Internet of Things in the implementation of a Smart City

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Abstract. A smart city is an infrastructure to develop, deploy, and promote sustainable development to address the challenges of rapid urbanization. The implementation of a Smart City across the world is due to various applications of Internet of Things. To monitor and manage the devices, IoT have the ability with actionable information from streams of real-time data. A smart city should include innovative features to improve the quality of life of a citizen with high degree of accuracy and integration of various technologies. The things which sense, measure, interpret, connect and analyze are the instruments that reside on the IoT System which enhances the infrastructure of a Smart City. In this review paper, we discuss the need of IoT towards the improved infrastructure in the implementation of a Smart City.

Keywords: IoT, Smart City, ICT Technologies, Smart Grids

1. INTRODUCTION

Internet of Things refers to a network of physical and virtual objects with other connected objects via the internet which enables the exchange of data to provide greater level of accuracy and service [1]. The physical objects like electronics, software, sensors are integrated and connected to Internet in an IoT System. The Internet of Things relies on Things of Intelligence. Sensing is the birthplace in the architecture of an IoT System. To guarantee the greatest amount of accuracy and integrity, the sensors should be able to provide precision, energy effectiveness and with robustness. The signal conditioning circuits play a critical role in converting the signals into vital information. The processors should combine hardware with sophisticated algorithms to provide IoT solutions with intelligence, functionality and localized decision-making. The connectivity should provide effectiveness, reliability and flexibility across a range of wireless protocols. The architecture of an IoT System is shown in Figure 1.

![IoT System Architecture](https://example.com/iot_system_diagram.png)

**Figure 1. Architecture of an IoT System**
The physical layer includes IoT devices, sensors, and actuators to aggregate data in real time scenario. The gateway provides the communication protocols between the physical layer and IoT Middleware to provide the sensed data through Wi-Fi, Ethernet, and GSM. The middle-ware layer manages the exchange of information between the real world sensed activities and the application layer. The application layer handled by the User is used to send commands to physical objects over the Internet via mobile applications, web applications, etc., The communication methods in an IoT System includes

- **Device to Device Communication** – includes IoT devices to communicate between one another by using Bluetooth, Z-Wave or ZigBee Wireless Protocols
- **Device to Cloud Communication** – connects the IoT device to exchange data with Internet cloud service and to provide control message through application service
- **Device to Gateway Communication** – establishes communication between the IoT device and the cloud to provide security, data or protocol translation
- **Back-End Data sharing Method** – enables the users to export and analyze data from IoT device and from the cloud

2. **Smart City**

Smart City is a conceptualization to implement innovative features in an urban area with recent technologies like ICT technologies to ease up the livelihood of its people. Smart City employs the integration of ICT technologies integrated with IoT to improve the livelihood conditions. A smart city should include infrastructure with smart buildings, smart healthcare, smart governance, smart energy, smart transportation, smart industry and smart security. Smart City is to create a society to use the technologies integrated with IoT to ease up the day to day activities [2]. Smart City optimizes the various functions of a city and drives the growth economically using smart technologies thereby improving the quality of life. Smart City collect and analyze data by using cloud based services and Internet of Things (IoT) devices to improve infrastructure, public utilities, services and more. The essential components of a Smart City are shown in Figure 2. Any city can be transformed into a Smart City with the help of IoT technologies in manufacturing, transportation, utilities, healthcare, smart buildings, e-governance, smart energy networks, waste management and consumer electronics. The IoT devices are built smarter with integrated Wi-Fi capabilities and sophisticated sensors on them with low power consumption and improved connectivity to Internet. Internet of Things (IoT) utilizes devices that can network and communicate with each other with the help of Internet.

![Figure 2 Infrastructure of a Smart City](image)

3. **IoT enabled Smart City**

Internet of Things (IoT) creates various opportunities in a city to use data obtained through devices to manage traffic, to reduce pollution, to protect environment, to provide security, to care about health conditions and an improved livelihood for the citizens. In this section, we discuss on various sectors where IoT helps to improve the infrastructure of a Smart City.
3.1 Smart Grids

The emerging IoT technologies can facilitate to monitor the generation and control the transmission, distribution of power to domestic and industrial applications. An electrical grid interconnects the generation, transmission and the distribution network. The drawbacks of existing power grids are inefficient monitoring, fault detection and recovery system. With the help of IoT technologies, a power grid becomes a smart grid to monitor and control the Grid. Smart Grid (SG) is a promising solution with a IoT with improved efficiency, more reliable, secure and stable than the traditional power grid [3].

Internet of Energy (IoE) refers to the integration of IoT and Smart Grid which enables flow of energy between them and provides information to determine the power consumption and can predict the energy demand. IoT technologies collect the real-time information to enable operation of a smart grid and to make decisions during problems in real time scenario. IoT technologies in energy sector interconnect the field sensors and actuators to manage the energy elements through cloud based services. For short range applications, we can use communication protocols like RFID technology, Bluetooth Low Energy, Near-Field-Communication etc.. For long range applications, we can use communication protocols like Low-Power Wide-Area (LPWA), LoRaWAN etc., Smart grids can remotely monitor and control the energy network in power transmission and distribution. The IoT in Smart Grids have the major challenges towards the integration of renewable sources, energy storage, distribution network for smart cities and smart building, grid robustness etc... 

3.2 Smart Buildings

Smart buildings provides a secure environment to the users and more comfortable, productive in terms of various building operations for its users. The concept smart buildings are possible with RFID tags, sensors, actuators, smart phones in association with IoT technologies [4]. A city uses different approaches to modify it with smart infrastructure like smart buildings to become a smart city. If a city is to be smart, it needs to have smart buildings and its integral components are as shown in figure 3

![Figure 3. Integral Components of a Smart Building](image)

IoT can deploy low cost wireless devices to monitor and control critical systems (e.g., HVAC) and can restructure the building into a Smart Building. A smart building with the IoT technologies refers to monitor and control the building operations and maintenance through advanced automation techniques. With the aid of the Internet, we can introduce services via web interfaces by translating the appliances data by using the specified applications to track or remotely control them. In smart buildings, by employing various smart lighting control methods, power consumption due to lighting indoor and outdoor can be reduced. The other common activities of the users are Lift Operation; usage of Air Conditioners, Water Consumption and Security can be monitored and controlled in a Smart Building to reduce power consumption. Open systems are the more common ones as they allow a larger number of options for the
end users. The most commonly used protocols in the Smart Buildings are the BACnet, Modbus and LonWorks etc. BACnet protocol is used to communicate between building devices. Who-Is, Who-Has, I-Have, are the protocol services used for device discovery. For data sharing, Read-Property and White-Property are used. Modbus is a standard communication protocol used for connecting electronic devices used in the Smart Buildings. The Modbus protocol is used in operation and maintenance of HVAC, lighting, life safety, access controls and transportation. The BACnet and Modbus are low cost communication protocols for Smart Buildings. LonWorks is useful for building automation applications designed on low bandwidth. With LonWorks technology, more than 100 million devices are installed to monitor the Building Automation Processes. The LonWorks protocol supports five communications media: twisted-pair, radio frequency, power line, coaxial cabling and fiber optics. LonWorks has the highest cost with a limited user base as it is restricted by a licensing fee

3.3 Smart Healthcare

IoT devices improve the healthcare infrastructure of a Smart City in the identification of people who needs the help of Healthcare Professionals. The status of patients can be easily tracked to provide better treatment and faster solutions to major health issues. In a Smart Healthcare enabled Smart City through integration of IoT Technologies the location of the ambulance are monitored to check its availability online. Also, the data related to blood products, different organs for transplantation can be checked through Online. To identify a patient and to avoid the risk of getting wrong drugs, doses the databases of patients are used and verified. To improve the employee’s behavior toward patients, the staff authentication is deployed using Smart Healthcare Infrastructure. Also, it helps to prevent human errors in the data collection and identifying a patient.

By diagnosing the patient conditions, providing real-time information on patient health indicators through IoT devices can be implemented in Smart Healthcare. Smart Healthcare can monitor the patient with the help of IoT enabled technologies. Smart Healthcare would include sensor wearable’s, sensors and devices for diabetes, heart rate and electrocardiogram (ECG), and smart things for insulin and inhalers. The major challenge for the Smart Healthcare is the requirement of interoperability. This important challenge is to deal with the unique protocols from medical sensors/devices from one manufacturer should be able to communicate with devices and servers from other manufacturers [5]. The other challenges identified in IoT for Smart Healthcare are,

- connectivity between smart things/devices
- access to the cloud-based services by smart things/devices
- device management with reduced maintenance for improved device availability and
- Informative analytics for better decision-making from healthcare data

3.4 Smart Waste Management

With rapid increase in population in a City, the issues related to sanitation and garbage management are degrading immensely. The unhygienic conditions created by waste deterioration contribute to the spread of infectious diseases to the citizens of a City. Internet of Things (IoT) can make the cities greener, safer, and quality of life can be achieved by connecting devices, vehicles used for waste collection through smart waste management system [6]. LPWAN, LoRa Communication protocols is mostly preferred for Smart Waste Management System. Waste Management System using IoT is to monitor and collect the waste/garbage on time in daily basis. By using IoT app installed public dustbins, it assists in the tracking of garbage levels in garbage bins. The master dustbin with a micro-controller associated with sensors will communicate the necessary information with the slave dustbins to improve the Smart Waste Management. The Master slave configuration of dustbins will help the authorities to overcome the connectivity issues in remote areas. To optimize the route for garbage collection vehicles, the garbage level data would be used in order to reduce the fuel costs associated with the vehicles. The load sensors
and moisture sensors will provide data related to garbage level and waste segregation in a dustbin. By checking any two parameters, the error rate of false alarm will greatly reduce.

3.5 **Smart Water Quality Monitoring System**

The industrialization and urbanization has greater role towards the water pollution in urban areas as the quality of water is a major challenge to the government authorities in the implementation of a smart city. The disposal wastes from chemical industries, dying industries, textile industries pollute the water. To operate the machinery or to exhaust the heat generated by machinery, they use water from rivers, water bodies etc. The level of dissolved oxygen decreases and increases the temperature of the water and upsets the balance of life [7]. The domestic sewage runoff, drainage from factories has great impact on the water quality. The poor quality of water spreads disease, causes death and leads to socio-economic problems. Water quality monitoring system should reduce water loss due to leakage and ensure the water free from contamination [8-10]. Hence, Water quality monitoring system is essential in the implementation of a Smart City which includes IoT devices for the collection of information at set locations. The system includes sensors such as temperature, pH, and turbidity, flow sensor to measure the physical and chemical parameters of the water. Smart Water Quality System provides the good quality water to the residents of Smart City.

3.6 **Smart Air Quality Monitoring System**

Industrialization and growing number of vehicles leads to air pollution which in turn affects the people with various diseases. The effects of air pollution include irritation of the throat, eyes, nose as well as more serious problems like bronchitis, heart diseases, pneumonia, lung infection and aggravated asthma. Air quality can be tracked over an Internet-based web server and will cause an alert if the air quality goes above a certain threshold level. The air quality can be monitored using IoT and the real-time data is accessed through the smart devices [9]. The smart devices are capable of measuring the temperature, humidity, CO, CO2, NOx and other hazardous particulate matters. IoT based Smart Air Quality Monitoring System can be used to monitor the air quality, harmful gases present in the air show temperature, humidity and other parameters related to quality of Air in the implementation of a smart city.

4. **CONCLUSION**

In this review paper, we presented the challenges and opportunities towards the implementation of a smart city. The communication protocols used for the design and implementation of smart infrastructures for a smart city are analyzed. A smart city with good infrastructure of smart grids, smart buildings, smart healthcare, smart waste management, smart water quality system and smart air quality monitoring system integrated with IoT technologies will ensure the livelihood of the citizens thereby improving the quality of life.

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