A Survey on Applications of Wireless Sensor Network Using Cloud Computing

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***Abstract*—**Popularity of cloud computing is increasing day by day in distributed computing environment. There is a growing trend of using cloud environments for storage and data processing needs. Cloud computing provides applications, platforms and infrastructure over the internet. It is a new era of referring to access shared computing resources. On the other hand, wireless sensor networks have been seen as one of the most essential technologies for the 21st century where distributed spatially connected sensor node automatically forms a network for data transmission and receive among themselves is popularly known as Sensor Network. For security and easy access of data, cloud computing is widely used in distributed/mobile computing environment. This is possible due to miniaturization of communication technology. 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.

***Index Terms*—**Cloud Computing, Distributed Computing, Internet, Sensor Network, WSN

1. INTRODUCTION

The communication among sensor nodes using Internet is often a challenging issue. It makes a lot of sense to integrate sensor networks with Internet [1]. 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 WSNs (i.e. WSN1, WSN2, and WSN3), 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.

The organization of our work is 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.

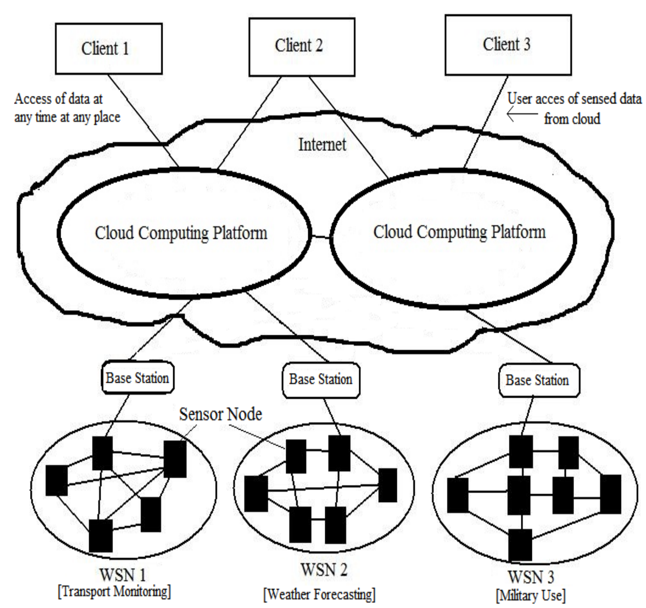

Fig. 1 WSN- Cloud Computing Platform

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 [2].

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 [2].

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.

C. Cloud Computing Models

The following models are presented by considering the deployment scenario:

1) Private Cloud: This cloud infrastructure is operated within a single organization, and managed by the organization or a third party irrespective of its location. The objective of setting up a private cloud in an organization is to maximize and optimize the utilization of existing in-house resources, providing security and privacy to data and lower data transfer cost [3] from local IT infrastructure to a Public Cloud.

2) Public Cloud: Public clouds are owned and operated by third parties. All customers share the same infrastructure pool with limited configuration, security protections, and availability variances. These are managed and supported by the cloud provider.

3) Community Cloud: This cloud infrastructure is constructed by number of organization jointly by making a common policy for sharing resources. The cloud infrastructure can be hosted by a third-party vendor or within one of the organizations in the community.

4) Hybrid Cloud: The combination of public and private cloud is known as hybrid cloud. In this model, service providers can utilize 3rd party Cloud Providers in a full or partial manner so that the flexibility for using the resources are increased.

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.[4,5] 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 [6], environment and habitat monitoring, healthcare applications, home automation, and traffic control [4, 7].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 [4]. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and bandwidth [4].

A sensor network is a computer network Composed of a large number of sensor nodes. [8] 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, communication links, 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.

B. Routing Protocols in WSNs

Routing protocols in WSNs are broadly divided into two categories: Network Structure based and Protocol Operation based. Network Structure based routing protocols are again divided into flat-based routing, hierarchical-based routing, and location-based routing. Protocol Operation based are again divided into Multipath based, Query based, QoS based, Coherent based and Negotiation based.

In flat-based routing, all nodes are typically assigned equal roles or functionality sensor nodes collaborate together to perform the sensing task. Due to the large number of such nodes, it is not feasible to assign a global identifier to each node. The examples of flat-based routing protocols are –SPIN [10,11], Directed Diffusion [12], Rumor Routing [13], MCFA [14], GBR[15], IDSQ & CADR [16], COUGAR [17], ACQUIRE [18], Energy Aware Routing [19] etc.

In hierarchical-based or cluster based routing, nodes will play different roles in the network. In a hierarchical architecture, higher energy nodes can be used to process and send the information while low energy nodes can be used to perform the sensing in the proximity of the target. This means that creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency. Hierarchical routing is an efficient way to lower energy consumption within a cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the BS. Hierarchical routing is mainly two-layer routing where one layer is used to select cluster heads and the other layer is used for routing. The examples of hierarchical-based routing protocols are – LEACH [20], PEGASIS [21], TEEN[22], APTEEN [23], MECN [24], SMECN [25], SOP[26], Sensor Aggregate routing [27], VGA[28], HPAR [29], TTDD [30] etc.

In location-based routing, sensor nodes' positions are exploited to route data in the network. In this kind of routing, sensor nodes are addressed by means of their locations. The distance between neighboring nodes can be estimated on the basis of incoming signal strengths. Relative coordinates of neighboring nodes can be obtained by exchanging such information between neighbors [37, 38, 39]. Alternatively, the location of nodes may be available directly by communicating with a satellite, using GPS (Global Positioning System), if nodes are equipped with a small low power GPS receiver [40]. The examples of location-based routing protocols are – GAF [31], GEAR [32], GPSR [33], MFR, DIR, GEDIR [34], GOAFR [35], SPAN [36] etc.

In multipath routing, communication among nodes uses multiple paths to enhance the network performance instead of single path. In Query based routing, the destination nodes propagate a query for data from a node through the network and a node having this data sends the data which matches the query back to the node, which initiates the query. Usually these queries are described in natural language, or in high-level query languages. In QoS-based routing protocols, the network has to balance between energy consumption and data quality. The network has to satisfy certain QoS metrics, e.g., delay, energy, bandwidth, etc for delivering data to the BS. In coherent routing, the data is forwarded to aggregators after minimum processing. The minimum processing typically includes tasks like time stamping, duplicate suppression, etc. In Negotiation based routing, protocols use high level data descriptors in order to eliminate redundant data transmissions through negotiation. Communication decisions are also taken based on the resources that are available to them.

4. APPLICATION SCENARIOS

Combining WSNs with cloud makes it easy to share and analyze real time sensor data on-the-fly. It also gives an advantage of providing sensor data or sensor event as a service over the internet. The terms *Sensing as a Service* (SaaS) and *Sensor Event as a Service* (SEaaS) are coined to describe the process of making the sensor data and event of interests available to the clients respectively over the cloud infrastructure.

Merging of two technologies makes sense for large number of application. Some applications of sensor network using cloud computing are explained below:

D. 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. [42].

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. This data can be used in a wide variety of applications. Some of the applications are - vehicle classification, parking guidance and information system, collision avoidance systems, electronic toll gates and automatic road enforcement.

In the above scenarios, both the applications require storage of data and huge computational cycles. 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.

A. 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 [43].

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.

B. 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 [41].

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.

C. Health Care

Sensor networks are also widely used in health care area. In some modern hospital sensor networks are constructed to monitor patient physiological data, to control the drug administration track and monitor patients and doctors and inside a hospital.

In the above scenario, the data collected from the patients are very sensitive and should be maintained properly as collected data are required by the doctors for their future diagnosis. In traditional approach the patient’s history database is maintained in the local nursing home. So reputed doctors who are specially invited from abroad to handle critical cases cannot analyze the patient’s disease frequently. They will only make diagnosis when they will visit the particular nursing home. This problem may be solved by forming a cloud where the critical data of the patients can be maintained and authorized doctors sitting in abroad can analyze the data and give proper treatment.

5. CONCLUSION

The communication among sensor nodes using Internet is a challenging task since sensor nodes contain limited band width, memory and small size batteries. The issues of storage capacity may be overcome by widely used cloud computing technique. In this paper, we have discussed some issues of cloud computing & sensor network. To develop a new protocol in sensor network, the specific application oriented scenarios are of important consideration. Keeping this in mind we have discussed some application of Sensor Network using Cloud Computing.

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