INTERNATIONAL RESEARCH JOURNAL OF ENGINEERING AND TECHNOLOGY (IRJET) E-ISSN: 2395-0056
VOLUME: 08 ISSUE: 04 | APR 2021 WWW.IRJET.NET P-ISSN: 2395-0072

Green Internet of Things (IOT): A Survey and Future Prospect

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Abstract— *Enormous innovation advancement in the field of Internet of Things (IoT) has changed the manner in which we work and live. Although the various benefits of IoT are improving our general public, it ought to be reminded that the IoT likewise devours energy, accepts poisonous contamination and E- waste. These place stress on the ecosystem and smart world. To build the advantages and diminish the mischief of IoT, there is an expanding want to move toward green IoT. Green IoT is viewed as the fate of IoT that is harmless to the ecosystem. To accomplish that, it is important to put a ton of measures to reduce carbon impression, moderate less assets, and promote effective techniques for energy use. It is the explanation behind moving towards green IoT, where the machines, interchanges, sensors, mists, and internet are close by energy proficiency and decreasing fossil fuel byproduct. Furthermore, I also survey different IoT applications, activities and normalization efforts that are presently under way. At last, we distinguish a portion of the emerging challenges that should be addressed in the future to empower a green IoT.*

Keywords : Green Wireless Sensor Network, Green Cloud Computing, Green RFID, Internet of Things, Green Internet, Green Machine to Machine, Green Communication Network, Pollution, Hazardous Emissions.

I. INTRODUCTION

The Internet makes the world as a little town where things are associated with one another and with the world through worldwide correspondence networks utilizing (TCP/IP) convention. The things incorporate specialized gadgets, yet additionally actual items, similar to vehicles, PC, and home machines, which are controlled through remote correspondence organizations. The Internet has changed radically the way we live and interface with one another in each circumstance traversing from proficient life to social connections [1]. Savvy availability of the current organizations and setting mindful calculation utilizing framework assets is the significant piece of the internet of things (IoT). Accordingly, IoT is everything around us which ought to be conveyed ''whenever, anyplace, any media and anything".

During the previous decade, the energy utilization levels have troubling rates because of the enormous size of computerized setting, number of endorsers, and the quantity of gadgets. The ascent in the quantity of associated gadgets will be up to 50 billion by 2020 [2] and 100 billion by 2030 [3]. Thusly, researchers expect an enormous information rate and a gigantic content size (multiple times more in 2030, than it was in 2010) at the value an uncommon fossil fuel byproducts into the climate. In [4], it has shown that the measure of carbon dioxide (CO2) outflows from the cell organizations will be 345 million tons by 2020 and it is required to increment in the later years. Because of this enormous (CO2) emanations, climate and wellbeing concerns, an inexhaustible or green innovation is turning into a pulling in research zone in the advancement of innovation. What's more, current battery innovation of gadgets is another significant concern which prompts a green innovation [5].

Green IoT is the act of assembling, planning, discarding PCs, workers, utilizing, and partner subsystems (i.e., printers, screens, and correspondences gear and capacity gadgets) productively and all the more much of the time yet with diminished impact on the general public and the climate [6]. Going towards for greening IoT, it is searching for new assets, limiting IoT negative effect on the soundness of human and upsetting the climate. The essential goal of greening IoT is to diminish Co2 outflow and contamination, abuse ecological preservation and limit the expenses of things working and force utilization. To make the climate better, lessening the energy utilization of IoT gadgets is required [7]. With the improvement of greening ICT innovations, green IoT addresses a high potential to help monetary development and natural supportability [8].

The fundamental target of this paper is to give an outline of green IoT as far as ideas, applications, innovations and difficulties. Segment II portrays Overview of green IOT. Segment III presents the Technologies for green IOT. Segment IV examines the Application of green IoT. Segment V presents difficulties and future examination headings of green IoT. At last, Segment VI finishes up the paper.

II. OVERVIEW OF GREEN IOT

The internet of Things (IoT) contains the gigantic expected development network use and the number hubs later on. Consequently, there is a need to lessen the assets for executing all organization components and the energy burned-through for their activity. Energy utilization is turning into a condition of-craftsmanship to accomplish a green IoT dependability and shrewd world execution. To have an economical keen world, the IoT ought to be portrayed by energy productivity to diminish the nursery impacts and carbon dioxide (CO2) discharges of sensors, gadgets, applications and administrations.

Green IoT has three ideas, to be specific, plan advances, influence advances and empowering advances. Plan innovations allude to the energy proficiency of gadgets, correspondences conventions, network models, and interconnections. Influence innovations allude to cutting fossil fuel byproducts and upgrading the energy effectiveness. Because of green ICT advances, green IoT turns out to be more effective through diminishing energy, lessening perilous emanations, decreasing assets utilization and diminishing contamination. Thusly, Green IoT prompts protecting characteristic assets, limiting the innovation sway on the climate and human wellbeing and lessening the expense essentially. Accordingly, green IoT is surely zeroing in on green assembling, green use, green plan, and green removal [9].

Fig.1 Green IoT

1. Green use: limiting force utilization of PCs and other data frameworks just as utilizing them in an earth sound way.

2. Green removal: restoring and reusing old PCs and reusing undesirable PCs and other electronic hardware.

3. Green plan: planning energy productive for green IoT sound segments, PCs, and workers and cooling gear.

4. Green assembling: delivering electronic parts and PCs and other related subsystems with insignificant or no effect on the climate.

III. TECHNOLOGIES FOR GREEN IOT

The empowering advancements for green IoT are called Information and Communication Technology (ICT) advances. Green ICT advancements allude to the offices and stockpiles empowering supporters of assemble, store, access, and oversee different data [10]. ICT innovations can cause environmental change on the planet [11-15] on the grounds that with the developing utilization of ICT increasingly more energy has been devoured. The thought for maintainability of ICTs has zeroed in on server farms enhancement through procedures of sharing framework, which prompts increment the energy proficiency, decrease CO2 discharges and e-misuse of material removals [16]. Greening ICT is empowering advances for green IoT which incorporates green RFID, green remote sensor organizations (GWSN), green machine to machine (GM2M), green distributed computing (GCC), green server farm (GDC) [10], green web and green correspondence network Consequently, greening ICT innovations assume a fundamental part to green IoT and give numerous advantages to the general public, for example, diminishing the energy utilized for planning, fabricating and appropriating ICT gadgets and gear.

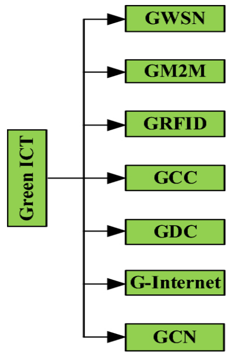

Fig.2 Green ICT technologies

A. GREEN RFID TECHNOLOGY

RFID is the consolidated term of RF and ID where RF alludes to remote correspondence innovation, and ID implies label ID data. It is considered as one of the promising remote correspondence framework used to empower IoT. Moreover, it needn't bother with view (LoS) and can plan this present reality into the visual world simple [17]. Moreover, RFID is a computerized information assortment, and empowering objects to associate through networks which utilize radio waves to recover, recognize and store information distantly. The utilization of electromagnetics in the radio recurrence and the utilization of shrewd standardized tags to follow things in a store are alluding to RFID joining. Putting away data on things is the motivation behind RFID. The order of RFID is inactive and dynamic [17]. Latent things have not batteries on the board, and the transmission recurrence is limited. Then again, dynamic RFID incorporates batteries that power the transmission signal.

As of late, there has been an expanding measure of explores on green RFID, the accompanying proposed strategies are needed for green RFID:

a) Reducing the spans of RFID labels since reusing the labels isn't simple;

b) Energy-productive methods and conventions ought to be utilized to maintain a strategic distance from label crash, label assessment, overheating shirking, changing transmission power level powerfully, and so on

There are such countless applications for RFID like transportation, creation following, delivering, getting, stock control, administrative consistence returns and reviews the board. Moreover, RFID benefits incorporate normalized, versatile methodology, solid and practical.

B. Green Wireless Sensor Network Technology

The combination of detecting and remote correspondence has prompted the development of remote sensor organization (WSNs) and address a key empowering innovation that encourages IoT to thrive. As of late, WSNs have been proposed for assortment of utilizations, for example, fire discovery [18], [19], object following [20] and ecological observing [21]. As needs be, the business utilization of WSNs is required to significantly increment soon. For the most part, a WSN comprises of an enormous number of static sensor hubs with low preparing, restricted force, and capacity limit, and questionable correspondence over short-range radio connections. The sensor hubs are furnished with different on-board sensors that can take readings from the environmental factors like temperature, level of dampness, speed increase, and so on Ordinarily, an amazing base station known as the sink is likewise a fundamental piece of a WSN. The sink intervenes between the sensor hubs and the applications running on a WSN. In numerous situations, the sensor hubs spend a huge piece of their lifetime in a rest mode to accomplish energy proficiency [22]. Like RFID frameworks, the WSN applications contribute emphatically to the climate by effectively utilizing assets and assisting with decreasing nursery impacts. The genuine capability of WSNs can be completely acknowledged just when information correspondence can happen at ultralow power, and the force supply can be disposed of. Doing so requires a genuine sans battery remote arrangement that can use energy collected straightforwardly from the climate. Energy gathering components [23]–[25] incorporate those that can produce power from the sun, active energy, vibration, temperature differentials, and so on Disposing of batteries will limit openness to the harmful substances inside batteries and make ready for genuinely green frameworks that don't unfavorably affect the climate.

C. Green Cloud Computing Technology

The Internet, which has affected the manner in which we impart and share data, is a worldwide arrangement of interconnected PC organizations. As of late, distributed computing has given elite registering assets and high-limit stockpiling to the end clients of the Internet. Cloud can offer critical monetary advantages, in that end clients share an enormous, halfway oversaw pool of capacity and registering assets, instead of purchasing and dealing with their own frameworks [26]. Distributed computing offers admittance to the processing assets by regarding assets as administrations, i.e., Infrastructure as a Service, Platform as a Service, and Software as a Service, and giving them flexibly dependent on client requests [27]. The server farms facilitating cloud applications devour tremendous measures of energy bringing about high operational expenses and huge CO_2 impressions [28]. Many figuring administrations are moving to distributed computing since it gives advantageous admittance to numerous assets. The development brings about the arrangement of more assets and expanded force utilization, which prompts more natural issues and CO_2 discharges. Thusly, proficient utilization of assets in the cloud is important to lessen energy utilization. The utilization of gadgets that burns-through less energy, virtualization, and self-advanced programming applications should be received to diminish energy utilization. In this way, the goal of green cloud isn't just to give proficient utilization of assets and the registering framework yet to lessen fossil fuel byproducts by limiting energy utilization. For green distributed computing, the two principle classifications of arrangements are equipment and programming that diminish energy utilization. Equipment arrangements attempt to plan and make gadgets that devour less energy without losing the nature of their presentation [29]. Then again, the product arrangements give effective programming plans that burn-through less energy by least usage of the assets.

D. Green Machine to Machine Technology

As of late, machines are progressively getting more intelligent and ready to assemble information without human intercession. Man-made brainpower (AI) is the drive behind the advancement of numerous new advances. Succeeding the possibility of a smart machine to machine (M2M) correspondence is important to be utilized on a significant scale. Machines ought to have great network to upgrade the advanced PC machines and other electronic gadgets for putting away enormous information. The advantage of such inbuilt radios correspondence is to ensure that M2M correspondence is protected and turns out effectively for a wide range of assignments like home, modern, clinical, just as business measures.

Machine gadgets access control (MDAC) procedures used to accomplish low energy utilization (EC) and furthermore adjust to a variable dissemination of MDAC [30]. An agreeable method is proposed for improving force utilization of the cell-edge clients and M2M helped networks [31, 32]. Notwithstanding creators in [31, 32], Bartoli et al., Datsika et al. also, Dayarathna et al., examined the vital strategies for collaborating M2M correspondence network with diminishing the force utilization [33-35]. The thought likewise upheld by Himsoon et al. [36], which examined the system of abusing agreeable variety to diminish power utilization. Transfer choice plan includes deciding the ideal hand-off hub as the one that diminishes the summation of sent force [37].

CR is a mix of electronic organization and a PC organization. It is utilized to frame a canny M2M correspondence between CR-based savvy meters to far off territory power the executives (RAPM). The explanation for the mix is to augment the force productivity of power appropriation and the range proficiency [38]. Moreover, Vo et al. [39] examined the combined organization design dependent on the adaptable, high-limit and savvy 4G long haul development (LTE) innovation, which underpins M2M availability in a start to finish (E2E) style.

The examination in [40] offers a few plans to accomplish green, security and unwavering quality in M2M associations utilizing proficient movement booking procedures. Thusly, the prosperous of M2M correspondences actually depends on absolutely overseeing and understanding the current difficulties: green unwavering quality, energy productivity, and security.

E. Green Communication and Networking

Specialists anticipate that the fifth era (5G) of remote correspondences (5G) will show up in 2020, and it will actually want to deal with around multiple times more portable information than today's cell frameworks [41]. It will accomplish client requests in moderate rates, much dependability just as remarkable applications [42]. It will likewise turn into a mainstay of the IoT innovation, connecting up fixed and cell phones turning out to be essential for another modern and financial upheaval. IoT and 5G are two of the most sweltering patterns in innovation. They are joined to change our future by interconnecting everything [43]. In any case, there are many arising difficulties are not too far off in planning IoT based frameworks that can productively be incorporated with 5G remote correspondences [44]. Security is probably the greatest test looked by IoT in 5G. Moreover, IoT innovation is described by little information bundles, monstrous associations of gadgets with restricted force source, and postpone open minded correspondence. In 5G, slender band framework configuration can improve framework inclusion, power utilization, and diminish terminal expense [45]. In [45], a few plans of IoT in 5G organizations to help enormous association thickness of low-rate, low-power gadgets have been proposed.

F. Green Internet Technologies

As of late, the green internet has become the essential concern. The internet ideas and advancements contributed is utilized to build up a shrewd and green framework [46]. The utilization of energy in the internet network gear is obscure in view of the generous energy. The estimation of the force utilization of organization hardware has unequivocally been considered for estimating the exactness and straightforwardness [47]. There is a colossal potential to diminish the web power prerequisites and decrease the intricacy utilizing synchronizing the activity of booking traffic and switches [48]. Dynamic geography the executives instrument in the green internet (GIDTMM) is constructed and distinguished the hub design and connection structure for energy utilization in network gadget [49]. Green internet of wired admittance organizations (WAN) in the information network is examined the force utilization of wired admittance networks assessed [50]. Besides, Suh at al. [51] investigated an impact of the development gear of information network for greening the web. The assessment power utilization and saving energy capability of information network gear are thought about.

The examination in [52] plans a green internet directing strategy, so the steering can lead traffic in a manner that is green. Additionally, the thought is examined by Yang et al. [53], which uncover the separated sustainable and non-environmentally friendly power for green web steering. Be that as it may, Hoque et al. [54] inspected strategy answers for improve the energy effectiveness of versatile hand-held gadgets for the remote interactive media streaming.

IV. IOT APPLICATIONS

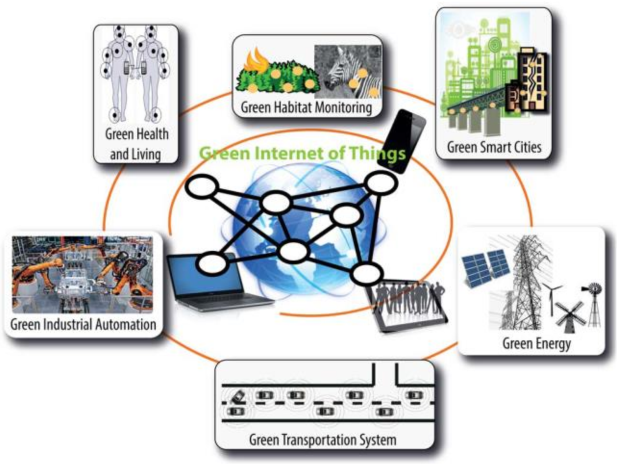

Fig. 3. Green IoT applications

A. Industrial Automation

1. *Smart Industrial Plants and Machine to Machine Communications:* Smart environments help to improve the automation of industrial plants by using RFID tags associated with the production items. As soon as the item reaches the processing unit, the RFID reader reads the tag and generates the appropriate event. The machine/robot receives notification of the event and picks up the production item for further processing. Simultaneously, a WSN can monitor a machine's vibrations to assess its health and can trigger an event if the vibrations increase beyond a threshold value. Once such an emergency event occurs, related machines and processes react accordingly. Upon receiving the emergency shutdown event, the robot immediately stops its operation. The plant manager can maintain a global view of all the elements while also monitoring the production progress, device status, and the possible side effects of a production line delay [55]. This lowers energy costs by providing

in-time event reports and ensuring that different machines will not run unnecessarily. This scenario presents a snapshot of potential energy savings; the overall impact can be much higher as a result of energy evaluation and planning conducted via WSNs [56] and by using appropriate software [57]. Furthermore, the increase attention given to green M2M communications should reduce the energy M2M subsystems utilize.

2. *Smart Plant Monitoring:* In recent years, energy efficiency has come to the forefront of corporate agendas across industries. Emerging technologies can efficiently monitor various parameters, such as temperature, air pollution, machine faults, etc., of an industrial plant [58], [59] to improve energy efficiency. In order to monitor an industrial plant, designers must first develop an energy profile for real-time energy consumption and compare it with a set of benchmarks. This involves capturing energy data related to the processes using IoT technologies. This will also help in identifying quickly the greatest energy consumers to determine how well they are doing. Determining the overall energy performance of a plant is necessary for making comparisons between current energy use and a consumption target that reflects current operations. Only then is it possible to conduct an analysis to determine the cause of deviations from the target and to take appropriate remedial actions. IoT-based methodologies help to plan the energy utilization better and give green arrangements.

B. Health and Living

1. *Real-Time Tracking and Identification:* This application aims to track and monitor patients and medical equipment. For example, monitoring patient flow can improve workflow in hospitals. In relation to assets, tracking assists with maintenance, availability, monitoring of use, and materials tracking to prevent left-ins during surgery. Energy efficiency can be achieved by having efficient tracking methods, such as collaborative cluster heads, which can be used in place of sensors for tracking [60], efficient RFID-based tracking [61], prediction techniques [62], etc. These advances can uphold patient recognizable proof to diminish hazardous patient episodes (like wrong medication, portion, and so on), electronic wellbeing records (in-and out-patient), and baby ID (to forestall jumbling).

2. *Smart Sensing:* Sensor devices provide patient conditions for diagnosis and real-time health indicators. Sensors can be applied both during in- and out-patient care, and hospitals can deploy heterogeneous wireless access-based remote patient monitoring systems to reach the patient everywhere [63]. In an effort to provide energy efficiency, developers are turning to compressive sensing solutions [64]–[66] where the signal is sampled at a sub Nyquist rate.

3. *Smart Sports:* There are many opportunities for IoT applications in the sports domain. Users are interested in knowing real-time statistics in the game, such as how fast a player shot a goal. Such information is also very useful for coaches planning for future games accordingly. Furthermore, these applications can easily monitor the players' health. Since players are generally physically active, designers can exploit energy harvesting schemes to take advantage of the physical activity of the players (movement, thermal, etc.) to achieve energy efficiency in these applications [67], [68].

4. *Smart Social Networks:* Living and interaction styles have changed a lot in recent years. Social networks enable the user to interact with other people to maintain and build social relationships. Indeed, events such as moving from/to our house/office, traveling, meeting common friends may automatically trigger an update to a status for a person's friends [69]. For energy awareness among users, social media can play a vital role and can indirectly contribute to a greener world.

C. Habitat Monitoring

1. *Smart Agriculture:* One of the most ancient professions of mankind is agriculture. For agricultural processes, modern tools and technology are needed to improve the production and quality of crops [70], [71]. Smart agriculture involves applying the amount of inputs (water, pesticides, and fertilizer), completing pre- and postharvest operations, and monitoring environmental impacts. Various efficient approaches, such as irrigation system [72], [73], smart underground sensors [74], and smart insect detection [75] have been designed to perform tasks for smart agriculture. Similar approaches can be applied to forest monitoring [76], [77] where the major focus is forest fire monitoring [78], [78], [79] since fires often result in significant damage to the environment.

2. *Smart Underwater Sensor Networks:* Underwater sensor network (UWSN) can be applied in oceanographic data collection, pollution monitoring, offshore exploration, disaster prevention, assisted navigation, and tactical surveillance applications. UWSN consist of a variable number of sensors that are deployed underwater to perform collaborative tasks using acoustic signals [80], [81].

D. *Smart Cities*

1. *Smart Buildings:* Efforts to make buildings smarter focus on reducing energy consumption by redefining building operations such as air conditioning, heating,

and lighting. Building automation can reduce the annual operating costs of buildings and lead to a green environment [82], [83].

2. *Smart Street Lights:* In general, the streetlight monitoring involves having control at the level of the streetlight transformer station. Conventional street lighting systems remain turned on until morning (and sometimes even later) and humans are required to turn off the streetlights. In some areas, where a few people are on the streets, the streetlights remain on for most of the night without purpose. The consequence is that a large amount of power is wasted. By implementing energy efficient WSNs monitoring systems, the majority of these problems can be solved [84], [85], resulting in significant energy savings.

3. *Smart Waste:* The high population density of urban areas makes solid waste management a significant problem. To reduce the environmental impact of waste dumping, many municipal and corporate bodies are involved in the development of efficient waste management systems [86]. Embedding RFID readers on waste bins can make them intelligent. When trash (with an RFID tag) is deposited into the bin, the bin can identify the type of trash to facilitate the recycling process [87]. Furthermore, the waste bins can communicate with each other (by routing information across them) to better manipulate the waste [88]. Such smart practices help promote a healthy environment.

E. Energy

1. *Smart Grid:* Public awareness about the changing paradigm of energy supplies, consumption, and infrastructure is increasing. As opposed to being founded on fossil assets or thermal power, the future energy supply should be founded to a great extent on different sustainable assets. The future electrical lattice should be sufficiently adaptable to respond to control changes by controlling fuel sources and the utilization by the shoppers. Such lattice will be founded on organized keen gadgets (apparatuses, age hardware, foundation, and shopper items) in light of IoT ideas.

2. *Smart Metering:* A smart meter periodically records the consumption of electric energy and transmits that information to the utility company for monitoring and billing purposes [89]. Smart meters enable two-way communication between the smart meter and the utility company [90]. Conversely, conventional meters just measure all out utilization, and give no data in regards to how the energy was burned-through. Then again, shrewd meters give site-explicit data that can offer various likely advantages to householders. These include a) an end to estimated bills; and b) a tool to better manage their energy use that can help to reduce their energy bills and carbon emissions [91].

F. Transportation

1. *Smart Parking:* The increasing availability of vehicles in recent years has created a problem of finding vacant places to park the vehicles, particularly in major cities. This situation contributes to air pollution, fuel waste, and motorist frustration. This problem can be solved by introducing a Smart Parking Systems, which is an efficient and cost-effective approach based on IoT technologies [92], [93].

2. *Smart Traffic Congestion Detection:* With the growing worldwide population, traffic problems, such as traffic congestion, etc., are increasing daily. By using the technology of vehicular ad hoc networks (VANETs), it is possible to avoid traffic congestion allowing vehicles to communicate with each other and to share road information to better understand road conditions. This will reduce carbon emissions and help to build a green environment [94], [95].

3. *Smart Logistics/Shipment:* Information collected through RFID, NFC, and sensors can enable real-time monitoring of the supply chain system. These advancements can likewise assemble item related data progressively to assist endeavors with reacting to changing business sectors in the most limited conceivable time. Generally, to realize customer requirement a typical enterprise requires around 120 days. In contrast, enterprises using advanced technologies (such as Wal-mart and Metro) only need few days to fulfill customer demands [96], [97]. Furthermore, fruits, meat, and dairy products travel thousands of miles from the production site to consumption sites and require constant monitoring to ensure quality standards. IoT empowered innovations offer incredible potential for improving the effectiveness of the food store network and for assisting with restricting the carbon impression [98], [99].

V. CHALLENGES AND FUTURE RESEARCH DIRECTIONS

Despite the fact that there are a colossal exploration endeavors to accomplish a green innovation, green IoT innovation is as yet in outset stage. There are many obstacles and challenges matters that need to be addressed. Hereunder, we list the key challenges:

- Integration between energy efficiency across the IoT architecture to achieve an acceptable performance.
- Applications should be green to minimize their effects on the environment.
- Dependability of green IoT with energy utilization models.
- Context-awareness with energy efficient IoT system.

• Both devices and protocols used to communicate should be energy efficient with less power consumption.

• Complexity reduction of the green IoT infrastructure.

• Tradeoff between efficient dynamic spectrum sensing and efficient spectrum management.

• Efficient energy mechanism for IoT such as wind, solar, vibration, thermal to make IoT promising.

•Productive cloud the executives concerning power utilization.

• Effective security instrument such encryption and control orders.

VI. CONCLUSION

In this paper, I have surveyed the green perspective of the IoT. I have discussed recent efforts in the green IoT area and also identified potential areas where the focus should be in the future for green IoT. I have identify the list of applications of IoT where the energy can be saved to have green environment. Based on the critical factors of ICT advancements, the things around us will get more brilliant to perform explicit undertakings self-sufficiently, delivering of the new sort of green correspondence among human and things and furthermore among things themselves, where transfer speed usage is augmented and perilous emanation moderated, and power utilization is decreased ideally. Future ideas have been addressed for efficiently and effectively improving the green IoT based applications. We believe that having industry interest in the area of green IoT makes its future brighter and having the academia fully involved will make the vision of green IoT realized.

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