

## The Development of Cloud Computing and Its Challenges for Taiwan

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**Abstract**—Along with the growing attention, cloud computing is not only changing the computing paradigm, but also the style of computing in which dynamically scalable and virtualized resources are provided as services over the Internet. Cloud computing introduces a lot of chances, as well as, challenges in the new trend. Taiwan has been well known as a major Information Communication Technology (ICT) manufacturing traditionally. Many Taiwan's hardware products have been top ranked in the global market. Taiwan has realized the trend that Cloud Computing is leading to and has reacted to integrate its resources from the government, industry, academia, and research centers, by initiating strong incentive programs for cloud computing, with an intension to transform an ICT Island into a Cloud Village. In this article, we describe the status of the development of cloud computing technologies and its future challenges for Taiwan.

**Keywords**- Cloud Computing, Open Source Software (OSS), Cloud Village

### I. INTRODUCTION

As one of the most expectative trend and new evolution for Information Communication Technology (ICT) in the 21th century, cloud computing, which has gained significant attention in recent years [1][10], is not only changing the computing paradigm, but also the style of computing where dynamically scalable and virtualized resources are provided as services over the Internet [1][11]. It introduces tremendous opportunities, as well as, challenges.

For the last two decades, Taiwan has been well known as a major ICT manufacturing island in which more than ten ICT hardware products have been top ranked in the world-wide market. Along with the previous E(Electronic)-Taiwan, M(Mobile)-Taiwan, and I(Intelligent)-Taiwan projects, in 2009, Taiwan government initiated the Cloud Computing Industry Development Program (CCIDP). CCIDP aims to assist cloud computing development of Taiwan from the

aspects of supply, demand, and management, and to transform Taiwan from an ICT Island to a Cloud Village. Taking advantages of the solid foundation of ICT hardware manufacturing, in the area of IaaS, Taiwan has been successfully migrating from component products such as server and storage to the Green Cloud Data Center Total Solution and cloud storage appliances [14]. In the areas of PaaS and SaaS, due to the relative weakness of the software industry compared to the strong hardware industry in Taiwan, the Open Source Software (OSS) has been a very good resource in driving the development of cloud computing systems. In sum, Taiwan has integrated its resources from the government, industry, academia, and research centers and has initiated strong incentive programs for cloud computing.

In this paper, we survey and discuss the status of the development of cloud technologies, as well as the corresponding challenges for Taiwan. The organization of this paper is as the followings: In Section II, we describe how the strengths of and resources from industry, government, academia, and research centers are integrated to promote Taiwan from an ICT island to a Cloud Village. Sections III explain the stages of cloud computing for Taiwan. In Section IV, open source software and applications for cloud computing are described. Finally, concluding remarks along with the challenges faced are made in Section V.

### II. MOVING TAIWAN FROM AN ICT ISLAND INTO A CLOUD VILLAGE

Since 2002, Taiwan has initiated several important projects to promote Taiwan into an ICT island, including *E-Taiwan*, *M-Taiwan*, and *I-Taiwan* projects, which are aimed to develop the information and communication infrastructure across the Taiwan Island, to boost industry competitiveness, to upgrade government performance, and to transform

Taiwan into an E-Leader in Asia. These projects had established a comprehensive communications network consisting of wired, wireless, mobile and broadband networks.

As a result of the above projects, services to the public including effective e-government services such as single window one stop service and *G2B2C* (Government to Business to Customer) e-document, online education, entertainment, health care, and transportation services have been supplied with high quality. These projects intended to make a *WISDOM* Taiwan (*W*: Wireless and broadband convergence, *I*: cultural and creative Industry, *S*: Superior e-government, *D*: Demand-driven applications, *O*: equal digital Opportunity, *M*: Manpower cultivation) have constructed a highly competitive IT infrastructure, as well as, encouraged innovative and creative integrated ICT services, which have constructed a very strong foundation to make Taiwan into an ICT island.

Starting from 2009, Taiwan government set up a Cloud Computing Industry Development Plan (CCIDP) to promote the development of cloud computing technologies, applications, solutions, and services. CCIDP program is expected to build up initiatives to the development of cloud computing industry in Taiwan. Cloud Computing services

include the integrated services from IaaS, PaaS, and SaaS. Without proper collaboration and integration among the service providers, the cloud computing services will have a lot of barriers to overcome in Taiwan. Taiwan Cloud Computing Association (TCCA), which involves all the major cloud computing players from government, industry, and academia, has been formed to coordinate domestic and international cloud computing alliances. Taiwan National Science Council (NSC) has also allocated extra funding to support cloud computing and Open Source Software (OSS) based technologies research. From the human resource aspect, Taiwan Ministry of Education (MOE) has provided extra funding to enhance the training of cloud computing engineers. Forty universities have been funded by MOE to put cloud computing and service courses to their syllabus. MOE has also collaborated with government funded research organization and enterprises such as ITRI cloud computing center, Quanta Computer Inc., Delta Electronics Inc., and T-Cloud Computing Inc. to offer cloud computing experimental environment to these universities. Ministry of Economic Affairs (MOEA) has offered funding and guidance to support enterprises moving into cloud computing services. More than six hundreds small and medium size enterprises (SMEs) have moved their ICT services to cloud computing services.

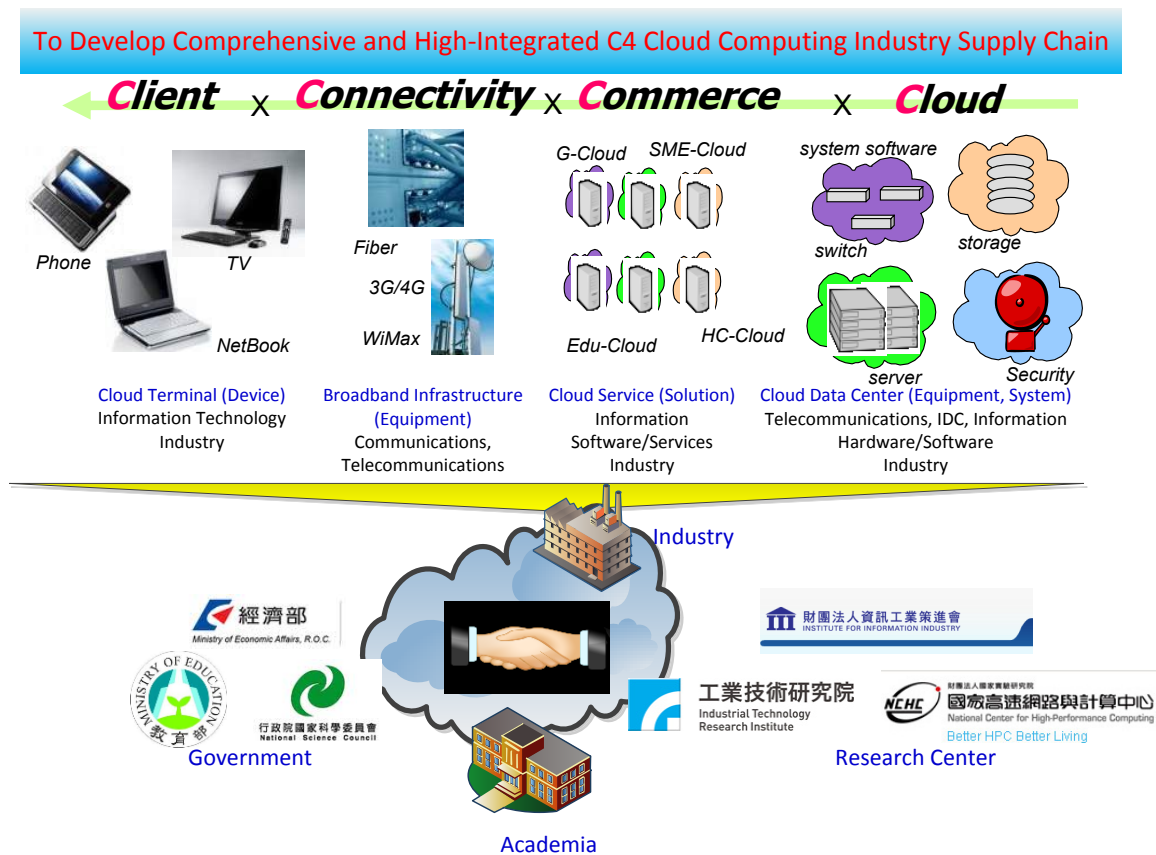


Figure 1. The C4 cloud computing industry supply chain in Taiwan

As shown in Figure 1, CCIDP has set up an ecosystem development strategy for a comprehensive and highly integrated C4 (Cloud, Commerce, Connectivity, Client) cloud computing industry supply chain, including the development of cloud systems and operating data centers (*Cloud*), the development of cloud applications (*Commerce*), continue to promote broadband development (*Connectivity*), and R&D cloud device products (*Client*).

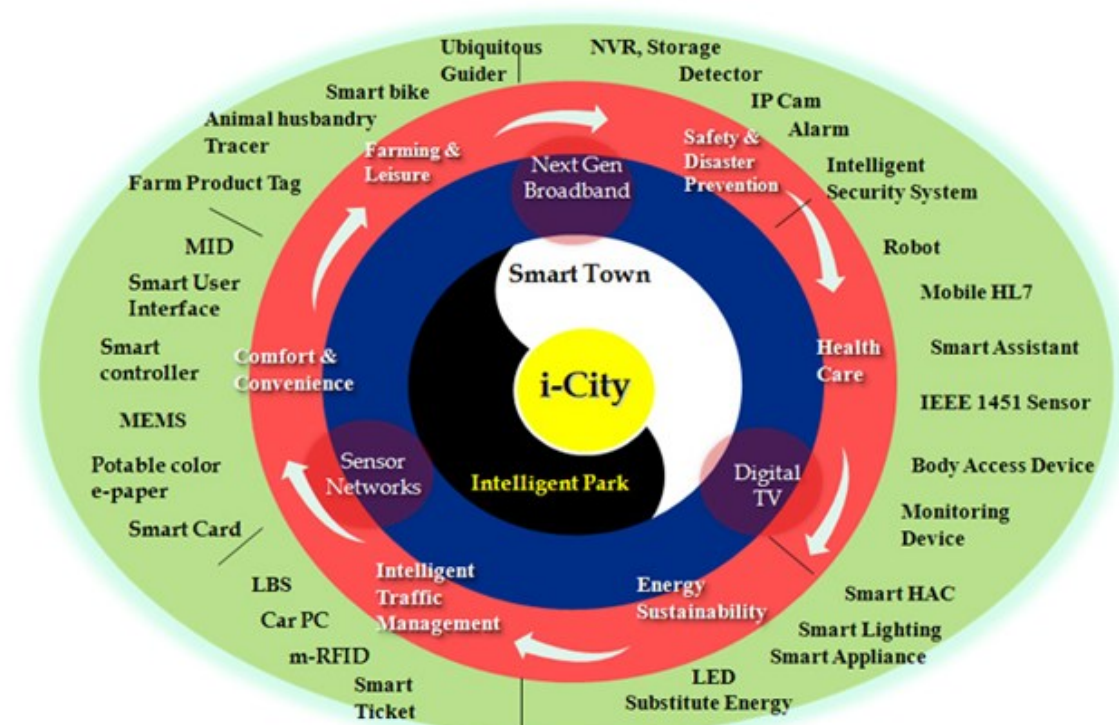
On the other hand, to promote the innovative and creative service, the Smart Living Technology and Service Program and the I-Taiwan i236 project [8], were planned to integrate the resources of government and industry. The goal of this project is, firstly, to foster cloud service companies to experiment their creative and innovative services in living zones and explore the successful services to worldwide market. Secondly, it encouraged traditional non-IT enterprises to apply ICT technology to increase their competitiveness. As a whole, the goal of i236 is to maximize the Taiwan industry global competitiveness.

As shown in Figure 2, the i236 project aims to create two types of smart living zones, which are Smart Town and Intelligent Park; system solutions with emerging technology will be developed using three communication networks, which are next generation broadband, digital-TV, and sensor networks, with innovative and sustainable service/business models for six applications, which are safety and disaster

prevention, health care, energy sustainability, intelligent traffic management, comfort and convenience, and farming and leisure applications.

The smart living zones plan has been placed in practice already at some selective areas, with the goals that a small town can be served with the applications of smart home, telecare, intelligent transportation, energy conservation, and sustainable energy. Living zone type 1 Smart Town is now field experimented at four cities, including Taipei, Nantou, Yilan, and Kaohsiung cities. Living zone type 2 Intelligent-Park, on the other hand, is experimented in the selective areas like the Taichung City Precision Machinery Innovation Technology Park and Kaohsiung Linhai Industrial Park.

Taiwan has a number of achievements and ongoing projects for cloud computing. Many of the cloud computing solutions are OSS based and focus more on the support of enterprise cloud computing. From large scale mobile green cloud data center solutions and plug-and-play storage appliances, enterprise cloud platform, to government cloud and education cloud, Taiwan has its own plans and strategies for the development of IaaS, PaaS, and SaaS. With all the integrated efforts and initiative programs, Taiwan has shown its strong ambition to move from an ICT island to a Cloud Village at full speed.



Source: i236 Smart Living Technology & Service Program  
<http://www.i236.org.tw>

Figure 2. Scope of i236 project

### III. THE SATGES OF CLOUD COMPUTING FOR TAIWAN

With the plans like CCIDP and i236, the Taiwan government has announced cloud computing as next important visioning future industry for domestic service, export technologies and appliances. In 2004, Taiwan initiated the “M-Taiwan” project. The first goal was to enhance the Taiwan broadband infrastructure, by constructing wired broadband infrastructure and by building FTTH pipelines and wireless communication network using WiMAX technologies. The second goal was to sponsor and promote creative and innovative mobile application development and services. The Taiwan government has encouraged relevant manufacturers and organizations, and related academic institutions to work together on the development of the WiMAX standards and products. Services based on WiMAX are now available in most of the metropolitan areas of Taiwan.

Leveraging upon the advantages of this infrastructure, Taiwan ChungHwa Telecom (CHT)[5] set up the Cloud Server Operator Center, the Cloud Computer Testing Center, the Cloud Computer Research Center, and the Cloud Service Experience Center in 2011. CHT has also released its IaaS program called HiCloud CaaS (Compute as a Service)[7], which includes features such as membership management, secure payment mechanism, quality control, searching, and real-time customer service, and which has become a major IaaS for most of Taiwan domestic SaaS providers. Some of the SaaS providers were originally using the IaaS provided by Microsoft and Amazon.

In 2009, the Taiwan Industrial Technology and Research Institute (ITRI) established the Cloud Computing Center for Mobile Applications (CCMA). The goal of the ITRI CCMA is to enable Taiwan to build data centers for the world. The Cloud Operating System (Cloud OS) developed by CCMA is an end-to-end software stack that runs cloud applications and operates a cloud center. It is designed for the conversion of physical data centers into an IaaS for supporting Amazon web services such as the services on a set of commodity hardware platform. The Cloud OS can multiplex virtual data centers on a physical data center. By using the Cloud OS, a cloud center operator can provide IaaS services; such as virtual data center provisioning, without any support from other software suppliers. Comparing with traditional OS (such as MS Windows and Linux), the Cloud OS operates at a higher level of abstraction in which the data center is considered as a resource to be managed.

The Taiwan Institute for Information Industry (III) has also announced its green cloud total solution lately. In 2011, III released the design of CAFÉ-CAKE. CAFÉ, the Cloud Appliance for Enterprise, is a cloud rack that can support users in building a private cloud of small cabinet systems for small and medium enterprise market. CAFÉ can apply

multiple uses of PC, blade chassis, and rack cabinet. The OS of CAFÉ is called CAKE, the Cloud Appliance Kernel Environment. The system is an open source based and full Chinese language software. The design concept is KVM Hypervisor (Kernel-based VM Hypervisor) that supports virtualization management capabilities, for example, the administrator can set the policy management virtual machine. That is, when the load is high, CAKE will generate a new virtual machine on a different computing node for better performance and load balancing; on the contrary, when the load is low, CAKE will enable the migration of virtual machines to another physical server to turn off the unnecessary machine operation in order to save energy. CAFÉ-CAKE therefore proposes attractive choices of green total solutions for enterprise cloud computing.

Our research group integrates both KVM and OpenNebula OSS to implement Tunghai Cloud IaaS environment to provide a virtual environment for users [13]. With supplying user friendly web interfaces, the complexity of the management and access to cloud resources can be reduced. Furthermore, the green power management is proposed for load balancing for virtual machine management on cloud[15]. It includes three main phrases: (1) supporting green power mechanism, (2) implementing virtual machine resource monitor, and (3) integrating a dynamic resource allocation. We have developed a mechanism to support cloud virtualization and reached Hadoop high availability which is called virtualization fault tolerance.

In addition to providing IaaS products and solutions for Taiwan cloud computing domestic market, Taiwan major ICT manufacturers have focused on developing cost-effective total solution for world-wide IaaS providers, including mobile green data container for public cloud service and small cabinet system for small and medium enterprise private cloud solution. We believe the transition from hardware component manufacturers to high value-added IaaS total solution providers can create great opportunities for continuing its high impact on the ICT exporting business.

An interesting project sponsored by Taiwan NSC is to work on a middleware for cloud computing based on the Service-Oriented Architecture (SOA) that employs the agent technology to monitor Quality-of-Service (QoS) requirements, Service Level Agreements (SLAs), dynamically analyze resource allocations and deployment. The purpose of the middleware for cloud computing is to provide complete transparency of the underlying technology and the surrounding environment and an easy, cost-effective, and secure way to access services from the cloud environment. NCHC has also built a PaaS platform by using Hadoop due to its capability to store and process vast amounts of data based on large clusters built of commodity hardware. This platform can add and remove MapReduce computing robustness and storage resources without shutting down the entire system.

To pursue the Chinese language based market, Taiwan has signed the Economic Cooperation Framework Agreement (ECFA) between the governments of the

People's Republic of China (mainland China) and the Republic of China (Taiwan). This cross strait agreement includes a plan to develop OSS-based PaaS.

Software as a Service (SaaS) allows customers to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web browser. The customer does not need to manage the underlying cloud infrastructure including network, servers, operating systems, storage or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.

Many SaaS applications, like services for ERP, CRM, accounting, training, government administration applications, etc., are under development in Taiwan following the trend towards cloud computing. Some of them are migrating from existing applications to the cloud environment and some are creating new SaaS, such as mobile devices applications on IOS and Android platform. Creating high value-added SaaSs and moving from product-oriented to service-oriented provisioning, and supporting pay-as-you-go or pay-as-you-use business model are currently well accepted concepts in Taiwan. Taiwanese IT companies should focus on innovative application services and initiating particular business models in SaaS to strengthen the competitive advantages of cloud computing. Most of the SaaS providers focus their market in Taiwan at this current stage and also aim at international market for their second step, especially for the Chinese market.

#### IV. OPEN SOURCE SOFTWARE BASED CLOUD COMPUTING SYSTEMS

Through the open innovation and global software development, OSS has been an important resource to speed up the cloud computing development. To promote open innovation and software development, Taiwan NSC has launched an open source project and cloud and security special track projects from 2003 and 2010, respectively. In order to ensure the quality and the documentation of the open source software, funded projects and the implementation of the system are required to follow the Capability Maturity Model Integration (CMMI) approach and the results are to be released based on open source spirits. Documentations including requirement, specification, design, and implementation of the open source based software development are mandatory. The NSC projects address different issues in cloud computing and provide a variety of tools and technologies, which collaboratively enhance the cloud system design such as its security via testing services. To support open innovation, NSC has collaborated with Open Source Software Foundry (OpenFoundry) of Taiwan Academia Sinica, and provided a platform that can be used as a software development environment with support for software download, and communication with corporations and overseas academics for research cooperation and result promotion. In 2011, 30 projects have been supported, these research topics cover infrastructure, security, healthcare,

virtualization, data storage, QoS and SLA, and service of cloud computing.

Table 1. Open source software for Taiwan cloud computing

	Open Source Software
IaaS	CloudOS, CAFÉ-CAKE, KVM, Xen, OpenVZ, Virtualbox, OpenNebula, OpenSTACK, OpenQRM, Ubuntu Enterprise Cloud (UEC), Eucalyptus, FreeNAS, Nimbus, Ceph, etc.
PaaS	Hadoop, Hadoop4Win, DRBL-Hadoop, OpenNode, AppScale, Cloudera, Google App Engine (GAE), Facebook App Platform, Cloud Foundry, JBoss, etc.
SaaS	eyeOS, Nutch, Crawlzilla, COSA, OpenERP, Vtiger CRM, OwnCloud, etc.

OSS has a high impact to academic research, industry system development, and the government projects in Taiwan. Table 1 shows the most popular OSSs that have been used in Taiwan. Its openness and availability have created opportunities for researchers and industry to be able to conduct experiments or develop cloud computing technologies and systems easily and cost effectively. Adapting the most popular OSSs can also increase the interoperability and elevating the chance for setting common standards for cloud computing platforms.

There are many open source projects for cloud computing systems in Taiwan's research organizations[12]. ITRI's CloudOS[4] System is the first large-scale cloud computing operating system which has integrated various kinds of management software. It can simultaneously satisfy tangible and virtual resource requirements, provide databank services, and also set up security management mechanisms. It can also allow users to be able to instantly switch usage to a different network and carrier functions between public and confidential Cloud OS platforms, helping companies to save on cost and the trouble of integrating different software for setting up a cloud computing service. Moreover, it can enable high-quality services comparable to Infrastructure-as-a-Service, similar to the offerings from international companies such as Amazon.

CAFÉ-CAKE [6] was developed by III and Ulteo, which includes technology for delivering Windows and Linux applications as well as web applications to the desktop through a unified and user friendly interface. Its architecture is shown as Figure 3. CAFÉ-CAKE is an open source project, and will significantly reduce the total cost of computing for enterprises, small to mid-sized businesses, as well as provide cost effective solution to governments, schools, and universities. These solutions will allow users to access their professional data and applications from almost any connected devices and will also provide enhanced security and significantly simplified management.

COSA (Cloud Object Storage Appliance) [9], developed by III, is a document object management system for small and medium business. It provides several features which include document object manipulation and management,



synchronization among different client devices, sharing among different users, and the support of access from heterogeneous devices. The objective is to extend such sophisticated features and ease the complexities to everyday users and applications.

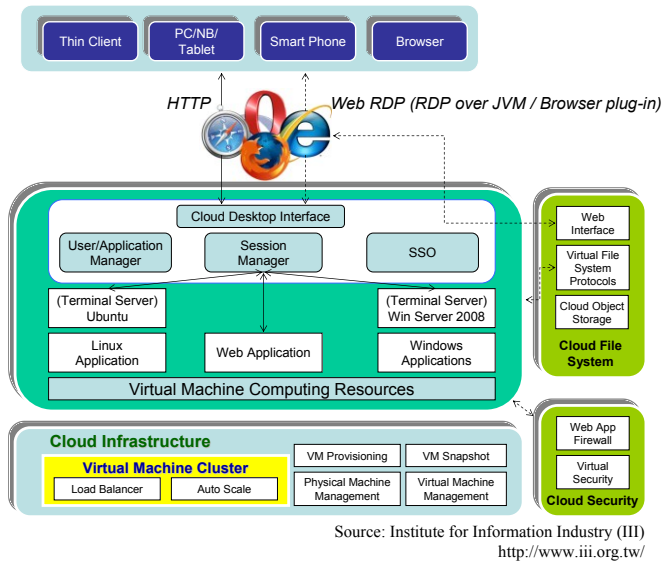


Figure 3. CAFÉ system architecture

NCHC has built cloud computing platforms using OSS, including Crawlzilla, DRBL-Hadoop and Hadoop4Win. Crawlzilla is a project about Enterprise Search Engine. DRBL-Hadoop is about massive deployment of Hadoop Cluster. Hadoop4Win is a project for Education Platform by running Hadoop and Hadoop distributed file system on Microsoft Windows OS.

In summary, OSS will be a very important source for the future development of Taiwan cloud computing, which not only can speed up the technology development but can also help the integration of cloud computing services due to the availability of source code. By utilizing innovative OSS with Taiwan self-developed technology in IaaS, PaaS, and SaaS, it is possible for Taiwan to develop total solutions for cloud computing, which can provide domestic as well as international services.

## V. CHALLENGES AND CONCLUSIONS

Cloud computing has great potential and capability for the new ICT evolution. By providing promising strategies, along with cooperative practices through the integration of resources from government, industries, and academics, Taiwan is still facing a lot of challenges on the development of cloud computing services and technologies.

OSS has been an important resource for the development of software applications in the past. Taiwan will continue to develop OSS-based IaaS, PaaS, and SaaS systems in the future. The alliance and integration of solution providers to form an effective supply chain of cloud computing services

will be another key issue. Finally, it also needs to promote innovative and creative cloud computing services.

With a very strong foundation on ICT manufacturing industry, Taiwan is able to produce hardware components cost-effectively in its supply chain. While the ICT market is moving from a product-oriented one to a service-oriented one, the profit margin of selling these computer components or devices is getting lower. Taiwan should develop high value added services in the future. In order to make this transition successfully and sustain its strength in ICT market in cloud computing age, Taiwan needs to promote and invest more on software industry.

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