Internet of Things (IoT) Based Energy System

Student Name : Arunabha Sarkar

College: Adamas University

Department: Electrical Engineering

Year: 2nd year, 4th sem

Duration: 2nd June 2020 to 14th September 2020.

Guide : Dr . Ranjan Kumar Behera

(Associate Professor at IIT, Patna).

Abstract: Integration of renewable energy and optimization of energy use are key enablers of sustainable energy transitions and mitigating climate change. Modern technologies such as the Internet of Things (IoT) offer a wide number of applications in the energy sector, i.e, in energy supply, transmission and distribution, and demand. IoT can be employed for improving energy efficiency, increasing the share of renewable energy, and reducing the environmental impacts of energy use. This paper reviews the existing literature on the application of IoT in energy systems, in general, and in the context of smart grids particularly. Furthermore, we discuss enabling technologies of IoT, including cloud computing and different platforms for data analysis. Furthermore, we review the challenges of deploying IoT in the energy sector, including privacy and security, with some solutions to these challenges such as blockchain technology. This survey provides energy policy-makers, energy economists, and managers with an overview of the role of IoT in the optimization of energy systems.

➢ Introduction:

In the era of new trends, IoT plays an important role in the market. A wide variety of modern technologies such as communication systems (e.g., 5G), intelligent robots, and the Internet of Things (IoT) are expected to empower the fourth industrial revolution. IoT interconnects several devices, people, data, and processes, by allowing them to communicate with each other seamlessly. Hence, IoT can help to improve different processes to be more quantifiable and measurable by collecting and processing a large amount of data. IoT can potentially enhance the quality of life in different areas including medical services, smart cities, the construction industry, agriculture, water management, and the energy sector. This is enabled by providing an increased automated decision making in real-time and facilitating tools for optimizing such decisions. The global energy demand rose by 2.3% in 2018 compared to 2017, which is the highest increase since 2010. As a result, CO2 emissions from the energy sector hit a new record in 2018. Compared to the pre-industrial temperature level, global warming is approaching 1.5 ◦C, most likely before the middle of the 21 Century. If this trend prevails, global warming will exceed the 2◦C target, which will have a severe impact on the planet and human life. The environmental concerns, such as global warming and local air pollution, scarcity of water resources for thermal power generation, and the limitation of depleting fossil energy resources, raise an urgent need for more efficient use of energy and the

use of renewable energy sources (RESs). Different studies have shown that a non-fossil energy system is almost impossible without efficient use of energy and/or reduction of energy demand, and high-level integration of RESs, both at a country level, regional or globally. In recent years, one has observed a fruitful convergence for various building technologies and systems to an IP-based infrastructure supported by the firm's intranet (in multitenant buildings a building-oriented intranet may be required). Technological convergence as it relates to building management and smart buildings is accelerating with the increasing deployment of IP-based endpoint devices under the thrust of IoT.

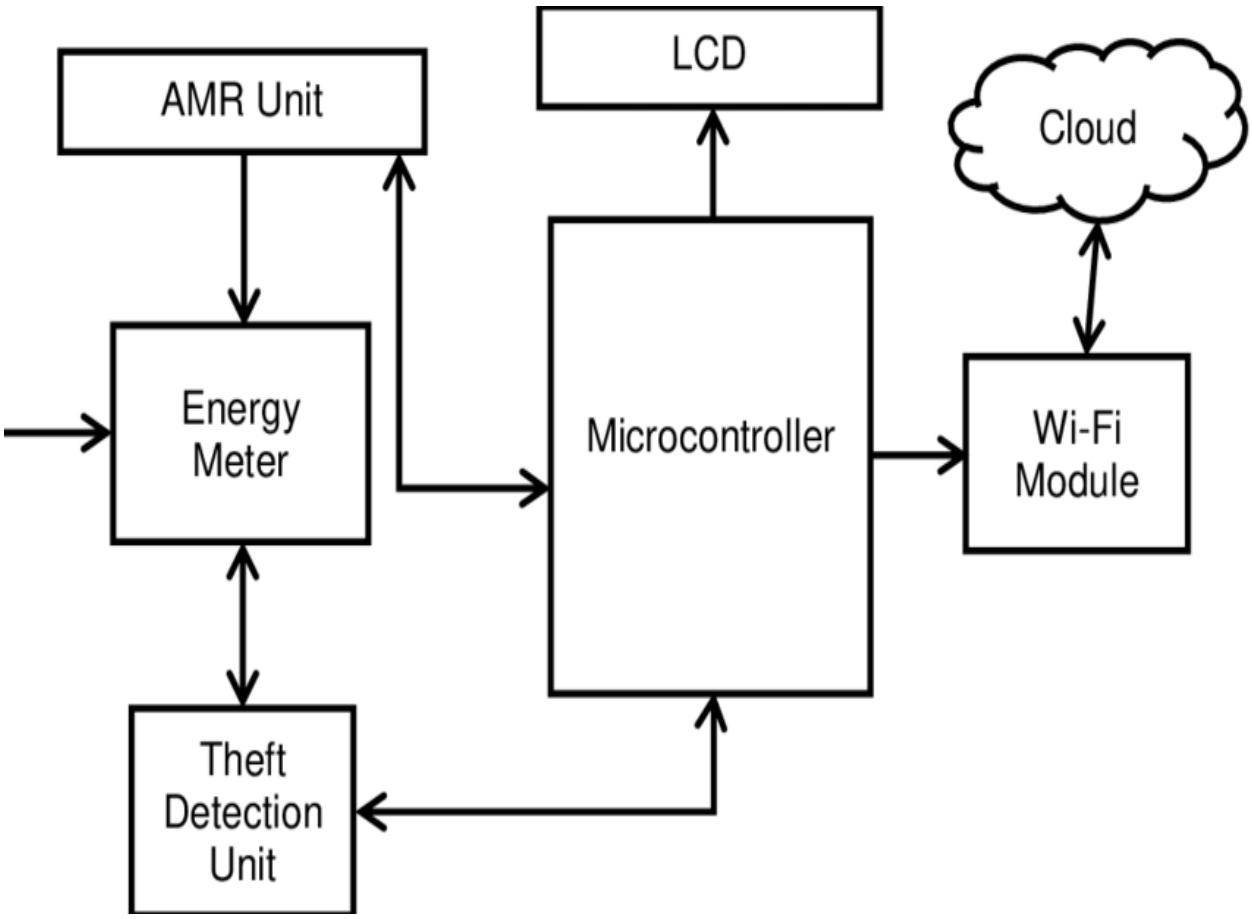
➢ Elements of IoT system :

IoT can be divided into major layers, including the device layer, network layer, cloud management layer, and application layer and others.

- **Connected devices:** Devices are the primary physical objects connected to the system. For Asset Control Systems, sensors are the components of the device connectivity layer. These smart sensors are continuously collecting data from the environment and transmit the information to the next layer.
- The latest techniques in semiconductor technology are capable of producing micro smart sensors for various applications.
- **Cloud Man**: The Internet of things creates massive data from devices, applications and users which has to be managed efficiently. IoT cloud offers tools to collect, process, manage and store a huge amount of data in real-time. Industries and services can easily access these data remotely and make critical decisions when necessary. The cloud services layer is where all the data storage and information retrieval will take place. The management layer is where authentication, user management, and data management are done.
- **Application Layer:** This layer gives a service to the user end and it hosts demand response management, dynamic pricing for smart grid systems and energy response management system.

- **User Interface:** User interfaces are the visible, tangible part of the IoT system which can be accessed by users. Designers will have to make sure a well-designed user interface for minimum effort for users and encourage more interactions.

➢ Block Diagram of IoT based Energy Meter :



➢ 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 have adverse environmental, health, and economic impacts due to air pollution and climate change to name a few. 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. In this section, we discuss the role of IoT in the energy sector, from fuel extraction, operation, and maintenance (O&M) of energy generating assets, to T&D and end-use of energy IoT can play a crucial role in reducing energy losses and lowering CO2 emissions. An energy management system based on IoT can monitor real-time energy consumption and increase the level of awareness about energy performance at any level of the supply chain. This section discusses the application of IoT in energy generation stages first. Then, we continue with the concept of smart cities, which is an umbrella term for many IoT-based subsystems such as smart grids, smart buildings, smart factories, and intelligent transportation. Next, we discuss each of the above-mentioned components separately. The rise of technology has driven energy costs up. Consumers search for ways to reduce or control consumption. IoT offers a sophisticated way to analyze and optimize use not only at the device level but throughout the entire system of the home. This can mean simple switching off or dim of lights, or changing device settings and modifying multiple home settings to optimize energy use.

IoT can also discover problematic consumption from issues like older appliances, damaged appliances, or faulty system components. Traditionally, finding such problems required the use of often multiple professionals.

Energy waste can easily and quietly impact business in a major way, given the tremendous energy needs of even small organizations. Smaller organizations wrestle with balancing costs of business while delivering a product with typically smaller margins and working with limited funding and technology. Larger organizations must monitor a massive, complex ecosystem of energy use that offers few simple, effective solutions for energy use management.

➢ IoT and Energy Generation :

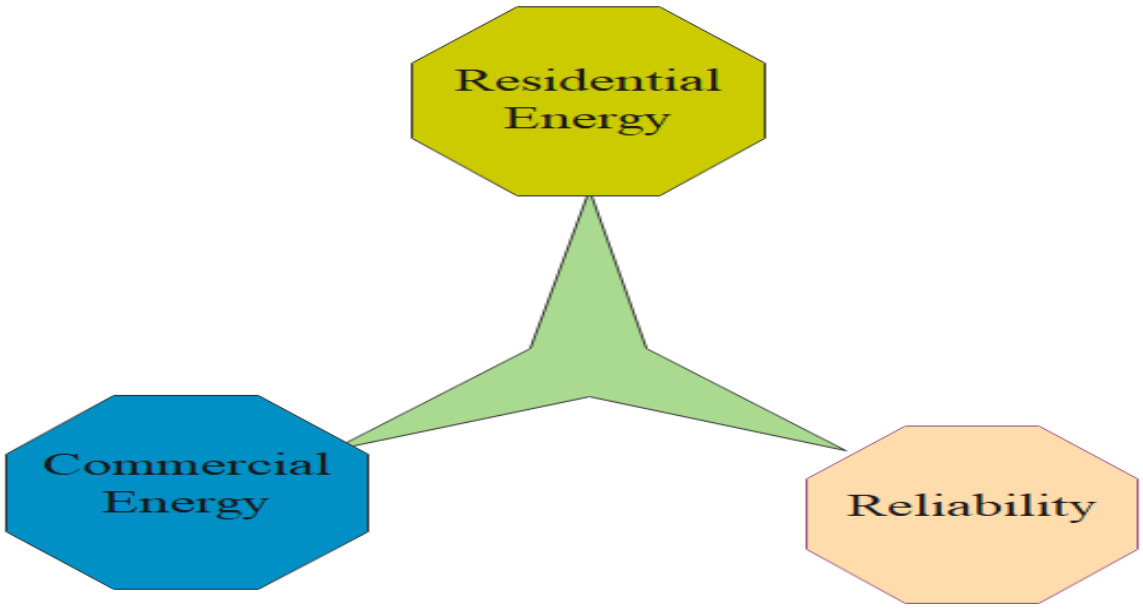
A smart, reliable, and efficient power supply helps in the smooth functioning of smart cities. The use of IoT in renewable energy production will help meet the energy demands of these smart cities efficiently.

The applications of IoT in renewable energy production involve sensors that are attached to generation, transmission, and distribution equipment. These devices help companies to monitor and control the working of the equipment remotely in real-time. This leads to reduced operational costs and lowers our dependence on the already limited fossil fuels. The use of renewable energy resources already provides a variety of benefits over conventional ones. The implementation of IoT will help us utilize these clean energy sources to a further extent.

Mainly this can be divided into three parts :

1. **Application of IoT in Energy system**
2. **Smart Grid**
3. **Smart Cities**

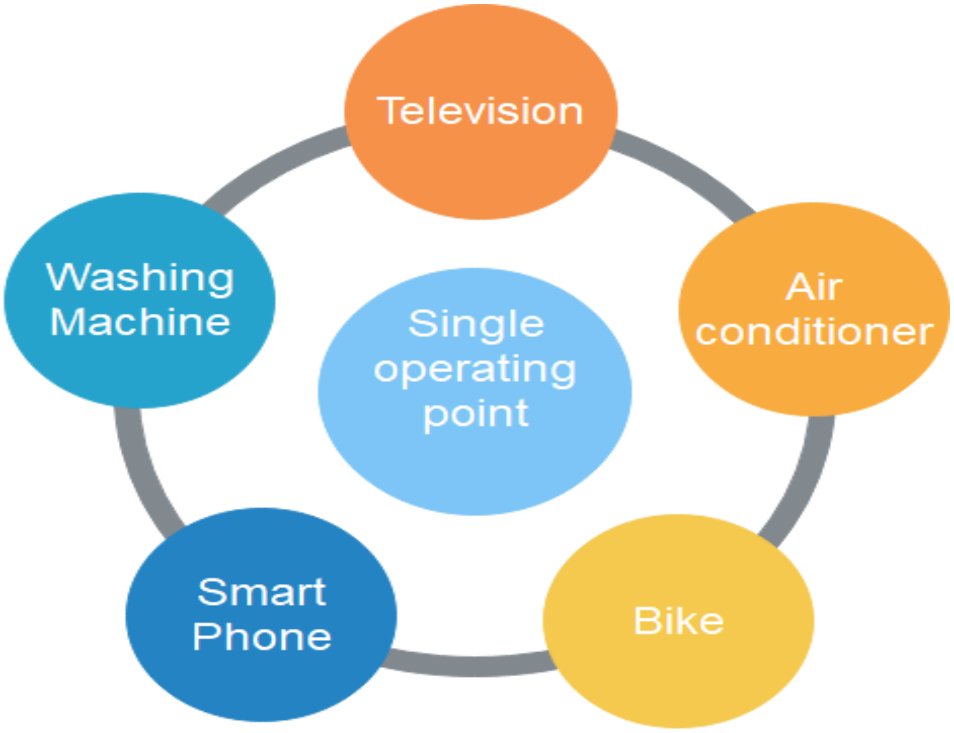
1. Application of IoT in Energy System :



The advantages offered by IoT in other industries also hold in energy consumption areas. IoT offers a wide variety of monitoring and energy control functions, with applications of commercial and residential energy use, devices and the energy source. The optimization offered by IoT stems from a detailed analysis that is mostly unavailable to most organizations and individuals.

Reliability :

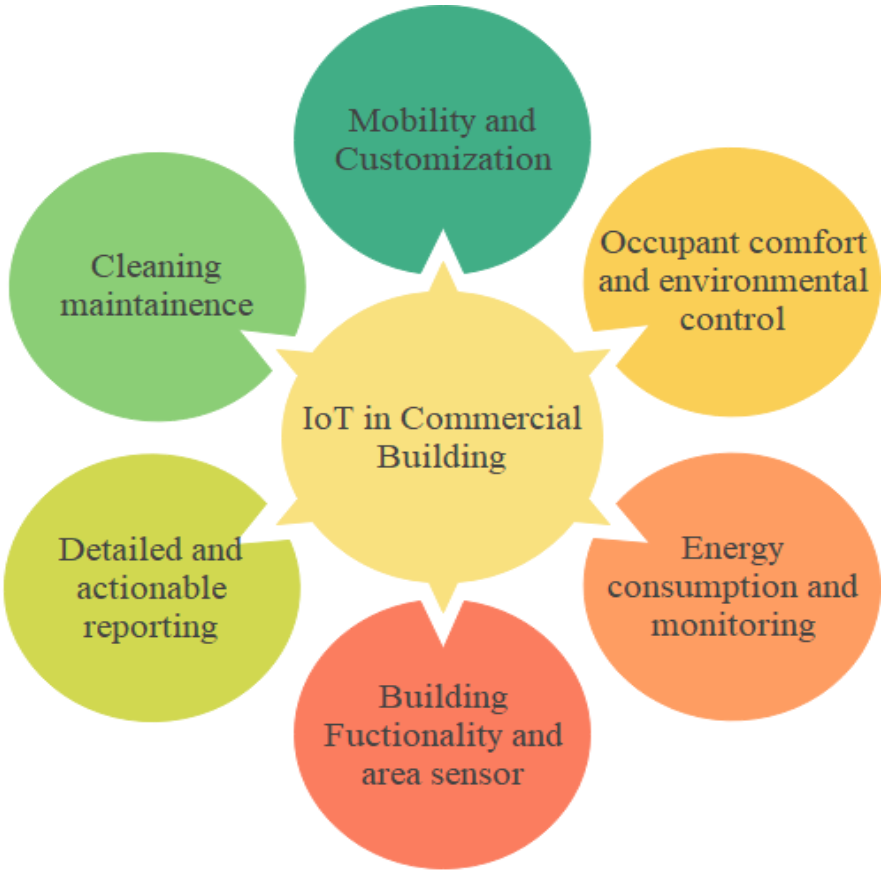
The IoT system through its actionable insights and analytics helps to ensure system reliability. Besides efficient consumption, IoT also prevents a system from getting throttled or overloaded. The system is protected against losses such as damaged equipment, downtime, and injuries by detecting threats to system performance and stability.



Commercial Energy :

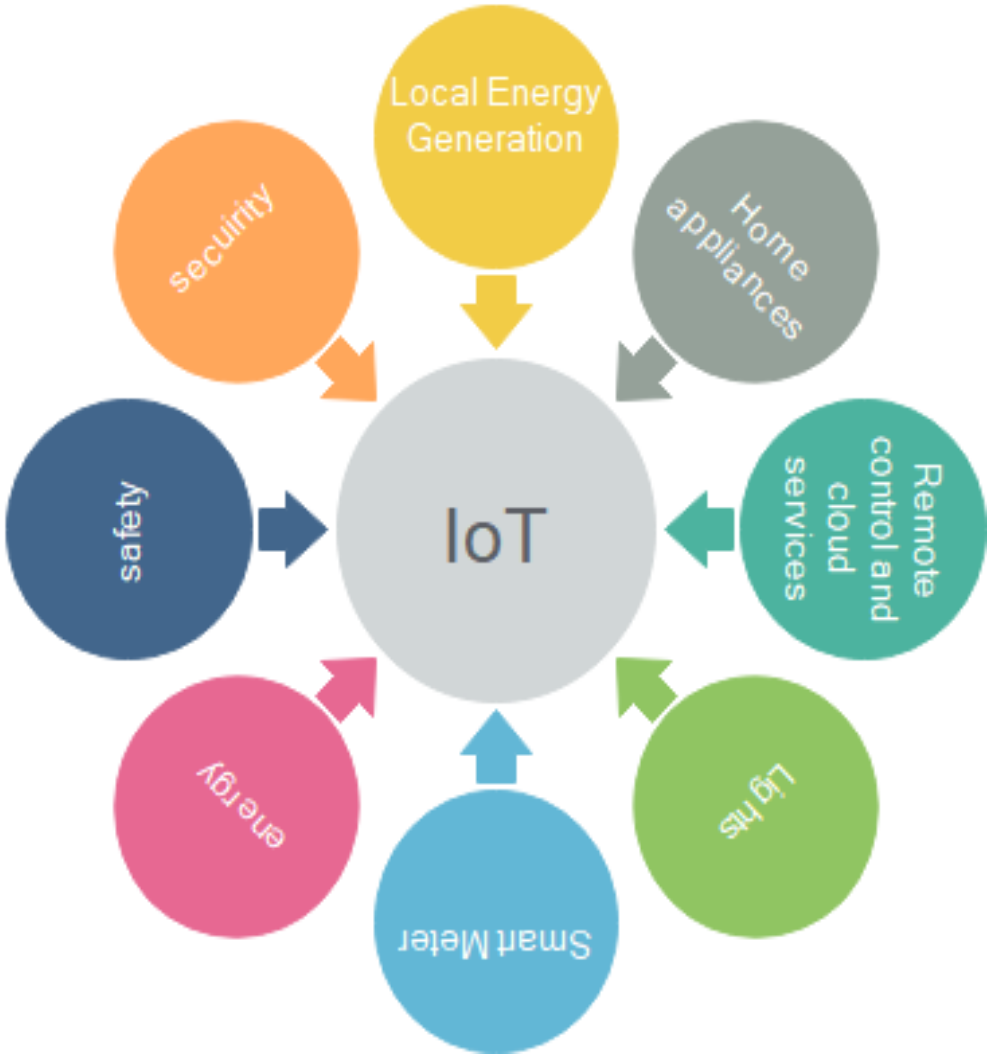
The tremendous energy needs of small organizations leading to more energy wastage can easily impact businesses in a major way. Smaller organizations deliver a product with smaller margins and wrestle with balancing costs of business while working with a limited number of funds and technology. Larger organizations have the responsibility to monitor a huge, complex ecosystem of energy use that offers few effective and simple solutions for energy use management.

IoT while maintaining a low cost and high level of precision simplifies the process of energy monitoring and management. All points of an organization's consumption across devices are carefully addressed. Organizations are provided with a strong means of managing their consumption by cost-saving and output optimization through the IoT system's depth of analysis and control. IoT systems take care of energy issues in the same way they treat functional issues in a business network that is complex and provide solutions for the same.



Residential Energy :

The surge in energy costs is a testament to rising in technology. Consumers are always in search of ways to control or reduce consumption. IoT offers sophisticated ways to analyze and optimize use not only throughout the entire system of the house but also at a particular device level. This can range from very basic functions such as dimming of lights, or be switching them off or modifying multiple home settings or changing device settings to optimize energy use.



2. Smart Grid:

Smart Grid works are becoming more widespread worldwide. Smart grids are a system that enables the communication between the supplier and the consumer. The most important component of the **IoT based smart grid** is the smart meters. **IoT for smart grid** is an issue that needs to be worked on for increasing the energy need, reducing the lost energies, increasing the production provided by the energy and many other reasons. Before explaining this topic, it is useful to explain what the Internet of Things technology is and where it is used.

In traditional grids, batteries were recharged by adapters through electricity cables and AC/DC inverter. These batteries can be charged wirelessly in a smart grid, using inductive charging technology. In addition, in a smart grid, the energy demand pattern of end users can be analyzed by collecting data through an IoT platform, for example, the time of charging mobile phones or electric cars. Then, the nearest wireless battery charge station can allocate the right time slot and that device/vehicle can be charged. Another advantage is that the use of IoT will lead to better control and monitoring of the battery-equipped devices, and therefore, first, the energy distribution can be adjusted, and second, the delivery of electricity to these vehicles can be guaranteed. This will reduce unnecessary energy consumption considerably.

3. Smart Cities :

Nowadays smart cities are new trends that are only possible because of IoT Based energy systems. The recent developments in digital technologies have provided a driving force to apply smart, IoT based solutions for the existing problems in a smart city context.

A **smart home system** can be something that makes our life quite easy. Starting from energy management where the power controls system in the AC appliances where we use the thermostat, all this is managed to cut down the power consumption that's taking place. A door management system, security management system, water management system are part of this as well. Still,

these are vital things that stand out in the smart home system. The limitation of IoT in smart home applications stops where our imagination stops. Anything that we wish to automate or want to make our life easier can be a part of a smart home, a smartphone system as well. In a smart city, different processes, i.e., information transmission and communication, intelligent identification, location determination, tracing, monitoring, pollution control, and identity management can be managed perfectly with the aid of IoT technology. IoT technologies can help to monitor every object in a city. Buildings, urban infrastructure, transport, energy networks, and utilities could be connected to sensors. These connections can ensure an energy-efficient smart city by constant monitoring of data gathered from sensors. For example, by monitoring vehicles with IoT, street lights can be controlled for optimal use of energy. In addition, the authorities can have access to the gathered information and can make more informed decisions on transportation choices and their energy demand.

➢ Challenges of applying IoT:

1. **User Interface:** Privacy refers to the right of individual or cooperative energy consumers to maintain the confidentiality of their personal information when it is shared with an organization. Therefore, accessing proper data such as the number of energy users as well as the number and types of appliances that use energy becomes impossible. Indeed, these types of data which can be gathered using IoT enables better decision-making that can influence energy production, distribution and consumption. However, to decrease the violation of users' privacy, it is recommended that the energy providers ask for user permission to use their information, guaranteeing that the users' information will not be shared with other parties. Another solution would also be a trusted privacy management system where energy consumers have control over their information and privacy is suggested.

2. **Security Issues:** The use of IoT and integration of communication technologies in energy systems enhances the threat and cyber-attacks to information of users and the energy systems from production, transmission, and distribution to consumption. IoT has already turned into a serious security concern that has drawn the attention of prominent tech firms and government agencies across the world**.** The hacking of baby monitors, smart fridges,

thermostats, drug infusion pumps, cameras and even assault rifles are signifying a security nightmare being caused by the future of IoT. So many new nodes being added to networks and the internet will provide malicious actors with innumerable attack vectors and possibilities to carry out their evil deeds, especially since a considerable number of them suffer from security holes.

3. **Connectivity:** Connecting so many devices will be one of the biggest challenges of the future of IoT, and it will defy the very structure of current communication models and the underlying technologies. At present, we rely on the centralized, server/client paradigm to authenticate, authorize and connect different nodes in a network. To maintain good connectivity in the IoT system, the decentralisation of the IoT system comes into the role**.** But when networks grow to join billions and hundreds of billions of devices, centralized brokered systems will turn into a bottleneck**.** Such systems will require huge investments and spending in maintaining cloud servers that can handle such large amounts of information exchange, and entire systems can go down if the server becomes unavailable.

4. **Architecture Design:** IoT-enabled systems are composed of a variety of technologies with an increasing number of smart interconnected devices and sensors. IoT is expected to enable communications at any time, anywhere for any related services, generally, in an autonomic and ad hoc fashion. This means that the IoT systems based on their application purposes are designed with complex, decentralized, and mobile characteristics. Taking into account the characteristics and needs of an IoT application, reference architecture cannot be a unique solution for all of these applications. Therefore, for IoT systems, heterogeneous reference architectures are needed which are open and follow standards. The architectures also should not limit the users to use fixed and end-to-end IoT communications.

➢ IoT features for Universal Home Gateway:

A versatile IoT Gateway may perform any of the following :

- Facilitating communication with legacy or non-internet connected devices.
- Data caching, buffering and streaming
- Data pre-processing, cleansing, filtering and optimization
- Some data aggregation
- Device to Device communications/M2M
- Networking features and hosting live data
- Data visualization and basic data analytics via IoT Gateway applications
- Short term data historian features
- Security – manage user access and network security features
- Device configuration management
- System diagnostics.

➢ Sensors in an IoT based System:

Sensors are types of the transducer. In a typical IoT system, a sensor may collect information and route to a control centre where a decision is made and a corresponding command is sent back to an actuator in response to that sensed input.

There are different kinds of sensors as follows:

Here some of the different kinds of sensors are discussed.

1. Temperature Sensor:

The temperature sensor mainly determines the amount of heat obtained from the source or environmental surroundings. They find application in air-conditioners, refrigerators and similar devices used for environmental control. They are also used in manufacturing processes, agriculture and the health industry. Temperature sensors can be used almost in every IoT environment, from manufacturing to agriculture. Temperature sensors include thermocouples, thermistors etc.

2. Humidity Sensor:

The amount of water vapour in the air, or humidity, can affect human comfort as well as many manufacturing processes in industries. So monitoring humidity levels is important. The most commonly used units for humidity measurement are relative humidity (RH), dew/frost point (D/F PT) and parts per million (PPM).

3. Smoke Sensor:

Smoke Sensor is one of the great applications of IoT in the modern era. Smoke sensors are used nowadays for detecting any kind sense of accident occurring in the room. It is just like an alarm and starts spraying the smoke inside the house. One of the greatest applications of IoT. Smoke Sensors have been using in various applications like homes, industries, etc. These sensors are very

convenient as well as easy to use by the arrival of the Internet of Things. Also, by adding a wireless connection to smoke detectors, the additional features can be enabled to increase security & ease.

4. Motion Sensors:

Motion Sensors are used for security purposes in life. These are also used in hand dryers, energy management systems, automatic parking systems, automatic door controls, automated toilet flushers, automated sinks, etc. These sensors are applicable for the Internet of Things to check them with the help of a computer otherwise smartphone.

5. Gas Sensor:

Gas Sensor is one of the main application of IoT based systems. They are used to detect toxic gases or any kind of harmful gases inside our homes. The most frequently used technologies are photo-ionization, semiconductor, and electrochemical. There are different types of gas sensors are available based on technical specifications & advancements to expand the connectivity of wired & wireless arranged within IoT applications.

6. Infrared Sensors :

Mainly Infrared Sensors are used to deal with health issues and health sensors for monitoring the flow of blood, BP etc. These sensors are used in smartphones for controlling, wearable devices for detecting the amount of light, detection of blind-spot within vehicles, etc.

7. Pressure Sensor :

The pressure sensors are used in IoT for monitoring devices and systems which are determined by force signals. As the range of pressure is outside the threshold stage, then the device gives an alert to the user regarding the issues that must be fixed. The best example of a pressure sensor is BMP180, which can be used in PDAs, mobile phones; external devices, GPS navigation devices, etc. These sensors are also applicable in aircraft and smart vehicles to decide altitude & force correspondingly. In a motor vehicle, TMPS (tire pressure monitoring system) can also be used for giving an alert to the driver while tire pressure is extremely less & it could make unsafe driving situations.

8. Proximity Sensor:

The proximity sensor is one of the applications of IoT based systems that are mainly used for the detection of any near device. These sensors are classified into different types like capacitive, inductive, ultrasonic, magnetic, and photoelectric.

➢ Residential Connectivity:

Residential Connectivity is one of the important points of the IoT system. The main purpose of bringing up IoT in humans is to develop a human society with one of the best features of IoT. The feature of residential connectivity brings life in an easy way that comes forward with the concept of a smart home. As you might have now understood the relationship between the internet of things and smart lighting, but you won't yet dwell on the depth of this connection.

Smart lighting has a very vital role in unlocking the power of IoT and building the smart application system. Lighting is a ubiquitous unit throughout your entire home or building and every light bulb is connected with a power supply.

Numerous companies have introduced innovative solutions for the IoT market that provide security, status and other convenient services. A connected system architecture comprises several wireless nodes ranging from simple remote control devices to complex wireless networks featuring a gateway to connect to the Internet. Even nowadays smart tv has been played a vital role also. The home without wires and any kind of short circuit make it feel better and life smooth.

➢ Conclusion:

In the conclusion, it can be said the future of all technology is becoming the application of IoT. Though tremendous no.s of research is going on in this field of IoT Based Energy Systems. Further analysis should be done on this topic for more explanation. IoT will lead to new standards and platforms (APIs, data analysis) in the nearest future. Practically all platforms are going to be open source as there is very little possibility to monopolize the IoT market by any, even the biggest, company. In recent years, governments and regulatory agencies around the world have increased their focus on commercial buildings, given the fact that buildings are large consumers of energy. Continued regulation is expected (at least in some parts of the world), including mandates for greenhouse gas emissions targets. Therefore, stakeholders should investigate evolving technologies such as next-generation BMS, PoE, IoT, cloud services, and converged networks to get a better handle on the issue, save expenses on the bottom line, and future-proof their environments and their investments. Here discuss some of the challenges of applying IoT in the energy sector, including the challenge of identifying objects, big data management, connectivity issues and uncertainty, integration of subsystems, security and privacy, energy requirements of IoT systems, standardization, and architectural design. Then highlight some solutions for these challenges, i.e., Blockchain and green IoT as future directions of research.

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