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Green Internet of Things in smart cities

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Abstract*— 'Change is the only constant thing in the world." The invention of computer resulted into wanting more better computer and greater and advanced features. The same goes on with IoT. The Internet of Thing also known as IoT is the ultimate building block for the smart objects. A search for better and environmentally sound function resulted into Green IoT. A Smart city comprises all the basic necessity but in a smarter version. From the bed light before sleeping to the automated alarm to wake one up. Everyone is surrounded by Smart objects. These objects have definitely made our life easier. However, a change in life may have both good and bad consequences. Despite the benefits of IoT the energy consumption is still on the rise. This problem brought the solution motivated by achieving a sustainable smart city incorporated with Green IoT. This not only saves the extra energy which it was utilised priorly by IoT but also works efficiently. The Green IoT is a new advancement in technology and this paper discusses about the merits, the demerits and various recommendation.

Keywords— *Internet of Things, IoT, Green IoT, Sustainable, Smart Cities*

1. INTRODUCTION

Over the years urbanization can become quite prominent. The greater job opportunities and better lifestyle make many people drawn to various countries. With more than 50 percent of the world population living in cities and nearly 70 percent of the world population projected to live in cities by 2050, it is expected that cities will face various challenges from sustainability and energy use to safety and effective service delivery. Advances in the effective integration of networked information systems, sensing and communication devices, data sources, decision making, and physical infrastructure are creating new opportunities to reduce traffic congestion, fight crime, foster economic development, reduce greenhouse gases, and make local governments more open, responsive, and efficient. More and more cities are beginning to harness the power of sensors, engage citizens equipped with smartphones, cloud computing, high-speed networks, and data analytics.[1] Smart cities are highly being promoted across the world. The Obama government announced various schemes in the year 2015 but the fight against the various issues still continues. Energy consumption is on the top of the list. This not only leads people to rethink if smart cities should really be promoted. Many benefits of Smart cities overweigh the demerits of the Internet of Things but to fix the problem we have the Green IoT.

2. OVERVIEW OF IOT AND GREEN IOT

''In a broad perspective, the IoT can be perceived as a vision with technological and societal implications. From the perspective of technical standardization, IoT can be viewed as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies. Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, while maintaining the required privacy.''[2]

Whereas Green IoT is totally different from what one refers to IoT it does have the basic functionality of Internet of Things it can save a larger amount of energy and thus result into a better option. Enabling the smart world, IoT is included by the NIC (National Intelligence Council) of U.S. among six ''Innovative Civil Technologies'' that will impact U.S. power grids. It is foreseen by NIC that ''by 2025, internet nodes may reside in everyday things, i.e., food packages, furniture, paper documents, and more.'' However, to enable a sustainable smart world, the IoT should be characterized by energy efficiency.[3]

3. OVERVIEW OF SUSTAINABLE SMART CITIES

Smart cities usually mean automated. The cities which work on minor instructions and bare minimum human effort. These cities lead to helping out people at the comfort on their fingertips. From waking to an automated alarm to a sleeping to instructing a light to turn itself off. These cities not only have better designed and well-equipped sensors and electronic devices. But also has a large

methodology to collect data in abundant and relearn and function accordingly which thus combines the process of both Machine learning and Artificial intelligence. These cities not only provide leisure and comfort but also a better data to government for the welfare of the citizens over the period of time.

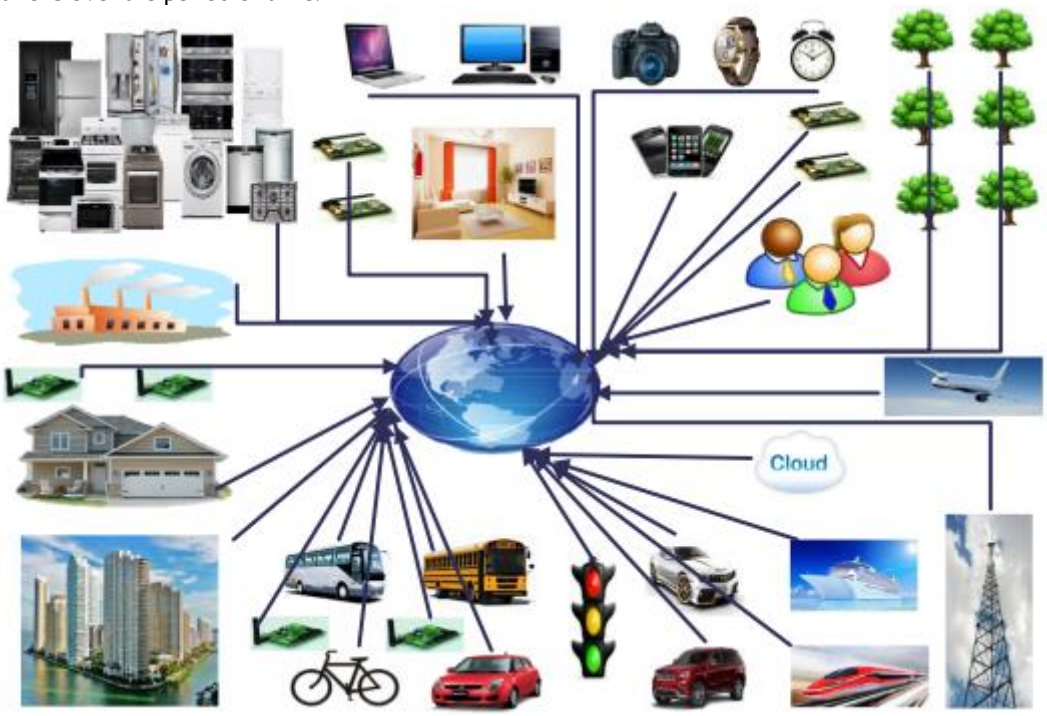

Figure 1. IoT and its uses

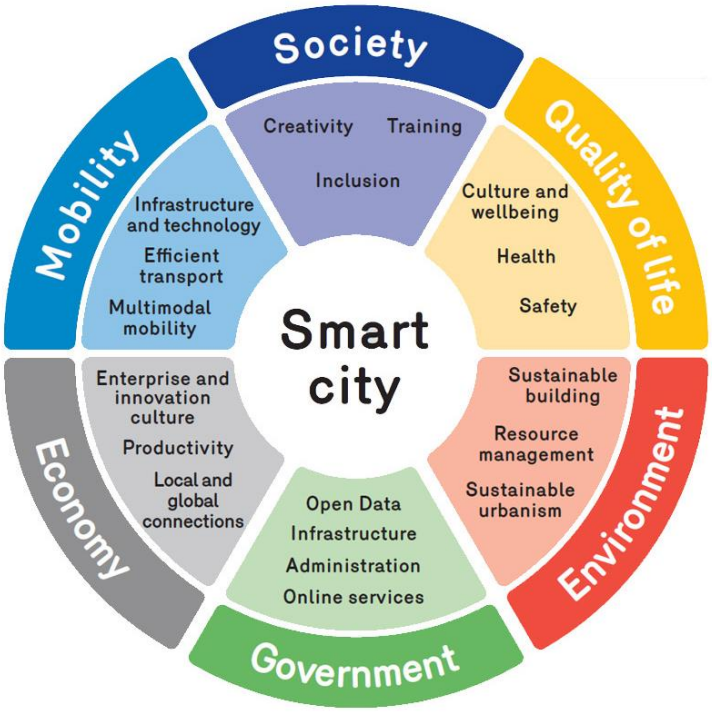

Figure 2. Facilities by Smart Cities

4. APPLICATIONS OF IOT

Smart Houses: To give an easy and tech-smart lifestyle one can make their household full of Smart devices. Smart Homes have devices such as microwaves, ovens, and even air conditioners. In addition to all of this, we have our lifestyle more and more enhanced and comfortable

Automation in the Industrial sector: Machinery can be self-automated in order to reduce the dependency on the laborers. Many forklifts and technologies have come up to make the workload minimal.

Smart Healthcare: Many healthcare facilities are quite famous over the years. Many embedded sensors and actuators are given for tracking patients' development and behavior to the medicines provided. A large amount of data is collected and analyzed in seconds.

5. ICT AND GREEN IOT

ICT is encapsulated under the umbrella consisting of various facilities like technologies and applicatioms (mobile, television, radio, sensors radio, cellular phones, computers, machines, networks, hardware, software, middleware, storage, satellite systems, videoconferencing, distance learning)

The tabular data below depicts the various branches of the same.

Scheme	Techniques
Green RFID	1) Reduce the sizes of RFID tags to decrease the amount of nondegradable material used in their manufacturing; 2) Energy-efficient algorithms and protocols for optimizing tag estimation, adjusting transmission power level dynamically, avoiding tag collision, avoiding overhearing, etc.
Green WSN	1) Make sensor nodes only work when necessary, while spending the rest of their lifetime in a sleep mode; 2) Energy depletion (e.g., wireless charging, energy harvesting mechanisms which generate power from the environment (e.g., sun, kinetic energy, vibration, temperature differentials, etc.)); 3) Radio optimization techniques (e.g., transmission power control, modulation optimization, cooperative communication, directional antennas, energy-efficient cognitive radio (CR)); 4) Data reduction mechanisms (e.g., aggregation, adaptive sampling, compression, network coding); 5) Energy-efficient routing techniques (e.g., cluster architectures, energy as a routing metric, multipath routing, relay node placement, node mobility).
Green CC	1) Adoption of hardware and software that decrease energy consumption; 2) Power-saving virtual machine (VM) techniques (e.g., VM consolidation, VM migration, VM placement, VM allocation); 3) Various energy-efficient resource allocation mechanisms (e.g., auction-based resource allocation, gossip-based resource allocation) and related task scheduling mechanisms; 4) Effective and accurate models and evaluation approaches regarding energy-saving policies; 5) Green CC schemes based on cloud supporting technologies (e.g., networks, communications, etc.).
Green M2M	1) Intelligently adjust the transmission power (e.g., to the minimal necessary level); 2) Design efficient communication protocols (e.g., routing protocols) with the application of algorithmic and distributed computing techniques; 3) Activity scheduling, in which the objective is to switch some nodes to low-power operation ("sleeping") mode; 4) Joint energy-saving mechanisms (e.g., with overload protection and resources allocation); 5) Employ energy harvesting and the advantages (e.g., spectrum sensing, spectrum management, interference mitigation, power optimization) of CR.
Green DC	1) Use renewable or green sources of energy (e.g., wind, water, solar energy, heat pumps, etc.); 2) Utilize efficient dynamic power-management technologies (e.g., Turboboost, vSphere); 3) Design more energy-efficient hardware (e.g., exploiting the advantages of DVFS (dynamic voltage and frequency scaling) techniques and VOVO (vary-on/vary-off) techniques)); 4) Design novel energy-efficient data center architectures (e.g., nano data centers) to achieve power conservation; 5) Design energy-aware routing algorithms to consolidate traffic flows to a subset of the network and power off idle devices; 6) Construct effective and accurate data center power models; 7) Draw support from communication and computing techniques (e.g., optical communication, virtual machine migration, placement optimization, etc.).
General green ICT	1) Turn off facilities that are not needed (e.g., sleep scheduling); 2) Send only data that are needed (e.g., predictive data delivery); 3) Minimize length of data path (e.g., routing schemes, network working mechanisms); 4) Minimize length of wireless data path (e.g., energy-efficient architectural designs, cooperative relaying); 5) Trade off processing for communications (e.g., data fusion, compressive sensing); 6) Advanced communication techniques (e.g., multiple-input multiple-output (MIMO), CR); 7) Renewable green power sources (e.g., oxygen, fresh water, solar energy, timber, biomass).

Fig 3: Various branches under ICT

6. IMPLEMENTING GREEN ICT PRINCIPLES

Green ICT Principles need to be implemented as soon as possible to develop sustainable smart cities and encompass green IOT in our daily lifestyle.

a) Turning off facilities: Despite the IoT-enabled devices needing internet and electricity all time. When it is not needed the devices can be turned off. The majority of the devices consume an equal amount of energy in standby mode as in when in use.
b) Sending Minimal Data: Multimedia data can be sent as much as required. The sending and receiving of multiple data can slow down the systems and also affect the devices in a long run. Sending and receiving needful data is highly advisable as it can stop the wastage of energy.
c) Minimise the length of Data Path: The length of the data path is to minimize up to a large extent in order to minimize the wastage of energy.
d) Minimise the length of wireless data path: Energy Efficient architectural designs can be used in order to decrease the usage of the energy.

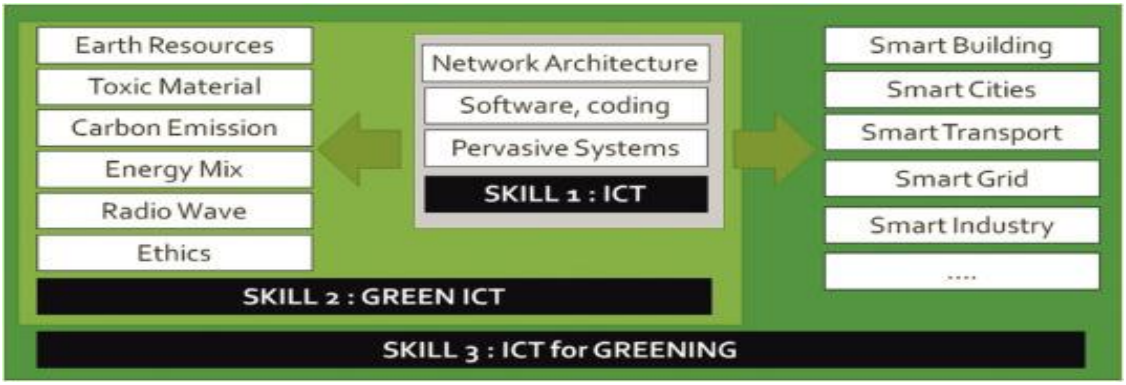

Fig. 4: Green ICT

7. OPPORTUNITIES OF GREEN IOT IN SUSTAINABLE SMART CITIES

Mobile Crowd Sensing: It is also widely known popular as McSense. It has basic sensors which detects the local information and area. Applications like Snapchat use it quite prominently. The architecture is mainly based on three aspects.

a) McSense: A centralized mobile crowd sensing system that receives sensing requests from clients and delivers them to providers; these entities are defined next.
b) Client: The consumers who are interested in collecting sensing data from smart phones using the mobile crowd sensing system.
c) Provider: A mobile user who participates and provides major chunk of data in mobile crowd sensing to provide the sensing data requested by the client.

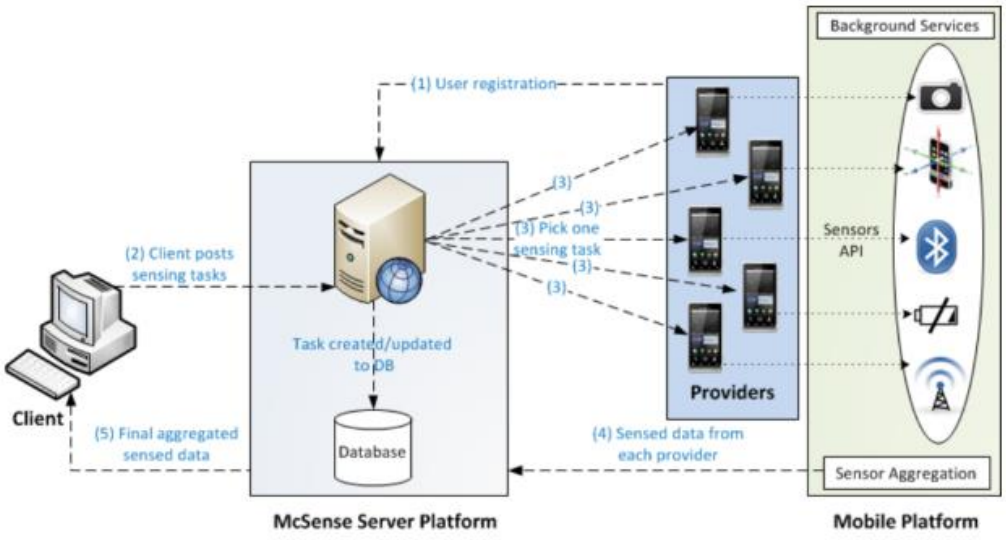

Fig 5: McSense Architecture

CYBER-PHYSICAL CLOUD COMPUTING

IoT is a networking infrastructure for cyber-physical systems (CPS), which are smart networked systems with embedded sensors, processors and actuators that are designed to sense and interact with the physical world (including the human users), and support real-time, guaranteed performance in safety-critical applications [4]. Cyber-Physical Cloud Computing (CPCC) is a new computing paradigm which can rapidly build, modify and provision CPS composed of a set of cloud computing-based sensor, processing, control and data services [5]. CPCC has many benefits, including efficient use of resources, modular composition, rapid development and scalability, smart adaption to environment at every scale, reliable and resilient [21]. Such a CPCC paradigm is very important in various SCC applications, such as smart transportation, smart grid, smart healthcare, and smart disaster management [6].

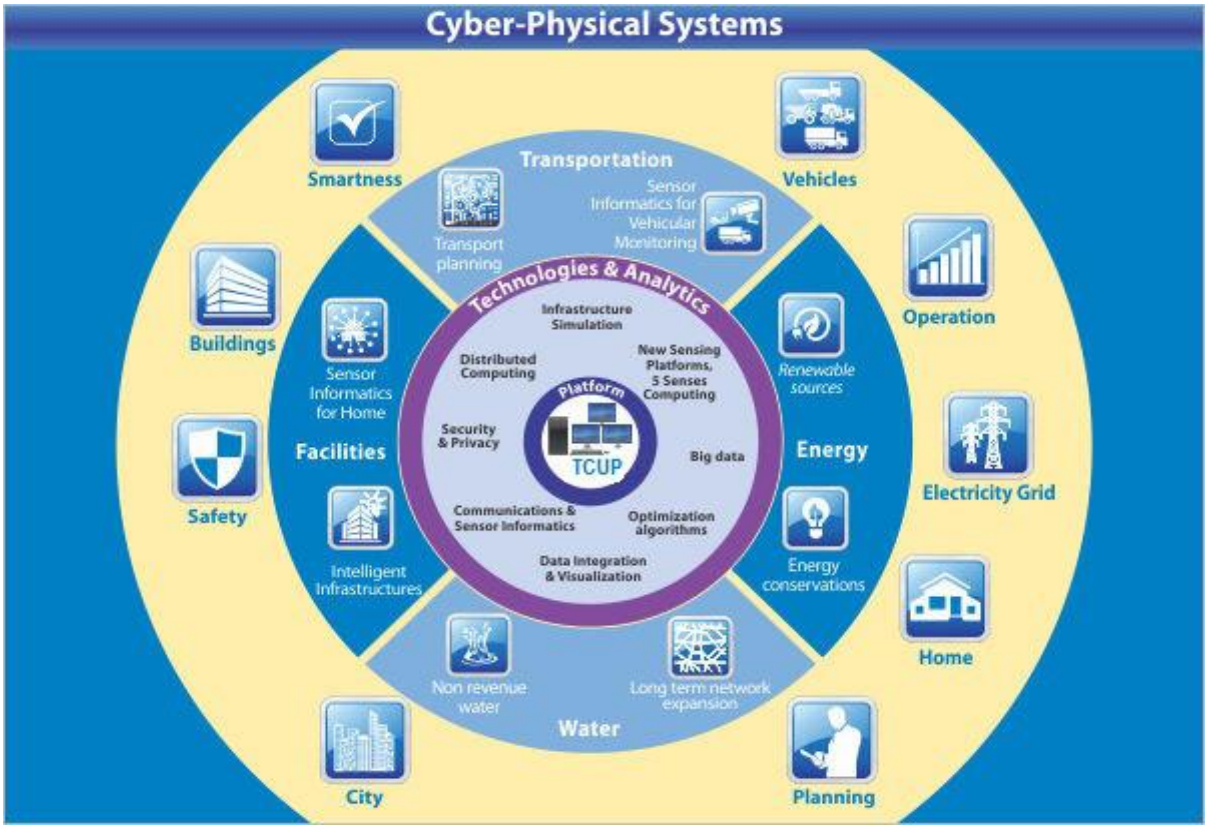

Fig 6: Cyber Physical Systems

8. CONCLUSION

To sum up, as the implementation of ICT principles is need of the hour people should be more aware about the Green IOT and its usage. Despite the varied number of challenges one can definitely save a whole lot of energy with the help of minor steps. The usage of energy is quite high and will lead to problems in the upcoming future as the sources are non-renewable and will run out.

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