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High-Performed Virtualization Services for In-Cloud Enterprise Resource Planning System

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Abstract. *The crucial problems of system failure due to unexpected down-time and failover between physical hosts have always been encountered in service-oriented hosts in enterprises like ERP system that will cause data loss and system operation terminated immediately. In order to resolve the problems mentioned above, this paper introduces high-performed high-availability in-cloud Enterprise Resources Planning, deployed in the virtual machine cluster, together with access control authentication and network security. As a result, the cost-performance (C-P) ratio evaluated from the experiments shows that the proposed approach outperforms two well-known benchmark ERP systems, namely in-house ECC 6.0 and in-cloud ByDesign.*
Keywords: In-Cloud enterprise r esources planning, High availability, Access control authentication, Network security, Cost-Performance ratio

1. **Introduction.** Nowadays the service-oriented hosts in enterprises like Enterprise Resources Planning (ERP) system have often encountered the crucial problem of unexpected down-time or system failure that will cause data loss and system operation terminated. Traditionally a real host is difficult to transfer everything to another host timely and then resume its task as usual, and further data cannot be updated to the latest ones. In this paper we introduce high availability architecture to in-cloud services for tackling the above-mentioned crucial problem of unexpected downtime or system failure. Besides this paper gives a scheme that makes good use of virtual machine cluster [1] [2] [3] to resolve the failover problem as well. This paper introduces in-cloud ERP [4] [5] in virtual environment, and mobile devices users can easily access in-cloud services via Wi-Fi/3G

with access control authentication [6]. As shown in Fig. 1, a open source ERP, Open-ERP [7], has deployed successfully. Additionally, its access control authentication [8] [9] has brought into the virtual machine to achieve identity verification, safe sign-in, and attendance audit, as shown in Figs. 2 and 3. Then, detecting potential BotNet [10] and malicious attacks [11] in the network can efficiently increase the network security.

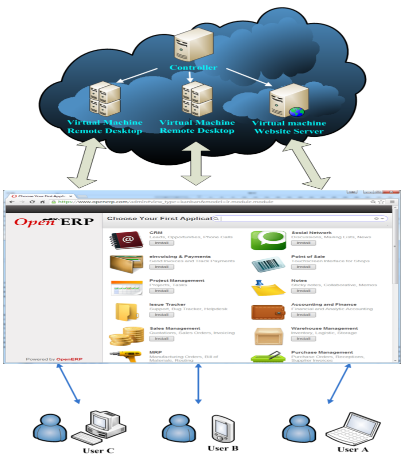


FIGURE 1. in-cloud Open- ERP deployment.

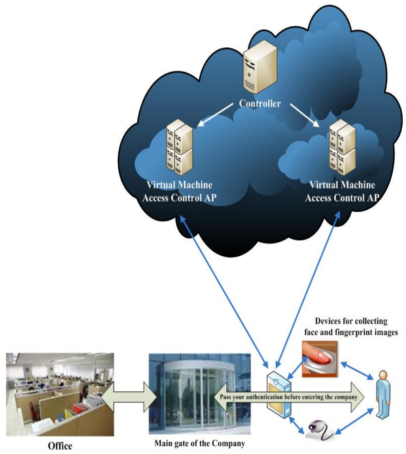


FIGURE 2. Access control in a firm.

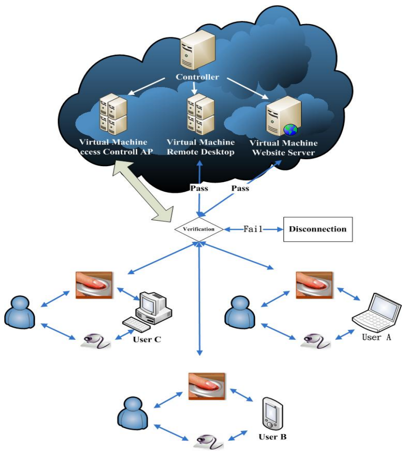


FIGURE 3. Access control authentication in cloud.

2. Authentication and network security for cloud-based ERP.

2.1. In-cloud ERP and authentication. Virtual machine clustering system in cloud is an integration of virtualization, virtual machines, and virtual services so that it can make existing resources be fully applied, such as VMware ESX/ESXi Server [12], Microsoft Hyper-V R2 [13] or Proxmox Virtual Environment [14]. This system can let users run many operating systems in a single physical computer simultaneously which largely decreases the expense of purchasing PCs. Most important of all, it has the following major functions, including virtual machine live migration, virtual storage live migration, distributed resource scheduling, high availability, fault tolerance, backup and disaster recovery, the transfer from physical machines to virtual machines, direct hardware accessing, virtual network switching, and so forth. This study introduces Proxmox Virtual Environment as the cloud computing and service platform with the virtual environment.

The kernel-based virtual machine (KVM) acts as the main core of virtual machine, and it has installed the kernel of Linux-based operating system. OpenERP is adopted in this study as ERP application which provides many solutions for open sources software in the future, having it more expandable, making a great progress on cost deduction. The in-cloud ERP is established as follows: (1) Build Proxmox VE virtual machine cluster and through WebPages manage the virtual machine. (2) Create a virtual machine and set up its guest operating system in Proxmox VE virtual machine cluster. (3) Set up OpenERP in virtual machine, inclusive of OpenERP AP, PostgreSQL database, and web interface for end-user. (4) Sign-in at http://localhost:8096 or http://IP:8096 with the browser on virtual machine, pop up a login page of OpenERP, and then sign-in to administrator to install the necessary modules as a result of an interface of user management (5) Set up AP Server for biometrics security [15]. When users sign-in, it will collect users biometric features with capturing devices at client side as the evidence of legal or illegal sign-in [16].

2.2. **Network security for in-cloud ERP.** The use of virtual machines to build firewall and gateway receives multiple benefits, that is, easy management, high scalability and low cost. For example, a virtual machine equipped with pfSense (http://www.pfsense.org/) or Zentyal (http://www.zentyal.com/) system is all quite easy to manage a network system as shown in Fig. 4. However ERP databases containing sensitive information is not allowed to access its data directly from the external network, instead to set up an intranet one for data access. According to a variety of different virtual machine managements, there are many different approaches to virtual network layout or configuration. For example, if virtual machine management has its own built-in NAT function, IT manager may install an OpenERP [7] into a virtual machine with two network interface cards, one connected to the external network via the bridge mode for internet, whereas the other connected internally via NAT mode for intranet. Without software firewall for protection, the network does not come up with a hardware firewall, apparently leading to less secure environment in which even common network attacks may also cause system crash as shown in Fig. 5. In addition to the scenario mentioned above, IT manager does not consider the use of the built-in NAT function in virtualization management, and in contrast takes alternative scheme into account employing pfSense or Zentyal to build a software firewall server. This way goes through port forwarding service to redirect http port packets to OpenERP. External network can not access the interior one where port forwarding service is not allowed or set. Besides its protection against the common network attacks can also ensure that the user interface gains both the security and stability as shown in Fig. 6.

3. **High availability for in-cloud ERP.**

3.1. **Virtual machine high availability.** (1) Virtual machine live migration: when an execution error occurs at a node and causes an interruption, virtual machines at that node can be migrated themselves to the other nodes in which the left tasks of the failure node are also to be continued herein. A prerequisite is to ask for a shared storage as well as two units or more servers, for example, a Proxmox VE system as shown in Fig. 7. (2) Virtual storage live migration: the system provides HA in virtual machines and accordingly HA will also support to virtual storage as well. Generally connecting a shared storage (e.g., SAN), the system may achieve the purpose of reaching a low downtime. When an execution error occurs at a node and causes an interruption, virtual storage at that node can be migrated itself to the other nodes to resume the left tasks of the failure node. (3) Distributed resource scheduling: Virtual machine management system such as Hyper-V [13] imports Non-uniform Memory Access (NUMA) mechanism for the resources allocation, in which computing cores and memory are divided into nodes, and each virtual

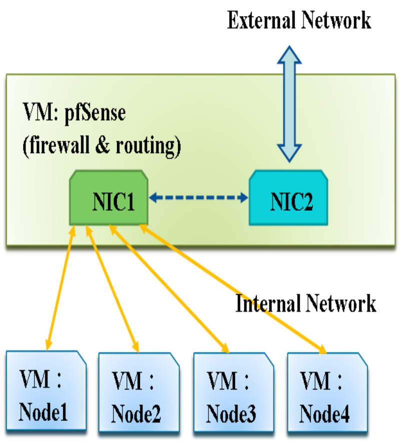


Figure 4. Application pfSense establishing firewall and gateway in cloud.

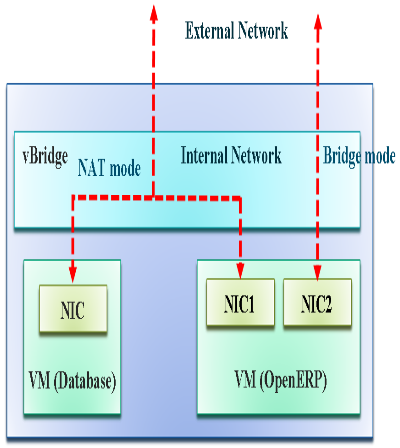


Figure 5. A built-in NAT function in virtualization management.

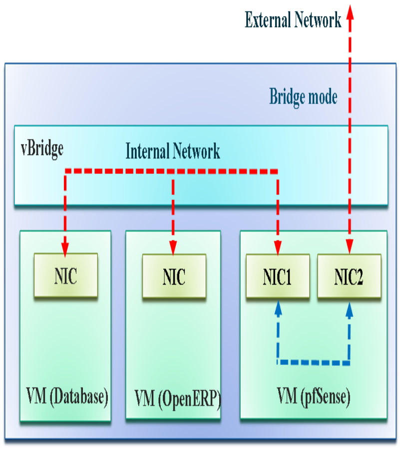


Figure 6. Application pfSense establishing network architecture.

machine attaches the corresponding node in accordance with the amount of the allocation of resources. That is, the resources of a virtual machine may be allocated from different server hardware resources as shown in Fig. 8. (4) Fault tolerance: The main principle of reaching a zero downtime such as VMware vSphere [12] is that when a primary virtual machine is running, the system automatically generates a redundant virtual machine, totally equal to the primary one, located in other servers to synchronize the task. Once the system detects the primary virtual machine failure, the running task is immediately transferred to the redundant virtual machine, this redundant virtual machine becomes the primary virtual machine at once, and the system will replicate another redundant virtual machine once again as shown in Fig. 9.

3.2. **Network high availability.** With Link Aggregation Control Protocol (LACP) [17], network interface cards can utilize Network Bounding techniques that will combine multiple network interface cards together, and in the meantime set the parameters of network interface card related to the HA function. For example, Linux systems can use the software ifenslave to gain fault-tolerant features in the combined network interface cards.

That is, as one of network interface cards fails, work load will automatically switch to another one to carry on the successive networking tasks as shown in Fig. 10.

3.3. **Storage high availability.** In general, storage device of iSCSI or NAS is able to provide hard drive array (RAID) function. If the system needs to consider both cost and performance, and fault tolerance solution, type of RAID 0+1 disk array is suggested to organize hard drive array. In addition, iSCSI or NAS storage device also probably risks the failure incident and hence the storage device needs to consider HA. At present, the storage device manufacturers have incorporated synchronous backup mechanism, but in contrary the traditional storage devices may not have this feature, which an additional server is required for implementing the synchronization between them as shown in Fig. 11. According to HA of virtual machine, network, and storage as mentioned above, a diagram of in-cloud platform with high availability is illustrated in Fig. 12. With the minimum facility required for HA structure, the system needs at least two high-performance computing servers, two high-speed network switches, and two high-reliability storages to establish a in-cloud platform with HA.

4. **ERP system assessment.** According to the functional mean time in average functional access time for each ERP application platform on Eq. (1), we derived the respective each platform mean time Eq. (2). After that a performance index is defined on Eq. (3) and sequentially normalized to be a value ranging from 0 to 1 on Eq. (4), where we refer to this as a normalized performance index corresponding to each ERP application platform. In Eq. (1), FAT_i is a functional access time for a specific function (e.g., Create New Customer Master Data, Create New Material Master, Create Sales Order, or Search Function) running in a ERP application, and accordingly FAT_i represents a functional mean time for various functions; in Eq. (2), PMT_k stands for a platform mean time for a variety of ERP applications (e.g., ECC6.0 [18], ByDesign [19], or OpenERP), and the coefficients λ_1, λ_2, ..., λ_M act as a weighted average; in Eq. (3), PI_k means a performance index for a specific ERP application platform; in Eq. (4), $\overline{PI}_k$ represents a normalized performance index for a specific ERP application platform.

$$FMT_j = \frac{\sum_{i=1}^{N} FAT_i}{N} \, , \; j = 1, 2, 3, ..., M \tag{1}$$

$$\begin{aligned} PMT_k &= \frac{\sum_{j=1}^{M} \lambda_j FMT_j}{\sum_{j}^{M} \lambda_j} \, , \; k = 1, 2, 3, ..., L \\ s.t. \quad & \sum_{j}^{M} \lambda_j = 1 \, , \; 0 \le \lambda_j \le 1 \end{aligned} \tag{2}$$

$$PI_k \equiv \frac{1}{PMT_k} \cdot Scale \, , \; k = 1, 2, 3, ..., L \, , \; Scale = 10^4 \tag{3}$$

$$\overline{PI}_k = \frac{PI_k}{PI_{k_{MAX}}} \, , \; k = 1, 2, 3, ..., L \tag{4}$$

The ERP cost about capital expenditure, operational expenditure, and business agility has broken into 3 items that are software cost, monthly cost, and downtime cost, respectively. In particular the downtime cost for each ERP application platform will be

Figure 7. HA optional setting of VM in Proxmox VE.

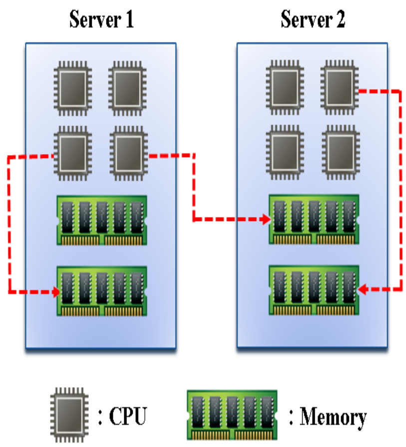


Figure 8. Hardware resources allocation based on NUMA in Hyper-V R2.

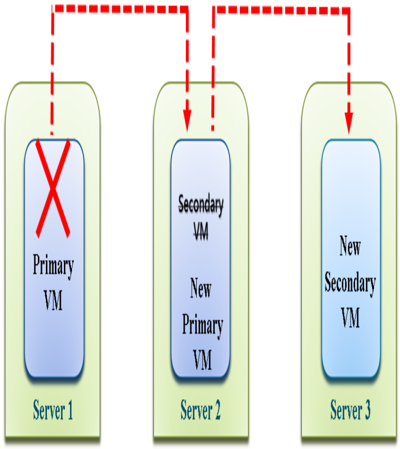


Figure 9. Fault tolerance mechanism by VMware vSphere.

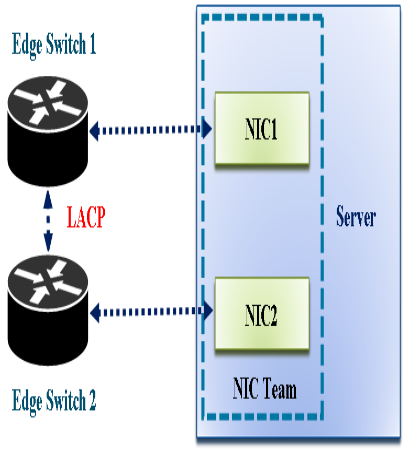


Figure 10. Realizing the architecture of network HA

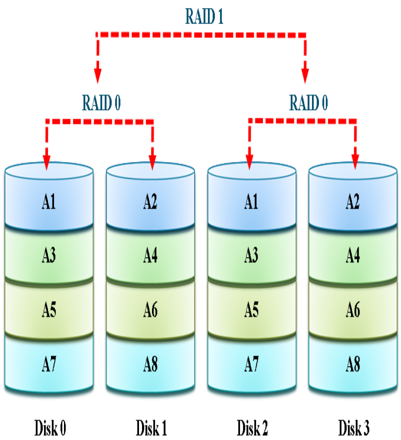


Figure 11. RAID 0+1 system diagram.

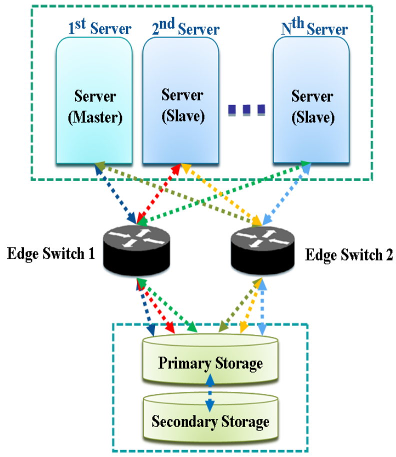


Figure 12. Implementation of an in-cloud platform with HA.

proportional to both the ratio of VM density (minor part) and the ratio of ERP performance index (major part). Here IT manager is proceed to the trial of ERP system as planned for a period of two years where we assume an unexpected downtime may occur once per year and the downtime cost of ECC6.0 is roughly estimated US$ 1000 at a time. Moreover, a formula for calculating the ERP system expenditure has been derived on Eq. (5) where $VMD_{ECC6.0}$ represents a VM density of a kind of virtual machine manager applied to ECC6.0 and VMD_k to the other ERP application platforms; $PI_{ECC6.0}$ stands for ECC6.0 performance index and PI_k for the other ERP performance indexes. For the second term in Eq. (5), $\cos t_{monthly}$ presents the operational expenditure month by month. There is no the cost of software package for Open ERP due to open source software. However, the cost of software package for ECC6.0 in service charge (approximate US$ 164,884 per year) is great than that of ByDesign (approximate US$ 24,733 per year).

$$\begin{aligned} &Cost_{ERP_k} = \left(\alpha \cdot \left(\frac{VMD_k}{VMD_{ECC6.0}}\right) + \beta \cdot \left(\frac{PI_k}{PI_{ECC6.0}}\right)\right) \cdot \cos t_{downtime\ at\ ECC6.0} \\ &+ \cos t_{monthly} \cdot period + \ \cos t_{software}\ , \\ &k = 1,\ 2,\ 3,\ ....,\ L \\ &s.t.\ \ 0 \le \alpha \le 1,\ \ 0 \le \beta \le 1,\ \ \alpha + \beta = 1 \end{aligned} \tag{5}$$

The assessment for the various ERP software package is evaluated according to so-called cost-performance ratio CP_{ratio_k} defined on the Eq. (6) where PI_k represents the performance index as shown on Eq. (3) and $Cost_{ERP_k}$ stands for the operation cost as shown on Eq (5).

$$CP_{ratio_k} = \frac{PI_k}{Cost_{ERP_k}}\ ,\ k = 1,\ 2,\ 3,\ ....,\ L \tag{6}$$

5. **Experimental results and discussion.** There are three experiments and a discussion presented in the following sub sessions.

5.1. **High availability testing.** First in order to verify the high availability of the network, after the network used the function of Network Bonding, IT manager removed one of the network cables form an edge switch for a few seconds to check whether or not the network satisfies fault tolerance at this situation. After a test of ping command for 50 times, as a result, the connection quality is good because there is no packet loss during the cable removal, achieving the goal of network high availability as shown in Fig. 13. Next in order to verify whether the servers and storage devices achieve high availability, IT manager shut down a server on which a virtual machine was currently running, while the server-mounted storage device will correspondingly fail. Test results show that failover completed successfully because the virtual machine correctly transferred (migrated) to another server as shown in Fig. 14.

5.2. **Access control authentication and ERP testing.** Users sign-in at http://IP:8096 with the browser on an Android smart phone to sign-in in-cloud ERP remotely via 3G/WiFi as shown in Fig. 15 and next based on biometric measures the process of access control authentication [20] [21] is activated to capture human face and fingerprint at mobile device, deliver them to back-end server for identification, and then return the result back to mobile device. It takes about 2 seconds for identity verification as shown in Fig. 16. After that we begin to test ERP routines. Users sign-in at http://IP:8096 with the browser on a personal computer to sign-in in-cloud ERP remotely via 3G/WiFi and then go for access control authentication at PC. After that we begin to test ERP routines on PC as shown in Figs. 17 and 18.

5.3. **Network security testing.** Without checking the instructions in the input field, testing tool has been forced to insert illegal SQL statements to access the sensitive information in database. This is a scenario for the simulation of malicious attacks into a sensitive database. Therefore, the use of two Open Source SQL Injection checking software as the testing tool, that is, Java-based development jSQL Injection and .NET-based development SQL Power Injector. With this tool to launch a series of automatic attacks into the presentation part of the web interface, thereby IT manager is able to check whether or not outsider can directly access to the database content. As a result, there is no SQL Injection vulnerability displayed in the testing tool and the following figures also show no database found in the target, as shown in Figs 19 and 20.

5.4. **Assessment and discussion.** According to the experiments of online testing in the daily use of ERP in enterprise within a week, it was found that the growth rate of the use of in-cloud ERP increased dramatically approximate 5.2 times than the stand-alone ERP. In terms of the hardware cost in Taiwan, it costs the user $1,002.5 on the hardware equipment for a stand alone ERP, i.e. in-house ERP, in which the additional cost will be paid for air conditioning monthly fee of $18.4, space rent of $26.7, and hardware equipment maintenance fee of $16.7. In regard with the amortization schedule using monthly payment for a period of two years, it costs $2,486.3 for monthly expenditure. In other words, it costs an average monthly usage fee of $103.6. In contrast, renting an in-cloud ERP service in virtual environment only need about $50.1 monthly payment and it saves 1.07 times the cost of in-house ERP, i.e., reducing the monthly expenditure a lot. In addition to monthly expenditure, we have to consider the cost of software package for ERP applications. Prices of them usually vary with different levels of functionality for a series of ERP products or various brands in the market. In particular, the high-level and complicated version of ERP commerce product, for example, Sap or Oracle, is more expensive than the standard one. As shown in Table 1, the comparison of the number of database accesses in ERP system and the monthly expenditure for ERP, the proposed in-cloud ERP is exclusively superior to in-house ERP. Two well-known benchmark ERP systems, ECC 6.0 [18] and ByDesign [19], are used to compare with the proposed one, according to ERP functional performance according to operational speed of various ERP functions where the proposed approach outperforms the others as listed in Table 2. Finally, ERP system assessment based on cost-performance ratio has been evaluated and clearly the proposed one wins the best grade as listed in Table3.

Table 1. ERP access frequency and its operational cost

Testing Item	Case A:, in-house ERP	Case B: ,in-cloud ERP	Ratio of Case B to Case A
Number of Access (times/day)	63	328	5.206
Monthly Expenditure (USdollars/month)	103.6	50.1	0.484

Table 2. ERP operational speed (unit: minute, second)

Function	ECC 6.0, (in-house ERP)	ByDesign, (in-cloud ERP)	OpenERP, (in-cloud ERP)
Create New Customer Master Data	7:10 min.	4:40 min.	3 min.
Create New Material Master	12:40 min.	10 min.	8:30 min.
Create Sales Order	5:20 min.	2 min.	1:30 min.
Search Function	2:10 min.	5 sec.	2 sec.
Average	6.83 min	4.19 min	3.26 min

Table 3. ERP cost-performance ratio (cost unit: US$)

ERP	Performance Index	Operation Cost	C-P Ratio	Operation Cost	C-P Ratio	Operation Cost	C-P Ratio
		α=0.5,β=0.5		α=0.2,β=0.8		α=0.4,β=0.6	
ECC 6.0, (in-house ERP)	146341	334,254	0.44	334,254	0.44	334,254	0.44
ByDesign, (in-cloud ERP)	238806	53,300	4.48	53,679	4.45	53,427	4.47
OpenERP, (in-cloud ERP)	306905	4,300	71.38	4,958	61.90	4,519	67.91

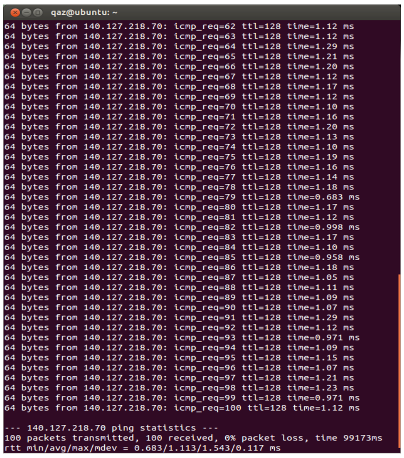
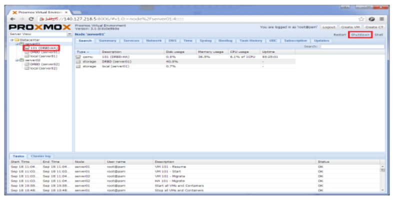
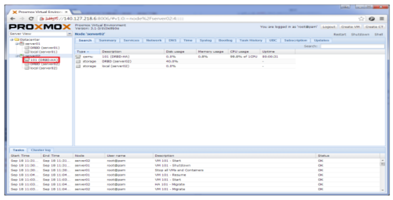


Figure 13. Ping command to check the network quality.



(a) Before VM migration



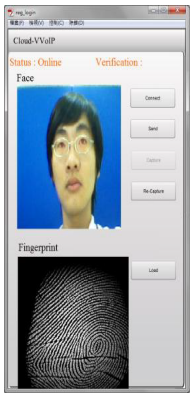
(b) After VM migration

Figure 14. Failover using a virtual machine migration.

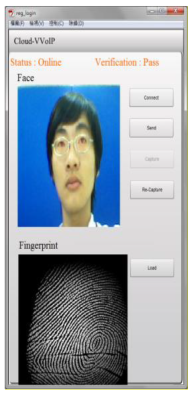
(a) List of products

(b) Sales order

Figure 15. Sign-in in-cloud OpenERP at smart phone.



(a) Capture images



(b) Identification

Figure 16. Face recognition and fingerprint identification at smart phone.

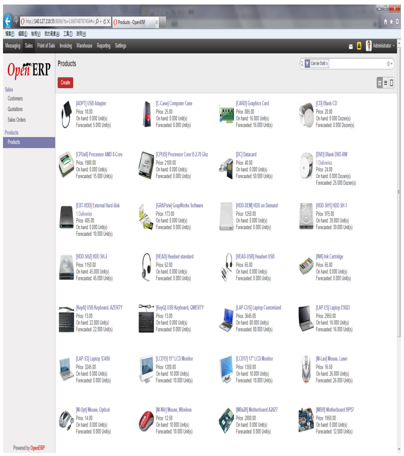


FIGURE 17. List of products of in-cloud OpenERP as sign-in at PC

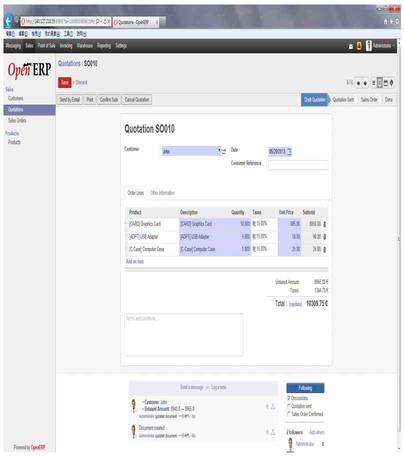


FIGURE 18. Sales order of in-cloud OpenERP as sign-in at PC.

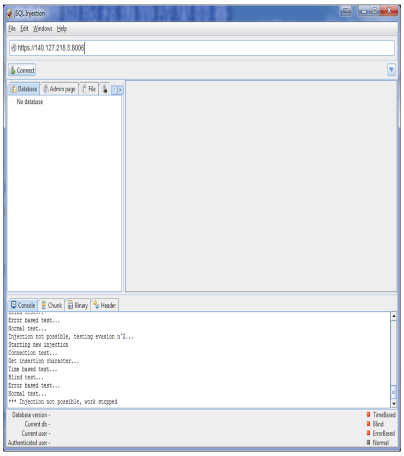


FIGURE 19. Test of SQL Injection attack using jSQL Injection v0.4.

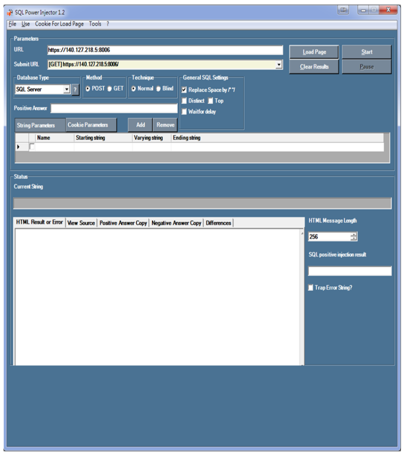


FIGURE 20. Test of SQL Injection attack using SQL Power Injector 1.2.

6. **Conclusion.** This paper introduces high availability architecture to build an in-cloud Enterprise Resources Planning (in-cloud ERP) deployed in the virtual machine cluster together with access control authentication and network security. This scheme can resolve the problem of unexpected down-time or system failure causing data loss and system operation terminated as well as the failover problem always has occurred between physical hosts. Access control authentication and network security have been designed to prevent the vulnerability of service-oriented hosts form external attacks like fraud and intrusion. As a result, the experiment show that the proposed approach in this paper outperforms two well-known benchmark ERP systems, in-house ECC 6.0 and in-cloud ByDesign.

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