# Design of Cloud-Based Green IoT Architecture for Smart Cities

**Gurjit Kaur, Pradeep Tomar and Prabhjot Singh**

**Abstract** In the smart cities, objects can smartly communicate with the people through Internet of Things (IoT). It will make smart cities a greener place by detecting pollution through IoT and environmental sensors. In order to maintain the sustainability of green place in smart cities, the emerging technology, i.e. Green IoT automatically and intelligently makes smart cities sustainable in a collaborative manner. Governments and a lot of organizations around the world are doing a lot of efforts to campaign the importance of the reduction of energy consumption and carbon production as well as emphasize on the Green IoT for smart cities. Various IoT related smart cities architectures are already presented in literature. But this work presents the concept of the "Green IoT" to create a green environment which will apprehend the idea of energy saving in smart cities. In this chapter, design of Green IoT architecture is proposed for smart cites with the focus to reduce energy consumption at each stage and ensure realization of IoT toward green. This proposed Green IoT architecture is based on the cloud based system which reduces the hardware consumption.

**Keywords** Green IoT · Green radio frequency identification · Green data center · Green cloud computing sensors · Green machine to machine · Green wireless sensor network

G. Kaur (✉) · P. Tomar
School of ICT, Gautam Buddha University, Greater Noida, Uttar Pradesh, India
e-mail: gurjeet_kaur@rediffmail.com

P. Tomar
e-mail: parry.tomar@gmail.com

P. Singh
Salesforce Inc., San Francisco, USA
e-mail: prabhjot27@gmail.com



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## 1 Introduction

In next generation, the internet will make the world where physical things would reliably be consolidated into information frameworks which would give savvy administrations to clients. These interconnected things, for instance, sensors or convenient contraptions would produce and accumulate volumes of data which can be further handled to find supportive information to reinforce savvy and universal administrations [1]. The ascent of the internet, the always expanding universality of information, and its low flag to-clamor proportion have added to the issue of data over-burden, whereby people have admittance to a greater number of information than they can absorb into important and significant data. A significant part of the accomplishment of Web 2.0 has been accomplished after a viable handling of this issue [2].

IoT alludes to a worldwide, distributed network of physical items that are equipped for detecting or communicating with other things, different machines or PCs. IoT is a main constituent of the upcoming smart world and can be characterized as a network device with self-configuring abilities derived from advanced protocols where virtual and physical objects can easily communicate. IoT empower network for all intents and purposes any physical protest that possibly offers a message, and will influence each part of life and business. This article takes a gander at the ideas and advancements in three application territories that Motorola is adding to now and in the coming years [3]. This will connect objects and people which can communicate through various sensors and actuators, radio frequency identifications via bluetooth connections, etc. Such "smart" objects arrive in an extensive variety of sizes and capacities, incorporating simple object with embedded sensors, household apparatus, mechanical robots, automobiles, trains, and wearable protests, for example, watches, arm ornaments or shirts [4]. Their esteem lies in the endless amounts of information they can catch and their ability for correspondence, supporting constant control or information examination that uncovers new experiences and prompts new activities. Through IoT, this world can become technically more advanced and intelligent where human beings can communicate with objects and the objects can communicate with other objects without any human interference. IoT object will communicate through sensors, actuators, bluetooth connections and Radio Frequency Identification (RFID) etc. [5]. Every object has intelligent interfaces, which provide desired information after incorporated into the intelligent information network. Ambient intelligence is a human interface allegory alluding to the earth of registering which knows and receptive to the nearness of human collaboration. The point is to place awesome accentuation on the part of being easy to understand and effective and offer help for human cooperation. We are as yet taking a stab at a future world where we will be encompassed by clever interfaces that are to be put in ordinary items. These items will then have the capacity to perceive additionally react imperceptibly to the nearness of individuals [6].

But IoT will influence our surroundings in a few diverse ways. Every object of IoT, from its creation, all through its utilization till disposal presents environmental problems. Manufacturing sensory objects, PCs, laptops, and their different segments consumes power, materials and chemicals, water and produces perilous waste. All these objects and systems will increment carbon dioxide outflows and affect the earth. Also, the aggregate energy consumption by servers, personal computers (PCs), screens, information exchange equipment and cooling systems for data centers is gradually increasing. Green house gas emission will increase rapidly by increase of energy consumption. Every PC being used creates about a huge amount of carbon dioxide consistently. All electronic objects, sensors and PC segments used in IoT will contain poisonous materials. Even customers dispose of a large number of old computers, electronic gadgets two to three years after purchase, and most of this end in landfills therefore polluting the earth environment. It is noted that about 20–50 million tons of computer parts and mobile phones are dumped every year which is the major chunk of waste. So there is huge pressure on IoT related industries, businesses and the individuals who design the IoT related objects and systems to make IoT systems environment friendly and green throughout its lifecycle i.e. from birth to death to rebirth [7].

As IoT is integrated with so many sensory elements to sense and communicate the data using advanced communication technologies which ultimately shoot up the energy consumption. But only Information and Communication Technology (ICT) accounts for about 2% of global $CO_2$ emissions. The entire world today is talking green and it's our social responsibility to save our environment. It's not green with envy, but green as in becoming more eco-friendly, energy saver, adherence to global standards, environment friendly, efficient usage of the computing resources like Energy Star, Restriction of Hazardous Substances, etc. so that the system could be managed more efficiently throughout its life and even at the time of disposal. Green Information Technology (IT) is the practice of environmentally sustainable computing. It aims to reduce the negative impact of IT system on the environment by designing, manufacturing, operating and disposing of computers, sensors, products etc. in an environmentally-friendly manner. The real objectives of Green IoT are to reduce the use of harmful toxic materials. It should have the capability to improve energy efficiency throughout its life and support the biodegradability and recyclability of obsolete products and the redundant plant waste. Green IoT follows energy efficient procedures using advanced hardware and software which will reduce the greenhouse effect even for the existing applications so the impact of the greenhouse effect will reduce on the IoT itself [8].

The constant advancement of Next Generation Internet (NGI) [9] enhances the interest for productive and secure correspondence fit for reacting viably to the difficulties postured by the rising applications. For secure correspondence between two sensor hubs, a mystery key is required. Cryptographic key administration is a testing errand in sensor organizes as the threatening condition of sensor systems makes it more inclined to assaults. Aside from asset limitations of the gadgets, obscure topology of the system, the higher danger of hub catch and absence of a

settled foundation makes the key administration all the more difficult in Wireless Sensor Network (WSN).

Technically, Green IoT based smart cities focus on green design, green manufacturing, green operations, green deployment, green retention and even green reuse with a very small impact on the environment. These green smart cities includes green smart aerospace and aviation systems, green smart homes, green smart buildings, green smart e-health, green smart logistics, green smart retail, green supply chain management, green smart transportation, green smart recycling, green smart environment monitoring etc. with minimal utilization of energy. In green IoT smart cities objects like mobile phones, computers, laptops, cars, and electronic appliances can communicate with each other with distinctive addresses in energy saving mode. These sensory devices are able to communicate intelligently via internet protocol and can provide green support in managing different tasks for the users. It can support various technologies [10] i.e. identification, communication, data and signal processing technologies with reduced energy consumption. During the design and development of Green IoT based smart cities energy efficient procedures needed to adopt.

## 2 Green IoT-Based Smart Cities

One of the biggest targets of the digital era is to design these green smart cities. Green IoT is an important technology to build green smart cities. Over the next ten years, buildings will be the main energy consumer which will emit greenhouse gasses on the earth. The best way for a building to become smarter by empowering owners and managers to collect energy and operational metrics into a single, centralized location and apply enterprise-wide analytical and optimization capabilities to gain insights from that information. There are some hardware and software systems which can provide important information related to electric demand and energy usage. By using real-time data gathering building managers can do the analysis to solve problems related to service proactively before they occur. Even they can visualize energy consumption, environment and portfolio performance for floor space, etc. Also, there is a need to make sustainable green smart cities in an economical way. This could include ICT based smart networking to reduce vitality transmission costs and enhance the versatility of these utility systems [11]. In IoT based smart cities, objects or things are made uniquely addressable by using a unique way of identification where these smart objects transmit the information like location, state, type, context or other sensory measurements to the other devices. These things are also heterogeneous in some capabilities. A green smart city includes green smart homes, green smart heath, green smart farming, green smart education system, green smart water system, green smart transportation and green smart retail etc. working very energy efficiently and keep the environment clean and green [12]. The main features of a smart city are represented in Fig. 1.

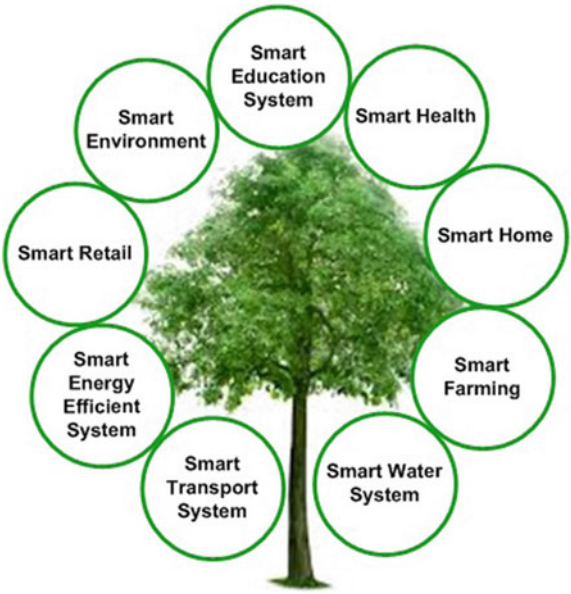


**Fig. 1** Features of green smart city

There are certain standards developed for these smart cities. For designing these smart cities there are global city standards for life of the cities, e-health, leisure, safety, education, transportation, water, finance etc. Smart governance, smart environment, smart mobility, smart people, smart economy and smart living are the key characteristics of the smart cities. The green smart cities have other important features like reforestation zones, greenhouses, green floors and roofs, green bridges, green urban areas, green energy management, fish voyage channels, flood restoration facilities, farmland, forest areas, which have the advantages of nature-based solutions.

There are some smart cities in the world which are taking care of the environment. Denmark is the first country in the world to pass an environmental protection law and engage large number partners to save its environment. The city of Copenhagen is considered as one of the best smart city around the world with the vision to become the world's first carbon neutral capital. So as to accomplish this yearning objective, the city is implementing new and innovative solutions for managing waste, transport, water and utilizes alternate energy sources efficiently. Carbon neutrality will bring about a superior personal satisfaction, advancement work creation and saving. Songdo city in South Korea has already automatic climate control facilities along with computerized accessibility. Its roads, water systems, electricity systems and waste management systems have electronic sensors which help to track and respond to the movement of residents. Dubai together with its neighboring city Abu Dhabi is also deploying over 5000 Wi-Fi hotspots to offer free internet to cover all other areas of a smart city, including healthcare, industrial, education, safety, telecoms, tourism and utilities, where 250,000 smart meters are

set to be deployed. In the safety arena, one of the city's government's plans is to introduce Google's Glass technology to the police to create the world's smartest police stations. The country is also taking urban landscape to an extreme with plans to build an artificial mountain, tall enough to make it rain more often in the desert nation. Even in India, the target is to build more than 100 smart cities. Barcelona is also rolling out more e-Government services, contactless services, more city apps, smart bus stops and more. Seattle has started a program to decrease vitality utilization by means of examination of ongoing information whereas San Francisco dispatches the I-80 Smart Corridor extend highlighting various cameras, sensors, and actuators, high innovation street signs.

There are certain standards developed for these smart cities. The application space skill for smart cities lies in International Organization for Standardization (ISO) TCs. Joint Technical Committee (JTC-1) commitments are imperative to empower a Smart City, with its norms about covering the data layer, application layer and support layer and additionally adding sensor layer. All types of communications and systems administration are controlled by the International Telecommunication Union (ITU), with commitment from JTC1/SC6 while security is added by JTC1/SC27. There are predominantly two foundations of city indicators i.e. ISO/TC268 and ITU-T Smart and Sustainable Cities Focus Group. ISO/TC268 is focused on sustainable development in society, where one of the working groups is focused on developing city indicators and the other in developing metrics for smart society infrastructures. These are indicators referred by the ISO/TR 37150 according to global city indicators, green city index arrangement and smart city acknowledged by ICT.

Worldwide city indicators cover up the general city life, for example, instruction, wellbeing, amusement, security, transportation, wastewater, water, back and so on. The global city indicators have now become an ISO Standard i.e. ISO 37120:2014 and ISO TC 8. This standard is being used by a number of smart cities. The green city index arrangement covers $CO_2$, water, transport and vitality etc. These are essentially focused on the indicators which are identified with ecological effect and, once again, are not specifically identified with ICT. This section provides a selection of the indicators used in the three sets reviewed in ISO/TR 37150:2014, and in the technical report on Smart and Sustainable City KPIs being developed by the ITU-T Smart and Sustainable Cities Focus Group [13]. A few indicators incorporated into the smart city acknowledged by ICT. To make the smart cities greener these are the vital indictors as represented in Fig. 2.

A city is not brilliant when the diverse systems which characterize it are not ready to impart and work together in systems. The communication among these things is mainly depend on emails, calls, video conferences, optical fiber links, social networks, broadband and distributed computing etc. Many smart devices in the city, which are the major parts of the city's physical infrastructure, depend on strong foundation the transmission carrying capacity i.e. bandwidth because this will help to transmit the important information throughout e.g. empty parking spots,


**Fig. 2** Green index indicators for smart cities

vitality utilize, auto accidents, climate conditions etc. This data can be accessed by the city through the mobile phones or other electronic devices or sensors and the system will suggest other intelligent alternatives for moving around the city. All together for the smart city system to work, all individuals and devices must have the capacity to communicate with each other. So ICT is a major part for the effective capacity of the above system [14].

The IoT will give them a typical domain where these heterogeneous things will have the capacity to communicate with each other utilizing standardized communication platform. Moreover, the computer and databases ought to have the capacity to impart and nourish into each other, empowering a smooth and effective data stream between the distinctive partners of the city. At the point when the physical foundation is included into the advanced systems the versatility of the city will be quite prominent. But the problem is how to communicate byte of data energy efficiently and hence this exponential traffic can choke the whole communication system. There is a need to rethink about the current architecture of the smart city. Even the sensors and devices of smart cities need to consume their own energy very carefully so that they not only to able to communicate for indefinitely long but also form extensive network even when infrastructure is weak or not available. So there is a need to develop a smart green IoT based architecture by using advanced communication and protocols which communicate the data energy efficiently in a more reliable way. The communication technologies and protocols need to be designed for the IoT platform where all objects or things are combined to analyze location, intent and even emotions over network energy efficiently. The integration of IoT and wireless sensor network can give fabulous solutions to establish communication services which will involve advanced communication protocols that connect smart devices in environment friendly way.

## 3 Features of Green IoT Smart Cities

In green IoT smart cities the main features includes are green smart home, green smart office, green smart healthcare system, green smart grids, green smart transport system, green smart farming, green smart waste management system and green smart environment.

### *3.1 Green Smart Home*

Due to global warming, more and more people are getting energy-conscious and looking forward to the energy management solutions for their home. The smart home will enable new opportunities for architects, builders, technology providers and homeowners at the same time. These new sensor-based home products are controllable from an owner's smart sensory devices such as a smartphone or tablets for controlling the Air Conditioners (AC) system, lights, managing doors and for operating other domestic functions of his personal device. For instance, based on the weather forecast information, a smart home can automatically open and close the windows. Today many service providers have already launched residential applications that can be controlled via the set-top box or web by allowing their users to monitor their houses from anywhere via smart mobile phones.

Apple Inc. has developed a Home Kit so that people can control their home in a smart way. Not only Apple but Google also developed a product called Nest which provides the home automation solution and provide security and energy saving tool for the smart home. It has self-learning equipment which learns the daily habits and does programming itself for the schedule that matches up with the living style. Another major player iRobot Corp developed robotic technology-based solutions called Roomba which integrate adaptive navigation and visual localization along with app control. It has the capability to clean carpets, help to keep clean floors of the entire house etc. Even LG developed its own software which will allow people to connect and communicate with their smart homes. This natural language processing based App is known as HomeChat which will enable the users to send texts to its compatible LG appliances. Google has also announced home automation Brillo operating system.

For this Green smart home concept, the management of the power is very much essential i.e. to understand the peak and optimal times for usage of appliances. For these Green Smart home, there is a requirement of real-time energy monitoring tools which can give the feedback regarding usage of energy and its cost which will help to take necessary decisions accordingly. Also, a good power management system should be installed which can turn on and off the appliances automatically. Modernized indoor thermostats can limit carbon impression. One option is to control the temperature inside the home via cell phone. By chance somebody leaves an entryway open; a smart thermostat can switch off the air conditioner or heater

automatically. Also an intelligent indoor system can ventilate the home while the owner is at work and turn it moves down before arrival back. Smart indoor regulators like the Nest can also take the temperature inclinations, making it much simpler to maximize energy efficiency. Smart home lighting arrangements can give more noteworthy control over the lighting at home thus makes the home more eco-accommodating. Indeed, even the smart window systems can lessen the Heating, Ventilation and Air Conditioning (HVAC) vitality utilization by keeping it cool and warm it when winter arrives. A smart water system can save gallons of water per year. Systems like Cyber Rain can be keenly adaptable to any size yard to screen and can be controlled by any internet associated gadget. Vitality administration systems like Savant watch out for the home's energy utilization so one can find which system, apparatus or hardware are utilizing the most vitality and after that control their utilization particularly amid pinnacle power value periods. So by utilizing these smart machines and innovations keen homes can consequently lessen the vitality utilization of the home and make it green.

Ambient Assisted Living (AAL) innovations incorporate the utilization of home inserted sensors and systems, body worn sensors, robots and inserts. As of late the business is demonstrating a developing enthusiasm for video and PC vision based arrangements and this due to the way that such items are continuously persuading less expensive to be created with cameras and sensors are being coordinated on the semiconductor itself [15].

## *3.2 Green Smart Office*

The Green IoT is an advanced concept for designing the smart offices. Green Smart office makes life easier and improves the business. This Green Smart IoT-based office is connected to the internet, sensors and mobile devices which will enable the employees to manage time, resources and space in an efficient way. These types of smart offices result in a high return on investment and reduce the operational costs. These green smart office solutions also ensure the greater productivity along with better resources and space management in a better collaborative way. If there are any problems while communication amongst the devices, technologies or platform of smart office solutions can automatically go for another solution and contribute towards more efficiency. The processes get automated and the office activities get optimized with the smart office.

One way to reduce your office's energy usage is to install dimmer switches for the lighting. Most offices have huge windows that allow in a lot of natural light, so the artificial light can be adjusted throughout the day depending on how much natural light is available. For example, employees can turn the lights all the way on in the morning, dial the dimmer down as the mid-day sunshine comes through the windows, and then crank it back up as the sun begins to set. The second option is to install motion sensor lighting so the lights are never left on when no one is in the

office even if the person who locks up at night forgets to turn them off. To use less energy on heating and cooling, smart offices can install programmable thermostats. These models should have the ability to preset temperatures so the office can be a comfortable temperature during business hours without wasting energy during non-business hours.

Adding plants throughout the office is also a smart way to go green. Plants can cool down the air around them, so one has not to rely on the air conditioner as much to keep the office at a comfortable temperature. There are smart tools which one can use with plants, like Plant Link, which is a device that texts the message when the plant needs water, sunlight or fertilizer.

## *3.3 Green Smart Healthcare System*

The healthcare industry can be the biggest beneficiary of the IoT revolution. By building green IoT-based systems in hospitals and clinics, along with establishing IoT-based outpatient monitoring solutions, hospitals can improve access to patient care, while increasing care quality and reducing operating costs. The basic building blocks of an IoT-based system are sensors that collect patient data, Internet gateways for transmitting that data and cloud computing to store and process this data. The cloud platform is also used to analyze this data to generate valuable insights for doctors and medical staff. The final stage involves the creation of web and mobile applications which the medical staff can use to decide on the next course of action [16].

In patient-centric IoT systems, the patients are also given mobile applications and even wearable devices for monitoring their health. Adidas Smart Run is a Global Positioning System (GPS) enabled running watch that has a built-in heart rate monitor for the athletes who want to avoid wearing a chest strap to track heart rate. The continuous measurement of heart rates will only fuel the big data challenge that the medical community is facing. However, intelligent algorithms that can interpret heart rate information will provide insights that may ultimately transform health care and disease prevention strategies. Softweb Solutions developed the cross-platform app that communicates with the Pebble watch and enables the patient or caregiver to manage their emergency contacts, medicine alerts. The caregiver also receives notifications for medicine, activities, dementia fence and fall detection.

In green smart healthcare systems all the monitoring devices, systems, machines etc. should work energy efficiently. Indeed, even the hospitals ought to execute a framework that conveys exact ecological control while incorporating effective control systems. It ought to give ideal lighting conditions by utilizing a mix of lighting control strategies, including occasion based booking, inhabitance location, coordinated exchanging, sunshine detecting, and undertaking tuning. It additionally guarantees that the central plant systems operate at peak efficiency at peak

efficiency by overseeing framework limit in light of building load requests and operational rules. It should have the component of interest controlled ventilation and and occupancy-based control in patient rooms, restorative workplaces, or exam rooms, to cut vitality utilization when these spaces are empty.

## 3.4 Green Smart Grids

The green smart grid is the combination of the traditional electrical power grid along with the recent IT technologies. The smarter control of these grid's is provided through high-speed, two-way communication, sensing the real-time coordination of all the devices via client meter or via end user gadget. So the smart grid is not characterized by a solitary innovation but rather it is a distributed, web based system which can provide better control of existing grid infrastructure. It integrates new assets with the existing operational systems and can engage these new devices to provide entirely new benefits to the grid. Such combination helps to get effective resource utilization which can optimize energy consumption. It has the features to exchange the generated power. It will allow dispatch the energy on the basis of demand. It will also empower clients to use energy more efficiently by accessing a complete data about their power utilize and having new management options. Due to these smart features the smart grid can operate energy efficiently [17].

## 3.5 Green Smart Transport System

For some transportation frameworks, the cost of growing the foundation is too high. Therefore, the concentration must move to enhancing the nature of transportation inside the current foundation. The second release of a hit, Intelligent Transport Systems: Smart and Green Infrastructure Design fundamentally inspects the victories and disappointments of transportation systems over the span of the previous decade. The new subtitle mirrors this current version's attention on meta-standards basic to pushing forward and effectively fabricating green smart transport systems that exploit keen/green advancements.

In green smart transport system for smart cities, IoT can solve the problem of toll charges, screening of travelers and their luggage, boarding business bearers and the merchandise moved via cargo etc. by supporting the security arrangements of the transportation. Observing automobile overloads through Personal Digital Assistances (PDAs) of the clients and sending of astute transport system will make the transportation of merchandise and individuals more effective. Transportation organizations would turn out to be more effective in pressing holders since the compartments can self-check and measure themselves. Utilization of IoT innovations for overseeing traveler baggage in airplane terminals and aircraft operations will empower robotized following and sorting, expanded per-sack read rates, and expanded security.

## 3.6 Green Smart Farming

In smart cities for smart farming procedures, cutting edge technologies and innovation are expected to enhance the generation and quality of crops. Smart farming includes applying the various inputs (water, pesticides, and manure), finishing pre and post harvest operations, and checking ecological effects. Different productive methodologies, for example, intelligent water system, smart underground sensors, and smart insect identification have been intended to perform undertakings for brilliant farming. Comparative methodologies can be connected to forest observing, where the real concentration is timberland fire checking since flames frequently result in critical harm to nature. So, by utilizing IoT empowered keen gadgets the characteristic assets can be utilized proficiently.

Green smart farming speaks to the utilization of present day ICT into agribusiness, prompting to what can be known as a third green revolution. Taking after the plant rearing and hereditary qualities upsets, this third green revolution is assuming control over the agrarian world based upon the consolidated utilization of ICT arrangements, for example, exactness gear, the IoT, sensors and actuators, Global Positioning Systems, Big Data, Unmanned Aerial Vehicles (UAVs, rambles), mechanical autonomy, and so on.

Green smart farming applications don't target just vast, traditional cultivating misuses, yet could likewise be new levers to help other normal or developing patterns in agrarian abuses, for example, family cultivating (little or complex spaces, particular societies or potentially cows, conservation of high caliber or specific assortments), natural cultivating, and upgrade an extremely regarded and straightforward cultivating as indicated by society and market awareness. Smart green farming can likewise give extraordinary advantages regarding natural issues, for instance, through more productive utilization of water, or enhancement of medications and data sources.

## 3.7 Green Smart Waste Management System

Green smart cities management system focus on reduction and segregation of waste at source, door-to-door collection, recycling and reuse of waste, generation of wealth from waste. The ideal smart green city attempts to produce a closed-loop system with zero emissions and zero waste. This means residents consume only what energy, water, and food inputs are necessary, recycling whatever waste is produced, and minimizing outputs of greenhouse gases ($CO_2$, Methane), air pollution and water pollution. Above all else, innovative waste management systems will be essential to the success of smart green cities. Currently, most of the produced things follow an unsustainable cradle to grave life cycle, which not only pollutes our environment but fails to recognize waste as a valuable resource. In order for a smart green city to use resources in a way that results in both cost and

energy savings and minimal contributions to climate change, it must follow a cradle to cradle cycle where all materials that are produced are utilized to the fullest extent possible. With the right technology, just about everything which are thrown away has the potential to be composted, recycled or converted through waste-to-energy processes into energy, biofuel, or biochar. IoT services can solve the problem of waste collection and can also enable dynamic scheduling and routing in a smart city. IoT cloud based framework can help for association of waste accumulation process and applications for waste truck drivers and administrators [18].

### *3.8 Green Smart Environment*

Expanding number of vehicles, urbanization and numerous modern exercises have increased air pollution extensively in the most recent couple of decades. Air pollution observing is a most tedious task. In advanced green smart cities the utilization of IoT innovation can make air pollution monitoring fewer complexes [8].

## 4 Approaches for Software and Algorithm Used in Green IoT Smart Cities

The main approaches like Green Data Center Design, Virtualization for going green, Green Power Management and Green Computing [19] for algorithm and software used in Green IoT smart cities are listed as follows:

### *4.1 Green Data Center Design*

A green data center is used to store, manage and dissemination of data of green smart cities. Its design is such that it consumes minimal power resources for operation and maintenance. It saves energy even for computing and supporting electronic resources such as cooling, backup, and lighting etc. It can work with solar, wind or hydropower. The entire infrastructure of the green data center is designed for low power and for reduced carbon footprint.

### *4.2 Virtualization for Going Green*

Through virtualization, multiple different operating systems can run simultaneously on the same physical hardware. So several physical systems for smart cities can be

combined into the single powerful virtual machine. So it reduces the original hardware cost, power, and cooling consumption. Virtualization and going green are good for the environment but it can be great to design green smart cities.

### *4.3 Green Power Management*

Due to the high energy consumption in peak hours, most systems for light industrial and commercial industrial market, consume more energy on peak hours, the price for electricity is high. Smart power management systems allow automatically to do power management functions for green smart cities.

### *4.4 Green Computing*

According to [7] and [20], Green computing is an environment friendly technology. It is the field of outlining, assembling, utilizing and discarding PCs, portable workstations, servers and different subsystems in such a way that it has minimum effect on the environment. It incorporates appropriate reusing approaches, utilized gear transfer suggestions, government rules and proposals for obtaining green PC hardware. Green figuring fundamental component is to cover control use, least paper utilization alongside the proposals for new hardware and reusing old machines. As PCs have poison metals and toxins which can transmit harmful radiations so never dispose of PCs in a landfill. One needs to reuse them. So green computing can be a key feature for making smart cities green.

## 5 Cloud-Based Green IoT Architecture for Smart Cities

In this section, Green IoT Architecture for smart cities is proposed which will take care of communication, standardization, interoperability aspects. The main feature of this proposed architecture is that it is based on the cloud platform which automatically reduces the consumption energy for many systems and makes the environment clean.

The proposed architecture of Green IoT consists of five layers i.e. Presentation layer, Application layer, Big data analytic layer, Network layer, and Smart City Sensor layer and infrastructure as shown in Fig. 3. The architecture defines the main communication paradigms for the connecting entities. It provides a reference communication stack along with insight about the main interactions in the domain model. It describes how communication schemes can be applied to different types of Green IoT networks. It is important that heterogeneous networks of sensors in different types of networks are able to communicate with each other.

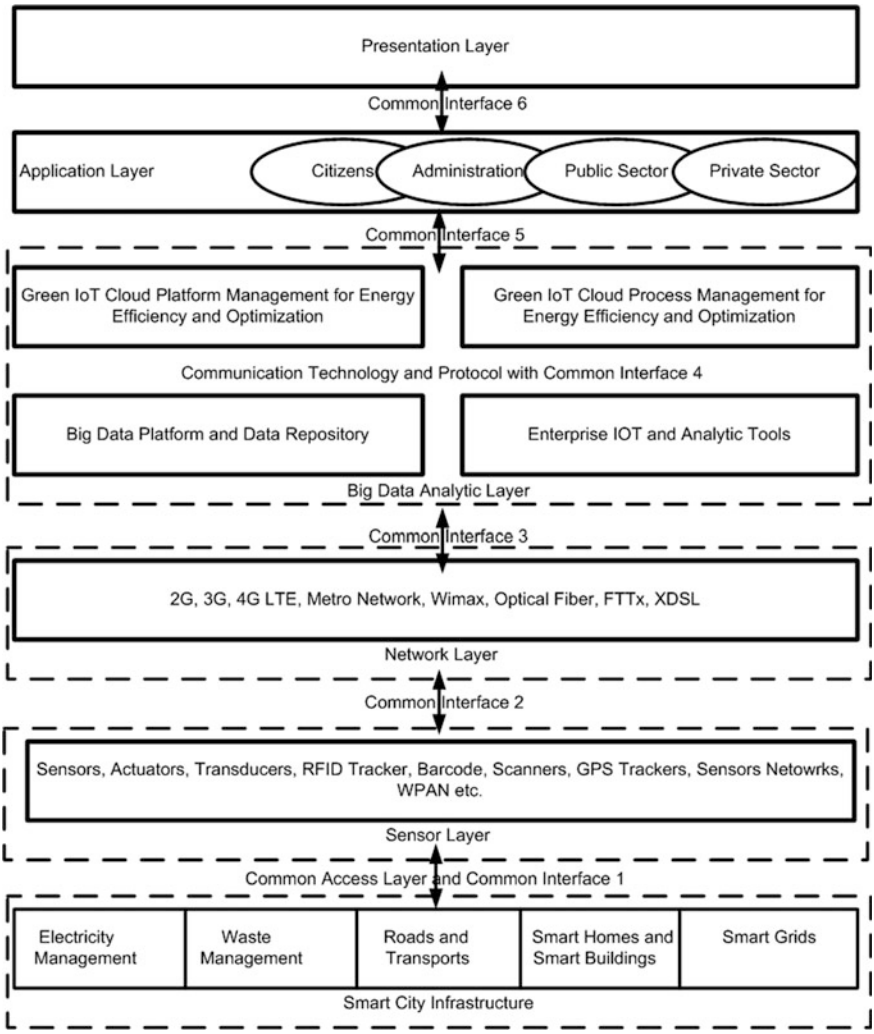


**Fig. 3** Cloud-based green IoT architecture for smart cities

## *5.1 Presentation Layer*

The presentation layer mainly receives the information from application layer. Information can be communicated in different formats via different sources. Thus, the presentation layer is responsible for integrating all formats into a standard format for efficient and effective communication. The presentation layer follows information programming structure schemes developed for different languages and provides the real-time syntax required for communication between two objects such

as layers, systems or networks. The data format should be acceptable by the next layers; otherwise, the presentation layer may not perform correctly. Various city systems like water supply system, power supply system, pollution control system, transport department etc. can share their information by using web portals, internet, mobile applications that are built on this layer. Using this layer both government departments as well as individuals can access the specific data according to their rights. This data can be used to design even more services which can enhance the operations of the city.

## 5.2 Application Layer

This layer put at the highest point of the stack is incharge of conveyance of different applications to various clients in Green IoT through different communication techniques. It analyzes the massive data and information through cloud computing, fuzzy recognition and other technologies. The smart cities applications can be for the user, administration, private and public sectors as shown in Fig. 3. With application layer the latest information collected from big data analytic layer rapid responses can be given to physical phenomena i.e. garbage and its monitoring, digital video monitoring, noise and dust monitoring, underground, fire control, smart education, urban transportation public utilities, smart home, public transportation, smart business, smart buildings, railway transportation, smart business park, smart water, building energy, air transportation, urban drainage service, smart transportation, digital urban management, smart business centers, smart parking, smart properties, smart gas measurement etc. All the ecological environment correspondence like smart air pollution monitoring, water quality diagnostics monitoring, supply consumption monitoring, monitoring water resources, key pollution source, automobile exhaust, monitoring environment protection, water resources monitoring management, comprehensive monitoring of energy are a part of this layer. These new services based on real time physical world data, improving infrastructure integrity, increasing efficiency of urban management and addressing environmental degradation.

## 5.3 Big Data Analytic Layer

The data management and information flow layer is of two types: Periodic and Aperiodic [21]. In periodic data management IoT sensor data requires filtering because the data is collected periodically and some data may not be needed so this data needs to be filtered out. In aperiodic data management, the data is an event triggered IoT sensor data which may require immediate delivery and response for example medical emergency sensor data. In this proposed architecture big data analytic layer is used and it has big data platform and data repository as shown in Fig. 3 for periodic and aperiodic data which will help in saving and optimization of

energy through enterprises IoT and analytic tools. The Green IoT communication technologies, networks and services approaches should be able to support dynamic environment through internet architecture evolution, protocols and wireless system access architectures with improved security and privacy. This layer provides the green IoT cloud platform and cloud process management for energy efficiency and optimization for the application layer. Even cloud can be segregated to fog to save more energy. It also control the management services like information analytics, security control, process modeling and device control to green IoT cloud platform and cloud process management. It is also responsible for an operational support system, security, business rule management, business process management. It has to provide service analytics platform such as statistical analytics, data mining, text mining, predictive analytics etc.

## *5.4 Network Layer*

The lower communication layers are mostly specific for Wireless sensor network and the network and higher communication layer should preferably use common protocols in order to allow interoperability across networks. The most viable communication standard for wireless sensor network is Institute of Electrical and Electronics Engineers (IEEE 802.5.14) which defines the physical and link layer for short distance communication for smart cities with low power consumption and at low cost. It operates at the Industrial, Scientific and Medical (ISM) frequency bands i.e. 800/900 MHz and 2.4 GHz. The other communication technologies like ZigBee, WirelessHart, WIA-PA and ISA.100.11a depending upon their distances to communicate [22]. The proposed architecture is covering additional frequency bands e.g. TV white space, regional bands which operate at ultralow power for different applications like train control. Bluetooth is also a wireless short range protocol. Bluetooth 4.0 adopts a technology Bluetooth 4.0 is a low energy protocol and lightweight variant for low power applications.

The main requirements of these communication technologies is the power consumption and small computational footprints for wireless sensor network so IP protocol suite is the main candidate for these layers. Even the previously specific standards who defined their own protocol can be shifted to IP. So the WSN and IoT IPv6 is the feasible solution for smart cities applications. The IPv6 over Low-Rate Wireless Area Net- work (6LoWPAN) working group defines the mapping of IPv6 on IEEE 802.15.4 e.g. RFC 6282:

## *5.5 Smart City Sensor Layer and Infrastructure*

This layer can supports different kinds of sensors operating with minimal power consumption and installed in different systems of the smart cities. There are three

types of sensing models i.e. RFID, Wireless Sensors Networks (WSN) and crowd sourcing. RFID is an automatic identification technique to detect the tagged objects. These passive RFID tags are not battery operated rather they can take the power from the reader's interrogation signal to communicate the ID to the RFID reader. These types of systems can be useful for many applications e.g. retail and supply chain management for smart cities. WSN plays an important role in urban sensing applications. It is a feasible solution for the applications related to transportation and access control which will collect process and analyze the important information gathered from a variety of environments. The wireless sensors are smaller in size, cheaper, more intelligent and widespread (e.g., embedded camera).

As the social networking is booming a new type of sensing paradigm i.e. smart phone technology has evolved by encouraging the citizens of the smart cities to contribute towards the smart city management. It plays an important role in government citizen interaction. So, this layer must be able to support massive volume of IoT data produced by wireless sensors and smart devices. IoT sensors are aggregated with various types of protocols and heterogeneous networks using different technologies. IoT networks need to be scalable to efficiently serve a wide range of services and applications over large scale networks.

## 6 Conclusion

The telecommunication systems play a very important role in smart cities. It must be highly reliable and available as well as flexible, economical, and environmentally conscious. To satisfy these difficult requirements, a new architecture of smart cities is proposed which will use cloud—IoT smart systems energy efficiently and make the cities green. By adapting the proposed communication technologies gives provision of a wide variety of services in smart cities. The proposed cloud services and visual communication tools using high speed broadband communication networks in smart cities can improve business in corporate and government sectors also. Meanwhile, sensor networks utilizing variety of wireless technologies in green smart cities give access to information on the flow of goods and the status of equipment and the environment. They also facilitate the use of remote control. This makes possible the implementation of smart cities that are safe, secure, and environmentally conscious. Sensor layer provides the all green IoT through WSN to the users for using different application through cloud platform and process. In future, cooperation between communities can be encouraged as sensors and actuators, communication technologies and control systems are becoming more primitive and intelligent. Further, there is a need to develop advanced solutions for computing and communication technologies, dynamic networking and reliable software engineering with minimal energy usage. Another real research zone is to anticipate an improvement way along which most recent advancements which can be utilized to enlarge existing smart cities frameworks and applications by adding extra elements.

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