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Green Internet of Things: A Research Direction on G-IoT Based Energy Efficient Smart City

***Sharmila S*[1]*, Kanagaraj A*[2]*, Finny Belwin A*[3]*, Linda Sherin A*[4]*, Antony Selvadoss Thanamani*[5]**

[1,2,5]Department of Computer Science, NGM College, Pollachi, Coimbatore, TamilNadu, India
[3]Department of Computer Science, Angappa College of Arts and Science, Coimbatore, TamilNadu, India
[4]Department of Computer Science, AMJAIN College, Chennai, TamilNadu, India

ABSTRACT

Smart cities are becoming important innovation and economic development hubs and thus need special attention and concentration. Sustainable, effective, and smart solutions for transport, governance, the climate, quality of life, and so on are needed for the drastic increase in urbanisation over the past few years. The Internet of Things (IoT) is a forum for global communication between millions of internet-connected electronic devices. Wireless and wired sensors, home appliances such as televisions, refrigerators, etc., Radio Frequency Identification (RFID), etc. were included in these devices and electronic appliances. The Internet of Things has many advanced and pervasive smart city applications. The energy demand for IoT applications is growing, while the number and specifications of IoT devices continue to rise. Smart city strategies must also have the potential to use resources effectively and manage the associated challenges. Energy management is seen as a crucial framework for the implementation in smart cities of complex energy systems. Smart cities have been fitted with numerous electronic devices on the basis of the Internet of Things (IoT), thereby being smarter than ever, due to the increasing advances in advanced metering and digital technologies. The goal of this article is to provide a thorough overview of the challenges and management of energy in smart cities. In addition, the IoT technologies for smart cities and the key components and features of a smart city are listed in this survey.

Keywords*: Green IOT, Smart City, Internet of Things, Big Data, Security, Privacy, Data Center, Sensors.*

****Corresponding Author***
E-mail: mcasharmi2007@gmail.com

INTRODUCTION

In order to achieve sustainable goals within urban context, IoT based smart city is a popular concept to endeavor. The utilization of IoT technology is the backbone of this concept. The concept of Internet of Things (IoT) was offered by Kevin Ashton in 1999, when the distribution of devices with intelligent sensors integrated with the appropriate communication tools started. Internet of Things are defined as self-organized systems having no conceptual limitations, being the part of the convergent systems and are designed to increase the efficiency of processes in these systems. In its turn the IoT-applications are defined as sets of connected or integrated objects or devices into the environment. These objects or devices use the standard communication protocols for information exchange. The results of the carried out investigations prove that at present the number of connected Internet of Things, exceed the number of the planet population and their variety and diversity include a lot of devices which can be used as unified block solutions while implementing the innovative projects of the future "smart cities".

The proposal of the Indian Government to build 100 smart cities in the country for which Rs. 7,060 crores has been allocated in the current budget could lead to a major and rapid expansion of the country's IoT. The launch of the Government's Digital India Program to 'transform India into a digitally empowered society and information economy' would also provide the requisite impetus for the growth of the country's IoT industry. The various initiatives proposed to be taken under the Smart City concept and the Digital India Program to setup Digital Infrastructure in the country would help boost the IoT industry. IoT will be critical in making these cities smarter. Some of the key aspects of a smart city are Smart parking, Intelligent transport system, Tele-care, Woman Safety, Smart grids, Smart urban lighting, Waste management, Smart city maintenance, Digital-signage, Water Management.

Among other things, IoT can help automate solutions to problems faced by various industries like agriculture, health services, energy, security, disaster management etc. through remotely connected devices. Apart from direct IoT applications, the IT industry also has an opportunity to provide services, analytics and applications related to IoT. Internet of Things involves three distinct stages. Such as 1. the sensors which collect data, 2. An application which collects and analyzes this data for further consolidation and, 3. Decision making and the transmission of data to the decision-making server. The Internet of Things (IoT) holds the promise to improve our lives by providing innovative services conceived for a wide range of application domains, ranging from personal to industrial environments, and facing several societal challenges in various everyday-life human contexts. The development of new "smart" devices, opportunities and services is expected to provide a new radical evolution of what the current and future cities will be. The idea behind the new vision of "Smart Cities" is to enable an improved wellbeing to the citizens from economic, social, and environmental perspective.

A smart city is a place where traditional networks and services are made more flexible, efficient, and sustainable with the use of information, digital and telecommunication technologies, to improve its operations for the benefit of its inhabitants. Smart cities are greener, safer, faster and friendlier. The different components of a smart city include smart infrastructure, smart transportation, smart energy, smart healthcare, and smart technology. It is these components that make cities smart and effective. Information and communication technology (ICT) makes it possible for traditional cities to be turned into smart cities. The two closely related modern Internet of Things (IoT) and Big Data (BD) technology systems make smart cities efficient and responsive. To allow smart cities to evolve, the technology has fairly matured. There is, however, a great need to make the majority of cities worldwide smart in terms of physical infrastructure, clean energy, ICT, IoT, and Big Data.

World population has increased significantly in the last decades and so has the expectation of living standards. It is predicted that around 70% of the world population will live in urban areas by the year 2050. At present cities consume 75% of the world's resources and energy which leads to the generation of 80% of greenhouse gases. Thus, in the next few decades there can be severe negative impact on the environment. This makes the concept of smart cities a necessity. The creation of smart cities is a natural strategy to mitigate the problems emerging by rapid urbanization and urban population growth. Smart cities, in spite of the costs associated, once implemented can reduce energy consumption, water consumption, carbon emissions, transportation requirements, and city waste [16].

INTERNET OF THINGS (IOT)

IoT is an emerging technology that uses the Internet and aims to provide connectivity between physical devices or "things". Examples of physical devices include home appliances and industrial equipment. Using appropriate sensors and communication networks, these devices can provide valuable data and enable offering diverse services for people. For instance, controlling energy consumption of buildings in an smart fashion enables reducing the energy costs [11]. IoT has a wide range of applications, such as in manufacturing, logistics and construction industry. IoT is also widely applied in environmental monitoring, healthcare systems and services, efficient management of energy in buildings, and drone-based services.

When planning an IoT application which is the first step in designing IoT systems, the selection of components of IoT such as sensor device, communication protocol, data storage and computation needs to be appropriate for the intended application. For example, an IoT platform planned to control heating, cooling, and air conditioning (HVAC) in a building, requires utilizing relevant environmental sensors and using suitable communication technology. In IoT platform IoT devices are used for data collection, transmission, and processing [3]. For example, an IoT gateway device enables routing the data into the IoT system and establishing bi-directional communications between the device-to-gateway and gateway-to-cloud.

The communication protocols enables the different devices to communicate and share their data with the controllers or the decision making centers. IoT platforms offer the flexibility to select the type of the communication technologies (each having specific features), according to the needs of the application. The examples of these technologies include Wi-Fi, Bluetooth, ZigBee and cellular technology such as LTE-4G and 5G networks. The data storage in IoT platform which enables management of collected data from the sensors. In principle, the data collected from the devices is very large. This necessitates planning an efficient data storage that can be in cloud servers or at the edge of an IoT network. The stored data which is used for analytical purposes, forms the fifth component of the IoT platforms. The data analytics can be performed off-line after storing the data or it can be in form of real-time analytics. The data analytic is performed for decision making about the operation of the application. Based on the need, the data analytics can be performed off-line or real-time. In off-line analytics, the stored data is first collected and then visualized on premises using visualization tools. In case of real-time analytics, the cloud or edge servers are used to provide visualization, e.g. stream analytics``.

IoT in the Energy Sector

Today, the energy sector is highly dependent on fossil fuels, constituting nearly 80 % of final energy globally. Excessive extraction and combustion of fossil fuels has adverse environmental, health, and economic impacts due to air pollution and climate change to name a few [1]. Energy efficiency, i.e., consuming less energy for delivering the same service, and the deployment of renewable energy sources are two main alternatives to diminish the adverse impacts of fossil fuel use [6]. An energy management system based on IoT can monitor real-time energy consumption and increase the level of awareness about the energy performance at any level of the supply chain.

IoT Data and Computing

Computing and analyzing the data generated by IoT allows gaining deeper insight, accurate response to the system, and helps making suitable decisions on energy consumption of the systems. Computing IoT data is a challenging issue, however. IoT data, known as Big Data, refers to an enormous amount of structured and unstructured data generated from various elements of IoT systems, such as communication networks, smart or intelligent devices, software applications and sensors. Due to the characteristics of Big data, which are big volume, high velocity, and high variety, it needs to be efficiently processed and analyzed. Processing the Big data is beyond the capacity of traditional methods, i.e., storing it on local hard drives, computing, and analyzing them afterwards. Advanced computing and analytic methods are needed to manage the Big data.

Energy Efficiency and information infrastructure of smart cities

The growing role of human beings in creating the Internet of Energy (IoE) requires the development of the new information technology and intelligent network-centric control algorithms. Smart city solutions use communication and networking technologies for dealing with the problems precipitated by urbanization and growing population. The Internet of Things (IoT) is a key enabler for smart cities, in which sensing devices and actuators are major components along with communication and network devices [2]. The sensing devices are used for real-time detection and monitoring of city operations in various scenarios. It is projected that in the near future, common industrial, personal, office, and household devices, machines, and objects will hold the ability to sense, communicate, and process information ubiquitously [7]. However, it is challenging to design a fully optimized framework due to the interconnected nature of smart cities with different technologies. Further, smart city solutions have to be energy-efficient from both the users' and environment's points of view [8].

Energy Management and Challenges for Smart City Applications

Home Appliances

Home appliances are the major sources of energy consumption. Demand management is a key for customizing energy use by managing the lighting, cooling, and heating systems within residential units. On the other hand, the intelligent operation of activities can also facilitate the optimized management and operation of energy [9].

Education and Healthcare

Considering the importance of educational and healthcare services, it is difficult to dematerialize them. However, it is possible to demobilize services for the reduction of energy consumption; for example, exploiting remote healthcare by visualizing sensors and mobile phones, and distance education can create a significant reduction in energy consumption.

Transportation

The energy use for transportation includes public transport, daily commuting to work in personal vehicles, leisure travel, and so on. In addition to the energy consumed by public transport and personal vehicles, they are also a major cause of pollution in cities. IoT-enabled solutions can be employed for energy management, such as traffic management, congestion control, and smart parking. This can significantly reduce energy consumption as well as CO_2 emission [16].

Food Industry

Energy consumption in the food industry is not only related to the storage, purchase, and preparation of food; it also includes diners moving into restaurants in search of food. IoT-enabled solutions can be used here for making optimized choices in terms of food availability. On the other hand, the transportation of the food can also be optimized by incorporating intelligent means of transportation.

Energy-Efficient Solutions for Smart Cities

With the increase in IoT applications for smart cities, energy-efficient solutions are also evolving for low-power devices. There are some energy-efficient solutions that can either reduce energy consumption or optimize resource utilization. Following are some main research trends for energy-efficient solutions of IoT-enabled smart cities [10].

Lightweight Protocols

Lightweight means that a protocol causes less overhead. IoT-enabled smart cities have to use various protocols for communication. There are several existing protocols in the literature such as Message Queue Telemetry Transport (MQTT), Constrained Application Protocol (CoAP), Extensible Messaging and Presence Protocol (XMPP), Advanced Message Queue Protocol (AMQP), 6lowPAN, and Universal Plug and Play (UPnP) IoT.

Scheduling Optimization

Scheduling optimization for IoT-enabled smart cities refers to the optimization of resources with the aim of minimizing energy consumption and subsequently reducing electricity usage. In this regard, demand-side management (DSM) is of prime importance; it refers to the manipulation of residential electricity usage by altering the system load shape and consequently reducing the cost. Broadly speaking, DSM comprises two main tasks: load shifting and energy conservation, where load shifting refers to the transfer of customers' load from high-peak to low-peak levels. By adopting this, electricity can be conserved and provide room for other customers.

Predictive Models for Energy Consumption

Predictive models for energy consumption in IoT-enabled smart cities are indeed of vital importance. They refer to the wide range of applications in smart cities, including predictive models for traffic and travel, predictive models for controlling temperature and humidity, and so on. Various prediction models such as neural networks and Markov decision processes can be incorporated here. Exploiting the predictive models will not only reduce the significant energy consumption but also lead to many societal benefits.

Cloud-Based Approach

Cloud computing has reshaped the computing and storage services, which can be used to provide energy-efficient solutions for IoT-enabled smart cities. More precisely, the cloud-based approach helps in managing the massive data center flexibility and in a more energy-efficient manner.

Low-Power Transceivers

Since the IoT devices in smart city applications operate on limited batteries, a low-power design architecture or operation framework is of superior importance for addressing the energy management in IoT-enabled smart cities. Mostly, the existing application protocols for IoT devices are not in accordance with the energy efficiency perspective.

Cognitive Management Framework

IoT devices are heterogeneous in nature, and the associated services are unreliable. Therefore, it is important to investigate a cognitive management framework that adopts intelligence and cognitive approaches throughout the IoT-enabled smart cities. The framework should include reasoning and learning in order to improve decisions for IoT networks.

GREEN IOT

The energy consumption of IoT devices is an important challenge, especially in large-scale deployment of these technologies in near future. To run billions of devices that will be connected to the Internet significant amount of energy is required. The big number of IoT devices will also produce a great deal of electronic waste. To tackle these challenges, a low-carbon and efficient communication networks are needed. Fortunately, these necessities has led to the appearance of the green IoT (G-IoT). The key component of G-IoT is its energy-efficient characteristics throughout the life cycle, i.e., design, production, deployment, and ultimately disposal.

G-IoT cycle can be applied in different IoT technologies. For example, in radio frequency identification (RFID) tags. To decrease the amount of material in each RFID tag, which is difficult to be recycled, the size of RFID tags are reduced. Green M2M communications is another example, which enables adjusting power transmission the minimum level, facilitates more efficient communication protocols using algorithmic and distributed computing techniques. In wireless sensor networks also the sensors nodes can be in the sleep mode and just work when necessary. In addition, radio optimization techniques, such as, modulation optimization or cooperative communication can be applied to reduce the power consumption of the nodes. Moreover, energy-efficient routing techniques, such as, cluster architectures or multi-path routing can provide efficient solutions. These above said approaches will reduce the energy needs of IoT systems.

THE INTERNET OF THINGS (IoT) TECHNOLOGIES IN SMART CITIES

The Internet of Things is the foundation of intelligent city implementation (IoT). The IoT is the technological foundation of smart cities, in other words. Smart cities need to have three main features: knowledge, interconnection, and IoT-enabled instrumentation. It can be claimed that smart cities can be made feasible by the use of IoT [12]. The use of smart phones, smart meters, smart sensors, and radio-frequency identification (RFID) in essence forms the IoT framework in the smart cities. The IoT framework consists of various components including electronics, sensors, networks, firmware, and software. IoT is the network of interconnected physical objects (called “things”) including computers, smart phones, sensors, actuators, wearable devices, homes, buildings, structures, vehicles, and energy systems. The IoT ensures the communication of many variety types of systems and applications for providing increasingly smart, reliable and secure services. A large variety of sensors including RFID, IR, and GPS, connect the buildings, infrastructure, transport, networks and utilities through ICT. Some of the IoT-related technologies are discussed in the following

- Radio-Frequency Identification (RFID):- RFID is used to carry out their automatic identification and assign a unique digital identity to each object, in order to be incorporated in the network and related to the digital information and service.
- Wireless sensor network (WSN):- WSNs could be integrated with RFID systems to gain some goals like obtaining information regarding the position, movement, temperature, etc.
- Addressing:- To monitor them through the Internet, it is vital to address the large-scale combination of artifacts in a unique way. Reliability, scalability and persistence, in addition to the aforementioned definition of uniqueness, denote the primary criteria for creating a unique addressing scheme
- Middleware:- In reality, middleware combines the functionality and communication capabilities of all the devices involved in a succinct way.

SMART CITIES: COMPONENTS AND CHARACTERISTICS

The components of smart cities are smart infrastructure, smart housing, smart transport, smart energy, smart healthcare, smart technology, smart governance, smart education, and smart people. Depending on their emphasis, various smart cities have varying levels of these smart components. Sustainability, quality of life (QoL), urbanization, and intelligibility are the different characteristics of smart cities. The sustainability of a smart city is related to city infrastructure and governance, energy and climate change, pollution and waste, and social issues, economics and health. The quality of life (QoL) can be measured in terms of the emotional and financial well-being of the citizens. The urbanization aspects of the smart city include multiple aspects and indicators, such as technology, infrastructure, governance, and economics. The smartness of a smart city is conceptualized as the ambition to improve economic, social and environmental standards of the city and its inhabitants. Smart economy, smart citizens, smart mobility, smart governance, and smart living are numerous widely cited facets of city smartness.

BIG DATA ANALYSIS IN SMART CITIES

The rapid processing of Big Data of poorly structured data in the "smart cities" projects involves a wide range of activities concentrated on the selection, transmission, transformation, storage and analytical processing of information flows concerning the state and processes of environmental pollution, weather, accumulation and utilization of wastes, water supply and other natural resources, heat and energy sources, sensory of city events and incidents [4]. At the same time, mining and transformation of data concerning urban life from social networks are carried out. The technologies of data transmission and selection formed by urban engineering components, are based particularly on the use of wireless sensors integrated into numerical industrial and service information-technological applications [5]. The combination of data obtained from both physical sensors and social sources contributes to the formation of full picture of city-wide processes, complexes, subsystems and structures.

SMART CITY DESIGN: CHALLENGES AND OPPORTUNITIES

The challenges for building smart cities are quite diverse and complex. A few include cost, efficiency, sustainability, communication, safety, and security [13]. These design challenges are governed by various factors including the natural environment, government policy, social communities, and economy. Cost is the most important factor of the smart city design. The cost includes design cost and operation cost. The design cost is a onetime cost of the smart cities. Operation cost is that cost that is required to maintain the smart city. Design cost needs to be small to make a smart city realization possible. At the same time small operation cost will make it easier for cities to operate on a long run with minimal burden on the city budget.

Cost optimization over the complete system lifecycle can be a challenging problem. Operation efficiency of the smart cities is an important challenge: higher efficiency can reduce the operational cost and improve sustainability of the smart city [14]. Cutting down carbon emissions and city waste is needed to enhance sustainability and efficiency, and reduce operation cost. Smart cities need to cope up with population growth while ensuring long-term sustainability with optimized operation cost. Smart cities need to be resilient to disasters and failures. Disasters can come from nature. Failures can originate for many reasons in the system such as a failure in ICT, or power failure. Natural disasters also can lead to failure of various components of smart cities.

These disasters and failures must be taken into account in any smart city design so that smart cities can recover from such circumstances efficiently within minimal time. These problems will impact the design and operating costs of smart cities. Smart cities are made possible due to the effective use of many smart components including ICT, sensors, and IoT and will need to process and store large volumes of data [15]. Security of the information and infrastructure is an important design challenge. Above all, public safety is a critical design challenge for smart cities as the safety of the inhabitants is of paramount importance, which can also increase design and operation budgets.

CONCLUSION

In order to build productivity, enhance sustainability, encourage economic growth and improve the quality of life of the people who live and work in cities, smart cities use data and technology. Today, smart city technology paves the way for the next wave of consumer investment and services. Smart cities need information on lighting, smart neighbourhoods, micro grids, electric cars, fibre and other smart solutions in order to work properly. All of these entail several complexities that still need to be addressed in the distribution of goods and services in the fields of distributed manufacturing, solar, energy management and infrastructure. A combination of data collection, processing and distribution technology, network and computer technologies and data protection and privacy measures are used by Smart City to promote application innovation to enhance the overall quality of life of its residents, including infrastructure, healthcare, transportation, entertainment and public services. Whether it's improving security, resilience, sustainability, traffic congestion, public security or municipal services, every community should invest in developing smart cities based on smart systems for a variety of reasons. These improvements lead to improving the protection of electricity, energy efficiency and economic stability of major urban centres, which are slowly but steadily becoming hubs of the 21st century's economic and social growth. Energy management has seen the advent of "smart things: smart networks, smart water and smart energy. All these components are becoming an integral part of the Internet of Energy (IoE), a modern intelligent network capable of sharing data, knowledge and energy in two ways. Big Data will help coordinate wind and solar energy with conventional energy sources in the smart cities of the future. Government and public efforts can build infrastructure to avoid energy scarcity and loss, in order to operate efficiently with big data and smart cities. In this article, we present a brief overview of Green IoT, smart city energy-efficient solution, smart city technology and smart city architecture challenges and opportunities.

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