Mobile Cloud and Grid Web Service in a Smart City

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***Abstract*— Smart City is a future city that heavily utilizes information and communication technology and allows the users to use the smart city services anytime, anywhere and with any accessing devices. In our smart city called UTOPIA, which has 3 tiers architecture, such as the smart city infra, the smart city middleware called SOUL and the smart city portal, administrators as well as citizens, can use smart phones, tablet personal computers, and other modern mobile devices to utilize smart city services through the smart city portal. Since big data are usually processed in real-time to provide smart city services, it is not easy at all to give the mobile cloud and grid web services in a smart city. In this paper, we introduce our mobile cloud and grid web services in a smart city, show some venues and explain the mechanisms of the cloud and grid web service in SOUL and UTOPIA.**

Keywords-Smart (Ubiquitous) City; Cloud Computing; Grid Computing; Web-Service.

I. INTRODUCTION

Recent advances in information and communication technology has enables us to build smart cities, future cities which are converged outputs of modern information and communication technology, urban engineering technology and other modern science and engineering technologies.

In the smart city, citizens do not feel alone and are not isolated in a huge modern city anymore but become a real owner of the city by being provided by the rich smart city service. Indeed, the smart city is toward the city which is of the citizen, by the citizen and for the citizen.

Ubiquitous city is a kind of smart city and tries to give users freedom of using the smart city service by allowing user to access the smart city service anytime, anywhere and with any accessing devices. Thus, administrators as well as citizens should be able to use smart phones, tablet personal computers, and other modern mobile devices to enjoy smart city services in the smart city.

Smart city covers a wide range of areas, such as environment, accident, facility, etc., deals with huge volumes of data usually and analyzes or/and converges a wide range of data to create meaningful information often in real-time. All these requirements are not easy at all to be satisfied and really challenging tasks. We have used state-of-the-art cloud computing and Grid computing technology to find our solutions.

We have been developing a paradigm of the smart city called UTOPIA [1]. It has a unique 3 tiers architecture and consists of the smart city infrastructure, the smart city middleware called SOUL and the smart city portal [1][2][3][4].

UTOPIA is based on a unique smart city Middleware called SOUL, which does brain role of the smart city; thus, we call it soul. It has an important part of the solutions for the mobile cloud and grid web services in UTOPIA. It manages the big data to provide smart city services in the environment of heterogeneous hard-wares, heterogeneous operation systems, and heterogeneous networks in UTOPIA.

UTOPIA provides user friendly web portal which is connected to SOUL, the smart city middleware [2][3]. For example, a user can use two dimensional or three dimensional visualization services in the portal. The portal supports a variety of smart phones. The wide and popular use of mobile phone brings the era of mobile service.

Grid computing has brought us the era of cloud computing and now mobile cloud computing is a very attractive state-of-the-art technology. With mobile cloud computing, smart phones and tablet personal computer are now expanding their territories beyond their limitations in computing power, data storage and software [5].

UTOPIA enables users to use services anytime, anywhere and with any device, thus, supports mobile devices and provides mobile cloud and Grid web services.

This paper introduces our mobile cloud and grid web services in UTOPIA, shows some venues and explains the architecture and principle of UTOPIA and SOUL and the mechanisms of the cloud and grid web service in SOUL.

This paper is organized as follows. Section 2 introduces UTOPIA and SOUL. Section 3 presents the Mobile Cloud and Grid Web Services. Section 4 explains the architecture and operational principle of the cloud and grid computing platform. Section 5 explains related works and compares them with our work. Finally, Section 6 gives the conclusion.

II. UTOPIA

The Smart City Consortium for Seoul has been leading the five million smart city project funded and supported by Seoul Metropolitan Government of Korea since 2005. It includes SK Telecom, LG CNS, etc., as industry members, and the laboratories from many well-known Korea Universities in Seoul as academic members.

We have developed a smart city paradigm called UTOPIA as shown in Figure 1. UTOPIA consists of 3 tiers,

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such as the smart city portal tier, the smart city middleware tier and the smart city infrastructure tier [1].

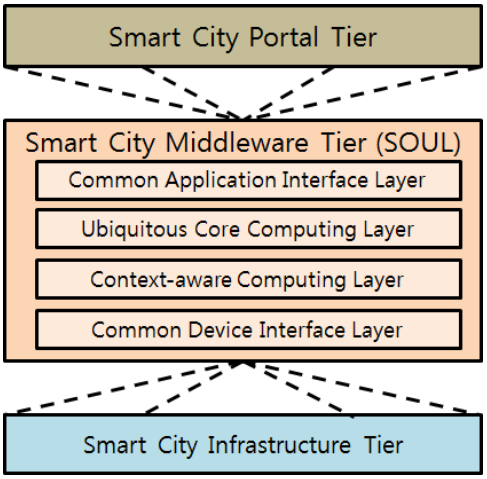

Figure 1. The three tier paradigm of UTOPIA for the Smart City.

The Smart City Infrastructure Tier includes sensors networked through USN, video cameras, GPS and appliances, and so on. It plays the role of a human body in a human being. The Smart City Middleware Tier, which we call SOUL, plays the role of soul or brain in a human being. The smart city portal tier provides web services and enables us to use mobile cloud and grid web service. It makes the other two layers transparent to users since users do not have to know their internals.

III. MOBILE CLOUD AND GRID WEB SERVICES

UTOPIA provides many intelligent services for the various kinds of applications. Some typical mobile cloud and grid web services are introduced in this section, as examples in UTOPIA.

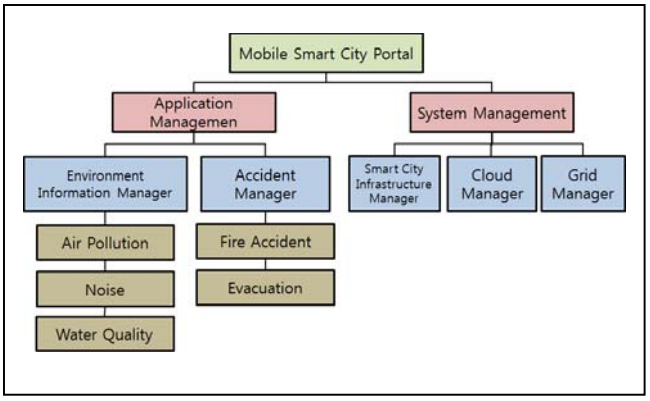

Figure 2. Typical Mobile Cloud and Grid Web Services in UTOPIA.

Some typical mobile cloud and grid web services are shown in Figure 2. The class of the mobile cloud and grid web service is largely divided into two parts. There are "Application Management" which is classified into the "Environment Information Manager" and the "Accident Manager", and "System Management" which is classified into the "Smart City Infrastructure Manager", "Cloud Manager", and "Grid Manager".

"Application Management" is an interface to deal with applications in SOUL. Environment Information Manager of Application Management System displays air pollution information, noise information and water quality information by using 2D/3D visualization functions in SOUL. "Accident Manager" of "Application Management" can provide fire accident management information, such as an evacuation path for emergency due to fire accident.

"System Management" consists of "Smart City Infrastructure Manager", "Cloud Manager" and "Grid Manager". "Infrastructure Manager" is a system component of SOUL to manage smart city infrastructure, such as Ubiquitous Sensor Network (USN), scalable video streaming, ad-hoc networking. Privileged users can control them through mobile web service. SOUL includes the cloud platform which is implemented with OpenNebula for big data processing in UTOPIA [6]. "Cloud Manager" is used to manage the "Cloud platform: of SOUL [5]. SOUL supports Grid resource management to process big data in real time with distributed computing resources. The Grid resource management system contains real time performance monitoring subsystem, process management subsystem with resource brokering, account management subsystem, unified file transfer management subsystem and access Grid management subsystem [7]. "Grid Manager" in "System Management" provides user interface to the Grid resource management system in SOUL [8][9].

A. *Environment Information Manager*

The "Environment Information Manager" shows noise information, air-pollution information and water quality information which are converged with GIS (Geographical Information System) map. Figure 3a shows snapshots of "Environment Information Manager".

"Noise" menu shows noise data and the 2D/3D noise map of a selected specific area that is generated by SOUL. To generate the noise map, SOUL uses cloud computing platform and Grid Computing platform. For the cloud computing, MapReduce is used [10][11][12]. The noise map can be visualized in 2D and 3D. As shown in Figure 3a and 2b, a user can select a specific zone and would see the noise level data and the noise map. The noise map shows the noise level distribution with specific color marks according to the predefined noise level which can be adjusted by users.

"Air pollution" menu shows the air pollution data and the 2D/3D air pollution map. SOUL also uses cloud computing platform which uses MapReduce in order to process the massive air pollution data and generate the air pollution map [13]. SOUL uses the 3D GIS data model that is based on the 2D GIS topology in order to make the 3D air pollution map. It enables users to use 3D spatial queries, analyses as well as the 3D visualization. A user can also select a specific zone for the visualization of the air pollution map and would see the air pollution level data and the air pollution map. The air pollution map shows the air pollution level distribution with

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specific color marks according to the predefined air pollution level which can be adjusted by users.

(a) (b)

Figure 3. Snapshots of the Environment Information Manager of UTOPIA in a smartphone : (a) A Noise Monitoring, (b) A 2D/3D Noise Map.

"Water Quality" menu supports tele-monitoring and tele-management [14][15]. Administrators of the smart city can monitor quality and quantity of water, observe the circumference in the canals, the waterways, the rivers, and the dams. They can control the water pumps, gates of canals, waterways, and dams remotely through mobile cloud and grid web service.

B. *Fire Accident Manager*

"Fire Accident Manager" informs administrator and citizen of UTOPIA the occurrence of fire event and optimal evacuation paths, and calls the most appropriate internal services of UTOPIA among services available at the situation.

(a) (b)

Figure 4. Snapshots of the Fire Accident Managerof UTOPIA in a smartphone: (a) A GIS map provided by the Fire Accident Monitoring, (b) An Evacuation path provided by the Fire Accident Monitoring.

Sensors report the data through ubiquitous sensor network to SOUL and SOUL infers the fire event using the sensed data [16]. When a fire event is inferred, SOUL calls context-aware services and sends the administrator the fire alarm through the mobile cloud and grid web service.

"Fire Accident Manager" shows the fire accident place in the GIS map as shown in Figure 4a. Figure 4b shows the current fire accident location in the fire accident building and an optimal evacuation route from a selected room in the building to exit safely.

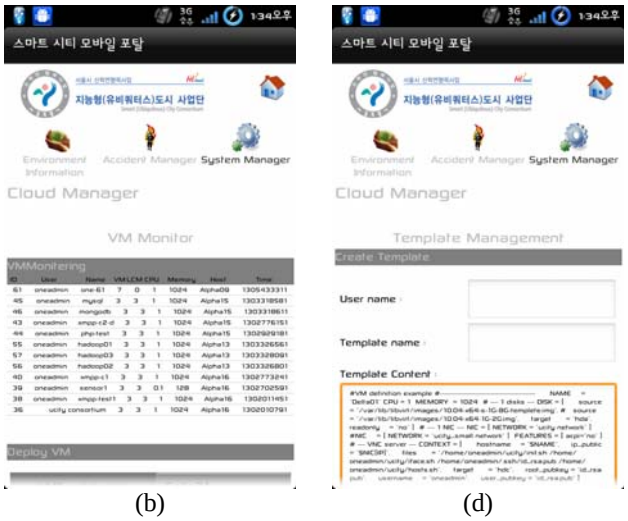
C. *Cloud Manager*

UTOPIA Mobile cloud and grid web service is the world's first approach to implement the cloud and grid platform into a smart city middleware so that the users can monitor the smart city and execute smart city services in Android based smartphone or tablet personal computers [5].

The Mobile cloud and grid web service is supported by Cloud Infrastructure Manager, Virtual Machine Job Manager, SSH client and vnc client. Cloud Infrastructure Manager plays the role of VM monitoring, VM template management, hosts management, users management and networks management. Figure 4 shows how it works in a smartphone in two cases.

Cloud Manager has sub-menus, such as VM Monitor, Template Management, Hosts Management, Networks Management and Users Management.

VM Monitor can show the state of virtual machine instances, enable users to deploy virtual machine instances in virtual machine template and to remove virtual machine instance in "Cloud Platform" of SOUL and provides vnc and SSH connection interfaces to access virtual machine instance.



(b) (d)

Figure 5. The snapshot of Cloud Manager of mobile cloud and grid web service of UTOPIA in a smartphone: (a) VM Monitor, (b) Templet management.

Figure 5a shows the user interface of VM Monitor. Deployment of virtual machine instances is made by pre-defined template image. Template Management manages description of template images.

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Figure 5b shows the user interface of Template Management. Hosts Management manages hosts in the cloud platform of SOUL. It can create and delete a host and enable and disable the given host.

D. Grid Manager

The Grid Manager consists of many components, such as real time performance monitoring, process management with resource brokering, account management, unified file transfer management and access Grid management. These components inherited the Grid resource manager of Seoul Grid Portal [17]. Figure 6 shows the snapshot of Grid Manager of mobile cloud and grid web service in a smartphone.

Figure 6. The snapshot of Grid Manager of mobile cloud and grid web service of UTOPIA in a smartphone.

E. Smart City Infrastructure Manager

"The Smart City Infrastructure Manager" enables the administrator of UTOPIA to do Ubiquitous Sensor Network (USN) Management, Scalable Video Streaming, Ad-hoc Network Management, Network Management, and so on, in SOUL with a smartphone or a tablet personal computer.

(a) (b)

Figure 7. The snapshot of operation of components in the Infrastructure Manager in a smartphone: (a) USN Manager, (b) Remote Device Manager.

Figure 7a shows how the USN Manager monitors USN in a smartphone. The USN Manager provides the administrator of UTOPIA with information, such as sensor ID, USN ID, USN topology, sensor working history, MAC address, IP address and so on of each sensor so that the administrator can manage these devices.

Figure 7b shows the operation of the Remote Device Manager in a smartphone. Functions of SOUL to control remote devices in a smartphone are based on Grid technologies, such as those in Globus Tele Control Protocol (GTCP) and Globus Toolkit 4 [18][19].

IV. CLOUD AND GRID COMPUTING PLATFORM

SOUL is an intelligent ubiquitous middleware which manages the Smart City Infrastructure Tier, offers smart city services, make a smart decision and give support the smart city portal tier. It is composed of four layers, such as Common Device Interface Layer, Context-aware Computing Layer, Ubiquitous Core Computing Layer and Common Application Interface Layer.

The Common Device Interface Layer (CDIL) provides the common device interface to the devices in the Smart City Infrastructure Tier. The Context-aware Computing Layer (CCL) processes data obtained from the CDIL and provides the intelligent context service to The Ubiquitous Core Computing Layer (UCCL). It does the intelligent reasoning. The UCCL is the core layer and has the cloud and Grid computing platform that provides various kind of cloud and Grid services. The Common Application Interface Layer (CAIL) support applications and provides a set of applications, such as the Environment Management, the Fire Accident Management, the Traffic Accident Management and so on.

The 4 layers cooperate together so that SOUL can provide various services. The administrator can control SOUL through the Smart city portal which has user friendly interface and provides web services. Furthermore, we added mobile and Grid web service providing facilities for the user who uses Android based smartphones and tablet personal computers [5]. Thus, users of UTOPIA can control and manage the SOUL and the smart city infrastructure tier easily, comfortably, conveniently and efficiently.

The mobile cloud and grid web service requires the cooperation of Cloud Manager, Virtual Machine Job Manager, SSH client and vnc client.

The Cloud Manager is the interface in the smart city portal and enables the smart city administrator to manage the cloud computing platform. It performs VM Monitoring, VM Template management, host management, user management and network management. Figure 8 shows the operation of the Cloud Manager.

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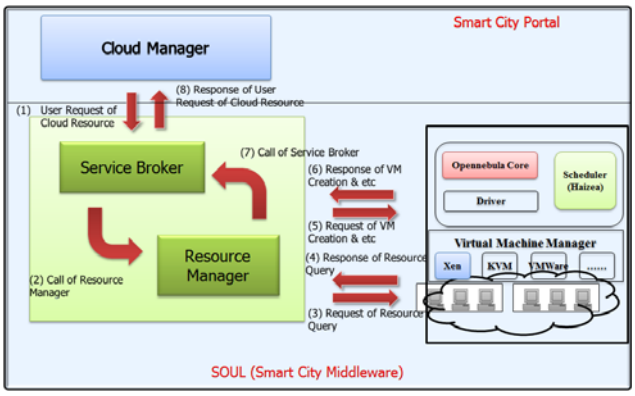

Figure 8. The cooperation of Cloud Manager in the Smart City Portal of UTOPIA with SOUL.

When a user requests the cloud resource to Cloud Manager, the Service Broker which is a gateway to the UCCL of SOUL processes the request. It calls the Resource Manager which manages the computing resource and cloud and grid platform in SOUL.

In order to find computing resources to respond to the user request, the Resource Manager queries a request to the Cloud Computing Platform and receives the result through XML-RPC API of OpenNebula. The Resource Manager sends the user request such as creation and deletion of virtual machine instance to the Cloud and Grid Computing Platform based on the result. The Cloud and Grid Computing Platform processes the user request and returns the response to the Resource Manager. The Resource Manager sends the result to the Service Broker. Finally, the user can see the result through Cloud Manager.

Virtual Machine Job Manager (VMJM) uses MVC model which makes the maintenance and extension of code easier and reusability better. VMJM executes web service, monitors web service, etc.

The web service can be executed only by authorized users and administrators. The user request is passed to the Resource Manager through the Service Broker. The Resource Manager checks the existence and status of the pre-created virtual machine instances. If the pre-created virtual machine instances exist, they are resumed by the Resource Manager. Otherwise, the Resource Manager creates a virtual machine from the suitable template. When the virtual machine instances are ready, the Service Manager executes the requested service on the virtual machine instances and sends the status information of the executed service to the Service Broker. Finally, the Service Broker sends the information and the user can see it through VMJM.

The operation of the monitoring web service is as follows. The user sends the service request to the Service Broker. The Service Broker passes the request to the Resource Broker. The Resource Broker requests the service list and the service status to the Cloud Computing Platform and returns the result to the Service Broker. The user can see the monitoring information through the Service Broker and the VMJM.

V. RELATED WORKS

The mobile cloud and Grid web service in smart city system, which has the smart city middleware based three tier paradigm, is unique since we cannot find any similar work like us.

Mobile cloud computing seems to be attractive since it can eliminate the constraints of weakness in computing power in mobile devices. H. T. Dinh at el. [20] defines that mobile cloud computing is a combination of mobile computing and cloud computing. Mobile cloud computing can have a variety of service model [21].

C. Doukas et al. [22] proposed @HealthCloud which is a pervasive health care information management system for mobile client system that has electronic healthcare data storage, update function and retrieval function using cloud computing. Its mobile cloud computing does not provide cloud management and job management on virtual machine through mobile devices.

E. E. Marinelli [23] introduced Hyrax that is a mobile-cloud computing platform. It uses Hadoop and runs in Android. It has a mobile cloud computing platform.

J. H. Christensen [24] proposed development methodology for smart mobile applications using Cloud computing and RESTful web service. The convergence of cloud computing and RESTful web service is similar to ours but it is the difference that ours is cooperatively operated with other functions in a smart city middleware in a smart city paradigm.

Eucalyptus [25], Globus Nimbus [26], OpenNebula [6] are open source cloud tools to construct and manage the cloud platform. They provide web interface. They are focused on managing cloud infrastructure and do not provide web services for the job management on the virtual machine. However, we provide the web services. Our mobile cloud and grid web service can execute and monitor smart city services on virtual machines anytime and anywhere through Cloud Manager and Grid Manager.

VI. CONCLUSION AND FUTURE WORK

This paper introduces mobile cloud and grid web services in a smart city paradigm called UTOPIA. UTOPIA has the 3 tier architecture, such as the smart city portal tier, the smart city middleware tier called SOUL and the smart city infrastructure tier.

SOUL has four layers, such as Common Device Interface Layer, Context-aware Computing Layer, Ubiquitous Core Computing Layer and Common Application Interface Layer. And the cloud and Grid computing platform belongs to Ubiquitous Core Computing Layer.

The mobile cloud and grid web services, such as Environment Information Manager, Fire Accident Manager, Infrastructure Manager, Cloud Manager and Grid Manager were explained. We showed that they can be serviced in Android smartphone or tablet personal computers. How the tree tiers of UTOPIA cooperatively support them was described and the internals of the cloud and Grid computing platform as well as the principle and architecture of UTOPIA and those of SOUL were explained. It is shown that the

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cloud and Grid computing platform, Cloud Manager and Grid Manager process big data in UTOPIA efficiently, easily and conveniently. We have a future plan to enrich the mobile cloud and grid web services in UTOPIA both in variety and quality by adapting new information technologies.

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