Implementing Cloud Computing in the Current IT Environments of Korean Government Agencies

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Abstract

This paper presents implementation strategies for building cloud-based IT environments for Korean central government agencies (K-Cloud Centers), to improve service delivery in the public sector and reduce the cost of government operations. This will be achieved by the introduction of cloud computing technologies in the data centers of the National Computing and Information Agency (NCIA). This paper also proposes an approach for building wide-area cloud-based IT centers for Korean local government autonomous entities (W-Cloud Centers), to enhance the efficiency of IT resource utilization via the consolidation of all IT resources operated by these local entities. Through the implementations of cloud computing in the public sector, the Korean government can realize a digital government capable of providing enhanced service environments, while reducing IT-related budgetary expenditures and protecting the environment.

Keywords: *Cloud computing for Korean government agencies, Cloud computing implementation*

1. Introduction

The information business in South Korea (hereafter simply referred to as Korea) was founded in 1978 and built its first national administrative network in 1986. It has been improving steadily since 2000, ranking 6^{th} in 2007 and 2008, and 1^{st} in 2010, in the e-Government Readiness Index of the UN Department of Economic and Social Affairs (UN DESA). Furthermore, in 2010, the web level and online participation quotient were both ranked 1^{st}. In contrast, the information and technology infrastructure declined in rank to 9^{th} in 2005, 10^{th} in 2008, and 13^{th} in 2010 [1]. The main reasons for this decline can be found in the inefficient management of the budget and the absence of an Enterprise Architecture (EA) plan for a systematized national Information Technology Architecture (ITA) [1]. From 2005 to 2007, the various server systems and infrastructures of most of the central government departments and public institutions were consolidated in Daejeon and Gwangju. However, the budget is still allocated to and managed by the individual administrative departments.

To resolve these issues, this paper proposes implementation strategies for building cloud-based IT centers for Korean central government agencies (K-Cloud Centers) by leveraging cloud computing technologies into the government data centers of the National Computing and Information Agency (NCIA), currently located in Daejeon and Gwangju. This paper also proposes an approach for building wide-area cloud-based IT centers for Korean local government autonomous entities (W-Cloud Centers), to enhance the efficiency of IT resource utilization via cloud computing and consolidation of all IT resources that are being distributed to and managed by the local autonomous entities. The ultimate goal is to build a digital government by organically connecting K-Cloud Centers and W-Cloud Centers into one big cloud-based infrastructure, to improve the delivery of public services to the Korean people and realize a green IT environment for all governmental and public institutions, with lower operating costs and lower energy consumption.

The remainder of this paper is organized as follows. Section 2 reviews the operational status and issues in the current IT environments of Korean government agencies. Section 3 presents the implementation strategies for the K- and W-Cloud Centers. The cloud computing technologies used to build the centers are also described. Section 4 discusses the expected effects of introducing cloud computing to the government agencies, and Section 5 concludes the paper.

2. Cloud Computing

Cloud computing is a hot buzz word in IT today, and its definition is still evolving. Gartner defined cloud computing as “a style of computing in which scalable and elastic IT-enabled capabilities are delivered as a service to external customers using Internet technologies” [2]. Wikipedia defined it as “the use of computing resources (hardware and software) that are delivered as a service over a network (typically the Internet)” [3]. More recently, the National Institute of Standards and Technology (NIST) published a definition of cloud computing as follows: “Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (*e.g.*, networks, servers, storage, applications, and services) that can be provisioned and released with minimal management effort or service provider interaction” [4, 5].

Following these cloud concepts, cloud computing can be seen as a new IT infrastructure that enables users to use IT resources by renting any scale of any computing resources at anytime and anywhere from remote locations via the Internet as a service, rather than purchasing the IT resources required [3, 6, 7]. Cloud computing service providers build a dynamically scalable, virtualized, and integrated IT infrastructure by deployment of hardware and software resources, and then provide rapid and elastic on demand resource delivery services to customers based on their IT infrastructure over the Internet [3, 7]. Figure 1 shows the structure of cloud computing.

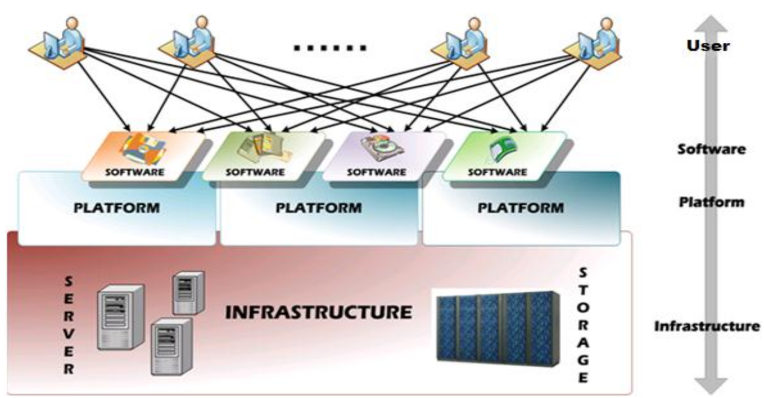


Figure 1. Architecture of Cloud Computing

The term “cloud computing” was first mentioned in 2006 by Christophe Bisciglia, a senior engineer at Google. Cloud computing then began to attract a great deal of attention as the next generation of IT after Amazon.com launched “Amazon Web Services” in 2006 and Google with “Google Apps” in 2007.

Cloud computing is seen as a natural evolution of grid and utility computing. It supports both grid and utility computing with additional features such as accessibility, scalability, flexibility, and reliability [8]. Figure 2 shows the evolution of cloud computing [9], and Figure 3 shows the key features of cloud computing adopted from existing IT technologies.

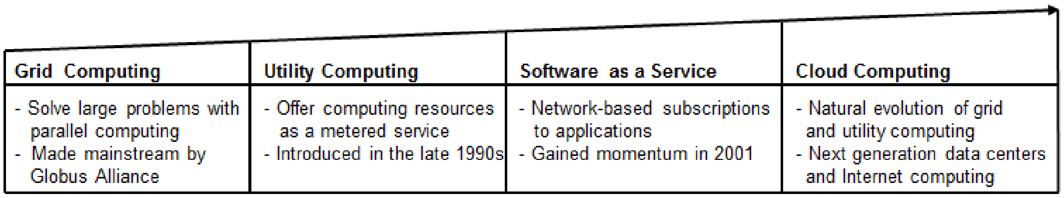


Figure 2. Evolution of Cloud Computing

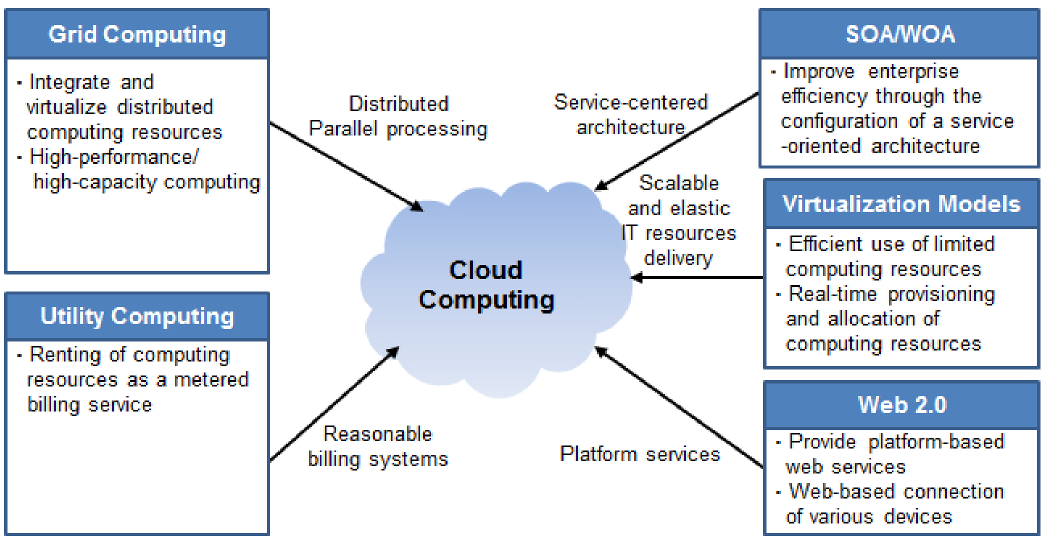


Figure 3. Key Concepts of Cloud Computing

The NIST describes the definition of cloud computing with five essential characteristics of cloud, three service models, and four deployment models. The five essential characteristics consist of: broad network access, measured service, on-demand self-service, rapid elasticity, and resource pooling. The three service models are comprised of: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). And, the four deployment models: with private cloud, community cloud, hybrid cloud, and public cloud according to providers and customers [5]. Figure 4 shows the features of the three service models and Figures 5 presents the characteristics of the four deployment models described by NIST.

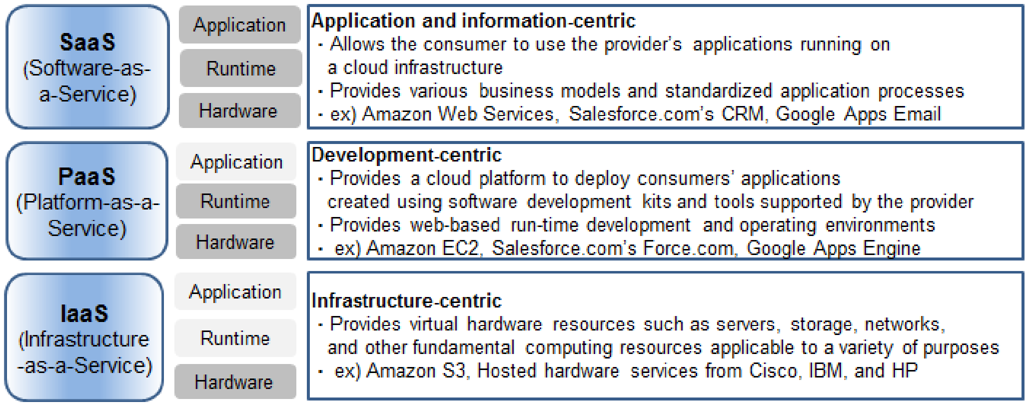
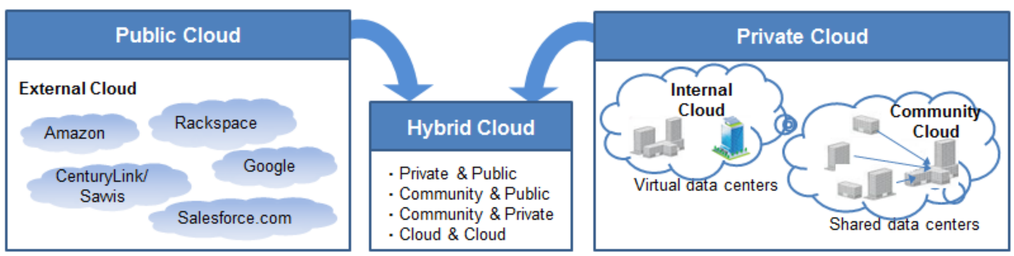


Figure 4. Features of the Three Cloud Service Models



	Public Cloud	Hybrid Cloud	Private Cloud	Community Cloud
Supply	Cloud service provider	Cloud service provider	Company IT Centers, CIO organization	
Customer	General consumer	Large/small and medium enterprises	Large enterprises	Large enterprises
Communication	Access via the Internet	Access through an Extranet(VPN)	Access via an Intranet (LAN)	Access via an Extranet (Private line)
KFS	Scale economies	Optimizing customers' investment efficiency	Top priority security and stability	Security and investment efficiency

* KFS(Key Factor for Success), VPN(Virtual Private Network), CIO(Chief Information Officer), LAN(Local Area Network)

Figure 5. Characteristics of the Four Cloud Deployment Models

3. Operational Status of Korean Government IT Environments

3.1. Central Government Agencies and Related Public Institutions

Before 2005, each department of the Korean government individually managed and operated its own IT resources for the country. Hence, investments in operating costs and manpower for these information resources were continuously redundant, resulting in efficiency issues in information management due to increased data processing costs. Along with this issue, most of the main information systems were located in general-purpose buildings that lacked standard equipment, increasing the risk of information loss through accidents such as fires and other natural disasters.

To solve these problems, from December of 2004 to October of 2006, the Korean government established the National Computing and Information Agency (NCIA) and built a government data center in Daejeon, consolidating 1,555 computer systems for 25 organizations, including the Ministry of Education, Science and Technology, the Ministry of Public Administration and Security, and Korea Customs Service. From April of 2005 to December of 2007, another NCIA data center was built in Gwangju, integrating 2,050 computer systems of 22 departments, including the Ministry of Construction and Transportation, the National Tax Service, and the National Police Agency. Through the establishment of these two NCIA centers, operation and management of the information systems of all central government agencies were successfully unified, ensuring the reliability of national information resources and protection against natural disasters. As of 2011, services for 47 government agencies were in operation [10]. Figure 6 shows the network configuration of the NCIA [10].

However, in spite of this centralized operation and management of national IT resources, computer systems are still being purchased by individual departments, and hardware systems are also separately allocated to and managed by each department. The computer resources are housed in the same buildings, but only physical location has been consolidated, and there is no actual integration of resources. The Korean government is trying to realize a practical integration of national IT resources by establishing an EA plan for a national ITA, but there are still institutional and technical issues to be resolved [11].

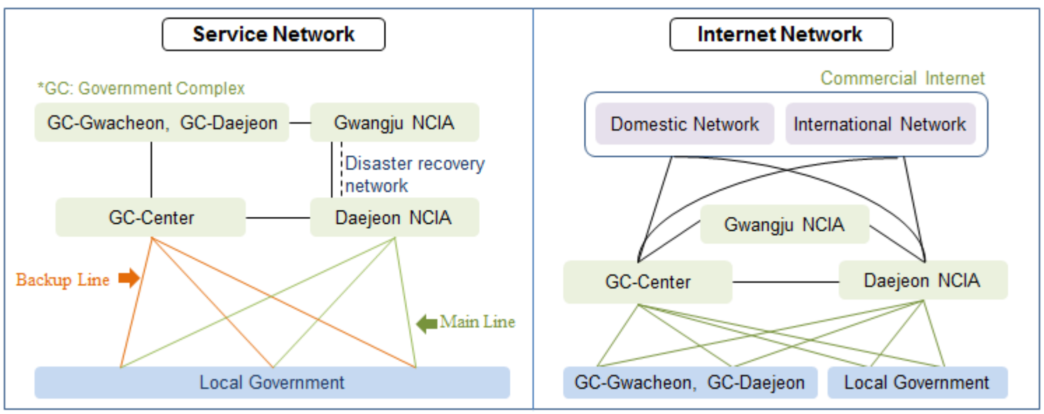


Figure 6. Network Configuration of the NCIA

3.2. Local Government Autonomous Entities and Other Public Institutions

According to the results of a survey on the computing network status of national organizations, conducted in December of 2004, 18.1% of the entire government information system was overloaded, necessitating immediate system expansion. The server composition ratio by capacity was 3% for large-scale servers, 20.6% for medium-scale servers, and 76.4% for small-scale servers, indicating that the percentage of small-scale servers was very high compared to the percentages of medium- and large-scale servers, resulting in significant increases in management costs. Furthermore, about half of the information systems were down more than once a month due to system failures, and 43% of the failures in a month lasted more than 30 minutes. After acknowledging these issues, from 2004 to 2007, the central government established the NCIA and built two NCIA data centers in Daejeon and Gwangju, consolidating the hardware infrastructures of all information systems for central government organizations and related public institutions [11].

However, local government autonomous entities and other public institutions still rely on a distributed operating method for their information systems. Consequently, significant problems can arise, posing various types of security threats, since systemized information systems and security facilities are difficult to equip when this type of distributed operating approach is used. In particular, it is hard to support recovery systems that allow a quick response to natural disasters. There is also a shortage of specialized technical manpower in every field, making it difficult to respond quickly to all types of system failures. Moreover, security systems for intrusion detection and prevention are only supplied to 65% of the local entities, and even such security systems do not be upgraded regularly. The duplex ratio of network backbones is only 31%. Thus, when a specific network backbone system fails, none of the network regions covered by the system can be operated until the corresponding equipment recovers.

Efficient workforce management is also necessary for operating various systems effectively. However, it is difficult to cultivate experts in every specific resource area, since core technical manpower is distributed among the various departments. Furthermore, the demand for online business processing increases as new information businesses are launched, but flexible specialized manpower is presently inadequate to satisfy this demand. Recently, there has been an increasing demand for interoperability and sharing of information systems among or within organizations, to improve the level of satisfaction with public services. However, such needs are also difficult to accommodate via current IT resource management approaches [12].

According to the results of a survey on the security level of IT resources (including personal computers (PC), networks, servers, databases, websites, system availability, and online trading) for a local autonomous entity from 2007 to 2009 as shown in Table 1, the security levels for PCs, databases and system availability were rated as “poor”, and the security level of online trading was rated as “dangerous” on a 4-point Likert scale (good, normal, poor, and dangerous) [12]. This is only an example of a single local autonomous entity, but other organizations are in similar condition.

Table 1. Electronic Government Public Services Security Level [12]

Security Area / Year	PC	Network	Server	DB	Web Sites	System Availability	Online Trading
2007	Poor	Normal	Normal	Poor	Normal	Poor	Dangerous
2008	Poor	Normal	Normal	Poor	Good	Normal	Poor
2009	Poor	Good	Good	Poor	Good	Poor	Dangerous

4. Implementation Plan for Building K- and W-Cloud Centers

To overcome the issues in the current IT environments of Korean central government agencies, the NCIA government data centers are transitioned to cloud-based centers (K-Cloud Centers) by applying cloud computing technologies. Issues pertaining to local government agencies are then addressed by consolidating the IT-related resources distributed to and operated in each local autonomous entity, and building two wide-area cloud-based centers, called W-Cloud Centers. The K- and W-Cloud Centers are then organically connected into one big cloud-based IT infrastructure for all government agencies.

4.1. K-Cloud Centers for Korean Central Government

The proposed implementation strategies for building K-Cloud Centers by introducing cloud computing technologies to the NCIA data centers are as follows.

First, an integrated management system must be developed by systematically defining business cooperation models between departments, as well as the administrative procedures for the computer resources in each department. The operational responsibilities for the integrated IT resources must also be clearly defined, and a portion of the IT-related budget allocated to each department should be integrated and jointly managed. In addition, service level agreement (SLA) policies should be established with the assistance of various legal systems.

Second, after establishing the basic environments for cloud computing, the NCIA data centers in Daejeon and Gwangju are transformed into cloud-based centers (K-Cloud Centers) by leveraging cloud computing technologies. Cloud computing technologies utilized to build the K-Cloud Centers are presented in Section 3.3.

Third, when a department or related public organization promotes a new information business that will make use of the IT infrastructure of a center, the center in question is informed of the requirements and usage period of the new business. If the center cannot meet the requirements, some information resources can be expanded as necessary. The budget for this is obtained from the budget allocated to the center, or if no budget has been secured for the center, the budget is redirected from the department requesting the infrastructure. When aging or deterioration of IT resources necessitates replacement and/or expansion of a system in any department, the corresponding K-Cloud Center is consulted, and the K-Cloud Center then purchases and manages the necessary equipment with full responsibility, instead of the department or public organization.

4.2. W-Cloud Centers for Korean Local Government

The goal is to establish two wide-area cloud-based centers (W-Cloud Centers) for local government agencies by dividing the six provinces, Gyeonggi, Gangwon, Chungcheong, Jeolla, Gyeongbuk, and Gyeongnam, into two districts. If one of these districts contains more large metropolitan areas or large equipped systems than the other, it is entitled to an additional cloud center. However, in view of the issues resulting from overlapping budget investments caused by inefficient management and multiple centers, the plan is to have only two centers, reorganizing the districts as necessary. The procedures for building the W-Cloud Centers are the same as those used for the K-Cloud Centers.

First, the server systems of related local autonomous entities and public institutions are consolidated into a corresponding W-Cloud Center, similar to the K-Cloud Centers of the NCIA. The integration procedure follows the same consolidation process for the various servers, storage devices, networks and security systems distributed to the local autonomous entities and related public institutions. Thus, in the first stage, location compaction of the IT resources is carried out, and then transition to a cloud computing environment is undertaken.

Second, cloud computing technologies are leveraged to the integrated IT resources and switches to provide a cloud-based IT environment, as in the K-Cloud Centers. Third, when a system in a W-Cloud Center needs to be replaced or expanded, there is a procedure similar to that used in the K-Cloud Centers for procuring the appropriate equipment. Fourth, after the W-Cloud Centers have been constructed, an interoperating and mutual backup system is established between the K- and W-Cloud Centers. Fifth, it is recommended that a system be developed for an online IT resource market for the trading of computer resources between the K- and W-Cloud Centers. By operating such a market among the cloud centers and/or private companies, a new method could be provided for generating profits, by promoting competition among the users of the system.

Figure 7 shows the configuration of the integrated K- and W-Cloud Centers.

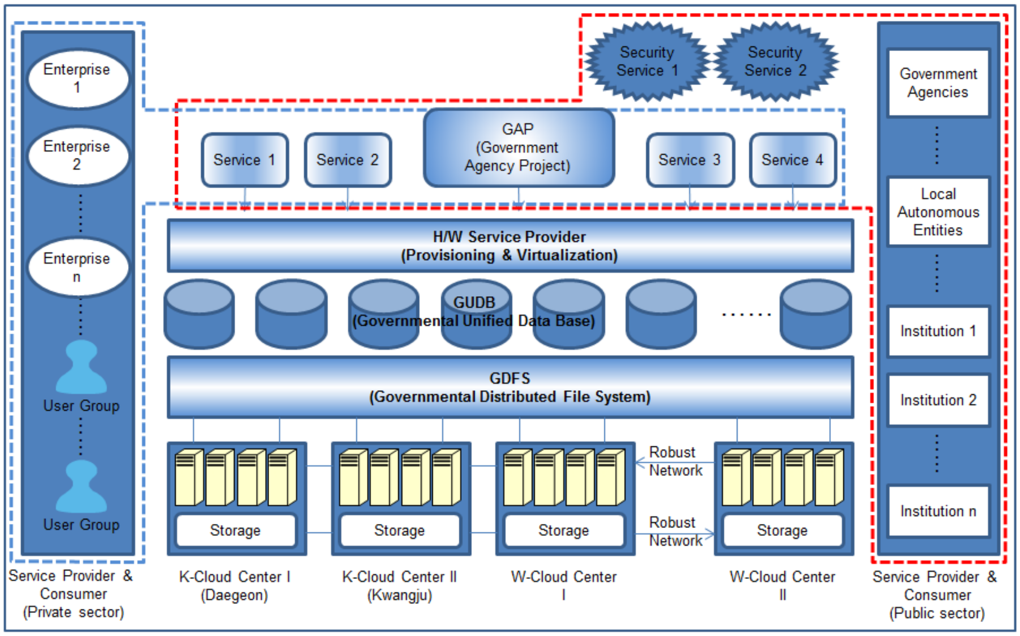


Figure 7. Configuration of the Integrated K- and W-Cloud Centers

4.3. Cloud Computing Technologies Used to Build K- and W-Cloud Centers

4.3.1. Resource Management Technology: To build a cloud-based consolidation center, various system resources, such as servers, storage and network systems, should be combined in one pool to realize a virtualization of the resources. Efficient management of the various types of resources in the pool requires resource management for a cloud computing environment, in which resource usage is monitored in real time, and the workload (derived from the monitoring results) is autonomously balanced among the resources via a self-management system. Furthermore, self-diagnosis and self-repair against various types of failures and accidents must be supported. Even more importantly, the relationship between stored data or information, virtualized server resources, and client computers should be dynamically defined to support the simultaneous operation of various user applications. In defining this relationship, data management technologies, such as mapping, partitioning, querying, moving, caching, and replication, should be properly applied to the cloud computing pool.

Among the available resource management technologies for building government cloud centers, Nimbus [13, 14] and ViNe (Virtual Network) [15, 16] can be considered. Nimbus supports dynamic configuration of an execution environment for the virtual machine created from a cloud computing pool. The execution environment of the virtual machine refers to the allocation of CPU or memory from the pool and the configuration of the software. However, the use of Nimbus would be hampered by the necessity of identically composing the network and system environments of all K- and W-Cloud Centers, since Nimbus does not effectively support an asymmetric network. On the other hand, ViNe provides a symmetric virtual network environment even when there are asymmetries between centers. Thus, if ViNe is used to construct a network environment between cloud centers, the speed of the network need not be uniform, and an official IP address need not be allocated to every system resource, making it easier to build an asymmetric network environment between the centers. Hence, ViNe is used to build the K- and W-Cloud Centers. Figure 8 shows the configuration of the K- and W-Cloud Centers, consolidated via the ViNe architecture [15].

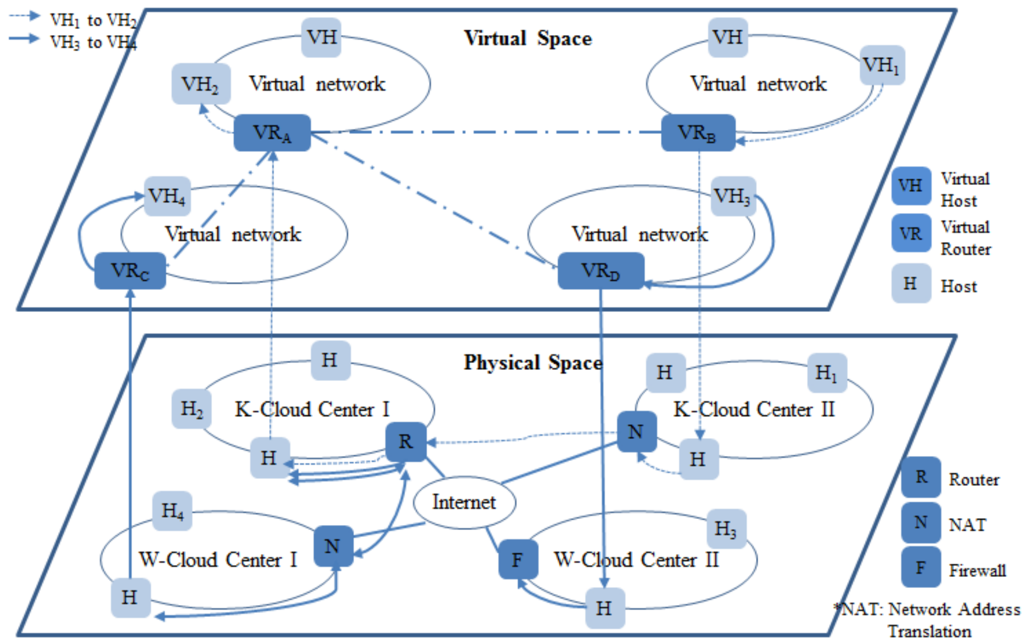


Figure 8. Configuration of the K- and W-Cloud Centers, Integrated via the ViNe Architecture

4.3.2. Distributed File System: Another important cloud computing technology for building the K- and W-Cloud Centers is the distributed data management technique to manage the huge amounts of data processed in the centers. A distributed processing technology based on stored data from parallel processing is also very important for handling user inquiries.

Google File System (GFS) from Google [17], Hadoop from Apache [18], and GLORY-FS from ETRI (Electronic and Telecommunication Research Institute) [19] can be regarded as applicable distributed file systems for the K- and W-Cloud Centers. This paper proposes a Governmental Distributed File System (GDFS) based on Apache's Hadoop as a distributed file system for the K- and W-Cloud Centers. The K- and W-Cloud Centers will generally require enterprise-scale storage so that GLORY-FS is not considered suitable for the present purposes. This is because it is not targeted for that scale of storage. On the other hand, Hadoop is an open-source project, which can bring reliability and scalability to distributed computing, and is also being used in many global IT companies, including Amazon.com, IBM and Yahoo. Thus, we believed that Hadoop can support solutions to the technical problems that may occur in the distributed data management of these cloud centers.

GDFS consists of a single name node that manages name spaces and controls file access by clients, together with numerous nodes that manage actual data storage. Since Hadoop provides a namespace hierarchy similar to that of a general file system, GDFS can support the basic features of a file system, including file creation, deletion, and modification. When a file is created in GDFS, it is partitioned into identically sized blocks (except for the last block). Multiple copies of the divided files are then stored in several physically distributed data nodes to protect against accidental loss at any particular node. When a file is deleted, it is not immediately removed from the system. The final deletion is performed after a certain time period. Delaying the final removal of a file not only aids file recovery but also decreases the load that may occur during the deletion process.

5. Expectations

A number of benefits can be expected when the cloud-based IT infrastructure is implemented in central and local government agencies and public institutions. First of all, the Korean government will be able to implement a ubiquitous green IT environment, thanks to the reduced carbon emissions and government operating costs obtained from the consolidation of various redundantly operated information systems. In other words, since purchases of unnecessary equipment can be avoided in the cloud-based IT infrastructure, a budget reduction can be expected, along with lower energy consumption.

Second, when IT resources are purchased in the current IT environments, most are operated in an on-premise mode, causing unnecessary expenditures and obstructing timely responses to user requests. However, in a cloud computing IT environment, resources are operated in an on-demand mode, reducing unnecessary costs and enabling prompt attention to user requirements.

Third, efficient management and arrangement of personnel resources is possible. In order to manage servers, storage devices and network systems effectively, the accumulated experience of many years and specialized knowledge are both necessary. To accommodate this demand, most government departments and public institutions are promoting the acquisition of related expertise by the corresponding personnel. Nevertheless, technical manpower is limited and the range of possible system errors is variable, making it difficult to respond to the issues. However, since all system resources are managed and operated by integrated specialized experts in cloud computing, various accidents caused by human error and inadequate operating conditions can be prevented. Furthermore, when system resources are managed individually by each organization, and a specific system resource generates errors, the information services provided by this resource are delayed or paused until the resource is recovered. However, such errors will not have a significant impact on service delivery in the cloud-based infrastructure, because a variety of information services are operated in a virtual system environment. Therefore, the overall status of the system resources and information services will be stable.

Fourth, in the current operating environments, system resources are managed and operated by each government agency, so that experts in some resource operations fields are redundant. However, in an integrated cloud-based operating environment, since the individual departments are not responsible for the maintenance of system resources, more efficient workforce management is made possible by relocating the expert manpower to other information fields.

Fifth, data centers are generally regarded as “electricity hogs”. The reason for this is that the actual IT resources in a data center consume only about 30~40% of the total energy. The remaining 60~70% is used for maintaining the temperature of the data center, and for transferring and converting the power itself. Such energy consumption will be reduced through location consolidation, resulting in further reductions in carbon emissions.

6. Conclusion

This paper presented implementation strategies for building cloud-based IT environments for Korean central and local government agencies (K- and W-Cloud Centers) by adopting cloud computing technologies. It also proposed an implementation plan for a ubiquitous green IT environment for all government agencies and public organizations by connecting K- and W-Cloud centers into one big cloud-based IT infrastructure. We believe that cloud computing is a desirable solution for future IT services, providing rapid, flexible, and high-quality service delivery to the public sector.

Through the establishment of a cloud-based IT infrastructure, the Korean government can obtain a number of benefits. First, the government can implement green IT that reduces the costs of the government operations and energy consumption by consolidating various redundantly operated information systems. Second, it provides an environment that can respond to user requests promptly via an automatic provisioning process based on on-demand operation. Third, more efficient management and arrangement of personnel resources are possible. Forth, the overall status of system resources and IT services will be stabilized, since various accidents caused by human error and inadequate operating conditions can be prevented in a cloud-based infrastructure.

The most important reason for introducing cloud computing to the public field is the reduction of at-large IT-related costs, which can serve as the best method to respond actively to a dynamically changing environment. Careful analysis of the investment benefits and opportunity costs is certainly necessary before transitioning from the existing legacy environment to cloud computing. In particular, the introduction of cloud computing to public agencies requires intensive analysis and preparation based on public interest and security [20]. Once the validity of introducing cloud computing technology has been established, a systemized plan such as EA should be chosen and promoted. A number of advanced countries, including the USA, UK, Japan and Germany, have already leveraged cloud computing in the public field, and realized budget reductions and carbon emission reductions for green IT implementation. Therefore, our government should eventually seek new and innovative solutions for the future IT service environment, to realize high-efficiency green government IT.

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