Review on Sensor Cloud and its Integration with Arduino based Sensor Network

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Abstract — **The expansion of embedded ICT infrastructure has resulted in the deployment of a wide range of embedded systems in our environment which indicate the need for reusable, manageable and flexible Wireless Sensor Network. Integration of WSN infrastructure with Cloud simplifies the system operation and maintenance as well as the cost and capable of providing services to multiple end users. The integration offers benefits whereby common processing, computational and analytical tasks can be hosted on cloud service and freeing the devices from running heavy applications, hence reducing power consumption and maximizing the lifetime of power units as well as the network itself. The sensor clouds are therefore gaining popularity for providing an open, flexible and a reconfigurable platform for many monitoring and controlling applications. This paper looks at the benefits and basic features of Senor Cloud Services and how Ethernet enabled Arduino microcontroller based sensor network can be integrated to send sensor data to them by looking at three popular cloud services.**

Keywords— **Internet of Things, Cloud services, Cloud computing, Sensor Cloud, Sensor Network.**

I. INTRODUCTION

The Internet of Things (IOT) [1] technology connects physical world objects to the internet and giving flexibility to monitor and manage these objects *or things* [2]. The term objects or things in this context are referred to as devices which sense the environment around us. The applications of IOT are vast including intelligent transportation, environment protection, government work, public security, smart home, intelligent fire control, industrial monitoring, elderly care, and personal health and so on. This sensing entity brings new perspective to the way in which we interact with the environment around us [3].

The spatially distributed autonomous sensors which monitor the physical or environmental conditions make up the sensor network [4]. A SN may be composed of thousands of small smart devices with computational capability and memory, having one or more sensors and a limited power supply. IOT has been inspired by consistent progress in emerging sensor technologies such as wireless sensor networks which allows wide and cheap deployment of sensors on a large scale [5].

The internet has currently more than 1 billion users worldwide, hence it makes sense to provide WSN service to this thriving community [6]. The internet of computers has become the internet of things, a global network that not only connects computers, but all kinds of processor-enabled machines/devices, such as mobile phones, domestic appliances and WSNs. In the year 2012, the number of internet connected devices reached 9 billion which included the traditional computer devices, mobile devices, and also the new industrial and consumer devices that are regarded as things [7]. The upcoming Internet of Things will comprise of proactive actors of everyday objects that surround us, generating and consuming information [8].

The integration of SN to the internet requires high performance computing and storage infrastructure for real-time processing and storage of data from SN as well as the analysis of processed information to extract events of interest [9]. For this matter, cloud computing is growing to be a promising technology to provide flexible computing, storage and software services in a scalable and virtualized manner [10]. Cloud Computing can be defined as the next stage in the internet's evolution, providing the means through which everything – from computing power to computing infrastructure, applications, business processes to personal collaboration – can be delivered to you as a service wherever and whenever you need [11]. Cloud computing presents various services like storage, software, data access, and computation that does not require physical location and system configuration knowledge to users regarding the system which delivers the services [4].

Sensor Cloud infrastructure [12] is a secondary form of cloud computing proposed by several IT people in present times. Sensor-Cloud is a new structure which can manage physical sensors on IT infrastructure [12]. By the commencing of sensor-cloud, several obscurities such as storage capacity of data collected by sensor nodes and the processing of these data have become unsophisticated. Many real life applications such as environmental monitoring, structural monitoring, disaster monitoring, telemetry, agriculture, healthcare, etc. can be assimilated to the sensor - cloud.

The primary objective of this work is to overview features and benefits of Cloud-based applications that offer dedicated services for managing sensor data online and how SN(s) based on Arduino platform can be integrated to some of these services to upload data. The next section elaborates the beneficial features of integrating SN with Cloud. Section 3 expounds the architectures involved in the integration; Section

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4 presents the three open cloud services and its integration layout with Arduino for data upload and finally section 5 concludes the paper.

II. BENEFITS OF INTEGRATING SENSOR NETWORK TO CLOUD

The connection of SN to the global internet allows remote access to the sensor network through the availability of its processing and storage capability on demand [13]. Cloud computing service framework offer services of shared network from which the users meticulously benefit from and are not required to be concerned with the implementation details of the services offered. The three distinct characteristics of cloud service which separate it from traditional application and service hosting is that it is provided on demand; it is 'elastic' where user can have as much or as little of a service at any given time and finally the service is fully managed by the service provider.

Several important features and benefits of cloud computing is highlighted below:

- *Negligible initial cost for hosting service:* The setup of entire hardware infrastructure (such as servers, network routers, firewalls, etc.) is not required by user on cloud computing for hosting online application and storage of sensor data.
- *Reduced administration costs:* Spending of time or money on administrative tasks in software and hardware systems such as maintaining of resources and services, assuring of non-failures, taking care of backups, etc. on sensor cloud is not required.
- *Analysis:* The integration of vast amounts of sensor data from sensor networks, cloud computing has potential to perform various kinds of analysis required by the users through the provision of scalable processing power.
- *Visualization:* The sensor data stored and data retrieved from several devices can be represented in various types of visualizations through the APIs of sensor clouds which aid the users for better monitoring of concerned environment and understanding of data flowing from the devices and sensor networks.
- *Collaboration:* Sensor-Clouds allow huge sensor data to be shared by different groups of consumers through association of diverse sensor networks.
- *Dynamic provisioning:* Sensor Cloud users can access information, data and control connected devices from anywhere by being connected to the cloud.
- *Multi-tenancy:* Services from different service providers can be integrated which meet the demands of users, providing flexibility with data and utilization of other resources which make the dealing with sensor data more efficient.

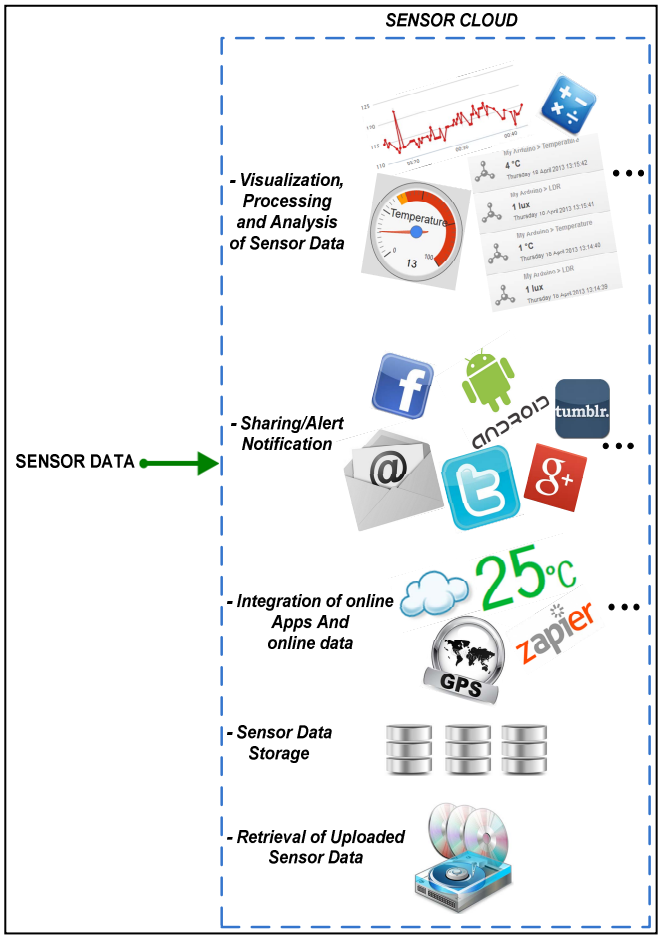

Fig. 1. Features of Sensor Cloud.

As described, there are many advantages of integrating SN with cloud. This enhances the expansion of technology and provides opportunities for exploration of other applications of sensor network.

III. SYSTEM ARCHITECTURE

When looking at the overall architectures and the types of services provided by cloud service providers, there are three major types [14]. Infrastructure as a service (IaaS) is a service where service providers take care of all essential hardware components including servers, network equipments, storage and backup and the users only have to gaze upon the computing service which is building and managing their own application software and platform. Platform as a service (PaaS) is where hardware and platform (i.e. Operating system) as well is provided by service providers and the users need only to be concerned with the development and deployment of their application. The third type is Software as a service (SaaS). In this particular type of service, service providers utilize their own infrastructure and platform to provide specific applications to the users.

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The Sensor-Cloud is a SaaS [15] architecture service looked forward to by students, researchers, professionals of SN for sensor data upload to the cloud. There are sensor cloud services that offer direct connection of devices to cloud as well as those that require modules and specific modem connections through which the devices and sensor networks can be linked to the cloud services.

As the integration of SN and cloud is thriving, more and more devices and networks will become connected to the internet. The routing protocol for the largest network in the world, internet, is the Internet Protocol (IP). The IP protocol served well for decades in its version 4 specifications (IPV4) that it is commonly referred as IP. Now with the introduction of version 6, addressing space has grown to a number close to 2^{128} addresses thus capable of provisioning $667x10^{23}$ addresses per square meter of earth surface [6]. With this protocol, the next generation of networks will emerge where more heterogeneity is expected on the internet. IPV6 version of internet protocol will therefore allow more devices to be connected to the internet. With this upgrade, every little object can be linked to cloud and contributing to expansion of sensor networks.

With ubiquitous SNs, a standard interface for discovering SN services and accessing SN data is essential [16]. The generic interface is provided by an Application Programming Interface (API) for wireless sensor networks (WSN API). WSN API eradicates the complexities of WSN communication protocols and architectures and offers easy to use and well defined approach to collect data from sensors. WSN API is not limited to any particular system but can be accessed from any platform, operating system and using any network technology. Hence in WSN's, Internal and External applications exist.

The Gateway API presents WSN to the user as a set of sensor applications and each sensor application provides a service to the user. The service can be temperature measurement service, humidity measurement service, etc. Hence all the service of WSN is accessed through Gateway API. The Node API which is implemented in WSN nodes receives the data packets from the WSN protocols and directs it to the respective sensor application. The Node API is also used by sensor applications to send packets to the network.

IV. INTEGRATION LAYOUT OF ARDUINO AND CLOUD SERVICES

This section looks at three common cloud-based services; ThingSpeak, Nimbits and Open.Sen.se and its integration layout with Arduino. Ethernet Shield for Arduino was used to enable internet connectivity for the microcontroller in this paper. The Arduino microcontroller can act as a sensor node or a Gateway node/sink for sensor network since same integration layout to the sensor cloud would be adopted.

A. ThingSpeak

ThingSpeak is an open application platform which is designed to enable meaningful connections between things and people. It allows integration of numerous devices and apps which can upload data to the web. It has real-time data collection, processing and data visualization. ThingSpeak has Write API Key to update channel.

Fig. 2(c) shows the data upload layout from Arduino to ThingSpeak Sensor Cloud. The Arduino IDE (sketch) needs to have its local Network setup in order to connect to the internet. An important Library that any Arduino sketch must have that is using Ethernet Shield in order to setup local network is the Ethernet Library. To connect to ThingSpeak service, the IDE must have the server address of the cloud service together with the Write API Key of the channel to modify and the field(s) in the channel to update. The Arduino sketch executes by attaining sensor data, checking/establishing connection using local network setting and defined cloud service information and uploading data to the cataloged channel field(s).

B. Nimbits

Nimbits is an open source platform where sensor data can be logged and shared on private and public clouds. The Nimbits GUI is like a tree structure having parent and child structure. The contents of the GUI can be organized according to the user since there can be depths of parent-child structure and as more stuff is added, it can be dragged and dropped around the tree as desired.

Fig. 2(a) shows the data upload layout from Arduino to Nimbits Sensor Cloud. The Arduino IDE includes name of the Nimbits server, Gmail address of the user (Nimbits account is created through google account), Nimbits Account Key and the datapoint(s) to be updated. The Arduino sketch executes by attaining sensor data, checking/establishing connection using local network setting, Service Server name, google account address, Nimbits Account Key and finally updates the defined Datapoint(s).

C. Open.Sen.se

Open.Sen.se is a web service with bright and colorful GUI, is Real-time and offers lots of flexibility with the way data is displayed. Sen.se believes that in an internet of everything where humans, nature, machines, objects, environments, information, physical and virtual spaces are all mix up, talk, intertwine, interact, enrich and empower each other in all sorts of ways.

Fig. 2(b) shows the data upload layout from Arduino to Open.Sen.se Sensor Cloud. To get Arduino device to talk to Open.Sen.se cloud service, it needs to be registered to it. The feeds are then added under the registered device where uploaded data are captured. The Arduino sketch includes the Library for Open.Sen.se service to assist the connection. Furthermore, the Arduino Device ID and Feed ID(s) must be defined as the destination of the data. When the IDE is executed, it utilizes Sensuino Library to establish connection. The feed(s) in the cloud service is modified according to the defined Feed(s) and Device in the IDE.

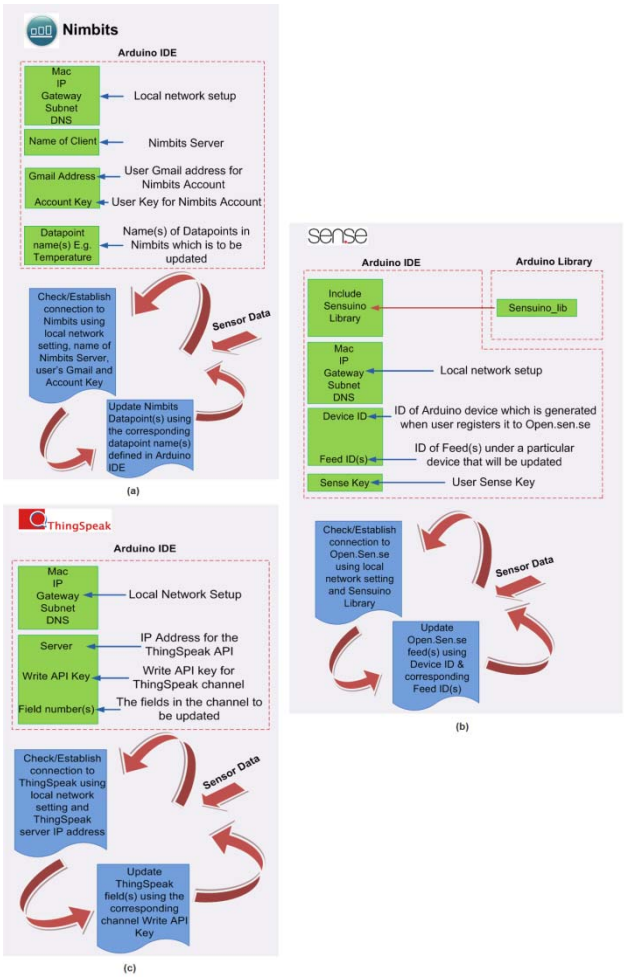

Fig. 2. Data upload layout of Arduino to Sensor Clouds (a) Nimbits (b) Open.Sen.se and (c) ThingSpeak.

V. CONCLUSION

This paper has looked at various advantages, benefits and features of Sensor Cloud services. Furthermore, Arduino based sensor network integration layout to few of these cloud services have been studied. The Sensor Network integration to these cloud services enables an open, extensible, scalable, interoperable and easy to manage sensor network that are used for numerous applications. Sensor cloud architecture enables processing and storing of the sensor data in such a way to be cost effective, easily accessible and timely available. With SN and cloud architecture, not only are the benefits of handling and processing of sensor data achievable but also the integration of other online services and Apps with sensor cloud for further analysis, processing and data sharing can take place.

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