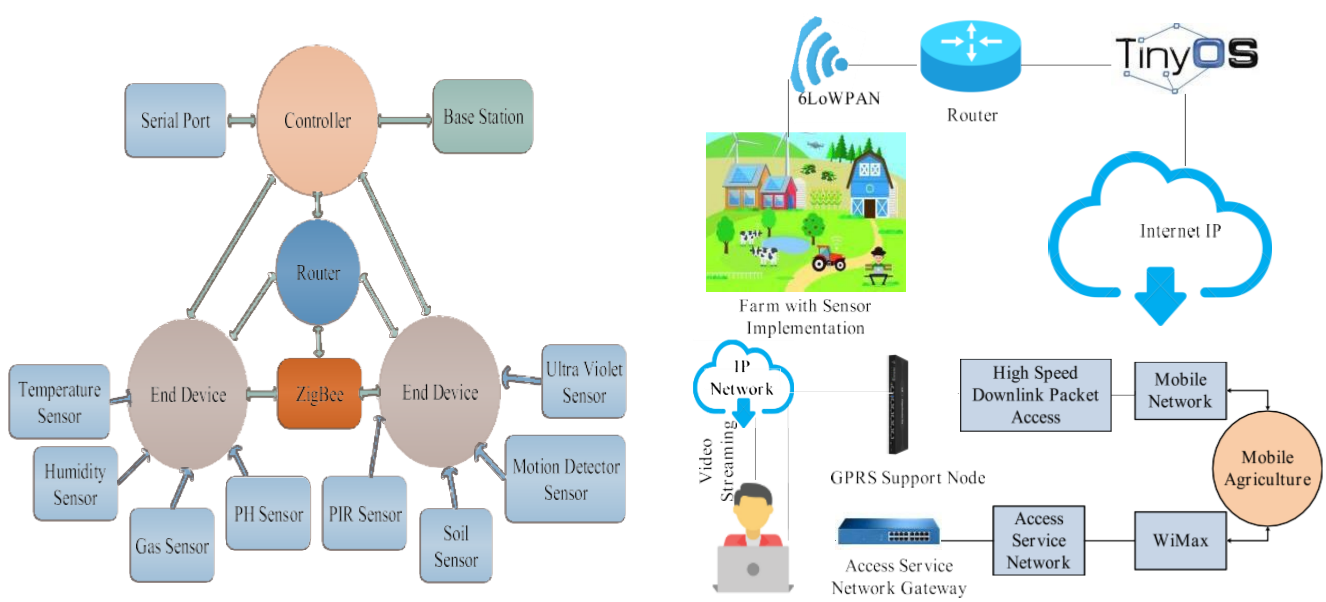

Figure 6. Farm remote monitoring in agriculture And Low power G-WSN topology.

Regarding green wireless sensors network (G-WSN), the following techniques must be adopted:

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).

Green Cloud Computing (G-CC):

In GCC, 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, GCC 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 carbon dioxide CO_2 emissions [17].

With respect to green GCC, potential solutions are shown as follows [33],[34].

a. Adoption of advance version hardware and software that decrease energy consumption. In this regard, hardware solutions should target at designing and manufacturing devices which consume less energy. Significant software solutions should try to offer efficient software designs consuming less energy with minimum resource utilization;
b. Power-saving virtual machine techniques (e.g. VMT consolidation, VMT migration, VMT placement, VMT allocation);
c. Various energy-efficient resource allocation mechanisms (e.g. auction-based resource allocation, gossip-based resource allocation, etc.) and related task scheduling mechanisms;
d. Effective and accurate efficient models and evaluation approaches regarding energy-saving policies;
e. Green GCC schemes based on cloud supporting technologies (e.g. networks, advanced communications, etc.).

7. Green Machine to Machine (M2M):

In the terms of Machine to Machine (M2M) communications, massive M2M nodes which intelligently gather the monitored data are deployed in M2M domain. In wireless network domain, the wireless network relays the gathered data to the base station for processing. The base station further supports various Machine to Machine (M2M) applications over network in the application domain. The mechanism of Machine to Machine (M2M) is shown in figure 7:

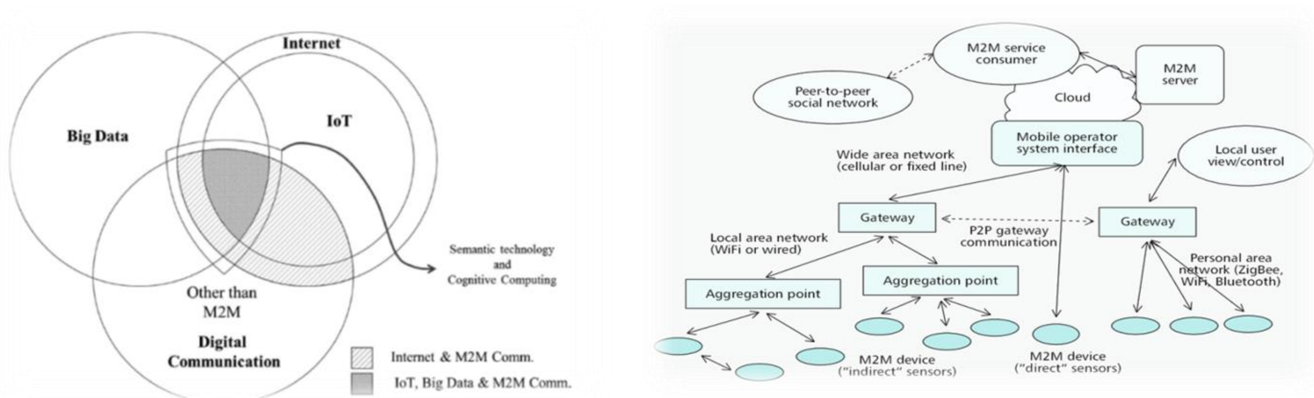

Figure 7: A high-level M2M system architecture with big data and G-IoT

Regarding environmentally conscious Machine to Machine (M2M) technology, the substantial machinery engaged in M2M communications presents a notable energy consumption challenge, especially within the M2M domain.

The following methods might be used to increase energy efficiency [28][30]:

i. Intelligently adjust the transmission power (e.g. to the minimal necessary level);
ii. Design efficient communication protocols (e.g. routing protocols) with the application of algorithmic and distributed computing techniques;
iii. 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;
iv. Joint energy-saving mechanisms (e.g. with overload protection and resources allocation);
v. Employ energy harvesting and the advantages (e.g. spectrum sensing, spectrum management, interference mitigation, power optimization) of green cognitive radio (G-CR).

Sustainable Data Center (SDC): The primary function of Sustainable Data Centers, abbreviated as SDCs, revolves around the storage, management, processing, and distribution of diverse data and applications, originating from users, devices, systems, and more. In the realm of handling these varied data and applications, SDCs confront a significant challenge of consuming substantial energy resources, leading to elevated operational expenses and leaving a substantial carbon dioxide footprint (CO_2). Furthermore, the proliferation of massive data volumes from numerous pervasive and ubiquitous IoT-driven entities (such as smartphones, active digital sensors, etc.) on the path toward an intelligent world escalates the urgency of enhancing energy efficiency within SDCs [14].

About Green Data Center G-DCs, possible techniques to improve energy efficiency can be achieved from the following aspects [15], [24], [33].

1. Use renewable or green sources of energy
   a. (e.g., wind, water, solar energy, heat pumps, geothermal, fuel cell, etc.);
2. Utilize efficient dynamic and efficient power-management technologies
   a. (e.g. Turbo boost, sphere);
3. Design more energy-efficient hardware techniques and vary-on and vary-off techniques;
   a. (e.g. exploiting the advantages of dynamic voltage and frequency scaling)
4. Design novel energy-efficient data center architectures to achieve power conservation;
   a. (e.g. nano green data centers)
5. Design energy-aware advanced routing algorithms to consolidate traffic flows to a subset of the network and power off the idle devices;
6. Construct effective and accurate big data center power models;
7. Draw support from communication and computing techniques
   a. (e.g. optical advanced communication, virtual machine to machine migration, placement optimization, etc.).
8. Conclusion

This chapter has encompassed diverse themes including ubiquitous statistical computing, the prerequisites for authentic ubiquitous computing tools and applications, and the domain of green computing. The exploration proceeded to delve into a scrutiny of technologies such as eco-friendly information and computing techniques that empower emerging innovations. Subsequently, a comprehensive exposition of the architecture of the Green Internet of Things (GIoT) Agriculture and Healthcare Application System (GIoT-AHAS) was undertaken. This architecture seamlessly integrates sensor-cloud computing, and the ensuing advantages of such an integration for GIoT-AHAS were meticulously enumerated. While Wireless Sensor Networks (WSNs) inherently confront certain challenges, these can be adeptly addressed through the implementation of digital sensor-cloud green infrastructures. These infrastructures specifically address: 1) the establishment of a Green Big Data management system, 2) the efficient and substantial utilization of resources, and 3) the mitigation of the high utility costs associated with GIoT-AHAS. The deployment of a green digital sensor-cloud infrastructure is a pragmatic and economical strategy, leveraging the existing foundation of green IoT-based cloud platforms.

Finally, future directions observed related to Green Internet of Things (GIoT) Agriculture and Healthcare Application System (GIoT-AHAS) architecture with the digital green sensor-cloud convergence is featured such as follows:

i. Application designing should be approached from an overall Green Internet of Things (GIoT) Agriculture and Healthcare Application System (GIoT-AHAS) energy consumption perspective, concerning about satisfying service, goodquality and significant performance;
ii. Characteristics and usage requirements of different applications needs better understanding;
iii. Realistic energy consumption models of various components of Green Internet of Things (GIoT) Agriculture and Healthcare Application System (GIoT-AHAS) are needed;

iv. Cost issues, digital Sensor-Cloud service access requires both the green digital sensor service provider and statistical computing and cloud service provider. Although, they have autonomous user's management, services and effective management, modes and methods of payments and pricing.

Some Selected components for Green Internet of Things (GIoT) Agriculture and Healthcare Application System (GIoT-AHAS)

Some Selected components for Green Internet of Things (GIoT) Agriculture and Healthcare Application System (GIoT-AHAS)

V. References

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