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Integration of Internet of Things (Iot) and Cloud Computing For Smart Cities

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***Abstract*—As the cities are growing with internet of things (IoT), it is necessary to provide flexible and centralized solution for it instead of the distributed and segmented approach. These kind of solution can be brought in the internet of things by using cloud computing and its various services. Cloud computing services provide the facility to work from everywhere, recoverability, less fault tolerance, security and environment friendly. The cloud services can be developed for specially internet. Thus, the internet of things can be integrated with cloud, to make advancements in the existing systems of IoT. In this paper, the various services and the key points of cloud computing and IoT have been discussed.**

***Index Terms*—internet of things, IoT, cloud computing, infrastructure, sensing, actuation, green cloud compu**

I. INTRODUCTION

The Internet of Things (IoT) is a domain in which devices are having the processing capacity and connecting capacity to transfer data over a network. IoT has advanced from the merging of remote advances of cloud computing. [1]

The two universes of Cloud and IoT have seen an autonomous advancement. When these two get joined, we can get advancements in the IoT solutions. From one viewpoint, IoT can profit by the essentially boundless abilities and assets of Cloud to compensate its technology. In particular, the Cloud can offer a powerful solution for running IoT and managing the addition applications that adventure the things or the information delivered by them [2]. Then again, the Cloud can profit by IoT by extending its degree to manage true things in a more conveyed and element way, and for conveying new administrations in a substantial number of genuine situations. The integral qualities of Cloud and IoT emerging from the distinctive proposition in writing and moving the Cloud IoT. Basically, the Cloud goes about as transitional layer between the things and the applications. This system will affect future application advancement, where data collecting, processing, and transfer will deliver new difficulties to be tended to, likewise in a multi-cloud environment. In the accompanying, we abridge the issues comprehended and the focal points got while embracing the Cloud IoT. Internet of things includes a lot of data sources (i.e., the things), which create an immense measure of non-organized or semi-organized information [2] having the three attributes run of the mill of Big Data [3], volume (i.e., data size), types (i.e., data types), and speed (i.e., data generation). Hence, it infers collecting, accessing, processing the analyzing the large amounts of data. Thus, Cloud is the most effective solution to store, process, analyze the data and manage information delivered by IoT devices [4]. This combination or integration provides the new scenario in which the cloud and IoT integration would be an emerging technology where the aggregation, integration, security and sharing with the third parties are answered [5]. Data in the cloud can be accessed through standard APIs [6], can be ensured by applying top-level security. IoT devices are having limited processing assets that don't permit nearby data processing. Data gathered is generally transmitted to all the more nodes where scalability is achieved by infrastructure and aggregation. The various features of Cloud and its flexibility give solution to the IoT [7], [8]. Data analyzing, decision making and data mining is easily available and secured one [9]. Different viewpoints would be to perform real time processing, to implement various IoT applications. Managing the complex events and the implementation is done through this integration [10]. The Internet of Things (IoT) consists of intelligent devices and self configuring nodes (things) interconnected. It needs the global.

Infrastructure Cloud computing gives higher computing resources for processing and storage. Thus, the IoT and Cloud computing are complementary technologies. Hence by integrating these two technologies can provide the better solution for internet of things [11]. We call this as CloudIoT.

II. BASIC CLOUD COMPUTING SERVICES AND INTERNET OF THINGS (IOT):

Cloud Computing has the advancements and provision of flexibility and reduced cost, enhanced security, fault tolerance, scalable, fine grained access etc [12]. The basic and important services provided by cloud that can be very useful solution for IoT can be discussed as follows:

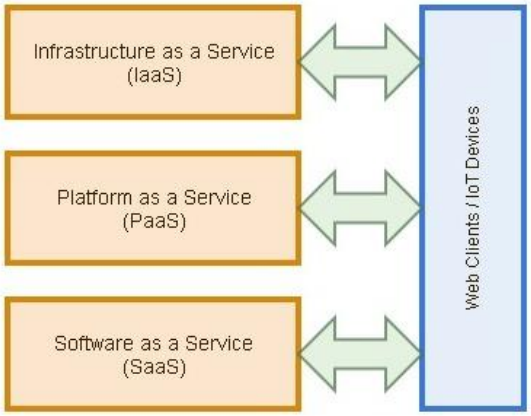

Fig 1. Cloud computing services and IoT devices

i) Infrastructure as a Service (IaaS)*:*

It is a kind of cloud service that provides access to computing resources in a cloud environment. These infrastructure resources are such as virtualized servers, storage, and networks etc. [17] Hence the IoT can use it to deploy the infrastructural components to be used in internet of things such as networking infrastructure.

ii) Platform as a Service (PaaS):

It delivers the computing platform. It includes operating system, software compilers, database etc. Application development can be carried out on a cloud platform. [17] The PaaS provides the tools and libraries to build, test, deploy, and run applications on cloud. It provides the development platform for advanced analytics applications. Internet of things can use this service for getting the platforms for the things. Mainly, operating systems for particular devices, databases etc.

iii) Software as a Service (SaaS):

This kind of service delivers the application software in deployed in the cloud and users are allowed to use it. It is the stand alone service. Internet of things can use the software as a service to get access of apps, embedded software for the devices.

As per integration of cloud computing and internet of things are concerned, it enables the advancement in the cloud services in accordance of the devices i.e. various things. This adoption is known as CloudIoT [3], [16]. The scenario of the advancement of the services can be discussed as follows:

iv) SaaS (Sensing as a Service):

The sensing as a service [3], [6], [8], provides the access to sensor data from everywhere. The IoT can consist of the things connected as wireless network that can sense, communicate, compute and potentially actuate and the information regarding the device, its identification, status, metadata, can be stored by the cloud.

It is emerging paradigm of cloud computing and big data. Sensing as a service means Bringing sensors, devices, networks, and users together on the "device cloud". Sensor-Cloud [17] aims at managing physical sensors by connecting them to the cloud, providing the service instances (virtual sensors) in an automatic way in the same fashion as these virtual sensors are effectively part of the IT resources.

v) SAaaS (Sensing and Actuation as a Service) *[4]:*

It enables control logics and processing implemented in the Cloud. The data that is obtained from the sensing is processed by actuation mechanism which is provided in the cloud service.

vi) SEaaS (Sensor Event as a Service) *[4],[7]:*

Sensor event holds the information such as the sensor's type, the time-stamp, accuracy and of course the sensor's data, dispatching messaging services triggered by sensor events. These can be served by cloud.

vii)DBaaS (Data-Base as a Service) *[5*]:

This service enables the database management in the internet of things. The data so generated is to be managed in the database management system. This service is called as database as a service.

viii) EaaS (Ethernet as a Service) / NaaS (Network as a Service) [5]:

Ethernet is an infrastructure and that can be served by cloud computing. To connect the remote devices, centralized connectivity can be provided by this service.

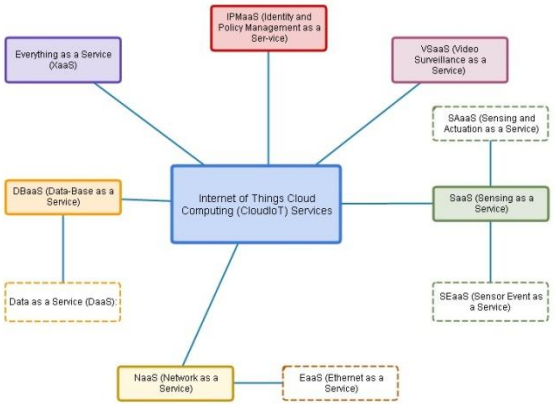

Fig.2 Different cloud services provided for internet of things and infrastructure development

ix) IPMaaS (Identity and Policy Management as a Ser-vice) [5],

It enables the security and policy imposition in the system. It gives policy and identity management of the devices.

x) VSaaS (Video Surveillance as a Service) [13],

Video surveillance service provides an access to recorded video and implementing complex analyses in the Cloud form anywhere by using streaming functionalities.

xi) Data as a Service (DaaS):

Data as a Service (DaaS), data services is similar to Software as a Service (SaaS). In this service, information is stored in the cloud and is accessible by a wide range of systems and devices. [5]

xii) Everything as a Service (XaaS):

In addition to this, XaaS (everything as a service model) is introduced. It allows the paid consumption of a service. In IoT context, it which deals to implement indexing and querying services of things, and provides them to end users, developers, provides, as a service. The cloud computing that is serving internet of things is called as Cloud of things CoT. [5]

III. INTEGRATION OF CLOUD COMPUTING WITH INTERNET OF THINGS, BENEFITS FOR SMART CITIES DEPLOYMENTS

When the internet of things are get integrated with clouds, the data is get centralized. Hence, the city government can have a platform for data analysis mining to make decisions and reporting regarding the internet of things. As cloud computing provides the virtual networking and flexibility, it is becoming popular in real applications. [11]

Cities can become smarter by using the cloud technology with internet of things though it is possible to implement the internet of things without cloud based services but it will have a segmented approach and not so managed. [14]

Cloud integration with internet of things in smart cities deployments can be useful in following ways [14]:

***(i) Data collection and storage*:** In smart city, there is requirement of specialized hardware, software and applications for data gathering that is collected from sensors, smart phones, water meters etc. This can be fulfilled by the cloud systems. After integration with clouds, IoT will get the necessary hardware as well of application software that will make sense of the devices. [15]

***(ii) Flexibility*:** For the growing data of internet of things, cloud can be suitable due to its flexibility and scalability. It is ideal businesses with growing demands. As the need of cloud services for a city gets increased, it is easy to scale up the cloud capacity. Similarly it is easy to scale down if required. [18]

(iii) Recoverability: As per smart city requirements, there should be the stable collection and storage of data. It will require the robust disaster recovery. Also for small businesses there are budget conditions, hence the cloud integration provides the budget solution it. The cloud integration gives the backup and recovery solutions. [18]

***(iv)Work from anywhere*:** With cloud computing integration with internet of things, it enables to share the resources at anywhere [18] from any devices. It offers more flexible solution for IoT for the smart cities.

***(v) Security and Policy*:** The most important requirement for the smart cities deployments is the security. The information is so exchanged in the IoT, the cloud integration would provide solutions for security. Because the data is stored in the cloud, you can access it no matter what happens to the devices. Hence security is provided centrally. The cloud service provider is responsible to enable security in the cloud systems. Hence the cloud integration would be more secured and centralized. [16]

(vi)Energy management and Environment Friendly and use of green cloud computing [19]: Integration of cloud and IoT [20] is like the combination of sensing and actuation systems, connected to the Internet. It optimizes the energy consumption as a whole. [21] In cloudIoT, the various devices are integrated into energy

consuming devices and be able to communicate with the utility supplier in order to effectively balance the power consumption and generation. Besides the home based energy management, the Cloud and IoT, provide systems to combine and process on energy and power-related functions as smart manner. It's goal is to improve the efficiency, reliability, economics and sustainability of the production and distribution of electricity and energy.[22]

The integration of IoT and Cloud computing applications provides the solution for such a Smart City that can be able to centralized services and that can be easily be scaled to support a large number of users. [20] Clouds and IoT, have to operate in wired and wireless network environments and deal with constraints such as access devices or data sources with limited power and unreliable connectivity. The Cloud and IoT integration is enhancing the (i) managing the devices and services by providing domain specific programming tools and environments and (b) smooth execution of applications through the dynamic and heterogeneous resources to meet quality of service requirements of diverse IoT. [21]

The Cloud resource management and scheduling system enable to dynamically prioritize requests and real time critical requests management as well as the energy management, power consumption and hence the environment [10][22].

IV. CONCLUSION:

The smart cities consist of internet of things (IoT) that are having segmented approach or distributed approach. When they are integrated with the cloud, the IoT become more efficient or flexible. There are various benefits of cloud computing such as the data collection can be easily done, centralized approach, security and policy, energy management etc. Thus cloud computing would be the good solution for internet of things for smart cities deployment.

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