Smart City: A new phase of sustainable development using fog computing and IoT

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Abstract. Fog computing is a distributed technology which performs computations at the edge of the network. IoT devices are generating large amount of data that too Heterogeneous in nature. In order to handle applications which, require time sensitive data and quick decision making, a reliable platform is required which can handle all the tasks in a robust manner considering fault tolerance and state migration. To process request originating from end user, an efficacious and pragmatic approach is to get the request served at the edge of the network rather than cloud envisioned with the aim to minimize the latency. Quick decision-making characteristic of fog computing makes it a smart choice for smoother processing and execution of smart city applications. As utilization of internet and IoT devices has boomed the industry, it is important to have reliable applications for day to day activities like payment of bills, traffic light management, health support system etc. The research study conducted explores multi-dimensional abstractions that can extend technological contributions in current epidemic situation.

Keywords: Smart City, fog computing, cloud computing, IoT, Big Data

1. Introduction
With the advent of technology and growing population, it is challenging to maintain sustainable development of cities. As urban population is growing at fast pace, so as the needs of people for having a good life style. An efficient and sustainable environment is required to cater the needs of urbanization. Internet of Things plays a vital role in fulfilling the requirements of this changing era [1]. Scope of IOT is vast, it has no borders. There is no standardized definition of this term. IoT can be defined as “The Internet of Things allows people and things to be connected Anytime, Anyplace, with anything and anyone, ideally using Any path/network and Any service”.
All the applications we are using in day today environment is all producing data at a tremendous rate. This data needs to be stored and analyzed in a proficient manner so that quick decision making can be utilized by applications like payment of bills, traffic light management, health support system etc. Cloud computing in integration with internet of things has improved the potential of smart city as all the data produced by various applications is stored and managed by cloud servers. But as the demands of customers are increasing it becomes difficult for cloud computing environment to fulfill all these requirements. Theoretically Cloud computing is supposed to have tremendous computation capability but it has certain downfalls as all the data produced by sensors and various applications is all stored and managed at cloud [2].

It becomes a tedious task to manage this data and utilize this data for performing computation in real time applications. Real time applications demand low latency, low bandwidth, quick decision making. The term “Fog computing” was introduced by Cisco to cater these needs.

2. An Overview Of Fog Computing
Fog computing is defined as a distributed computing infrastructure for the internet of things (IoT) that extends computing power and data analytics applications to the “edge” of the network. Fog computing provides additional features to existing cloud paradigm by extending the computation capabilities towards the edge of the network [3]. Architecture of fog computing enables decentralized computing by giving opportunity to end devices to interact with each other and simultaneously sharing resources. This sharing can be done efficiently as it is backed up by the existing cloud architecture [4]. A significant goal of fog computing is to make “Big data” “smaller”. The number of IoT devices is increasing at a fast pace, these devices is equipped with sensors, camera and machines.

So an efficient mechanism should be there at the edge nodes to handle this bulk data. As all the information generated by these devices is not useful for future prediction there should be proper filtering mechanism at these nodes so that only relevant data is stored at edge devices. As edge devices have very less functionality, computability and storage capability [5] . So this mechanism should be smart enough to tackle this Big Data and filtering problem.

As shown in fig.1 position of Fog Layer is shown in this Layered structure. Fog Layer consist of Fog node and Fog aggregate node. At the top most layer, cloud computing is placed. A brief overview of these layers is provided below:

2.1 IoT Devices
IoT devices are the smart devices having limited resources; they are connected to the fog nodes in order to cater their needs of high computation capability. These devices are connected to a network having wired or wireless connection to the internet. Example of IoT devices are smart phone, laptop, CC tv surveillance camera, health care system, municipality cleanliness system etc. Such systems are highly utilizable for Smart City applications [6]. These devices have limited storage and limited computation ability so some backbone is required in order to manage the high computational requirement of such smart city applications[5] [6].Some the examples of wireless techniques are RFID, NFC, HART, and Zigbee etc.

2.2 Fog Nodes and Fog Aggregate Node
Fog nodes are the devices which provide services to the end devices or IoT Devices. Various authors have perceived fog differently according to their understanding and learning. A fog node has various implications by different authors. Various definitions represent different perspective by different authors, although they share a common idea. Fog nodes have capability of data storage, computation and networking capabilities [7]. These distributed fog devices are the core of this three-layered architecture. They are not the fix devices they could be mobile devices, having different specification operating over diverse platforms. Fog nodes play a critical role in providing services to those smart city
applications which require quick response like a health care system, for example if the system does not send an alarm to the hospital authorities in case of an emergency than it is of no use, so timely action plays a critical role in such applications. Various topological orderings are supported by fog nodes. Decision regarding location of placing Fog nodes can be taken based on the type of application. Location could be within an organization, factory, hospital, along railway track and along the highway etc.

In the presented architecture, fog layer has a second important part- fog aggregate node. Fog aggregate node acts one level above the fog nodes. Each fog node is further connected to fog aggregate node. Time of response is higher for fog aggregate node because they span a larger area of service as compared to fog node. They are utilized when less sensitive data is required to be operated on.

2.3 Cloud Layer
Fog aggregate nodes which are discussed previously are connected to cloud layer. This layer has the maximum storage and computing capability among all the three layers. Cloud layer can serve fewer sensitive data, here fewer sensitive data refers to those data which do not require quick response from the server [5]. From example information about travel history of a person is an important parameter to be considered for the prevention of disease. It is good to keep a record of it in this pandemic time (considering Covid 19). However, all the users and applications do not need timely services. Services of cloud can be utilized to store and process such type of information.

In the upcoming section in this paper an outline of IoT and Smart City concept is represented in terms of their key points, architecture and challenges. Also an emphasis has been given to importance of Big Data management in smart cities.

3. Internet Of Things
Digital devices such as sensors, actuators, mobile phones and smart appliances have evolved exponentially, contributing to massive commercial Internet of Things (IoT) goals. Different devices can be interconnected and communication between them through the Internet can be established. Combining these digital technologies was daunting or unfeasible in the past. Similarly, the collection of information for day-to-day activity management and long-term development plans in the city is important [6]. For
example, certain information on public transport, such as location and use in real time, allocation of parking spaces, traffic congestion, as well as other data such as weather conditions, air and noise pollution level, water contamination, energy usage, etc., must be collected continuously. Different technologies were used to address the unique features of each system. The technologies required cover a broad range of breadth from the physical level to the data and application layers. Often, physical layer is called as layer of perception [7]. Layered architecture of data is shown in Fig.2. A brief overview of layered architecture of IoT is as provided below:

3.1 Perception Layer
This is the lowest layer in IoT architecture also known as abstraction layer. This layer is equipped with sensors and imparts functionality to end device to sense and gather data. It is included in IoT architecture for the calculation of physical quantities. Sensor layer interconnects the physical and digital world [8]. This layer collects, store and processes the real time application data. Fog edge node can be integrated in this layer to enhance the functionality and processing speed of services.

3.2 Gateway and Network Layer:
Gateway and network layer provides a robust and high-performance infrastructure for IoT devices. As in the purposed architecture fog computing is supposed to be integrated with IoT infrastructure to cater to the requirement of customers for low latency and bandwidth [8]. Gateway and network should be designed in such a manner so that various organizations can share and use the distributed architecture of fog computing.

3.3 Management Service Layer
Management of all the collected data from end devices is an important concern to be addressed, as data is collected from sensory units continuously [9]. Efficient data analytics mechanism are required to extract meaningful and useful information from the massive data collected. Streaming analytics can be utilized to process real time data. One more responsibility of this layer is to ensure the security and privacy of data as data is supposed to be compromised among different applications.

3.4 Application Layer
Application layer provides a graphical user interface for using IoT applications. These IoT applications play the chief role in functioning of smart city properly [10]. Examples of such applications are healthcare systems, transport management, parking space utilization, food supply chain, Municipal Corporation etc.

In the subsequent section of this paper smart city and their key point are discussed. Various applications can be included under the umbrella of smart city as smart cities have wider scope.

![Fig.2: Layers of IoT](image-url)
4. Smart City
The term Smart city has different implications to different people. Its importance varies from place to place, country to country depending on the degree of growth, willingness to improve and reform, the residents' opportunities and expectations[10][11]. A smart city in India would be different as compared to developed countries like Russia, China, and America etc. Every place has its own needs depending upon the geographical location and lifestyle of its citizens. Smart city can be addressed as the summation of expectations of any smart city designer or developer in a country [12] [13]. This imagination has a robust infrastructure and applications which will best serve the needs of its residents and belonging. Various services can be provided in smart cities some of them are listed below with their key points [14][15][16] (Fig.3).

4.1 Energy Management
Smart cities must have a smart grid system in order to manage the electricity supply. It must include intelligent meters and street lighting so that resources can be utilized efficiently and no wastage is done. Data acquisition related to bills, uses and other details must be done smartly; it must include a supervisory control. This system should encourage more and more utilization of solar energy green projects can be implemented in building green buildings and homes. Smart city can also include a system which will be responsible for managing renewable resources aptly.

4.2 Metropolitan Mobility
Nowadays it has become a basic necessity of cities to have a good traffic management system. Traffic system should be smart enough to handle integrated public transport, smart electric vehicles. This should also include sustainable mobility plans for environmental resources.

4.3 E-Governance and citizen services
A robust back bone is the key to success of any plan. E-Governance can be considered as the back bone of a smart city. Municipal services should be managed smartly by authorities so that the citizens have minimum need to visit municipal offices for day to bill payment and complaints. Smart facilitation of citizen services, integrated operation among various departments, data analysis and decision services are the important part of e-governance system of a smart city. Single application for window clearance business must be provided to its citizens in order to boost mobile governance. GIS map for city
department efficiency and intelligent disaster management solutions are also needed in order to handle natural occurring disaster situation.

4.4 Water Management
Water is the essential part of life for all living beings. It should be used judiciously, without water there is no life on earth. In order manage its uses and minimize its wastage smart meters should be installed in house offices and industries. Water supply management should be handled digitally. Autosensed leakage identification and preventive system should be there in order to minimize wastage. Quality of water should be monitored and accordingly water supply should be managed.

4.5 Waste Management
Real time data monitoring of container and waste bins should be done. For example if bins are overloaded it should immediately send a message to concerned team so that it can be replaced by an empty bin. Intelligent scheduling system of waste categorization, collection and disposal should be performed. Resource optimization mechanism based on actual needs should be utilized in order to maximize the performance of smart waste management system.

4.6 Smart Spaces
Spaces in smart city must be smart spaces like grocery supply chain must be managed online so that there is no time lapse for meeting the demands of the customers. Industrial areas must support intelligent automation. Urban heating and cooling system can be a part of such industries. For supporting such industries micro infrastructure such as sensor networks can provide a better support for implementing smart projects.

4.7 Smart Environment
Green and efficient building are the integral part of a smart city. Besides making smart buildings it should be taken care that no nonrenewable resources are getting wasted. Data centers which will handle and maintain the data to support various applications of smart cities must be sustainable. Smart Pollution control system having monitoring capability of toxicity of air must be installed. Intelligent Meteorological station network can be an important part of smart environment so that weather information can be utilized by various applications of the city. Automatic Forest fire detection and prevention, smart Earthquake early detection system can be accompanied with smart meteorological system

4.8 Smart Communication and Surveillance
Optical fiber connectivity and city-wide wi-fi connectivity can provide support to various applications of smart city. Surveillance cameras and command center analytics must be handled smartly so that crimes can be minimized. Smart home security system and traffic system must be surveilled by an intelligent system so that police can take actions timely.

4.9 Smart Healthcare
Smart hospitals, improved clinical workflow and telemedicine can significantly improve the healthcare services. Patient interaction can be enhanced by utilizing various applications designed specifically for smart healthcare systems. Certified smart card readers for patient data security, updated health care information system and M-Healthcare can be an integral part of smart healthcare.

4.10 Smart Education System
Smart pedagogy and intelligent learning environment have played a key role in maintaining the education of students and researchers during the pandemic time. Various online learning platforms has provided a huge number of courses to sharpen the skills. Webinars and online workshops have played a key role in exchange of knowledge. Smart class management tools and smart simulation labs have ensured that there is no hinderance in attaining knowledge when educator and learner can not have a face to face interaction.
In this section all the key technologies were mentioned which can play a significant role in designing smart city, above discussed applications can be designed to solve various complex issues of a smart city.

5. Requirements Of Smart City
The previous section describes some key smart infrastructure mechanisms which can be helpful in fulfilling the dream of a smart city. Developing countries need a robust foundation over which these proposed smart infrastructure can function efficiently [14]. This section discusses the key requirements which are essential for transforming a city into a smart city.

5.1 Management of Big Data and heterogeneous end devices
Applications of smart city produce large amounts of heterogeneous data in different formats, as this data is originating from different types of devices having different specification. This data is obtained on a daily basis, in variable quantities. It is critical to have effective tools and techniques to ensure the efficient use of this data [14]. Big data management includes policies for development, procedures, and various structural designs to be implemented. It is challenging to manage heterogeneous data originating from heterogeneous devices. Specialized techniques are required to classify this data so that analysis can be done and a good management technique can be implemented.

5.2 Big Data Management platforms
Big data management platforms are required to analyze and manage large volumes of data. In order to process this, we require reliable software and hardware which will deliver high-performance computing capabilities [15]. Such applications must support stream processing and fault tolerance. Some of the examples of Big Data Analytics platforms are Apache Mahout, SAMOA, HPCC, Hadoop Map Reduce, Stratospher, and IBM Infosphere Streams [18].

5.3 Smart network infrastructure
Most smart city Big Data applications need connections to networks. In order to be connected, various components which have integrated sensing and internet connectivity are required such as smart vehicles with a GPS system and artificial intelligence, smart home appliances with audio and smart phones connectivity [16]. The smart set of connections infrastructure should be proficient of migrating or moving data between the server and end device. The centralized solution is better suited to big data however in order to improve latency and access time a decentralized environment such as fog is much efficient. In big data applications, it's necessary to maintain the quality of the decision making process.

5.4 Advanced software and algorithms
Big Data applications have only one of its kind demands. High volume and high speed processing is a must-have to meet these requirements. Conventional algorithms that are used in regular applications may not be sufficiently efficient to process smart city data. Big Data applications have unique demands [17]. High volume and high speed processing is a must-have to meet these requirements. The algorithms utilized by applications prior to the concept of smart city may not support extensive requirement of smart city applications. The algorithms should have additional features to fulfill the needs of smart city application data. They must be designed by taking considerations of voluminous data, variety of data types, distributed end devices and critical time saving, quick decision taking capability. However an important concern while designing these algorithms is geographical positioning of end devices and mobility of end devices. To maintain data and applications in complex environments these algorithm solutions must be competent and trustworthy.

5.5 Security and Privacy of Sensitivity of data
In smart city environment multiple applications work over citizen’s private and sensitive data. So it is the sole responsibility of the designer to take care of security and privacy data. If an intruder gets this information, it can be misused easily. So the data shared with these applications must be encrypted and
hidden from such malicious attacks [17]. It is important to safeguard the data collected from different smart city applications. Information protection, trust and data confidentiality are main security issues.

5.6 Smart Citizen
A rising country's people must be informed and aware about using the Internet of Things applications in their everyday life. Active participation of citizen is needed in sharing the necessary information and feedback about the various aspects and problems encountered with smart city applications so that the applications can be updated and new functionality can be added to those applications[12][13]. Citizen awareness will play key role in the smart city applications to boost their efficiency and results.

5.7 Role of Government
Smart city governing entities play an important part in making a smart city. Government needs to offer solutions and instructions to people who don't know the technology. They can provide accountability and openness to the community. Active citizen participation and coordination requires smooth running of all smart city applications.

6. Challenges
This section presents the challenges faced in implementation of smart city in integration with computing and IoT devices. It is challenging task to develop and design applications for smart cities. The main focus of developers while building smart cities is to make dynamic and extensive applications for citizens of smart city so that various tasks can be handled smartly with minimum delay [18]. Hence it is essential to develop distributed and flexible technologies. The basic challenges common in all the applications are data analytics, accessibility and cost. Some of the key challenges are as following:

6.1 Sources and characteristics of Big data
Heterogeneous Data is produced in various varieties from different sources. The data produced is in the form of text, photos, video, audio, data from social media etc. To preserve and categorize unstructured data format into structured data format, the developer must utilize big data tools to manage heterogeneous data.[19]. The conventional data mining algorithms and software tools can't handle the data size and complexity because of heterogeneous end devices and heterogeneous data produced by such applications. It is challenging to handle the issues such as data management , system architecture , data assessment, distributed big data mining, data evolving all time, compression of data, data visualization and secrecy of data[20].

6.2 Smart Environment
The next most challenging thing for development companies is coping with the exchange of information among dynamic and heterogeneous users of diverse smart city applications. Since we know, all government officials use their own storage facility which contains confidential, sensitive and personal information. The major challenge faced by developers is the sharing of sensitive data between different applications. The safeguarding of confidential data is quite important. Many of the consumers have their private details on mobile phones in this modern period. Citizen’s personal information, such as personal IDs, addresses, contact data, etc are very confidential and cannot be publicly shared and utilized for other tasks without the consent of the citizen. Governments need to make a mechanism to ensure that citizens' privacy is not compromised [19].

6.3 Quality of Data
The smart city applications will generate large volumes of data therefore developers need to track relevant and trustworthy information. Some portion of the generated data would be redundant or irrelevant, so maintaining such data will not be productive. Diverse resources are necessary for data storage and retention. Only quality data should be stored in distributed databases in order to render effective data maintenance. The challenge for developers is to maintain a higher level of data consistency, integrity and heterogeneity.
6.4 Security and privacy
Safety and privacy concerns are the most critical challenge to be faced in a smart city that uses big data, as we discussed in the previous segment, it is one of the smart city's key requirements [16]. The personal information is not open to sharing. Protecting data from malicious attacks and the unauthorized use is critical. Smart system consists of integrating various systems across multiple networks, requiring a high degree of protection as the data travels through different network types.

6.5 Cost
Cost poses a basic problem. Great efforts are needed to distinguish the relevant data from the junk data. Eighty-five per cent are noisy or worthless of the data generated. Verification, separation and refinement of the data from the noisy junk is a very hard thing to do. In this era, all the organizations depend on traditional data management methods already established. As the new innovations like cloud storage and virtualization help to strengthen the intellect and commitment to have data solutions. These innovations, however, incur higher costs that must be met by all organizations. As we know, Data is rising rapidly. The organizations are striving hard to find efficient ways to manage the data to reduce the overall cost of managing big data [20]. New tools & technologies are needed for developing efficient Big Data solutions. Smart city planners need high level hardware and software. Cost is a sensitive topic since the viability of a program designed for people is decided. The Government needs cost-effective strategies to create effective solutions.

7. Conclusion and Future Scope
Fog computing plays fundamental role in implementing smart city applications; consistent tools, techniques and infrastructure which can handle varying needs of applications are required for managing smooth functioning of all the applications and services of smart cities. Fog computing will help in servicing the diverse needs of IoT devices and applications. Data Analytics will help in analysing and finding patterns in data generated by smart devices connected through various modes. As data produced will come from various heterogeneous sources, it is challenging to provide real time processing for data sets. In the race of developing countries, it becomes important for a country to make its cities smarter. No definition of smart city is sufficient to explain the meaning of it as it is evolving day by day. Smart cities provide better facilities to its citizens with real time servicing.

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