Cloud Computing for Internet of Things & Sensing Based Applications

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Abstract— **Internet of Things (IoT) is a concept that envisions all objects around us as part of internet. IoT coverage is very wide and include variety of objects like smart phones, tablets, digital cameras, sensors, etc. Once all these devices are connected with each other, they enable more and more smart processes and services that support our basic needs, economies, environment and health. Such enormous number of devices connected to internet provides many kinds of services and produce huge amount of data and information. Cloud computing is a model for on-demand access to a shared pool of configurable resources (e.g. compute, networks, servers, storage, applications, services, and software) that can be easily provisioned as Infrastructure (IaaS), software and applications (SaaS) . Cloud based platforms help to connect to the things (IaaS) around us so that we can access anything at any time and any place in a user friendly manner using customized portals and in built applications (SaaS). Hence, cloud acts as a front end to access Internet of Things. Applications that interact with devices like sensors have special requirements of massive storage to storage big data, huge computation power to enable the real time processing of the data, and high speed network to stream audio or video. In this paper, we describe how Internet of Things and Cloud computing can work together can address the Big Data issues. We also illustrate about Sensing as a service on cloud using few applications like Augmented Reality, Agriculture and Environment monitoring. Finally, we also propose a prototype model for providing sensing as a service on cloud.**

Keywords- ***Internet of Things, Sensor Networks, Cloud Computing, CDAC Scientific Cloud, CStaaS***

I. INTRODUCTION

The Internet of Things (IoT) [1][12] refers to uniquely identifiable objects (things) and their virtual representations in an Internet-like structure. Internet of Things refer to everyday objects, that are readable, recognizable, locatable, addressable, and/or controllable via the Internet using either RFID[2], wireless LAN, wide-area network, or other means. These objects includes not only the day to day usable electronic devices or the products of higher technological development such as vehicles and equipment, but also include things like food, clothing, and shelter; materials, parts, and subassemblies; commodities and luxury items; landmarks, boundaries, and monuments; and all the miscellany of commerce and culture. Ubiquitous computing [3] refers to a new genre of computing in which the computer completely permeates the life of the user. Internet of Things (IOT) will comprise of billions of devices that can sense, communicate, compute and potentially actuate. Data streams coming from these devices will challenge the traditional approaches to data management and contribute to the emerging paradigm of Big Data [5]. IoT has burst onto the stage, interconnecting everyday objects over the Internet, which acts as inexhaustible sources of information. The phenomenon has required a combination of three developments. First, miniaturisation, with technology being available in hands of users through smart devices any-where, any-time. Secondly, an overcoming of the limitations of the mobile telephony infrastructure. And thirdly, an intelligence in the applications and services that make use of the vast amount of data created via the IoT Sensor networks[28] and convert this data into useful information to enable real time decision making and scientific discoveries. However, to date, limited support has been provided for the development of integrated environmental monitoring and modelling applications [29]. Specifically, environmental dynamism makes it difficult to provide computational resources that are sufficient to deal with changing environmental conditions. This paper proposes that the Cloud Computing model is a good fit for IOT[7] applications with the dynamic computational requirements of environmental monitoring and modeling. Figure 1 depicts that the evolving technologies like IoT, sensor networks and cloud computing complement each other.

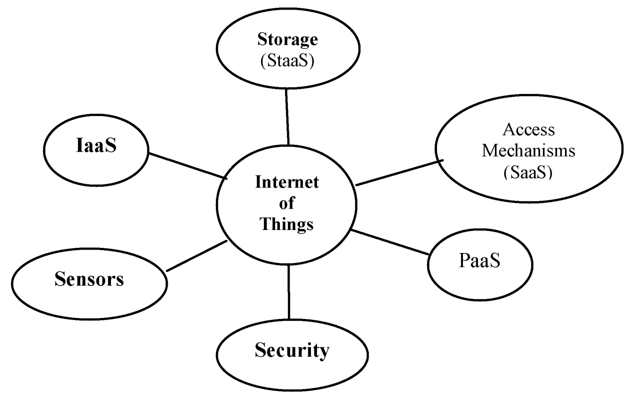

Figure 1. Internet of Things, Sensing and Cloud Computing

Cloud computing [4] is a model for on-demand access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, services, and software) that can be easily provisioned as and when needed. Cloud computing provides an abstracted interface aggregates the resources to gain efficient resource utilization and allow users to scale up to solve larger science problems. It enables the system software to be configured as needed for individual application requirements. For research groups, cloud computing will provide convenient access to reliable, high performance clusters and storage, without the need to purchase and maintain sophisticated hardware. It has been said by Pete Beckman, director of Argonne's Leadership Computing Facility that "Cloud computing has the potential to accelerate discoveries and enhance collaborations in everything from providing optimized computing environment for scientific applications to analysing data from climate research, while conserving energy and lowering operational costs". However, there are various challenges of HPC on demand like performance, power consumption and collaborative work environments.

Big Data [32][35] is defined as a collection of complex and large datasets that are difficult to process with available database management tools. Big Data can originate from technologies such as sensors, cluster computing, internet and computer networks[33]. According to Gartner [34] Big Data has three dimensions- volume, variety and velocity. Volume refer to large transactions, variety refers to data-types (tabular data, documents, video, images, e-mails, stock ticker data), originating from social media and mobiles, and velocity refers to structuring of data and making it available for access and delivery. The challenges associated with Big data, are to capture, search, share, visualize, store the data with the existing database technologies, and processing & analysing the data. Big Data analysis benefit the decision making capability in various domains such as science, astronomy, environment studies, commercial, economy, medical, social networking etc[34]. Organizations like Google, Microsoft, and IBM are researching for technologies and techniques to handle Big Data in reasonable time. In medical stream, MRI imaging, CT Scan and genetic analytics creates huge digital data related to patients[33], when analysed gives fundamental insight in the environmental & genetic causes of the diseases, that leads to advancement in diagnosis techniques. Mobile apps are generating huge amount of context-aware data in form of images, audio, video, text, mails etc. IOT also contributes a big portion to the Big Data. Environment sensors monitoring the content of gases present in the air, and generate data. The effective mining of the collected data helps the climate simulators to predict the effect of the gases on the atmosphere.
In IoT every device will have an IP and are on IP connected network, based on dedicated hardware. Exchanging the sensor data, in such an environment results in expensive infra structure. Cloud can be a most promising & cost-effective solution to connect, manage and track the IoT. Cloud models suitable for IoT are:

- IaaS, for sensor & actuator business models and resource access models.
- PaaS provide access to the IoT data and control services.
- SaaS, for monitoring services application domain.

II. SENSORS AND SENSING SERVICES

Sensors [6] are sophisticated devices that are frequently used to detect and respond to electrical or optical signals. A Sensors convert the physical parameters (temperature, blood pressure, humidity, speed, .. etc.) into a signal which can be measured electrically. Sensors devices areas a part of IT resources (e.g. CPU, memory and disk) for end users. It enables to provision service instances automatically, to monitor sensors and to control sensors. These functions can be used via the user interface via web browser. Today many types of sensors are being used for different applications in various areas. The most common type of sensors available are: body sensors, environmental sensors, etc. The number of sensors is increasing for various purposes. Sensors and sensor networks are being used by various services such as Environment, Healthcare [30] and Government [31] services. As the sensors are closely coupled to a type of service, other type of services cannot use these sensors easily. As various types of useful data is gathered by sensors, sharing sensors data by other services can accelerate service innovations.

III. SENSING AS A SERVICE ON CLOUD

The terms Sensing as a Service (SnaaS) and Sensor Event as *a Service* (SEaaS) [20] are coined to describe the process of making the sensor data & event of interests are available to the clients & applications respectively on–fly over the cloud infrastructure. Applications of sensor-network using cloud computing are explained in the Sensor Applications in subsequent sections.

Sensor cloud[21] is an infrastructure that allows truly pervasive computation using sensors as interface between physical and cyber worlds, the data-compute clusters as the cyber backbone and the internet as the communication medium. Sensor cloud integrates large-scale sensor networks with sensing applications and cloud computing infrastructures. It collects and processes data from various sensor networks. Enables large scale data sharing and collaborations among users and applications on the cloud. Delivers cloud services via sensor-rich mobile devices. Allows cross-disciplinary applications that span organizational boundaries.

A. Features of Sensor Cloud

Sensor Cloud enables users to easily collect, access, process, visualize, archive, share and search large amounts of sensor data from different applications. Supports complete sensor data life cycle from data collection to the backend decision support system. Vast amount of sensor data can be processed, analyzed, and stored using computational and storage resources of the cloud .Allows sharing of sensor resources by different users and applications under flexible usage scenarios .Enables sensor devices to handle specialized processing tasks.

B. *Sensor Cloud infrastructure*

It is the extended cloud computing to manage sensors. It provides sensor devices as a part of IT resources (e.g. CPU, memory and disk) for end users. It enables to provision service instances automatically, to monitor sensors and to control sensors. These functions can be used via the user interface via web browser.

Sensor owners allow the cloud computing service to use their sensor devices similar to IT resource owners. Sensors are costly devices and the maintenance of the battery driven sensor is quite high, with this sharing through cloud sensor provide can effectively maintain this cost with the rent generated with various applications sharing the devices.

We focus on the service model and service life-cycle [21] of the sensor-Cloud that gives the overview how sensors are provided as the service to the end user over the cloud.

- *Service Model :*

The service providers prepare service templates as service catalogue. The service requesters select the service template menu from the predefined service catalogue and request a service instance Service providers create the service templates including sensors and also without sensors. So the service requestor can request for the service instance without sensor capabilities by selecting templates with no sensors and can also request for service instance with sensors by selecting the templates with sensor capabilities if required. The service requesters can start new service with sensors and extends their existing sensor service.

- *Service Life Cycle*:

The service lifecycle [21] is divided into the two phases depicted in figure 2. One is service catalog definition phase. The other is service providing phase.

a. **Create Service Catalogue.** Service provider service catalogue consists of menu which presents the service specifications as IT component (OS, Network speed, Database etc) and sensors from the range of available sensors. From the these service templates service instances are created that meets the user/groups requirement.
b. **Service providing Phase:** The end user request the service providers for the service instance by selecting the service template matching his requirement once the service instance is generated user is acknowledged and have the full control on

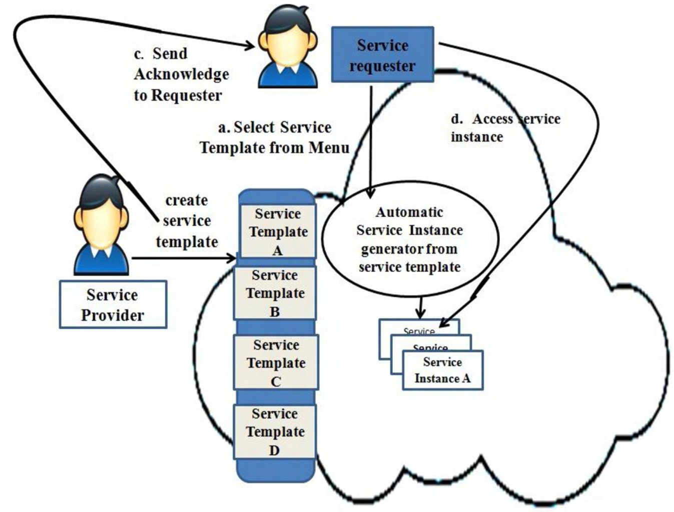

Figure 2. Service Lifecycle in sensor cloud for the requested service

c. that service instance. After the user is finished with his task the service instance is released and billing is done as per the usage.

C. *Research Challenges of Sensor Cloud*

The Sensor Cloud research challenges [22] are:

- Complex Event processing & Management: Relevance of the real-time sensor data to different applications.
- Massive Scale & real-time data processing: To classify the data as video, voice, image etc., and call relevant services.
- Large scale computing framework: Needed for the applications that make decision with data sets from multiple types of sensors located at different locations.

D. *Applications Benefited on Sensor Cloud*

Some applications like transport monitoring [20][24] that includes traffic signal control, congestion control, navigation, dynamic traffic lights are WSN applications compute and data intensive applications get benefited with storage and computational power offered on the cloud. Military [25] sensor applications are benefited with such infrastructure as it is more secure to send the sensor data over the cloud infrastructure then on internet, weather forecast [26] applications are compute intensive with cloud infrastructure these application can process the sensor data in real time. Health care [27] applications on cloud remotely analyze and diagnose the patients, drugs stock etc.

E. *Security & Privacy Issues In Sensor Cloud*

As per the authors in [23], the adversaries of the environment can lead to collection of improper data: like artificially raised temperatures. Security threats from hackers: can inject malware into physical sensors upon having an access. The sensor data in raw/processed form can be stolen/ tampered on cloud. Infected client can cause security breaches to the Sensor-cloud system. The communication channel between client, sensors, and cloud are vulnerable to side-channel information leak [23]. These issues have to be addressed to have secured and protected sensing platforms.

IV. CDAC SCEINTIFIC CLOUD FOR IOT

A. *Scientific Cloud*

High Performance Computing (HPC) allows scientists and engineers to solve complex science, engineering and business Applications that require high BW & low latency networks, High Compute and Storage capabilities. Acquiring HPC resources and Setting them is an involved, and time consuming process. Usually Applications wait in long queues to get an access to shared clusters and huge storage. Scientific applications need complex parallel environments and software libraries to run the applications successfully. Cloud Computing is a model for on-demand access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, services, and software) that can be easily provisioned as and when needed. CDAC Scientific Cloud (CSC) [13] is an effort to provision the on-demand access to HPC resources (Computational-IaaS and Storage-StaaS) and environments. IaaS services [13] for CSC enables on demand access to the computational resources to the users. Using IaaS & StaaS services of CSC for Internet of Things, the sensor data produced by the devices can be stored and processed, as CSC inherently supports elasticity & scalability. The applications for IoT need to embed the CSC APIs to support the elasticity in their applications..

B. *Storage as a Service for IOT*

Storage as a Service is the capability of supplying data storage capacity over Internet. Centre for Development of Advanced Computing(CDAC) promotes the usage and contributions to open source software. Sensor Networks produce petabytes of data that needs to be stored and processed and analysed. Cloud computing plays an effective role via one of its offering storage as a service. CDAC's Storage as a Service (CStaaS) is based on open source OpenStack Swift[8]. This Object based Storage software provides scientists and researchers partners with a convenient and affordable way to store, share, and archive data, including extremely large data sets. It provides a flexible, configurable, and expandable solution to meet the needs of more demanding applications. In this, files (also known as objects) are written to multiple physical storage arrays simultaneously, ensuring at least two verified copies exist on different servers at all times. The various interfaces

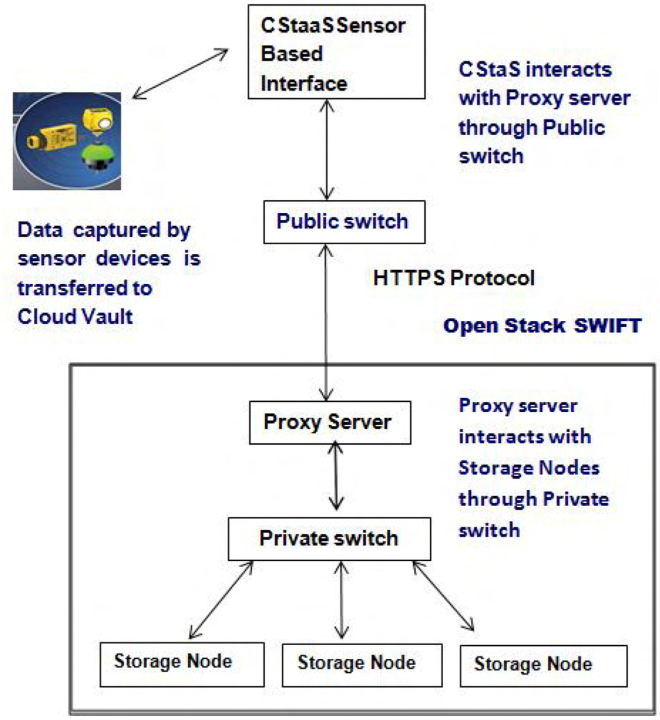

Figure 3. Internet of Things, Sensing and Cloud Computing

through which user can access CStaaS are Web application, Java APIs, Desktop application-Cyberduck[9], Mobile application. Web interface will allow access to the CStaaS files through browser.

Figure 3 illustrates the usage of CStaaS for IOT. The collected data can either be stored in sensors, or transmitted to the storage on cloud. Several problems arise when data are stored in sensors. First, as sensors are equipped with a limited memory or storage, which prohibits the storage of large amount of data accumulated for months or years. Second, as sensors are battery operated, the stored data can be lost, if the sensors are depleted of power [36].

Sensors nodes [37] are programmed with the required application software to collect, encode, and transmit data through wireless communication channels. Sensor node consists of OS and network management components that collects the data from a serial port, transforms and load this information in the CStaaS sensor based interface. Data produced by sensor of networks can be stored in CStaaS via CStaaS sensor based interface which is designed in such a way to collect data from any number of heterogeneous Sensor nodes. The CStaaS sensor based interface acts like a middleware between sensor and cloud. After collecting data from Sensor nodes it is passed to storage nodes (having huge petabytes of storage capacity) over a secured network (No intruder can read data while it is transferred as it is encrypted) via proxy server. Data stored in storage nodes cannot be accessed directly by any intruder without valid credentials as it stored in encrypted object format. Stored data can be accessed over a 10 GBps network, by the owner having valid credentials, at any time.

C. *Scientific Cloud for IOT*

The sensor and instruments used for gathering the data and providing the data have limited amount of computational power. For making the decision using the data gathered by the things we need the huge amount of computation power. Scientific Clouds (Infrastructure as a service) makes it possible for the devices (things) even with limited computational capabilities, perform intricate computations required for effective performance of the assigned task. The things need to only have the sensors and the actuators and their decision making capabilities can be facilitated through the almost infinite computational capabilities of the cloud.

We can put a server to provide the computation but we can't dynamically increase and decrease the capacity of those server. The maintenance and hardware up gradation is also a challenging task. While scientific cloud will provide the huge computational power on demand. The data will be sent to the cluster on scientific cloud it will process the data and send it to the devices to response back. If more computational is required the cluster on cloud increases the number of nodes in cluster to give the quick response and if the hardware is underutilized it will reduce the number of nodes in cluster to save the power and money. In this way Scientific Cloud will provide huge amount of computational power on need and this model will be energy and cost efficient as in user will be charged how much he have used the resources. Figure 4 depicts the prototype model for supporting Internet of Things.

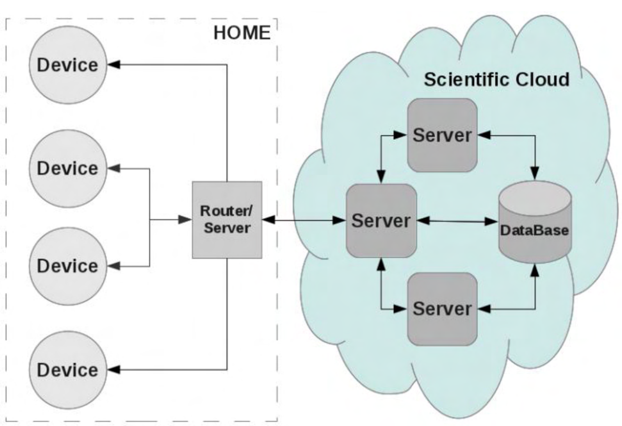

Figure 4. Prototype model of Cloud supporting Internet of things

V. APPLICATIONS FOR SENSING AS A SERVICE ON CLOUD

A. *Augmented Reality (AR):*

AR [10] is adding things on top of real world objects. The real world objects are captured by visual sensors to process and find out the context hidden in them. The data can also be combined with a compass and GPS to intelligently guess what are we looking at. Once we get the context information we then add relevant things on top of the real world. To accomplish the AR effect, all that is needed is 3D point data in some particular format and an application that can consume it.

Typically, smart phones and mobile devices have limited storage capacity. Digital images and other content that is used for the AR applications takes a lot of space, this issue can be resolved by the use of cloud computing by creating content databases.

In order to support data requirements of AR in cloud we may need graphics servers, computing servers, mobile servers, mobile communication network equipment, mobile terminals, routers, web servers and PCs. Other than this the advantages of SaaS can be leveraged for AR in cloud. The few advantages are:

- Availability via web browser
- On demand availability
- Quicker access
- Greater Capacity

These advantages support the concept of AR in cloud.

B. *Agriculture and Environment Monitoring*

Farmers in India face lot of agriculture related problems. Land size is generally in hectares, so it is difficult for a farmer to analyze conditions like temperature, moisture, soil condition etc every day. It is Difficult to analyze the infected crop from a 100-200 hectare field, which leads to huge damage and to store the analyzed data for future reference as farmers are illiterate. It is not easy for a labor to tell the infected crop condition to the experience farmer as lack of technology. Also farmers find it difficult to predict the rainfall and also which soil and climate is best suited for which crop or vegetation as they don't have any past written records. Farmers don't try to cultivate new variety of hybrid crop, as lack of knowledge, experience and records like climate and soil needed for a new crop. The Solution[11] for the above mentioned problems is to place sensors out in its fields to collect readings on temperature, soil &moisture levels and to collect the data and recommend when to start planting or what crops may be well-suited to a specific field. Online footage can also be taken from the video cameras out in the fields. Workers can also take pictures on their mobile phones of potential problems like an infected crop. Damage to crops because of rats, wild animals, birds etc can be avoided by placing smart devices in fields. Sensors placed in crop soil that measure moisture levels can determine whether or not a particular section of a crop needs irrigation. Additional efficiency could be gained by integrating with weather data using cloud storage and prediction using huge compute power of cloud computing, both by using forecast and historical data. The utilization of cloud computing would also create a simple path towards expansion. Additional compute and storage capability would always be present without the need for capital planning and purchase.

VI. CONCLUSIONS

Internet of Things though has been achieved at a primitive level using RFIDs; it would be a robust platform like the cloud, which could serve as an efficient backbone for achieving a network of sensors and actuators which can be employed gainfully for improvising the performances of the day to day gadgets/activities. C-DAC has rich expertise in sensor, HPC, Networking, Grid, and Cloud technologies and scientific Application development is looking forth in a big way to contribute to IOT. C-DAC's Scientific Cloud Research [13] contributing to the HPC as a Services in Cloud for Small, Medium, and Large research team in HPC. Various collateral issues associated with the implementation of Sensing as a Service in Scientific Clouds have been analyzed in this paper. Gartner hype cycle for cloud computing 2010 identifies cloud web platforms & public clouds at hype stage and suggest 2 to 5 years period for settlement. The field being nascent, further work is required towards mitigate practical implementation challenges of the sensing as a service in clouds for IOT.

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