Edge Computing Based IoT for Smart Cities

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Abstract
Edge computing deals with computation performed at the edge of networks and devices whereas the Internet of Things focuses on data communication over networks. Edge computing has the capability to overcome the issues of data privacy and response time thereby reducing energy consumption. In this paper, we provided the comprehensive survey focusing on integrating Edge Computing with IoT for the design and development of Smart City Vision which incorporates information and communication technologies to enhance the quality of life factors for the people in the city. Initially, we provide an overview of Edge computing and IoT and the relationship between them are explored. Furthermore, the paper will present and discuss the guidelines and framework to be adopted for establishing the Smart City Vision.

Keywords - *Internet of things, Edge Computing, Wireless Sensors, Smart City, Servers.*

I. INTRODUCTION

The Internet of things is a developing paradigm that provides direct integration of the physical world into computer-based systems, resulting in improved effectiveness, economic benefits, and reduced human effort. IoT has received prominent attention in recent years. It is the association of physical devices, vehicles and other things embedded with software, sensors, actuators, and connectivity which enable these things to connect, collect and exchange data [1]. It enables devices/objects to observe, identify and understand a situation without being dependent upon human help.The reason for the proliferation of IoT is that numbers of devices are interconnected to form a network which not only collect data but also share real-time analytics and decision making.

The application of IoT is deployed in the Smart City Vision which aims to enhance the quality and performance of urban services such as energy, transportation and utilities in order to reduce resource consumption, wastage and overall costs[1].Sensor devices play a vital role in Smart City Vision in acquiring the information. However in order to implement the smart city mission huge amount of data will be generated, which is difficult to process by the sensor devices since they have limited storage and low computation capabilities.

This also becomes a challenging task for IoT since it needs to deal with data privacy, security, and resource management [1].Cloud computing can be used as a solution to this problem. However Continuous data transmission and retrieval process create a stress in the cloud. It can cause delay to process all the data at the control center if sufficient bandwidth is not allocated. Moreover, the distance of the cloud from the network devices can lead to substantial energy consumption.

To address these issues, edge computing is adopted to enhance the current technology and to deal with big data issues. In Edge computing, the massive data generated by different kinds of Internet of Things (IoT) devices can be processed at the network edge instead of transmitting it to the centralized cloud infrastructure due to bandwidth and energy consumptionconcerns [2]. The concept of edge computing is to extend the cloud computing and data processing capabilities to the network edge so that the real-time bandwidth issues can be resolved.In addition, the security and privacy issues can also be improved in edge computing based IoT. Here we anticipate that the edge of the network is changing from data producers to data consumers as well as data consumers [2].The objective of the paper is to provide a reference framework for designing Smart City Vision by incorporating the techniques of edge computing based IoT.

The rest of the paper is structured as follows. Section II discusses the concepts of IoT and Section III provides the overview of Edge computing. Section IV describes the devices required for implementing IoT. The integration of Edge computing and IoT is presented in Section V. Section VI outline the services that are commonly related with the Smart City Vision. Finally paper concludes in section VII.

II. INTERNET OF THINGS

The term "Internet of things" was likely coined by Kevin Ashton of Procter & Gamble, later MIT's Auto-ID Center, in 1999.The term IoT is created from two words "internet" and "things".The Internet is the system of interconnected networks that use the protocol to link the devices. Things refer to any types of objects in the world, it can consist of either electrical or non-electrical gadgets.Computing and controlling all those objects are composed into asingle huge information system referred to as IoT. IoT structure supports the communication between "things" and allow fordistributed computing and the development of distributed applications.

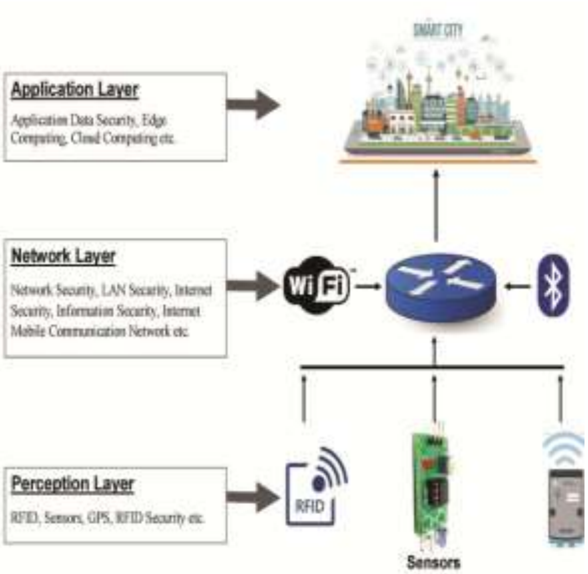

Fig.1: Layered Architecture of IoT

The architecture of IoT supports data acquisition, processing, storage and transmission in three different layers[ ].The data acquisition module is responsible for accessing sensors and collects information which takes place in the perception layer. Next, the processed data is transmitted to different applications through interfaces or gateways with the shortest route via the network layer. The application layer receives the data transmitted from the network layer and uses the data to provide the required services or operations. It provides the storage service to backup received data into a database, or provide the analysis service to evaluate the received data for predicting the future status of physical devices [1].

III. EDGE COMPUTING

Edge computing is a distributedarchitecture that features decentralized processing power, facilitating mobile computing and Internet of Things (IoT) technologies. In edge computing, data is managed by the device itself or by a local computer or server. Instead of doing all the computation in the centerof the cloud, edge computing provides storage service and computing to devices (nodes) at the edge of the network.In edge computing, not only data but also data operations should be cached at the edge.

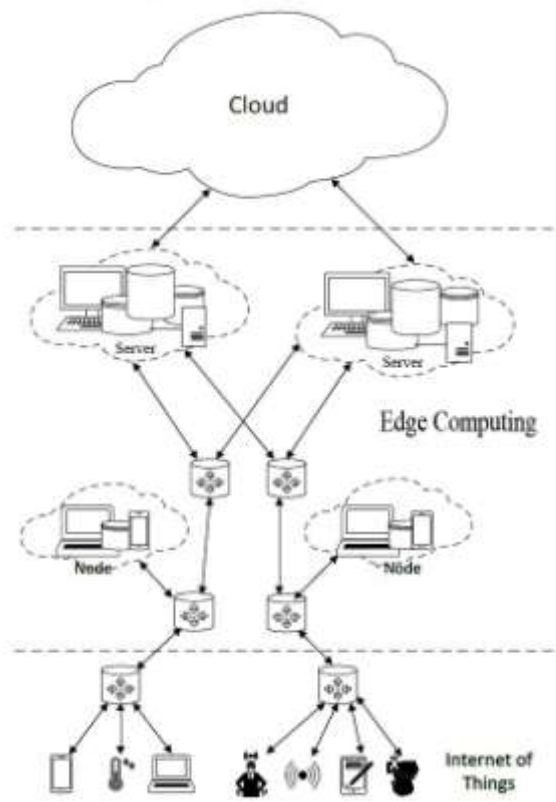

Fig.2: Edge Computing Architecture

From the perspective of edge computing, it states that data processing should happen close to the data source. The Edge computing can be utilized for smart city considering the following characteristics:

A. Handling huge quantity of data

A city with the population of 1 million will produce 180 PB data per day by 2019 [2], contributed by public health, safety, transports etc. Implementing centralized cloud servers to maintain all these data is a difficult process. In this case, Edge computing could be an efficient solution since it processes the data at the edge of the network.

B. Reduced Transmission time

Applications such as public safety require low latency which can be accomplished by edge computing paradigm since it could reduce the transmission time and simplify the overall network structure. Decision making and data processing can be executed at the edge of the network instead of transmitting the entire data to the central cloud.

This both characteristics eliminate costs to ensure that applications can be used efficiently in remote areas. In addition, there is no need to move the data into a public cloud adds a useful layer of security for data.

IV. DEVICES

The devices that are essential for the proposed system is provided based on their usage.

A. IoT Nodes

Here we consider the devices that are responsible for producing data to be delivered to the control center. IoT nodes may be categorized based on a wide number of characteristics, such as powering mode, networking role (relay or leaf), sensor/actuator equipment, and supported link layer technologies [1]. Mobile devices, such as smartphones, tablet PCs, or laptops, may also be an important part of an IoT, providing other ways to interact with it[1].

B. Servers

Data are collected, stored and processed in the backend servers. They act as an interface between IoT data feeders where they can facilitate access to smart city services. They store and process the information produced by the IoT nodes such as sensors.

C. Gateways

The main goal is to provide communication between end devices. An IoT gateway integrates sensor data, interprets between sensor protocols, processes sensor data before sending it onward and more. IoT gateways perform numerous functions such as device connectivity, protocol translation, data filtering and processing, security, updating, management and more.

V. INTEGRATION OF IOT AND EDGE COMPUTING

In this section, we present how to integrate IoT with Edge Computing.

A. Edge Computing based IoT

Cloud computing is a grown technology which provides computing services or data storage over the internet. It provides the benefits of flexibility, efficiency, and ability to store and process data. However, when cloud computing is used in IoT, new challenges will appear.In order to address these challenges, the edge computing concept is provided. Edge computing is able to extend cloud computing to be closer to the things it supports.Instead of doing all the computation in the center of the cloud, edge computing can provide computing and storage service to devices (nodes) at the edge of the network.

An edge computing node can be any network device with the capability of storage, computing, and network connectivity (routers, switches, video surveillance cameras, servers, etc.).These devices can be deployed at anyplace with a network connection, and collect the data from IoT devices associated with IoT applications. Various types of IoT data can be directed to the appropriate place for furtheranalysis based on performance requirements. The high prioritydata that needs to be addressed immediately can be processedon edge computing nodes, which are the closest to the IoT devices that generate the data[ ]. The low priority data, which is not delay-sensitive, can be directed to some aggregation nodesfor further processing and analysis [2].

Nonetheless, several challenges need to be managed by the edge computing infrastructure particularly in the allocation of resources to IoT devices. Since edge nodes have limited computing and storage capacity it needs to efficiently manage when the number of servicerequests arises at each time.Whileedge nodes are allocated to offer services, different requirements need to be considered, including service availability, energy consumption, and even revenue. Thus, how to optically map the fog/edge service nodes to IoT devices to meet requirements of IoT applications remains a compelling issue [2].

In order to overcome this issue, the resource allocation in edge computing based IoT can be divided as resource allocation between end devices and edge nodes and resource allocation among edge nodes[2].

B. Resource allocation between end devices and edge nodes

In order to satisfy all the services requested by the end users simultaneously, each end-users are provided with the satisfaction function to assess the allocated resources to implement the requested service [2].The satisfaction function can be represented as

$$S(r) = \begin{cases} \log(1+r) & 0 \le r < r_{min} \\ \log(r_{max+1}) & r \ge r_{max} \end{cases} \quad (1)$$

where S is the satisfaction function, r is the allocated resources, and r_{max} is the maximum resource, which is required to provide the requested service[2].With this satisfaction function, the main objective of the edge node is to maximize the overall satisfaction of all end-users[2].

In edge computing-based IoT, a number of edge nodes are connected, if an edge node does not have adequateresources to provide the requested services from nearby end-users, while its neighboring nodes have extra resources, theedge node can move some local data to its nearbynodes to process and store the data.

C. Resource allocation among edge nodes

All the edge nodes are connected with each other via the network connections and share their computing and storing resources to provide service for end-users[2].If an edge node does not have sufficient resource to provide requested services, it can move the services with low priority level to be processed to its nearby nodes which have spare resources.

The spare resources of an edge computing node can be represented as

$$R_{Spare}^{f} = R^{f} - \sum_{i=1}^{n} r_i^{max} \qquad (2)$$

where, R_f is the resource that edge node f has, and r_i^{max} is the maximum resource needed by end-user i. If $R_{Spare}^{f}$is less than “0”, edge node f does not have enough resource and need support from neighboring nodes and the particular edge node can be denoted as the resource-poor node. Otherwise, the node can be signified as the resource-rich node.

VI. SMART CITY MISSION SERVICES

The objective of the Smart City is to promote cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment. The purpose of the mission is to make economic growth and improve the quality of life of people by facilitating local area development and harnessing technology, especially technology that leads to Smart outcomes.

A. Structural Health Monitoring

Include maintenance of the common structures such as aircrafts, ships, dams, buildings, and other civil structuresby implementing damage detection strategy.The damage includes changes to the geometric properties or boundary conditions to the structure. Continuous monitoring techniques are adopted to observe the actual conditions of each building and rapidly identify the damage occurred. Initially, the building structural integrity measurements are collected by sensors installed in the structures are stored in the central data repository. A communication paradigm exists between sensors and central data repository. Instead of processing data at the repository, it can be performed at the edge of the devices which can reduce the latency.

B. Waste Management

With rapid increase in population the issues related to garbage management remains a major issue.To avoid this problem, edge computing based IoT provide solution by means of embedding sensors in public dustbins which will monitor the level of garbage in bins. The data regarding garbage levels will be stored in the server. When the level reaches the maximum level the edge computing node will send command to the authority for the collection of garbage. Additionally by detecting the level of load allows the optimization of the waste containers thereby reducing the cost and improve the quality of recycling [4].

C. Air Pollution Monitoring

To protect the public from the damage caused by the toxic contaminants present in the air is the more challenging and expensive task [5]. Air pollutant compounds may be found in the air either in gas form or solid form. These pollutants have the serious effect on human health. To such an extent, edge computing based IoT can provide means to monitor the quality of the air in crowded areas, parks, bus stations etc., and let the information to be communicated to the people. A system integrated with several air pollution sensors and general positioning system (GPS) can be used for data acquisition.It can utilize the wireless mobile public networks. The system sends the data to the database server interfaced with edge nodes for storing the pollutants levels and make this data available on the Internet.

D. Noise Monitoring

The sensor devices are connected to the computing system to monitor the fluctuation of parameters of noise levels from the normal level and transmit this data to the server. Noise can be in the form of acoustic pollution. The proposed scheme can be used as a monitoring service to store and process the measured values of noise produced in units of decibel at any given hour in the places where the service is adopted [6].If detects any noise issues, it can alert the authorities to take control measures. Mainly noise monitoring can be implemented in industrial zones, residential areas, airports, schools, hospitals, etc.

E. Traffic Congestion

Manages the traffic jamming by finding the current status and density of traffic along with the environmental conditions with the help of sensors. Each and every vehicleis monitored by considering the information like speed, fuel level, route name, latitude and longitude of vehicle etc., This information can be extracted and forwarded to the central server. The edge nodes will analyze these data in all individual routes and notify if any traffic violation happens. The database can be made available to the traffic police department via internet.

Additionally proposed scheme presents a scheme for enhancing security in vehicles by applying certain prioritization rules, using digital certificates and applying trust and reputation policies for detecting hijacked vehicles [7].

F. Salubrity of buildings

Monitor the salubrity of the atmosphere in public buildings (schools, colleges' administrative offices and museums) by means of sensors [16]. The information will be stored in the central server and by the use of edge nodes this data can be accessed by all. By managing these parameters it is feasible to improve the level of comfort of the persons that reside in these environments which in turn produce effective yield.

G. Energy Consumption

Power is the one which needs to be monitored and controlled as per the need since electricity consumption is increasing day-by day.The proposed system provide the service to monitor the energy consumption of the city, facilitate the authorities and people to obtain a clear outlook of the amount of energy required by the various services (transportation, traffic lights, lighting, etc.,)[1].The amount of electricity used will be calculated and stored in the database. This information will be monitored continuously andif more power is utilized, the edge nodeswill send alert to the people to reduce the usage of electricity. From this the power consumption can be effectively implemented.

H. Smart Lighting

The system optimizes the street lamp intensity according to the time of the day, the weather condition, and the presence of objects.Enhances energy consumption by switching off lights when it is not needed. The system automatically detects the presence of objects on the street and appearance of sunlight based upon the sensors. Two types of sensors can be used light sensor and photoelectric sensor [10].The captured data can then be transferred to the central control system where the data gets stored and processed. Based on the information the edge nodes can switch ON and OFF the lights at needed timings and also can vary the intensity of the street light according to the necessity [10].

I. Smart Parking

The proposed system designs a smart parking system which enables the user to find the nearest parking area and the availability of parking slots in the respective parking area [8].It mainly motivates the reduction of fuel consumption and excessive travelling time over filled parking slots. The parking system uses sensors to detect the empty parking places and sends this data to the server, this stored data can be accessed by the usersthrough the edge nodes. This enhances the people to check the status of parking slots before starting their journey. By the usage of smart parking system provide simple and economic solution to reduce the carbon footprints in the atmosphere.

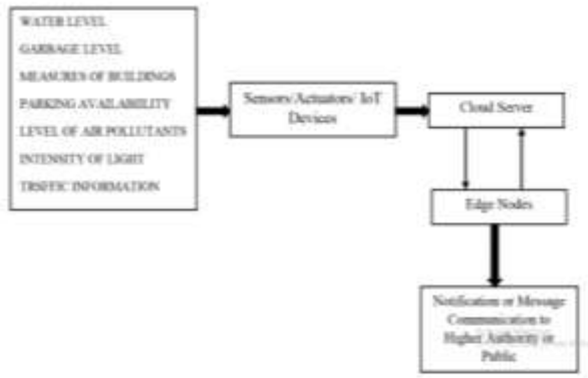

Fig 3. Architecture of Proposed System

J. Water Management

Water plays a vital role for life of humans. We present a technique to manage and plan the usage and distribution of water. Placing sensors in the water tank continuously inform the water level at the current time. This information will be updated on the cloud and able to visualize the water level on smartphones through edge nodes via internet. According to this information about water level in the tank the motor functioning will be automatically controlled [1].The quality of the water in the tank will also be monitored by the sensors. Additionally the purity of water should be monitored in the swimming pool.

Globally sea level has been rising at an accelerating rate. The level of water in sea can be monitored with the help of StormSensenetwork [12] using water-level sensors. This data will be transferred to the server which will be processed by the edge nodes .This data can be used as forecasting measure and alert the people during floods or any other harmful incidents. Furthermore the pollution levels in sea also should be properly notified.

VII. CONCLUSION

In this paper, a review about IoT and edge computing has been presented including architectures as well as the integration of IoT with edge computing to support the Smart City Mission isprovided.Additionally, the devices required for implementing the proposed scheme is discussed.By processing data at the edge of the network ensure shorter response time and better reliability. Furthermore,bandwidth could also be savedsince data could be handled at the edge instead of uploading to the cloud. By utilizing the application of edge computing based IoT the services associated with the Smart City Vision can be implemented. In order to address the challenges of resource allocation, satisfaction function was suggested in which if edge nodes have no resources to process the requesting services, it will move to the neighboring node to store the data. The proposed system will increase the overall efficiency for implementing the Smart City Vision. The current work can be extended by including the techniques for overcoming the security issues.

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