A Survey on Sensor Cloud: Architecture and Applications

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Abstract

Cloud Computing is a part of computer science and it enables providing Internet services to external customers via very scalable computing capacities. It is abstracted, high-scalable and controlled computer infrastructure which hosts applications for end-users. Data and services are located in shared, dynamic and scalable set of resources based on technologies of virtualization and scalable application environments. Wireless Sensor Networks can be used for collecting these data because they present distributed systems which consists of different sensor nodes. Sensors are spatially distributed and they are used for measuring different values, such as temperature, humidity, sound levels, pressure, environment variables etc.Many researchers have cited different types of technology in this context. But the application scenario are of important consideration while designing a specific protocol for Sensor network with reference to Cloud Computing. In this paper, we surveyed some typical applications of Sensor Network using Cloud computing as backbone. Since Cloud computing provides plenty of application, platforms and infrastructure over the Internet; it may combined with Sensor network in the application areas such as environmental monitoring, weather forecasting, transportation business, healthcare, military application etc. Bringing various WSNs deployed for different applications under one roof and looking it as a single virtual WSN entity through cloud computing infrastructure is novel.

Keywords:Wireless sensor networks, Cloud, computing

1. Introduction

Today, the boundaries between the physical world and the digital world continue to blur due to advances in the areas of ubiquitous computing and wireless sensor networks. The communication among sensor nodes using Internet is often a challenging issue. It makes a lot of sense to integrate sensor networks with Internet .At the same time the data of sensor network should be available at any time, at any place. It is possibly a difficult issue to assign address to the sensor nodes of large numbers; so sensor node may not establish connection with internet exclusively.

Cloud computing strategy can help business organizations to conduct their core business activities with less hassle and greater efficiency. Companies can maximize the use of their existing hardware to plan for and serve specific peaks in usage. Thousands of virtual machines and applications can be managed more easily using a cloud-like environment. Businesses can also save on power costs as they reduce the number of servers required. Fig.1 consists of WSN, cloud infrastructure and the clients. Clients seek services from the system. WSN consists of physical wireless sensor nodes to sense different applications like Transport Monitoring, Weather Forecasting, and Military Application etc. Each sensor node is programmed with the required application. Sensor node also consists of operating system components and network management components. On each sensor node, application program senses the application and sends back to gateway in the cloud directly through base station or in multi-hop through other nodes. Routing protocol plays a vital role in managing the network topology and to accommodate the network dynamics.

Cloud provides on-demand service and storage resources to the clients. It provides access to these resources through internet and comes in handy when there is a sudden requirement of resources.

This paper contains as follows. In Section 2 & Section 3 we have presented an overview of Clouds and Sensor Network. In section 4 we have discussed various application scenarios of Sensor Network using Cloud Computing. Lastly, Section 5 concludes our work.

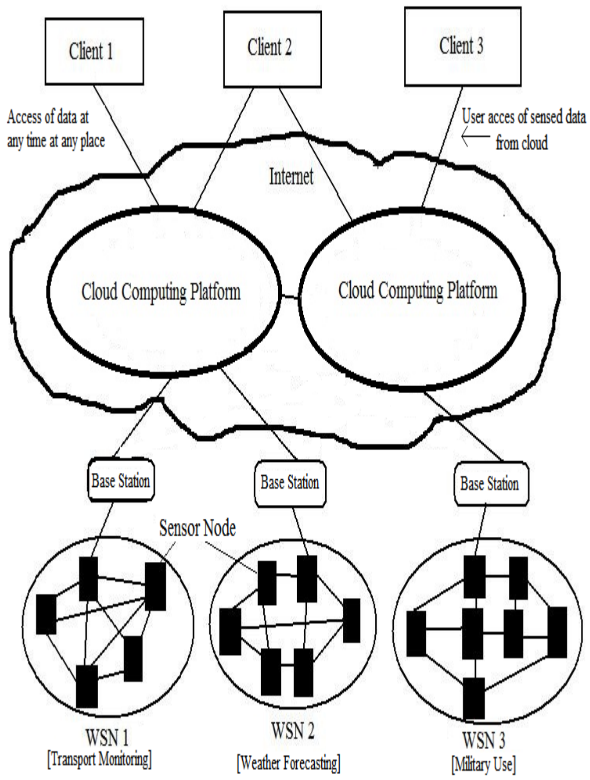

Fig. 1 WSN- Cloud Computing Platform

2. CLOUD: OVERVIEW

Cloud computing is a term used to describe both a platform and type of application. A cloud computing platform dynamically provisions, configures, reconfigures servers as needed. Servers in the cloud can be physical machines or virtual machines. It is an alternative to having local servers handle applications. The end users of a cloud computing network usually have no idea where the servers are physically located—they just spin up their application and start working. Advanced clouds typically include other computing resources such as storage area networks (SANs), network equipment, firewall and other security devices. Cloud computing also describes applications that are extended to be accessible through the Internet. These cloud applications use large data centers and powerful servers that host Web applications and Web services. Anyone with a suitable Internet connection and a standard browser can access a cloud application. Many formal definitions have been proposed in both academia and industry, the one provided by U.S. NIST (National Institute of Standards and Technology) [2] appears to include key common elements widely used in the Cloud Computing community: 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 .

A. Features

The following are the essential features of cloud computing:

1) Service on demand: The request of the clients to avail resources can be fulfilled automatically without human interaction.

2) Elasticity of demand: There is no formal agreement or contract on the time period for using the resources. Clients can use the resources whenever they want and can release when they finish.

3) Abstraction: Resources are hidden to clients. Clients can only use the resources without having knowledge regarding location of the resource from where data will be retrieved and where data will be stored.

4) Network access: The client application can perform in various platform with the help of mobile phone, laptop and PDA using a secure internet connection.

5) Service measurement: Although computing resources are pooled and shared by multiple clients (i.e. Multi-tenancy), the Cloud infrastructure can measure the usage of resources for each individual consumer through its metering capabilities.

6) Resource pooling: The resources are dynamically assigned as per clients' demand from a pool of resources.

B. Services

The cloud provides following three services:

1) SaaS(Software as a Service): This model provides services to clients on demand basis. A single instance of the service runs on the cloud can serve multiple end user. No investment is required on the client side for servers and software licenses. Google is one of the service providers of SaaS.

2) PaaS(Platform as a Service): This model provides software or development environment, which is encapsulated & offered as a service and other higher level applications can work upon it. The client has the freedom to create his own applications, which run on the provider's infrastructure. PaaS providers offer a predefined combination of OS and application servers. Google's App Engine is a popular PaaS example.

3) IaaS(Infrastructure as a Service): This model provides basic storage and computing capabilities as standardized services over the network. Servers, storage systems, networking equipment, data centre space etc. are pooled and made available to handle workloads. The customer would typically deploy his own software on the infrastructure. The common example of IaaS is Amazon.

3. Sensor Network: Overview

A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance. They are now used in many industrial and civilian application areas, including industrial process monitoring and control, machine health monitoring , environment and habitat monitoring, healthcare applications, home automation, and traffic control. Each node in a sensor network is typically equipped with a radio transceiver or other wireless communications device, a small microcontroller, and an energy source, usually a battery.

The size of sensor node may vary from shoebox down to a grain of dust. The cost of sensor nodes is also varies from hundreds of dollars to a few pennies, depending on the size of the sensor network and the complexity required of individual sensor nodes . Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and bandwidth . A sensor network is a computer network Composed of a large number of sensor nodes. The sensor nodes are densely deployed inside the phenomenon, they deploy random and have cooperative capabilities. Usually these devices are small and inexpensive, so that they can be produced and deployed in large numbers, and so their resources in terms of energy, memory, computational speed and bandwidth are severely constrained. There are different Sensors such as pressure, accelerometer, camera, thermal, microphone, etc. They monitor conditions at different locations, such as temperature, humidity, vehicular movement, lightning condition, pressure, soil makeup, noise levels, the presence or absence of certain kinds of objects, mechanical stress levels on attached objects, the current characteristics such as speed, direction and size of an object. Normally these Sensor nodes consist there components: sensing, processing and communicating [9]. The development of sensor networks requires technologies from three different research areas: sensing, communication, and computing (including hardware, software, and algorithms). Thus, combined and separate advancements in each of these areas have driven research in sensor networks. Examples of early sensor networks include the radar networks used in air traffic control. The national power grid, with its many sensors, can be viewed as one large sensor network. These systems were developed with specialized computers and communication capabilities, and before the term sensor networks came into vogue.

A. Terminology

Following are the important terms which are used widely in sensor network:

1) **Sensor:** A transducer that converts a physical phenomenon such as heat, light, sound or motion into electrical or other signal that may be further manipulated by other apparatus.

2) **Sensor node:** A basic unit in a sensor network, with processor, memory, wireless modem and power supply.

3) **Network Topology:** A connectivity graph where nodes are sensor nodes and edges are communication links.

4) **Routing:** The process of determining a network path from a source node to its destination.

5) **Resource:** Resource includes sensors, links, communication processors and memory and node energy.

6) **Data Storage:** The run-time system support for sensor network application. Storage may be local to the node where the data is generated, load balanced across a network, or anchored at a few points

3. Motivation: The Need for a Sensor Cloud

SensorCloud is useful for a variety of applications, particularly where data from large sensor networks needs to be collected, viewed, and monitored remotely. The case for WSN enables novel and attractive solutions for information gathering across the spectrum of endeavor including transportation, business, health-care, industrial automation, and environmental monitoring. Despite these advances, the exponentially increasing data extracted from WSN is not getting adequate use due to the lack of expertise, time and money with which the data might be better explored and stored for future use. The next generation of WSN will benefit when sensor data is added to blogs, virtual communities, and social network applications. This transformation of data derived from sensor networks into a valuable resource for information hungry applications will benefit from techniques being developed for the emerging Cloud Computing. Traditional High Performance Computing approaches may be replaced or find a place in data manipulation prior to the data being moved into the Cloud. In this paper, a novel framework is proposed to integrate the Cloud Computing model with WSN. Deployed WSN will be connected to the proposed infrastructure. Users request will be served via three service layers (IaaS, PaaS, SaaS) either from the archive, archive is made by collecting data periodically from WSN to Data Centres (DC), or by generating live query to corresponding sensor network.

4.1. Cloud Computing Vs. Sensor Cloud Computing

4.1.1. Cloud computing

‘‘Cloud computing refers to both the applications delivered as services over the Internet and the hardware and systems software in the datacenters that provide those services’’. A cluster of computer hardware and software that offer the services to the general public (probably for a price) makes up a ‘public cloud’. Computing is therefore offered as a utility much like electricity, water, gas etc. where you only pay per use. For example, Amazon’s Elastic cloud, Microsoft’s Azure platform, Google’s AppEngine and Salesforce are some public clouds that are available today. However, cloud computing does not include ‘private clouds’ which refer to data centers internal to an organization. Therefore, cloud computing can be defined as the aggregation of computing as a utility and software as a service. Virtualization of resources is a key requirement for a cloud provider for it is needed by statistical multiplexing that is required for scalability of the cloud, and also to create the illusion of infinite resources to the cloud user. holds the view that ‘‘different utility computing offerings will be distinguished based on the level of abstraction presented to the programmer and the level of management of the resources’’. To take an example from the existing cloud providers, an instance of Amazon’s EC2 is very much like a physical machine and gives the cloud user almost full control of the software stack with a thin API. This gives the user a lot of flexibility in coding; however it also means that Amazon has little automatic scalability and failover features. In contrast, Google’s App Engine enforces an API on the user but offers impressive automatic scalability and failover options. Microsoft’s Azure platform is something in between the aforementioned providers by giving the user some choice in the language and offers somewhat automatic scaling and failover functions. Each of the aforementioned providers has different options for virtualizing computation, storage and communication.

4.1.2. Sensor Computing

With the recent explosion of wireless sensor networks and their applicability in civilian and military applications, there is an emerging vision for integrating sensor networks into the cloud. Practical systems like Microsoft’s SensorMap and Asia Pacific Environmental Sensor Grid are attestations to the enormous potential for sensor networks to be integrated into the cloud. In this framework users need not own sensor networks. Sensor Network owners after a mission need not disband the networks. There is a symbiotic relationship wherein sensor network owners can provide a variety of services to customers for profit. Customers also benefit from a variety of remote services without being physically close to the environment of interest. However, despite the benefits of sensor-clouds, security issues are largely open. A variety of new threats and attacks are possible, and existing solutions in standalone sensor networks will not be applicable in the cloud. The vision of this paper is to introduce the sensor-cloud computing and overview the application of sensor cloud computing.

5. APPLICATION SCENARIOS

A. Weather Forecasting

Weather forecasting is the application to predict the state of the atmosphere for a future time and a given location. Weather monitoring and forecasting system typically includes- Data collection, Data assimilation, Numerical weather prediction and Forecast presentation .Each weather station is equipped with sensors to sense the following parameters wind speed/direction, relative humidity, temperature (air, water and soil),barometric pressure, precipitation, soil moisture, ambient light (visibility), sky cover and solar radiation. The data collected from these sensors is huge in size and is difficult to maintain using the traditional database approaches. After collecting the data, assimilation process is done. The complicated equations that govern how the state of the atmosphere changes (weather forecast) with time require supercomputers to solve them.

B. Military Use

Sensor networks are used in the military for Monitoring friendly forces, equipment and ammunition, Battlefield surveillance, Reconnaissance of opposing forces, Targeting, Battle damage assessment and Nuclear, biological and chemical attack detection reconnaissance etc [14].The data collected from these applications are of greatest importance and needs top level security which may not be provided using normal internet connectivity for security reason. Cloud computing may be one of the solution for this problem by providing a secure infrastructure exclusively for military application which will be used by only Defense Purpose.

C. Transport Monitoring

Transport monitoring system includes basic management systems like traffic signal control, navigation, automatic number plate recognition, toll collection, emergency vehicle notification, dynamic traffic light etc.In transport monitoring system, sensors are used to detect vehicles and control traffic lights. Video cameras are also used to monitor road segments with heavy traffic and the videos are sent to human operators at central locations. Sensors with embedded networking capability can be deployed at every road intersection to detect and count vehicle traffic and estimate its speed. The sensors will communicate with neighboring nodes to eventually develop a global traffic picture which can be queried by users to generate control signals. Data available from sensors is acquired and transmitted for central fusion and processing. They also require analysis and prediction of data to generate events. Access to this data is limited in both the cases. Integrating these WSN applications with the cloud computing infrastructure will ease the management of storage and computational resources. It also provides an improvement on the application data over the internet through web.

D. The Government sector

With an increasing demand for transparency in government, eGovernance is being adopted by public authorities across the world. In order to not only enhance the effectiveness of eGovernance but also to experience cost benefits, countries such as USA and UK have defined the Cloud as an integral part of the government's IT strategy , and are gradually moving towards a nearly paperless government. However, the traditional model of governance is still prevailing in countries such as India. These models restrict the process of bringing government services closer to the public, thereby giving rise to operational inefficiencies, cost overruns, ineffective communication, and data duplication. The Cloud provides public agencies with distinct advantages to meet new ‘open’ government requirements. Cloud services make available an environment that provides government agencies with access to a shared pool of easily usable computing resources (such as hardware and software). As these benefits directly impact the effectiveness of governance, the Cloud has gained the attention of government agencies the world over.

E. The Education sector

The last decade has seen the education sector make tremendous advances in meeting its social and business goals. Technological breakthroughs and the evolution of new teaching methodologies are greatly improving the reach of education. However, the recent recession has threatened to impact this progress while also having the potential to actually reverse positive trends. Increasing cost of education, and shrinking financial support are a few factors adversely affecting the education sector. In this scenario, the Cloud appears to be just the solution needed. Besides being cost effective, the Cloud is also expected to reduce issues related to the sourcing and management of IT infrastructure of schools and universities, allowing these institutes to concentrate on their core competencies. Though the education sector has been cautious / conservative in adopting new technologies, the Cloud presents benefits that cannot be ignored. The Cloud in the education sector could shorten the timelines that are required to realize the goal of 'Education for all' and quicken the building of 'Metauniversities’.

F. Small and Medium Enterprises (SMEs)

As users, the SMEs in particular are expected to benefit the most from the Cloud. This is primarily because they are unable to make high up-front investments required for the setup of traditional IT systems and solutions. The Cloud gives SMEs the ability to source high end computing solutions in an environment that is based on utility computing. SMEs are also adopting Cloud services to gain greater agility.

G. Ubiquitous Healthcare

Sensors like heat sensors, bed sensors, stove sensor, camera and accelerometer sensors etc. can be used together in monitoring for very aged residents to prevent from any casualty without being harmed and interrupting them .These sensor services can provide the perception to older residents in health services.

H.Environmental Monitoring for emergency/disaster detection

In environmental applications it can be used to detect the earthquake and volcano explosion before its eruption by continuously monitoring them through the use of several numbers of different sensors like strain, temperature, light, image, sound, acceleration, barometer sensors etc through the use of wireless sensor networks.

I Telematics

Sensor-Clouds can be used for telematics means to deploy the long distance transmission of our computerized or information to a system in continuum. It enables the smooth communication between system and devices without any intervention

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J Google Health

It is a centralization service of Google that provides personal health information and serves as Cloud health data storages. Google users are allowed to monitor their health records by logging into their accounts at collaborated cloud health service providers into the Google health system.

K Microsoft Health-Vault

This cloud platform is developed by Microsoft to store and maintain health and fitness related information. Health-Vault helps users to store, gathered and share their health relevant information and it's data can be acquired from several pharmacies, cloud providers, health employees, health labs, equipments and from the users itself.

L.Agriculture and irrigation Control (Field server sensors)

Sensor-Cloud can be used in the field of agriculture to monitor the crop fields in order to upkeep it. For this a field server is developed that comprises of a camera sensors, air sensor, temperature sensor, CO_2 concentration sensor, soil moisture and temperature sensors etc. These sensors continuously upload the field data via Wi-Fi access point to the field owner to track the health of their crops . This can also be used for harvesting.

M. Earth observation

A sensor grid is developed for data gathering from several GPS stations, to process, analyze, manage and visualize the GPS data [39]. This GPS data would then be uploaded onto the Cloud for efficient monitoring, early warning, and decision- making capability for critical situations like the volcanic eruptions, earthquakes, tsunamis, cyclones etc. to the users all around the world.

Table 1: Technical comparison of different messaging approaches and algorithms being used in several papers of Sensor-Cloud.

Papers	Using traditional SOAP messages	Using SPWS messages	Using data caching or hop-by-hop processing	Using QoS-based routing	Using SGIM	Using SPMC	Using event-matching algorithms	Using matrix-matching algorithms	Using orthogonal neural network algorithm	Using orthogonal neural network algorithm
4	NO	NO	NO	NO	YES	YES	YES	NO	NO	NO
5	NO	NO	YES	YES	NO	YES	YES	NO	NO	NO
6	NO	YES	NO	NO	NO	NO	NO	NO	NO	NO
7	NO	NO	YES	NO	NO	NO	YES	NO	NO	NO
8	NO	NO	NO	YES	NO	NO	YES	NO	NO	NO
[9,10]	NO	NO	NO	NO	NO	NO	YES	YES	NO	NO
[11,12]	NO	NO	YES	NO	NO	NO	NO	NO	NO	NO
13	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO
14	NO	NO	YES	YES	NO	NO	NO	NO	NO	NO
[15,16,17]	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO
18	YES	NO	NO	NO	NO	NO	NO	NO	NO	YES

6. Conclusion and Future Work

In this paper, we surveyed the use of Sensor-Cloud architecture in the context of several applications. The Sensor-Cloud architecture enables the sensor data to be categorized, stored, and processed in such a way that it becomes cost-effective, timely available, and easily accessible. Earlier, most WSN systems which were included to several controlling/monitoring schemes were closed in nature, zero, or less interoperability, specific application oriented, and nonextensible. However, integrating the existing sensors with cloud will enable an open, extensible, scalable, interoperable, and easy to use, reconstructible network of sensors for numerous applications.

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