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A SURVEY ON ARCHITECTURES, APPLICATIONS AND ISSUES OF SENSOR-CLOUD

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ABSTRACT

Wireless Sensor Networks have been growing in many areas like healthcare, surveillance, disaster sensing, agriculture, defence, weather forecasting, smart home and manufacturing. A sensor network is a sensor node that is connected spatially to form a network automatically for receiving data transmission among them. The limited resources for wireless sensor networks are real-time transmission with high demands and its processing. In the distributed computing environment, the cloud computing has its own popularity with data processing needs and storage for its cloud environments. Cloud computing can be referred to an era of providing applications, infrastructure and platforms with accessing of shared computing resources over the network. Therefore in the present days, Sensor-Cloud integration provides a high scalable, flexible and open reconfiguration platform for controlling and monitoring the applications.

Keywords: Wireless Sensor Network, Virtualization, Cloud Computing, Virtual Sensors, Physical Sensors.

1. INTRODUCTION

Cloud computing[1] is a new computing paradigm in which the virtualized technologies such as VMs, are built through next generation data centres to provide reliable services as a personalized resource collection to meet a specific service-agreement. The data can be accessed by any consumers from "cloud" for the required applications. The US NIST (National Institute of Standards and Technology) defines the cloud computing concept which was the future generation computing paradigm.

"Cloud computing is a model for enabling convenient , on demand network access to a shared pool of configurable computing resources(e.g. Networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction[3]".

Wireless sensor networks is an invincible trend for the research advancement and applications in industrial, military sensing, distributed robotics, air traffic control, pressure, temperature and commercial fields[4], [5]. A radio transceiver would be loaded with each node in the sensor network. The sensor nodes consist of three parts: processing, communicating and sensing [6].

Camera sensors, thermal sensor, microphone sensor are most few sensor devices in sensor network. The applications and services are attached closely to provide useful data [7]. The affects in the overall network topology arise due to obstructions that would have a limited communication between nodes while monitoring the environment [8].Sensor-Cloud infrastructure [9] was proposed and evolved by many IT people in present days. The sensors that are been scattered through the network is managed by cloud computing that defines the Sensor-Cloud infrastructure. Health-related applications such as blood sugar follow up, diabetics monitoring, and cardiovascular disease are deployed by using Sensor-Cloud infrastructure. Some telemedicine interfaces were being used to report the individual data like blood sugar, heart rate and pulse rate [10].

Sensor-Cloud can be defined as a process to collect the information for sharing on big scale through different sensor networks.

What is a Sensor-Cloud?

According to IntelliSys, Sensor- Cloud can be defined as follows:

"An infrastructure that allows truly pervasive computation using sensors as an interface between physical and cyber worlds, the data-compute clusters as the cyber backbone and the internet as the communication medium [11], [12]".

According to MicroStrains's Sensor-Cloud definition:

"It is a unique sensor data storage, visualization and remote management platform that leverage [sic] powerful cloud computing technologies to provide excellent data scalability, rapid visualization, and user programmable analysis. It is originally designed to support long-term deployments of MicroStrain wireless sensors; Sensor-Cloud now supports any web connected third party device, sensor, or sensor network through a simple Open Data API [13]".

This paper presents a study on Sensor-Cloud. Section 2 of this paper provides a brief study on different architectures of Sensor-Cloud. Section 3 discusses the different entities and components involved in the Sensor- Cloud Integration. Section 4 discusses the different applications of Sensor-Cloud. Section 5 describes the different issues and their challenges in the Sensor-Cloud infrastructure. Finally we conclude and summarize the survey in Section 6.

2. ARCHITECTURES OF SENSOR-CLOUD

Sensor-Cloud –based enables us to develop the user-based application which is flexible enough by creating the web-based application platform for sensor data. Sensor-Cloud has different architectures that are been discussed in this paper.

2.1 WSN-Cloud Computing Platform

Fig. 1 illustrates the WSN-Cloud Computing Platform [14].

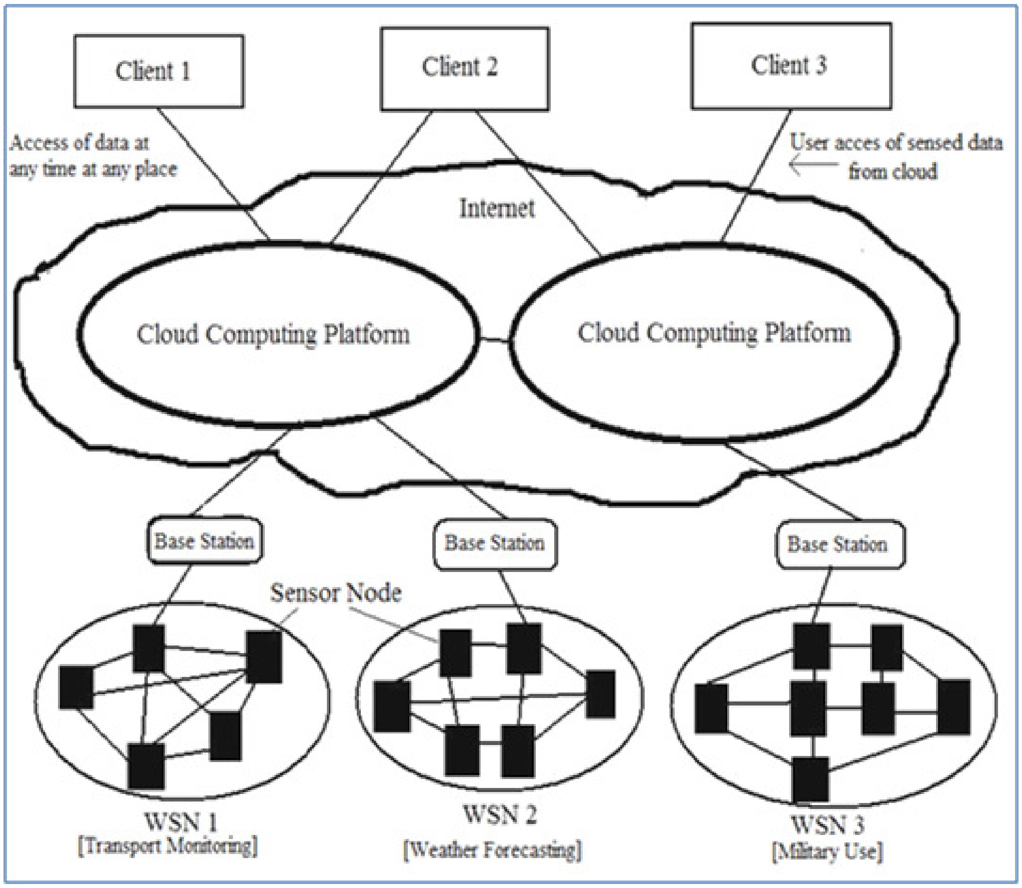

Fig. 1: WSN-Cloud Platform

Fig. 1 illustrates the clients, WSNs and the cloud infrastructure. The physical sensor nodes in the wireless sensor networks have different applications like weather forecasting, transport applications and military applications etc. The system provides services to the clients. The operating system components and the network components are maintained by the sensor node. The application that are been sensed by the application program in the sensor node are sent back from the cloud to the gateway through multi-hop or the base station through the nodes. The accommodation of the network dynamics and the network topology are managed by the routing protocol which plays a very vital role. The storage resources, ondemand service and access to these resources through internet are provided by the cloud when there is sudden requirement of resources.

2.2 Sensor-Cloud Architecture with Virtualization

Fig. 2 illustrates the sensor cloud architecture with the virtualization [15]. The virtual sensors are becoming part of the cloud that is used to virtualize the wireless sensor networks. To certain extent, the interaction between the real world WSN and the cloud is been decoupled. The data present in the virtual sensor will be running with the operations executed in the cloud as a realized fact of decoupling. Additionally it splits the security into two parts: virtual sensor vs. cloud and real sensor nodes vs. virtual sensor.

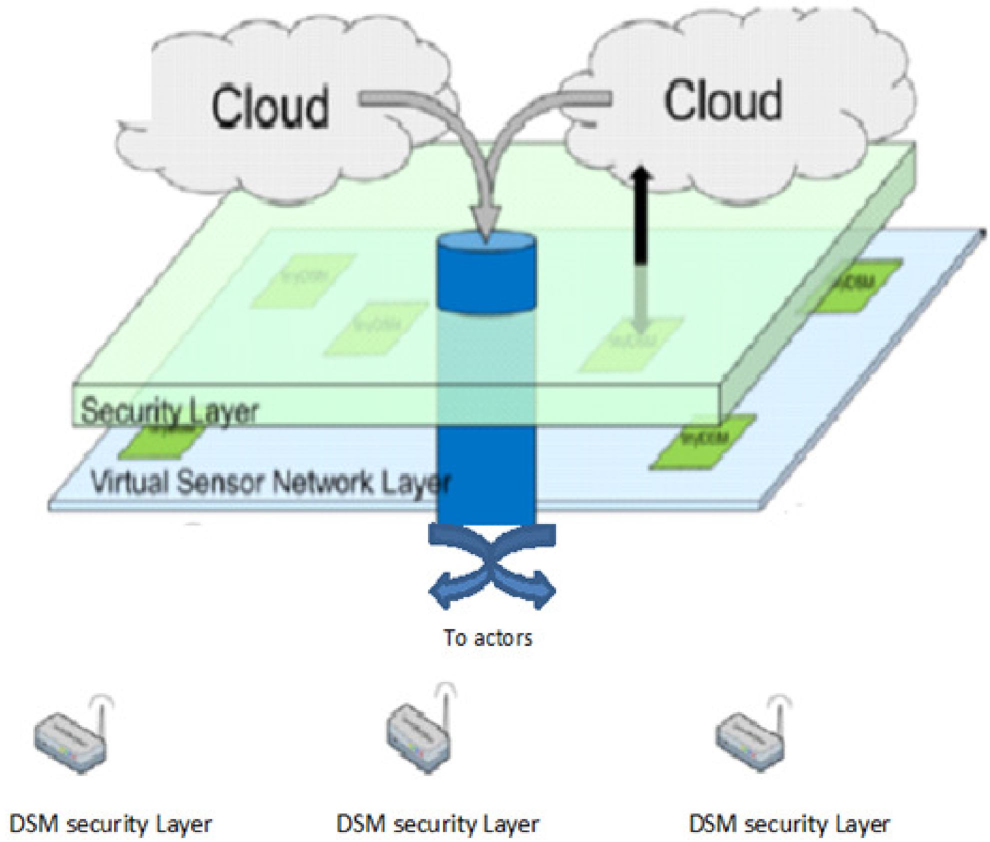

Fig.2: Sensor-Cloud Architecture with Virtualization

In the system the different abilities of different domains are considered for energy and power consumption. The access methods and user interaction are also been involved in these domains. The combination of cloud and WSNs makes the user interactions possible that makes the WSN relatively in danger. The unauthorized operation should not take place and thus WSN should be protected by providing security. The adaptable security and the energetic efficiency are necessary to allow the flexible and seamless integration of WSN in the cloud. The virtualization will be provided in emergency situations when the physical nodes need to react with the application that is running on the cloud. Here, it allows the direct communication from the application of the cloud but does not compromise security for efficiency. The direct cloud is proposed for real time sensor communication if predefined conditions are fulfilled and reflected in virtual sensor network.

3. SENSOR-CLOUD INTEGRATION

The different owners with various sensors can join Sensor-Cloud infrastructure. The physical sensors are registered and deleted by each owner. Users can create Service Template (ST) or Virtual Groups by subscribing data for particular physical sensors [27]. Users can easily add, remove or share the configurations of template as well as sensors as per the need. Fig. 3 shows the overview of the architecture of the Sensor-Cloud Integration.

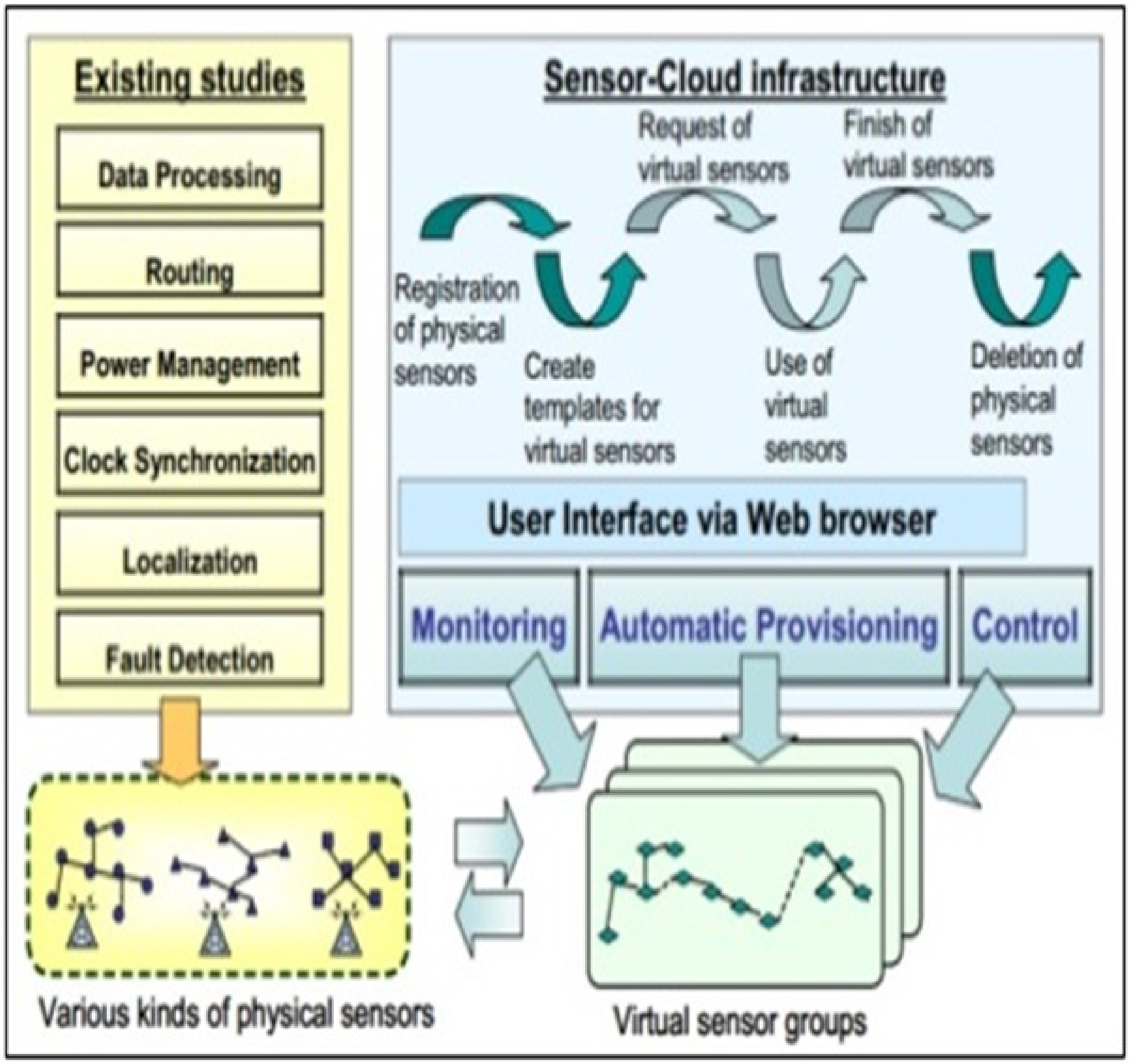

Fig. 3: Sensor-Cloud Integration

3.1 Design Considerations

In order to integrate the Sensor-cloud, several design considerations are considered as follows.

1) Virtualization: In the real scenario, there are different kinds of sensors that are scattered over the spatial area. Irrespective of locations specified to physical sensors, the virtual sensors are proposed Fig. 4 describes the relationship among physical sensors [27], virtual sensors and virtual sensor groups. One or more physical sensors can create one virtual sensor which is dependent on the user application area. One or more virtual sensors can create a virtual sensor group.

Creating the sensor groups would enable usage of the virtual sensors freely that are included in the groups as owned sensors. The virtual sensors can set the frequency to check the status by deactivating or activating the sensors through data collection. Some inconsistent commands are issued to control the multiple physical sensors that are freely used by the sensors. The user's virtual sensors are controlled by virtualizing. The physical sensors are virtualized as virtual sensors that are been controlled by the users freely [27].

2) Standardization and Automation*:* Different kinds of physical sensors have different functions in terms of sensing the environment. Each physical sensor can provide its own functions for data collection and control. Standard like Sensor Mark-up Language (SML) mechanism enables users to access and concern the physical sensors for the difference among them [27].

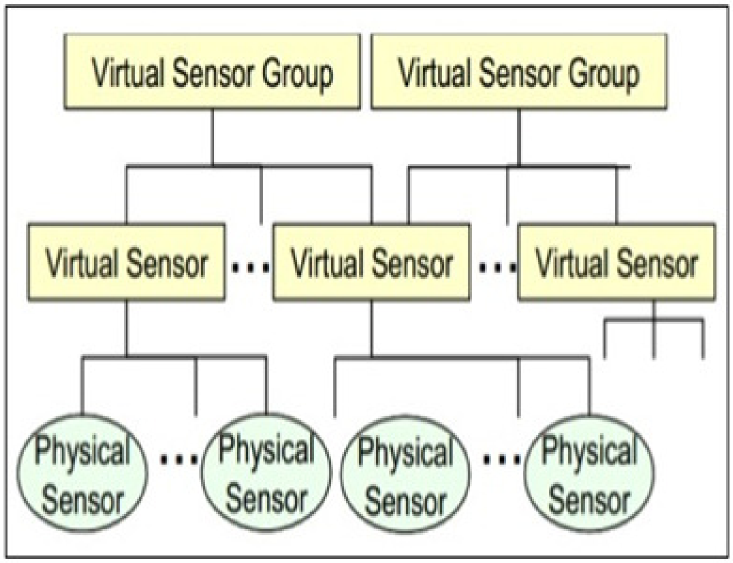

Fig. 4: Relationship among Virtual Sensors and Physical Sensors

Automation (in terms of response of data) reduces the cost and improves the service delivery time. The template of a virtual sensor or virtual sensor group are selected and templates are been created for different types of physical sensors through Sensor-Cloud infrastructure. Sensor-Cloud infrastructure supports the full lifecycle of on-demand service delivery from finishing to use virtual sensors, creating templates, registration of physical sensors, requesting of virtual sensors, starting, provisioning and deleting the physical sensors.

3) Monitoring: The virtual sensors should be checked for the availability by the application owner to monitor the status for sustaining the service quality if the application cannot use the sensor data of virtual sensors of Sensor-Cloud infrastructure [27].

4) Grouping: It is not necessary that each application should use all kinds of physical sensors. Certain constraints (location) are matched by types of sensors for each application [27]. Each virtual sensor groups and virtual sensors are controlled by the users. The virtual sensor groups are typically created by the Sensor-Cloud infrastructure through which new virtual sensors groups are selected and created by users. The data collection frequency and the access control are set for the virtual sensor group by the users.

3.2 Entities involved

Different entities are involved in the Sensor-Cloud integration.

1) Sensor owner*:* A sensor owner is a person who owns has physical sensors which are deployed over the area of interest. The rental fee reflects the usage for the physical sensors which is one of the advantages for sensor owner. Sensor-Cloud infrastructure registers the properties of physical sensors through sensor owner and deletes it when the sharing is quit [27].

2) Sensor-Cloud Administrator: Sensor-Cloud Infrastructure service is managed by the Sensor-Cloud administrator. The IT resources are managed for monitoring the virtual sensors and the user interfaces [27]. For some typical virtual sensor groups and virtual sensors, the templates are prepared by the administrator of Sensor-Cloud. The delivery service in the Sensor-Cloud infrastructure is changed by the administrator.

3) End User: An end user can be defined as an actor who uses the sensor data with one or more applications. The requirements from the templates are satisfied by the requests of virtual sensors or virtual sensor groups of an end user [27]. These templates are easily configurable, sharable and removable and easily can be created.

3.3 Components in Architecture

Sensor-Cloud architecture contains different components as follows.

1) Portal Server: The available operations are determined by the user's role who logs into the portal through a web browser. The menus for the logging out, logging in, destroying the virtual sensor groups, provisioning the user-related charges are showed by the portal server [27]. Creating, deleting and modifying the templates for virtual sensor groups would be one of the menus for Sensor-cloud administrator.

2) Provisioning Server: The portal server requests are been provisioned for the virtual sensors by the provisioning server. The predefined workflows are contained in the server along with the workflow engine. The workflows are executed in a sequence [27]. When a request is received for provisioning, the IT resource pool are checked and reserved. The existing virtual sensors are provisioned by retrieving the virtual sensor templates to a new virtual sensor. The virtual sensor groups' definitions are updated by the provisioning with the monitoring agents.

3) Virtual Sensor Group*:* The provisioning server automatically provisions the virtual sensor group on the virtual sensor. One or more virtual sensors are owned and controlled by the end user who has a virtual sensor group [27]. For example, by activating or deactivating their virtual sensors, the frequency of data collection takes place. The virtual sensors status can be checked for the status by the data collection frequency. Web browser controls the virtual sensor groups directly.

4) Monitoring Server: The agents in the virtual server send the data to the monitoring server which stores the received database of the about virtual servers. Web browser makes the monitored information available for the virtual sensors [27]. The status of the servers are been monitored by the Sensor-Cloud administrators.

3.4 Data Centric Sensor-Cloud Infrastructure Framework

A data centric Sensor-Cloud Infrastructure is proposed to make the data always available for users through the cloud. The architecture was proposed for Wireless Sensor Networks through Internet, Service Oriented Architecture (SOA) and integration of Cloud Computing [27]. The major components of the framework are Request Subscriber, data processing unit (DPU), Identity and Access Management Unit (IAMU), Publisher/Subscriber Broker and Data Repository (DR) as shown in the Fig. 5. The data gathered for WSN is processed and added to DR that is passed through gateway to DPU. Through a secure IAMU, the user is connected to access the stored data based on successful connection establishment and the access policies. If a request is made by the user it is forwarded to the RS, then a request subscription is created and forwarded to the Pub/Sub Broker. The Pub/Sub broker also receives the data that is sent from the DPU through the gateway. The data can be accessed from any location in the world. The major criticality of the sensor network is ideally they are energy efficient. In order to communicate over a long distance, short range hop communication is preferred. Towards the destination node, the information is distributed from the source over intermediate nodes.

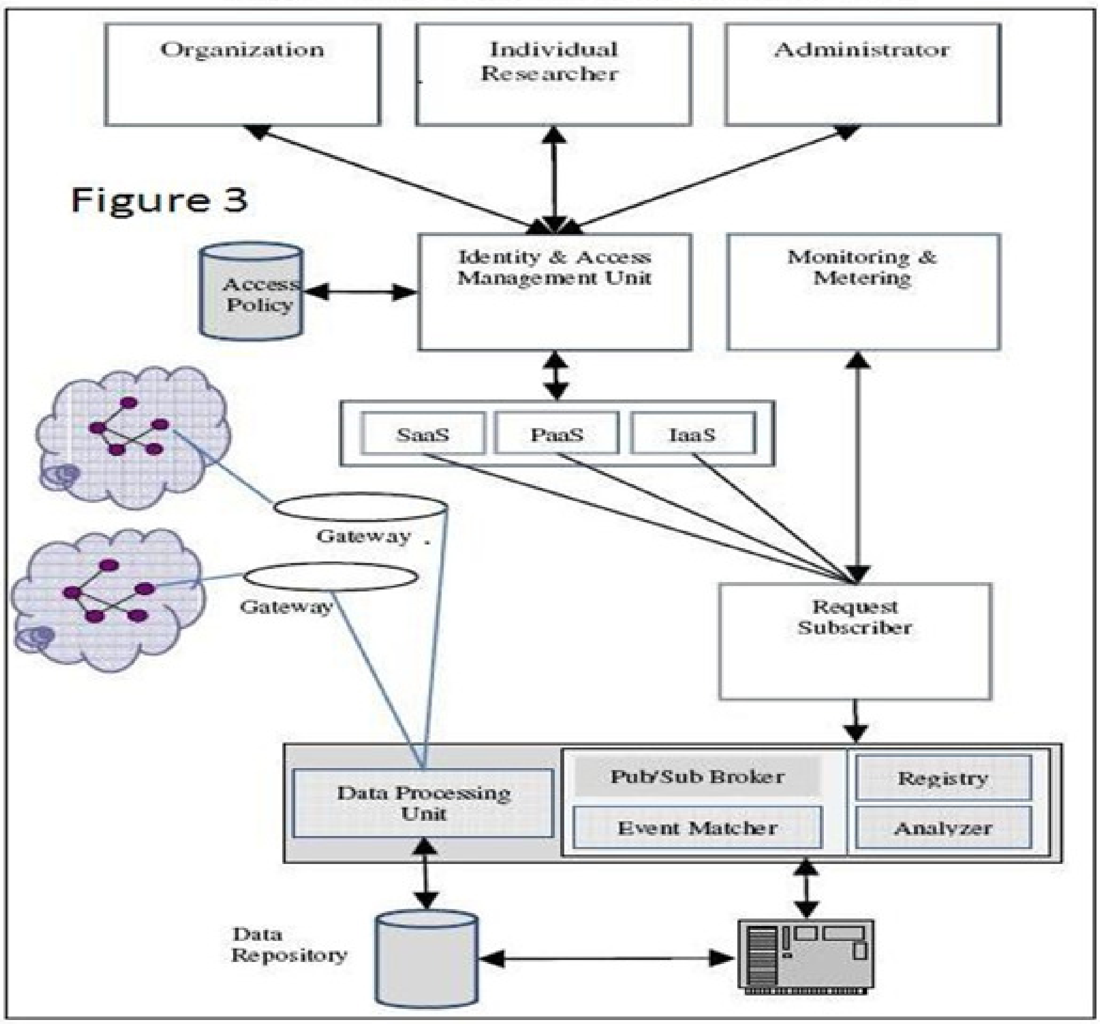

Fig. 5: Proposed Architecture of Sensor-Cloud

3.5 System Architecture

The proposed system architecture [27] is illustrated as shown in the Fig. 6.

1) **Portal:** The user interface is provided by the portal for Sensor-Cloud infrastructure.
2) **Provisioning:** The automatic provisioning of virtual sensors including virtual sensor groups are provided.

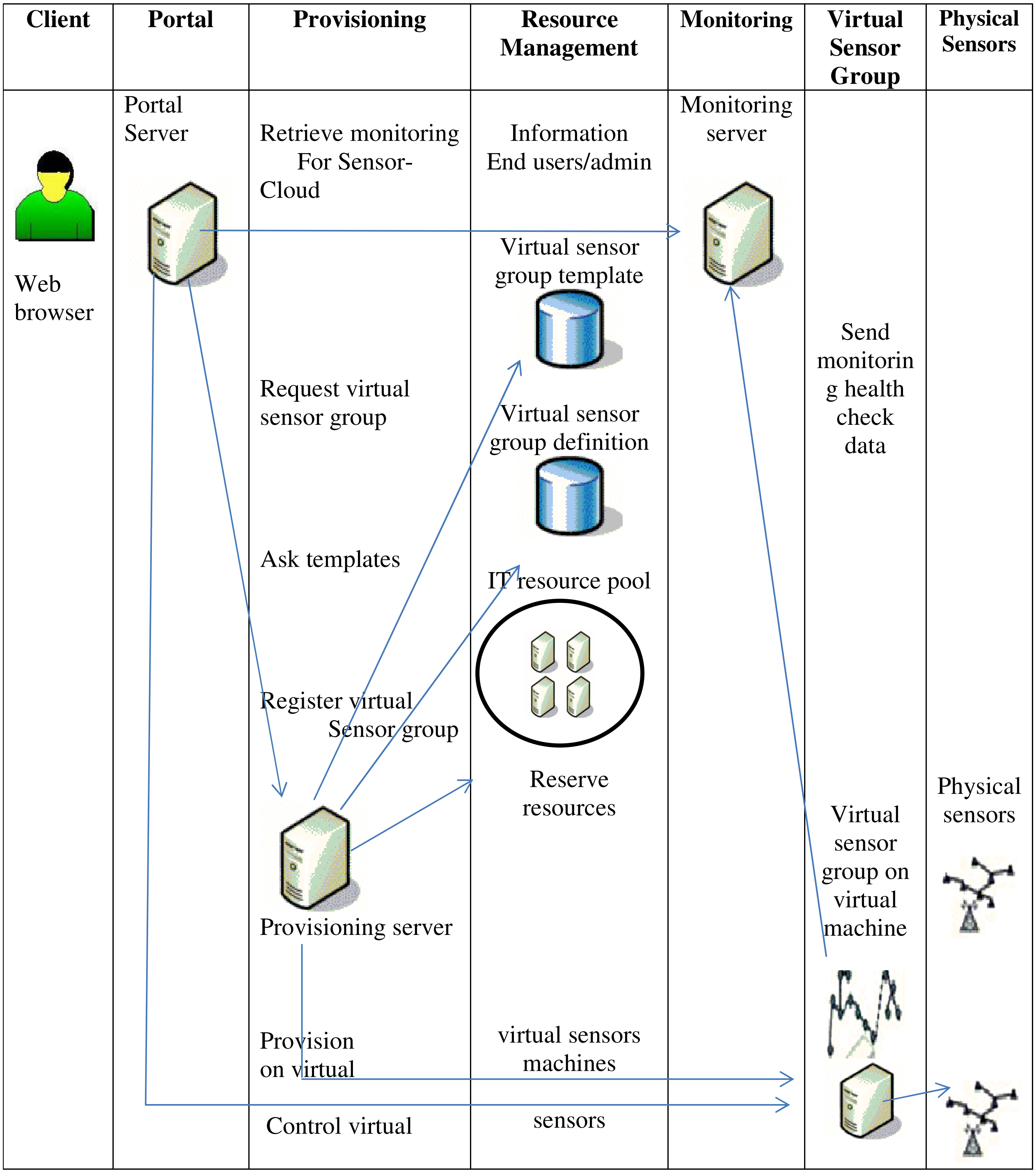

Fig. 6: Proposed System Architecture

3) **Client:** The user interfaces of Sensor-Cloud infrastructure are accessed by the users through web browser.
4) **Resource Management:** The template for provisioning the virtual sensors in the IT resources are used by the Sensor-Cloud infrastructure.
5) **Monitoring:** The monitoring mechanisms are provided by the Sensor-Cloud infrastructure.

6) **Virtual Senor Group:**Sensor-Cloud infrastructure provisions the end users with virtual sensor group.
7) **Sensors:** Sensor-Cloud infrastructures use the sensors.

3.6 Components for Message Exchange in Architecture

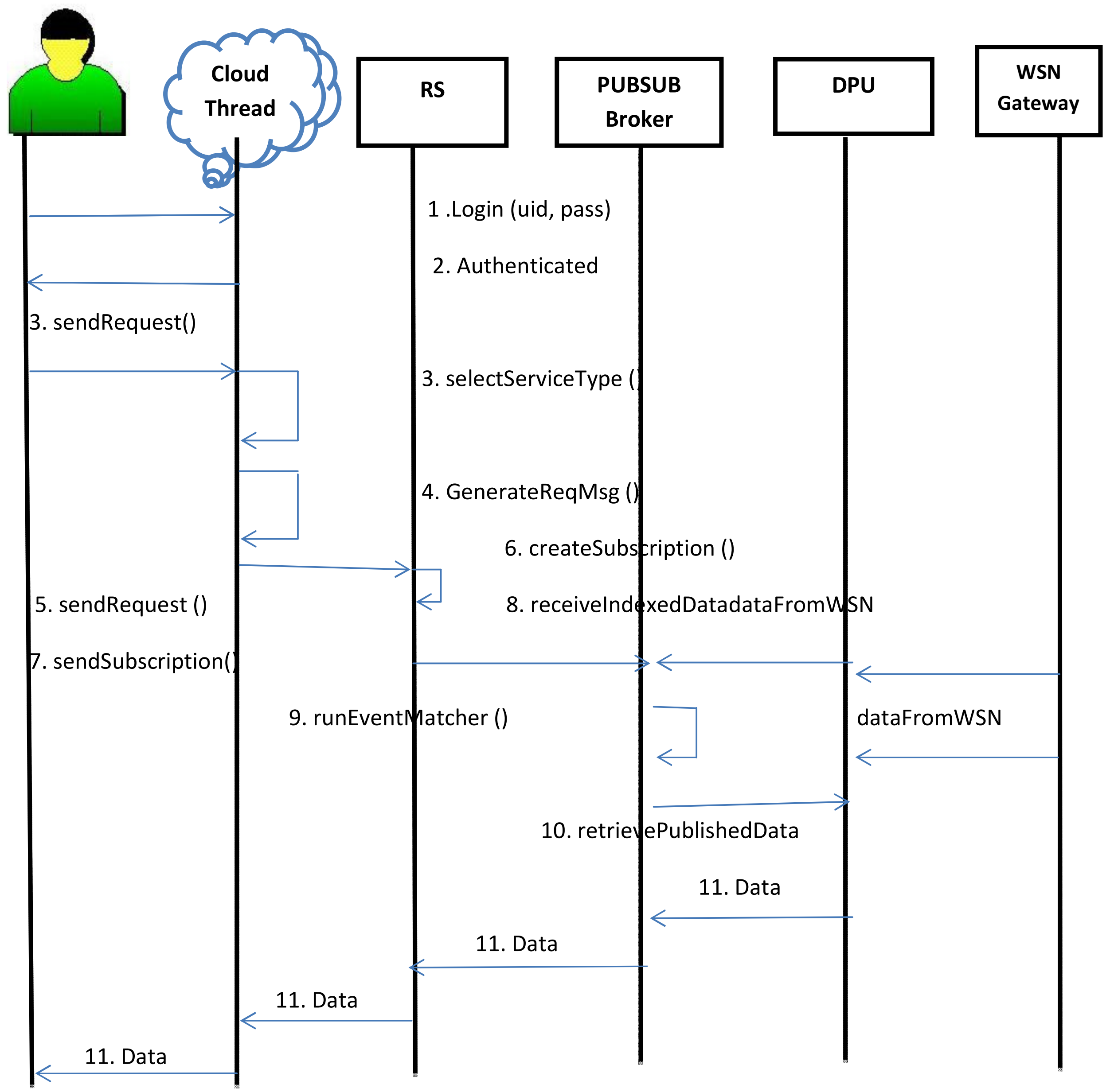

Fig. 7: Communication Flow of Proposed Architecture

1) Access Control Enforcement Unit: ACEU consists of EN to authenticate the users. The three servers are AuthenticateServer (AS), SS and Ticket Granting Server (TGS). The AS receives the request that was sent to EN.In order to authenticate the users with AS, Kerberos are implemented by EN [28].

2) Access Control Decision Unit (ACDU):ACDU is defined as a unit used to enforce the policy rules. It consists of policy storage and RBAC processor. The SS is used to communicate with AECU. To access to the resources, the user will receive the constrained access policies after successful authentication.

3) Communication flow between User and IAMU*:* Fig. 7 shows the overall communication in the system.

3.7 Service Oriented Sensor-Cloud Infrastructure Framework

The cloud services focuses on the availability of service for end users. In Sensor-Cloud infrastructure, most frameworks are supported by proposed system models by creating service instances immediately when request is made as in Fig. 8.

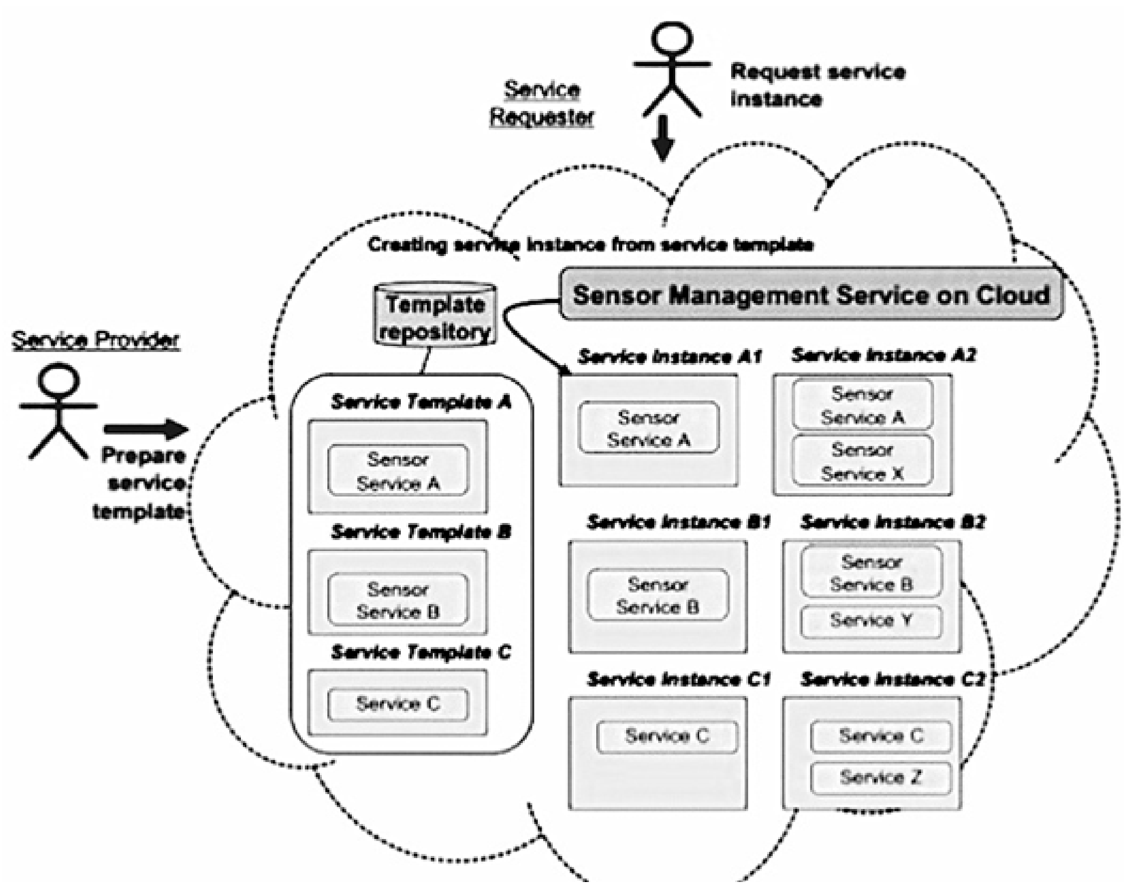

Fig. 8: Service Model

Before cloud computing service, different configurations are provided by each service providers based on the requester's requirements. The service template is prepared by service providers as service catalog. The request is made by the service requesters from the predefined service catalog based on the service template menu. Necessary service instance can be used by the service requesters to add new service for extending resources.

Existing sensor services use sensors directly on sensor services. The sensor details like configuration, location and specification are known to sensor services. The hiding of code complexity is done by optimizing the service provider and thus the ultimate results are used as service template.

3.8 Service Lifecycle

The service lifecycle has two major phases as described in the Fig. 9.

3.8.1 Service Catalog Definition Phase

The service instances are created by service providers with different configurations for requester's requirements. Service templates are created by service providers as service catalog. The menus that describe service specifications are included in the service catalog.

Linux (OS), traffic analysis service (service), the sensors in the Tokyo (grouped sensors) and software (middleware) are described in the menus. The service templates are defined as the catalog menus by the service providers [27]. The service catalog that is defined by the service templates will duplicate the specification's service instances for various users by creating service instances.

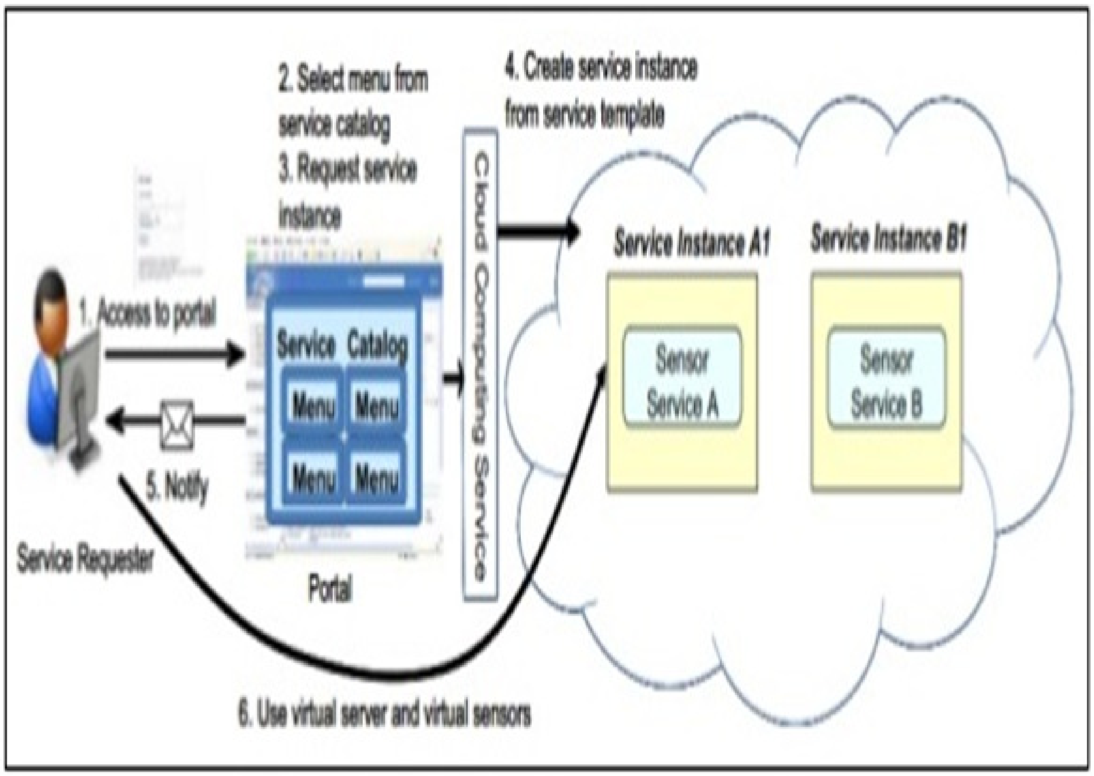

Fig. 9: Service Lifecycle

3.8.2 Service Providing Phase

The prepared service catalog would allow the service requesters to select the service menu for these requirements by requesting service instances. The service instances can be accesses by other users after registration. The cloud computing service would enable the service requesters to receive the notification for accessing their service instances freely. The sensor service provider would enable us to start new service through service instances .The service instances are released by the service requesters from the portal when they become unnecessary. The report will be checked and they will be paid for the usages. The number of request made for each menu will be known to the service providers as the menu will be selected from the service catalog. The unpopular menus are modified and removed by service providers after analysing the requests. The upgrading of popular menus would enable to add new menus.

4. APPLICATIONS OF SENSOR-CLOUD

There are many existing and emerging applications of Sensor-Cloud as follows.

4.1 Existing Applications of Sensor-Cloud

Based on the Sensor-Cloud infrastructure, there are many existing applications as follows.

4.1.1 Pachube Platform: It allows the data to be connected to the sensor and is the first online database service providers [16], [24]. It configures IoT products and services which is a scalable infrastructure and real-time cloud based platform. It is an open easily accessible API for managing the sensor data.

4.1.2 IDigi: It minimizes the barriers which is a machine-machine platform as a service that is cost effective solutions. It manages stores and connects the remote assets devices easily. It provides communication among enterprise applications and remote device assets [16], [26].

4.1.3 Thing Speak: It is an open API to retrieve and store data over the Internet [16], [25]. The sensor logging applications and location tracking applications are created using this platform. It overcomes the heterogeneous data access related access.

4.2 Emerging applications of Sensor-Cloud

Based on the Sensor-Cloud infrastructure, there are many emerging applications as follows.

4.2.1 Google Health: It serves as cloud health data storages that provides health information and acts as a centralization service to Google [16], [17]. The health records can be monitored by logging into their accounts. The Google health system collaborates with the cloud service providers to monitor the records.

4.2.2 Earth Observation: To gather data from several GPS stations, a sensor grid is developed to process, analyse, manage and visualize the GPS data [16], [18]. The efficient monitoring decision-making capability for situations like volcanic eruptions, earthquakes, tsunamis, cyclones,, early warning are done by uploading the GPS data onto the cloud.

4.2.3 Telematics: The computerized information to a system continuum can be deployed for transmission over long distance in Sensor-Cloud by using telematics. The smooth connection between system and services without any intervention are enabled [16], [19].

4.2.4 Wildlife Monitoring: Sensor-Cloud can also be used in forests, for tracking the wildlife sanctuaries [16] and so forth in real-time the endangered species are monitored regularly.

4.2.5 Tunnel Monitoring: Inside the tunnel bridges, the sensing light levels are distributed and implemented using WSN for adapting light functionality with necessary input information. The tunnel information adds the data to the cloud and in real time it can monitor the light intensity. It saves the energy spent for lightening the day and avoids the automobile user's casualty [16], [20].

4.2.6 Ubiquitous Healthcare Monitoring: Most often wearable sensors like accelerometer sensors, ambient light and temperature sensors can be used for health monitoring in Sensor-Clouds. The patients' health related data like blood sugar, tracking sleep activity pattern and body temperature can be collected. The Bluetooth's wireless interface (BWI), ultra wideband (UWB) should be supported by wearable sensor devices and they are connected wirelessly to any smartphone through an interface for streaming data [16], [21].

4.2.7 Agriculture and Irrigation Control: In the field of agriculture, Sensor-Cloud is used to monitor the crop fields and for the use of harvesting. A field server is developed that compromises of an air sensor, camera sensors, soil moisture, temperature sensor and so forth. The field data are uploaded using sensors to track the health of their crops to the field owner through Wi-Fi access point [16], [22].

4.2.8 Transportation and Vehicular Traffic Applications: To provide an efficient, sustainable, equilibrium and stable tracking system, Sensor-cloud can be used. Early existing technologies like GPS navigation can only track the current location and status of vehicle [16], [23]. On the other hand, the cloud computing is used to implement the vehicle monitoring and incorporate centralized web service.

Few centralized server stores the data that would reside in the cloud. The accessing of these data on cloud will be done by the vehicle owner via portal to visualize the vehicle information and can retrieve all data on the cloud in real time.

5. ISSUES AND CHALLENGES OF SENSOR-CLOUD INFRASTRUCTURE

Sensor-Cloud infrastructure would deal with different issues and challenges as follows.

5.1 Authorization Issues: A web-based interface to authenticate the different types of users through different authorization roles in the health related results like care-givers, patients, helpers, doctors remotely [16]. The care givers will be restricted from reaching the patients by providing the privacy to some extent that will be taken care.

5.2 Power Issues: The continuous transmission and processing of data in the smart phone would lead to the major issue that is the power issue that drain out the mobile battery [16]. The Sensor-Cloud infrastructure would find difficult in connecting mobile phone gateway and thus it is the problem in tackling the power issues.

5.3 Collective Intelligence Harvesting: The big challenge is the massively collocated information from the cloud that enables us to maximize the intelligence development. The decision level fusion mechanism and the appropriate data are used by enhancing the decision-making capability [16] of the heterogeneous real-time sensor data.

5.4 Network Access Management: In order to improve the link performance, Sensor-Cloud infrastructure deals with various numbers of networks [16]. To optimize the bandwidth for these networks, a proper access management is used to provide efficiency.

5.5 Energy Efficiency Issues: The wireless sensor networks and the cloud computing would handle the same basic disadvantage and the processing capacity of nodes would enable the energy efficiency for a limited storage. Due to continuous monitoring of data for a longer duration, Sensor-Cloud infrastructure would tackle the situation by using the middleware [16]. The middleware should have the Sensor nodes to collect the huge sensor data from it. To avoid the load transmission, it compresses the sensor data and sends it to the middleware that is acting as a gateway on the cloud side which is then decompressed and stored.

5.6 Bandwidth Limitation: In the Sensor-Cloud infrastructure, due to increase in the cloud users the number of sensor devices, the current big challenge to be handled is the bandwidth limitation [16]. The cloud users with huge device assets are contained in the gigantic infrastructure to manage the bandwidth allocation with many methods proposed. Thus, it is very difficult to allocate bandwidth for every users and devices.

5.7 Pricing Issues: The service management, customer's management and different methods would involve the sensor-service provider and the cloud service provider. The main issues are how different entities should distribute the price, how to make the payment and how the price should be set? [16] Due to cost deployment, the heterogeneous network drops to connect and therefore monitoring and controlling the environment applications that result in the growth for large number of devices.

5.8 Maintenance Issues: The service failure should be coped by the cloud for the user's loyalty. To ensure the continuous and smooth flow of services, the implementation of redundancy techniques is required for the regular maintenance [16]. The multiple data centres are been distributed geographically by backing up the data regularly across the world.

5.9 Resource and Hardware Compatibility: In the cloud computing environment, the hardware compatibility and software compatibility can be solved by sharing the services of hardware and software resources [16]. Due to weather condition or some calamity, resources may be lost. In order to handle this issue, a single logical view is used by the users/clients to view the data that is distributed across remote sensors and several sensor proxies through the architectures.

5.10 Interface Standardization Issues: The Sensor-Cloud users and the cloud are provided the interfaces by using the Web interfaces. As the web interfaces are not designed for smart phones, it may cause overhead. In the case of signalling and interacting between Sensor-Cloud users and the cloud, the compatibility would be the issue for the implementation at seamless services [16]. Thus, for the accessing of the services with the cloud, the big issue would also be the interoperability.

5.11 Security and Privacy Support Issues: Due to authorized transactions, the integrity of the data is ensured through fewer standards. The data at the cloud centres should be known to the consumers so that it is well encrypted [16]. Sometimes supervision of the information that is present in the cloud is not done properly and thus the private health data become public due to inaccuracy.

5.12 Storage Issues: Transferring data from phone to server and storage of data at server side are one of the engineering issues. Reconstruction of data will be assisted on the server side by using timestamps [16] with each data packet to tackle this problem. At the remote sensors of Sensor-Cloud infrastructure, the physical environment of the correlated behaviour is easily fit for the concept of storage with architecture.

6. CONCLUSION

Typically, sensor networks have limited bandwidth, small size batteries and memories which lead to a challenging task to communicate using internet. There is a way to overcome the limitation by using Cloud computing architecture. Therefore, the integration of Cloud computing and wireless sensor network leads to Sensor-Cloud. Sensor-Cloud infrastructure is open, scalable and interoperable and eases of use. In this paper, we surveyed on the different architectures and the applications of Sensor-Cloud. Sensor-Cloud has different issues that are been discussed in this paper that lead to complex situations of the real world. Thus, the ability of the cloud computing and the sensor network leads to the success of the Sensor-Cloud approach to ensure the compatibility in the technology.

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