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An Integration Framework of Three-Dimensional Wireless Multimedia Sensor Network with Cloud Computing for Surveillance Applications

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Abstract

Objectives: Three-Dimensional Wireless Multimedia Sensor Networks (3-D WMSNs) are the type of WSN. These networks deal with multimedia content such as images in various formats, video, and audio etc. Moreover 3-D WMSNs are widely used for surveillance applications, underwater monitoring, aerial surveillance, urban warfare, monitoring infrastructure of national importance etc. **Methods/Statistical Analysis**: The system presents an integrated framework of three-dimensional wireless multimedia sensor network with cloud computing for surveillance applications. The integrated framework of 3D WMSNs with cloud computing is suitable for monitoring and surveillance in multi-floor buildings or marine environment. The client utilizes http protocol to interact with framework. At the server side, the sensor nodes collect the data and transfer the data to cloud where it is stored and processed in a distributed environment. On the client side, the user utilizes web services to retrieve data from the distributed SQL databases. **Findings:** User can fully access cloud service using devices that have internet capabilities. The work focuses distributed computing and resource allocation of processing three-dimensional wireless multimedia sensor data, and performance evaluation over various parameters settings in a cloud environment. **Application/Improvements:** We utilize CloudSim for simulating the cloud computing environment. The benefits of the system include basic computing hardware and reasonable storage capacities making it suitable for any 3D WMSN which provides real time monitoring and surveillance.

Keywords: 3-D WMSNs, Cloud Computing, CloudSim, Surveillance

1. Introduction

Three-Dimensional Wireless Multimedia Sensor Networks (3-D WMSNs) are the type of WSN. These networks deals with multimedia content such as images in various formats, video, and audio etc. Some of the examples of such three-dimensional deployments are: 1. Sensors deployed in a building with multiple floors, 2. Underwater monitoring with acoustic sensors and 3. Spatial monitoring of large volumes where sensor nodes can be deployed on the trees of different heights in a forest[1]. The multimedia sensors, events and/or targets are located in 3-D space. Three-dimensional wireless multimedia sensor networks consist of several multimedia nodes distributed according to an appropriate deployment strategy in a given Region-of-Interest. These multimedia nodes are suitable for monitoring and surveillance applications. A typical multimedia node consists of a processor unit, storage unit, sensing unit, transmitter and receiver unit. The sensing unit collects data of various types such as video, audio, and image format. Following this, multimedia data is processed with the help of a processor unit. The processed data is sent to the Base Station (BS) with the help of a transceiver unit. Further, the communication from multimedia sensors to a BS follows many-to-one communication. Multimedia data is then transferred from BS to other networks or cloud for storage and processing. Wireless Multimedia Sensor Network applications

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are classified into tracking and monitoring applications as shown in Figure 1. WMSNs are widely used for surveillance applications, underwater monitoring, aerial surveillance, urban warfare, monitoring infrastructure of national importance etc. Cloud computing provides powerful and scalable abilities to process and store data collected from 3-D WMSNs. Further, an integration of 3D-WMSNs and cloud provides a framework for storage, processing, and data visualization suitable for surveillance applications. The remainder of the paper is organized as follows: Section 2 provides a brief description of 3-D WMSNs along with various issues in three dimensional wireless multimedia sensor network applications. Section 3 presents an overview of Cloud and CloudSim environment. Section 4 discusses an integrated framework of 3-D WMSNs and Cloud. We present performance evaluation of our proposed framework with various parameters settings in Section 5. Finally, we give some concluding remarks and discuss future work in Section 6.

2. 3-D WMSNs

3-D WMSNs are widely used for surveillanceapplications, underwater monitoring, aerial surveillance, urban warfare, monitoring infrastructure of national importance etc. These networks are also used for vehicle movement on battlefield terrain, human tracking, battle-field monitoring, and tracking enemy movements on different terrains. Further, 3-D WMSNs are deployed as underwater sensor networks and support various types of applications such as tsunami warnings, pollution awareness and monitoring etc. Underwater Sensor Networks (UWSN) consists of several nodes deployed with the help of a suitable deployment scheme. The nodes work in collaboration with BS to evaluate various water quality parameters such

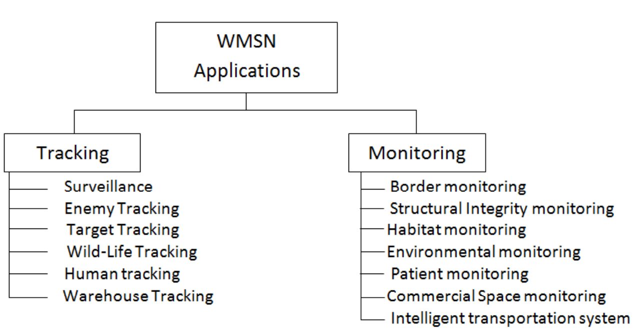


Figure 1. Monitoring and tracking applications of WMSN.

as ph level, depth approximation, turbidity etc. These sensors would therefore help in quantifying changes in the marine surroundings. Such observation in marine environments helps to evaluate and plan for an eeffective critical response plan.

2.1 Issues in 3-D WMSNs

3-D WMSN design issues for resource constraints sensor node includes data gathering, storage, and processing for surveillance applications. In addition efficient architecture, data aggregation, security, and application specific quality of service are also important design parameters. Further, the communication is acoustic for 3-D underwater networks. This often leads to various problems such as suitable deployment scheme for UWSN, limited bandwidth, signal dissipation, and node failures. The integrated framework provides an effective way to share data and access to real time data processing.

3. Cloud Computing

Cloud computing is a category of on-demandcomputing service. On-demand computing service also known as ("pay-as-you-go") charges the customer based on usage of service. Recently there is a rapid growth in the demand of cloud computing as it offers storage, computing, and software "as a service". The customer data can be stored to a cloud network such as Bio feed sensory data. Bio feed sensory devices are attached to human body and measure vital parameters such as heart rate, blood pressure etc. Further, the large amount of collected data for a typical WMSN surveillance application is send to cloud for storage and computing purpose. Cloud computing consists of independent, networked hardware and/or software resources[2]. Further, Cloud computing applies the concept of virtualization for optimal usage of hardware and/or software resources. In simple terms cloud computing is the virtualization of a pool of resources, under data center's for hosting cloud applications, which are made available to everyone on subscription basis. In cloud computing the hardware and software resources are made available by the providers for different users or clients. Cloud computing provides a service-driven business modes[3]. The computing resources along with hardware resources are provides as services On-demand. Service providers offer cloud services with predefined Quality of Service (QoS) terms through the Internet as a collection of easy-to use, scalable, and economically feasible services to the clients. The cloud services fall under three categories: Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS)[3]. Infrastructure-as-a-Service is referred to as the allocation of the infrastructural resources which is mostly in terms of the virtual machines. Platform-as-a-Service is referred to as providing platform layer resource which also includes the operating system and application integration platforms. Software-as-a-Service is referred to as providing on–demand application and software which are provided to the requestor through the internet[3]. Some of the leading providers include well-known names such as Amazon, Google, Microsoft, SAP etc. Amazon is the leader amongst all cloud providers and provides. Amazon EC2 Elastic Cloud Computing, both belong to IaaS service model. EC2 both work on a concept of pay-as-you-go model. Therefore, the number of people using these services are exponentially increasing with the increase in deployment of new applications on the cloud as well. One such application deployed in Australia is to monitor quality of drinking water. The sensor nodes collect vital water quality parameters such as temperature and turbidity[3]. Such networks can further be integrated with cloud so as to store, analyze, and visualize data in real time scenario[4–7]. In the next subsection, we provide the definitions used in our work along with the details of the simulation tool used in our work.

3.1 Definitions

- Data centre: Data centre refers to a set of hosts and is responsible for managing Virtual Machines (VMs). It creates the VMs in hosts after receiving requests for Virtual Machine from brokers.
- Datacenter Broker: This class represents a broker acting on behalf of a user. It modifies two mechanisms: The mechanism for submitting VM provisioning requests to data centres and the mechanism for submitting the tasks to VMs.
- Host: Host executes actions related to management of VMs like creation, destruction and update task processing to VMs. A host has a defined policy for provisioning memory, processing elements, and bandwidth to virtual machines. It is associated to a datacenter and it can host virtual machines.
- VM: Virtual Machine represents the software implementation of a physical machine that executes applications. Each virtual machine divides the resources received from the host among tasks running on it.
- Cloudlet: A cloudlet class is also known as a task. This class is managed by the scheduling policy which is implemented in Datacenter Broker Class.

3.2 Model Framework

The model used in this work is based on CloudSim[8–11] for simulating the cloud computing environment. CloudSim works as a holistic software framework for modelling and testing the performance of the algorithms implemented. CloudSim provides a platform for dynamic resource provisioning by utilizing data center's functionality of working as a repository. Moreover, users can access, implement and deploy applications on the basis of their requirements. The reason why it is more efficient to simulate our own cloud is because it is difficult to analyze the working of real-time cloud in accordance to the algorithms implemented due to its lesser flexibility and scalability. CloudSim is responsible for behavior modeling and system modeling of various cloud components. The components that can be modeled are cloud resource policies, Virtual Machines (VMs) and Data Centers (DC). CloudSim provides environment to design, analyse, and simulate large applications in an effective manner. Such scenarios are very difficult to perform utilizing real-cloud environment. Figure 2 illustrates the basic Cloudsim framework architecture. Simulation layer allows us to specify the

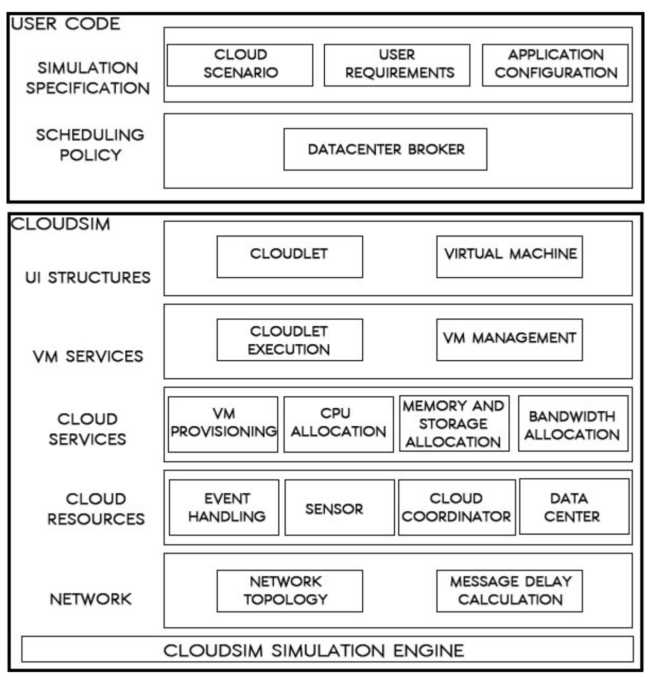


Figure 2. CloudSim layered architecture (Adapted from[8]).

simulation scenario by specifying configurations for datacenters, specifying user requirements, managing application execution and monitoring the system state. By extending basic entities of this layer we can implement various configurations. Scheduling policy can be specified in the scheduling policy layer this allows us to simulate the implementation of various scheduling policies on any hardware configuration. Cloudsim simulation provides dedicated management interfaces for VM's, storage, memory and bandwidth if we wanted to test various allocation policies for hosts we would have to implement various strategies in this layer.

4. System Development

The proposed system consists of two parts 3D-WMSNs and the cloud data center. Sensor nodes are responsible for data collection and transmit the gathered data on request or *on-demand* basis. The data is stored, processed, analyze, and visualize in the cloud data centre. Further, the cloud server uses the concept of distributed computing with virtualization for efficient processing efficiency and power. Distributed computing works on the premise of dividing a larger system into smaller more manageable units. Each smaller unit would work as a slave computer that would process the task or process and then send back the results to the master computer. Figure 3 presents the proposed network architecture for 3-D WMSNs composed of heterogeneous sensor, gateway that provides the collected data to a cloud platform. Three types of 3-D multimedia networks are shown in Figure 3. These are Airborne, Underwater and underground sensor networks. Further, these networks can be attached with solar panel which in turn increases the lifetime of the networks. The cloud system consists of a master server computer and number of virtual slave server computers. Figure 4 illustrates the state transition diagram of the virtual machines in the framework. We now discuss the flow of interaction among framework components as shown in Figure 5. The interactions among different components of the proposed framework are shown in the sequence diagram including the following steps:

- The user login to the framework by using his/her information.
- In case the authentication of the user is valid an acknowledgement is send to the user.
- The user sends a successful request after login.
- Once the request is received the cloud component of the framework identifies the type of service. In case the request service requires real time data cloud sends send request () message to 3-D WMSNs for collection of real time data.
- The requested data is send back to the user.

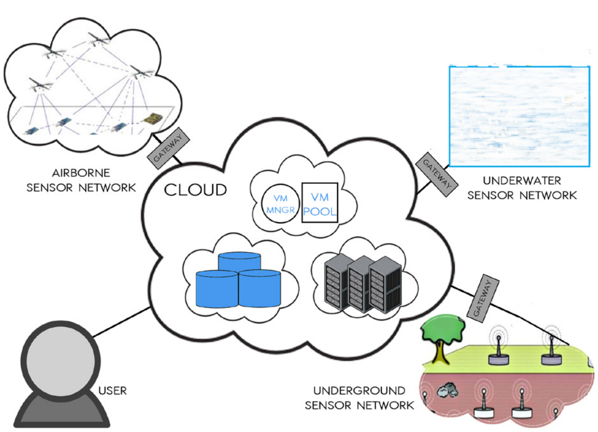


Figure 3. Sensor cloud integration framework.

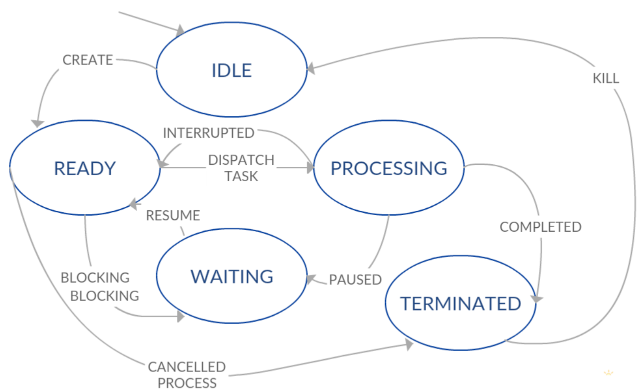


Figure 4. State transition diagram of virtual machines being used.

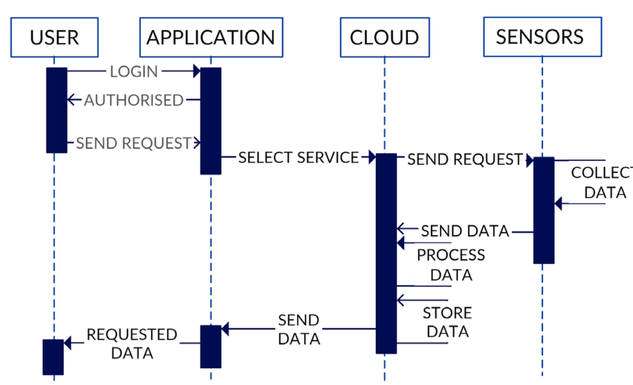


Figure 5. Sequence diagram of the framework.

4.1 Model Development

The model development is done with the help of CloudSim. Datacenter component in CloudSim models the primary hardware infrastructure services of the Clouds. Datacenter's host component refers to a set of hosts for managing Virtual Machines (VMs). Based on policy, the requests received are allocated processing power of the CPU. Further, a VM lifecycle comprises of creating a virtual machine and provisioning of a host to a VM. In addition, migration and VM destruction are important operations of VM lifecycle. A datacenter is composed of a set of hosts, which during their lifecycles work on the basis of managing the virtual machines.

As defined in previous sub-section host is a component that represents a physical computing node in a Cloud. Further, a host is assigned a processing per CPU core, memory and storage. Virtual Machine Provisioner component assigns application specific VMs to the host. Based on various design objectives and optimization goals a large number of customized solutions are provided by the component. These solutions in turn help to implement new VM provisioning policies. However, VM Provisioner allocates First-Come-First-Serve as a default policy to allocate VMs to host. Two well-known allocation policies are: Time-shared policy and space-shared policy. In a timeshared policy the capacity of a core is dynamically distributed among VMs, whereas in a space shared policy assigns specific CPU cores to specific VMs. In addition, assignment of cores to VMs can be on-demand basis or any other user-specified policy. Using the classes imported through the framework of CloudSim we integrate the datacenter and the datacenter broker with one another to connect and interact with the virtual machine. We now provide performance analysis of the framework in the next section.

5. Performance Analysis

In this section we test our simulation framework for various parameters settings. We perform the simulation utilizing CloudSim environment over Linux platform. Further, we perform test on the machine with x-86 architecture and 8 GB of RAM memory. Table 1 illustrates various parameter settings for our simulation environment.

5.1 Experiment 1

We run our first experiment on two hosts where first and second host runs on 1000 and 100 Million of Instructions Per Second (MIPS) respectively. In our first set of experiment we run 150 MIPS through the cloudlet associated with the VM1. We also define another VM2 associated with the same host which runs at 20 MIPS and the cloudlet associated with it runs 150 million of instructions. Further, the parameters associated with datacenter includes x86-architecture working on Linux operating system with unique configuration name. Our first set of experiment focuses on the energy consumption of the virtual machines. Further, we plot three well-known techniques to model energy management and utilization. The three techniques are 1. Dynamic voltage and frequency scaling, 2. Using maximum frequency, 3. Dynamic voltage and frequency scaling integrated with migration of the virtual machine if the host utilization is above the limit predefined. Figure 6 illustrates the scenario for a

Table 1. Parameter settings

Description	Parameter
System Architecture	x86
VM allocation Policy	TS (Time shared) and SS (Space Shared)
Workload	Random workload
No-of Users	2
No of Datacenters	2
VM Description	
MIPS	250
RAM	512MB
Size	10000MB
No of CPU	1

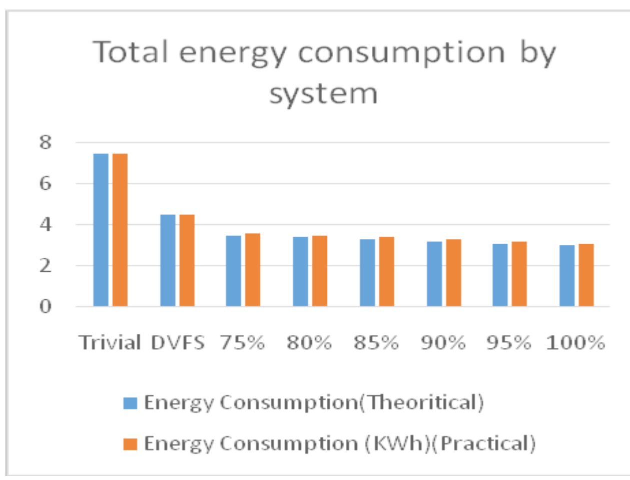
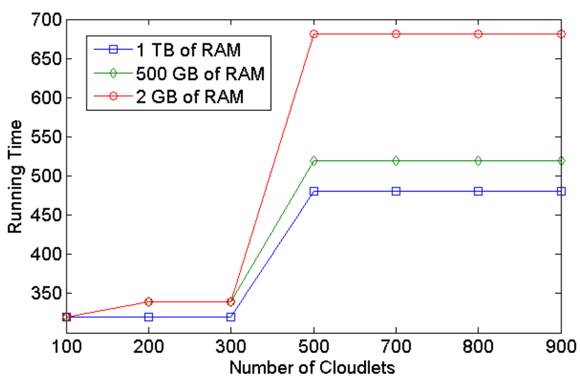


Figure 6. Plot of total energy consumption by system.

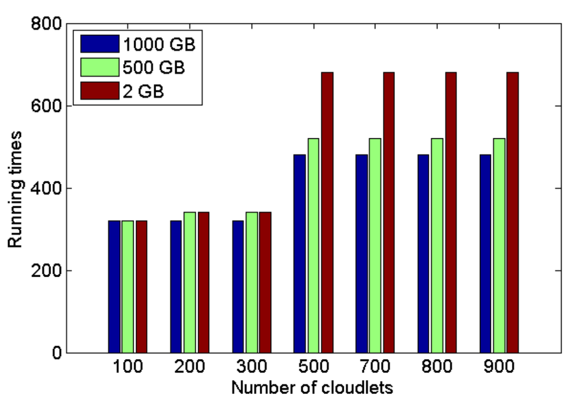
typical theoretical and practical energy consumption for various scenarios. We plot the values in Figure 6 based on the work of researchers in the field of cloud computing. As shown in the Figure energy consumption for theoretical and practical settings are comparable to each other.

5.2 Experiment 2

In our second set of experiment we compare the difference in the processing and waiting time of the processes. We increase the processing powers of the virtual machines with an increase in the RAM. Figure 7 (a) and Figure 7 (b) plot the running time versus number of cloudlets for line and bar graph respectively. As shown in the figures, with an increase in the memory of the VM the performance increases by a few milliseconds. This is due to the fact as the RAM directly affects the execution time which a VM would take to process requests. Thus RAM in a VM is directly proportional to the MIPS of the VM.



(a)



(b)

Figure 7. **(a)** Plot of running time versus number of cloudlets with 1TB, 500 GB, and 2 GB of RAM. **(b)** Bar Graph: Running time versus number of cloudlets with three RAM settings.

5.3 Experiment 3

We further use the VM provisioning in CloudSim. We test efficiency of the algorithm and policy which should be used to increase performance. A single datacenter which has 100 hosts is chosen for the scenario. A CPU runs on the efficiency of 1000 million of instructions per second with a 2GB RAM and 1TB of external storage. We make a request for 400 virtual machines where one CPU runs on the efficiency of 250 million of instructions per second equipped with a 256GB RAM and 1GB of external storage. Further, each virtual machine requires an approximate of 10 minutes for the instructions. The metrics selected for comparing the allocation policies of time sharing and space sharing is done with the help of two parameters. The parameters are average waiting time of execution of the cloudlets and the throughput obtained. We compute the average execution time and waiting time for all the cloudlets. As shown in Figure 8, we observe that throughput of time shared is better as compared to space shared allocation policy. Figure 9 presents the average waiting time for time shared and space shared allocation policy. We observe that the average waiting time of space shared policy is high as compared to time shared allocation policy. From the above experiments we observe that there is a decrease in execution time with an increase in RAM size. Further, as we increase the number of cloudlets we obtain a more prominent as we increase the number of cloudlets. Moreover, the performance of Virtual Machines increases with an increase in the RAM size. Space shared allocation policy gives a better throughput as compared to time shared policy. This difference becomes more prominent with an increase in the number of cloudlets. Further, time shared allocation

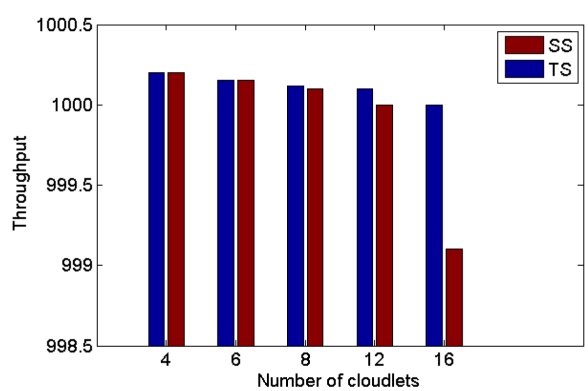


Figure 8. Plot of throughput versus number of cloudlets for TS (Time Shared) and SS (Space Shared) allocation policy.

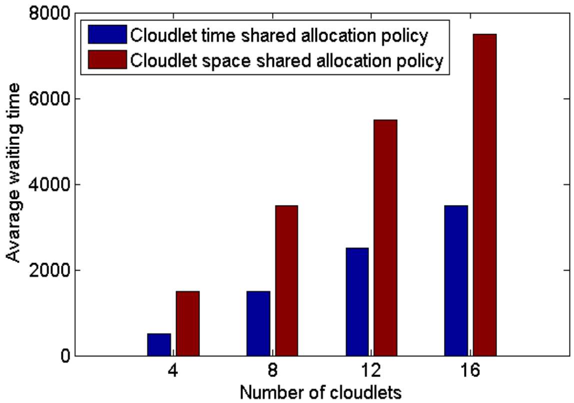


Figure 9. Average waiting time in VM allocation policy.

policy provides a significant lower average waiting time when compared to space shared policy.

6. Conclusion

The proposition of a 3-D WMSNs monitoring and surveillance system integrated with cloud computing is presented. The cloud computing environment integrates with 3-D WMSNs for implementation of airborne, underwater, and underground sensor network services. We presented a heterogeneous, modular architecture framework. In this paper we presented important design issues of the 3-D WMSNs and cloud integration framework. All the projected functionalities are kept as our future scope of work.

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