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Promises of Cloud Computing: Underlying Technology That Supports Transformation "From Possession to Utilization"

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1 Introduction

The term "Cloud" represents a system of information processing based on the internet, which is often depicted metaphorically as a cloud floating over the sky. Computations and information processing are carried out, not by the computing machines at your fingers, but by computing resources cloud computing center located somewhere in the cloud, and the results are brought to your display.

Cloud computing is considered an evolution of the systems of computing power utilization from batch processing, remote processing, time-sharing processing, personal computing, and client-server systems. In a broader context, cloud computing is considered to embrace IT technologies and utilization activities overall in the near future, which will serve as the engine for transformations on people's personal lives, business activities and social frameworks, as these are promoted by the development of IT technologies and the prevalence of the internet.

Therefore, the term "cloud" allows a variety of interpretations depending on the viewpoint and on what aspect of it is in focus. There is a lot of debate about it, producing divergent opinions even among experts in this field.

In the report published by the Ministry of Internal Affairs and Communication "Report from the Panel on ICT Vision - the Strategy to Realize Smart Ubiquitous Network Society," June 5, 2009,[1] and the report from the "Study group on cloud computing and Japan's competitiveness"[2] which started from July 22, 2009, under the initiative of the Ministry of Economy, Trade and Industry, the terms "Cloud" and "Cloud Computing" are used in a broad sense that encompasses the whole of information-communication processing that will become increasingly dependent of the Internet. By the same token, this report uses the "cloud" in place of "cloud computing," and overviews the services it provides and its future potentials. This report largely skips the detailed descriptions of technological elements, as the readers can find many appropriate references elsewhere (see, for example, reference[3]) However, a short explanation of the environment surrounding the cloud (so-called "ecosystem") is given in this report.

All the potentials of cloud computing are not guaranteed to come to fruition in the future, and we cannot tell when they will become a reality. Mainframe computers, although being made a mockery of as surviving dinosaurs, are still in use. It is only natural to consider that a variety of computers and systems, including legacy systems, will continue to be used depending on the application.

We should rather see the innovative nature of cloud computing in such aspects as design scalability and the operational scheme of software that enables establishing cloud computing centers, an effort towards favorable TCO (Total Cost of Ownership) in a comprehensive manner with an eye to reduce CO_2 emission, and the underlying basic concept "from possession to utilization" and the realization of a scalable market on a global scale.

2 What is Cloud Computing

2-1 Services Provided by Cloud Computing

The services provided by cloud computing are broadly classified into the following three categories: (a) provision of hardware resources such as CPU, memory and storage, i.e. HaaS (Hardware as a

Services)/IaaS (Infrastructure as a Service), (b) provision of application software including word processors, spreadsheets, and customer management systems, i.e. SaaS (Software as a Service), and (c) provision of development environments for programmers, i.e. PaaS (Platform as a Service).

First, we will look into the overview of the HaaS (i.e. provision of hardware resources). To obtain this service, the user first accesses the website of the cloud service provider (the user is assumed to have already gained authentication), and input the required information for the cloud computer on the service screen: this includes configuration information of the computer (CPU specifications, memory capacity and HDD, the operating system to be used, etc.), period of use, and the utility rate. Upon receiving the request, the cloud center prepares a "virtual" computer in the data center according to the requirements from the user, and the user is allowed to use it through the Internet as if he/she has a real-life computer at his/her hand for the period he/she requested to use it.

The cloud hardware services currently available include Amazon Elastic Computer Cloud (EC2), Simple Storage Service (S3), Microsoft's Azure, and others provided by internet service providers such as IIJ and Nifty. Amazon EC2, considered the herald of these lines of services, allows users to rent a part of Amazon's internet-controlling computer resources and charges the user on an as-used basis. IBM's Blue Cloud, on the other hand, aims at providing enterprise users with cloud services and it includes provision of dynamically scheduled computer resources for the development and testing of products in the IT and telecommunication areas. The underlying cloud center lines up tens of thousands of low-cost servers for the provision of cloud services at a low price.

Next, we explain the overview of the cloud software service, SaaS (Software as a Service). This service makes the applications (mail software, business software, etc.) deployed in the cloud center available to users through the Internet. Charging systems include as-used basis, license, as well as a free-of-charge scheme.

At present, major cloud software services include Google Apps (including Gmail, famous for its free-of-charge provision of up to 7GB capacity) and Salesforce CMR (the client management application provided by Salesforce.com).

The application software provided through the use of the Internet does not require installation on the individual PC; users are able to operate the software through a Web browser and memory and storage can be expanded as needs arise. For example, Google's Gmail allows the use of email communications by simply setting up a mail account through the use of a personal authentication function provided by a cell-phone system. This service provides, despite the fact that it is free of charge, a range of high-level functions such as spellchecking, mail search and grouping, schedule alignment with group members, a sharable calendar, security protection (e.g. spam mail elimination), as well as allocation of disk space for mail storage. These functions are available to users without the need to install software on his/her own computer, and anyone who has an internet connection can access these services as a web service through the browser. This represents a typical SaaS application.

Next, we explain the overview of PaaS (Platform as a Service), referring to Figure 3. A software developer can develop his/her own application utilizing the development environment deployed in the cloud data center through the use of the Internet. The developed software will be made accessible to other users by starting the software on the cloud data center's server. The developer may not even know the location of the physical server on which his development environment and data reside. These factors can lead to a substantial reduction in terms of time and cost for establishing and deploying a development environment.

As typical embodiments of cloud platform services at present, we can name the Google App Engine (provided by Google) and Force.com (provided by Salesforce.com). These provide the development and execution environment for user programs on the Web server. Microsoft has also started to offer the Windows Azure Platform: this platform is gaining attention among Windows software developers because it provides the conventional Windows development environment.

One of the most distinguishing characteristics to be pointed out about the cloud is its extensibility. Resources such as CPU, memory, and storage can be added and expanded as need arises, or automatically. The cloud also offers the flexibility to release redundant resources, delisting them from billing lists. The pay-as-you-go plan is the mainstream charging scheme employed for both hardware and software usage. This gives the user the advantage of very low

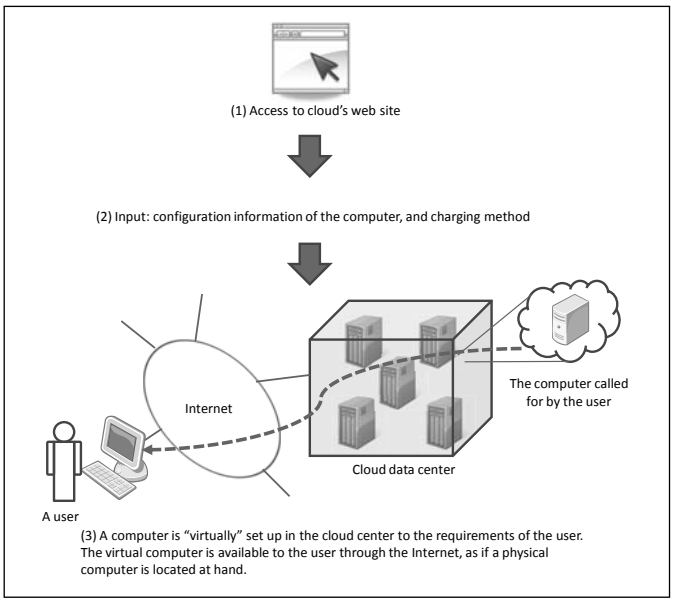

Figure 1 : Hardware Service Provided by the Cloud (HaaS)
Prepared by the STFC

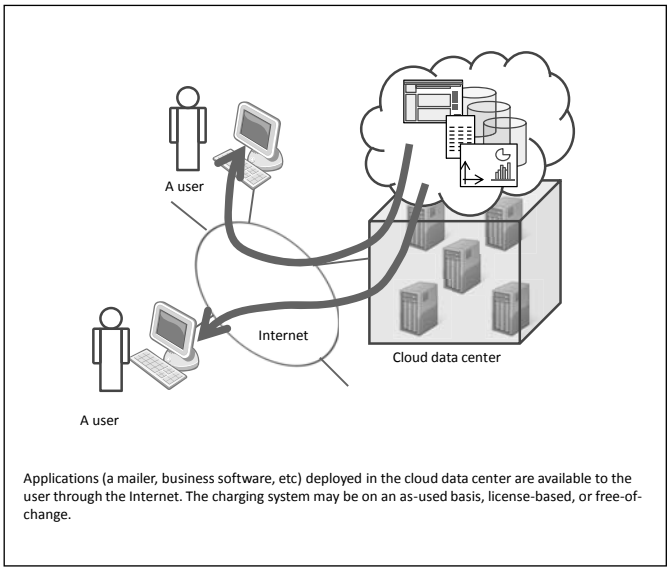

Figure 2 : Software Service Provided by the Cloud (SaaS)
Prepared by the STFC

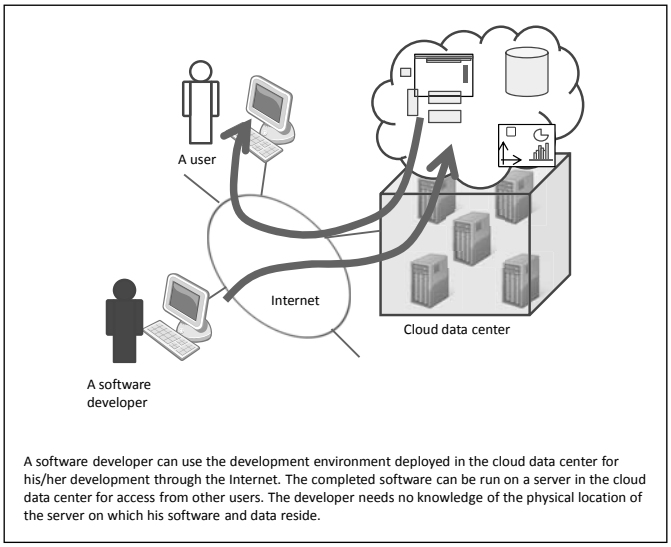

Figure 3 : Platform Service Provided by the Cloud (PaaS)
Prepared by the STFC

initial investment because he/she does not have to purchase the computer system. Cloud computing also releases users from troublesome and costly operations such as maintenance and version updates, because all of the operations are carried out in the cloud center.

2-2 The Environment Surrounding Cloud Computing and Underlying Technologies

2-2-1 Environmental Elements

The discussion of cloud computing technology (hereafter referred to as "Cloud") needs to be viewed alongside environmental factors, because a technology component, even if it is not novel per se, can bring out a new effect as the result of interactions with the environment.

The decisive driving factor, at least at present, that leads Japanese enterprises to introduce the Cloud, is cost reduction. However, a more important aspect to be noted is that the general paradigm shift "from possession to utilization" and the system change toward promotion of communication supports the basis of the Cloud, and development of the Cloud further strengthens these trends.[4]

The reasons for so much attention being paid to the Cloud is the view that it is poised to respond to current and future needs of society. First of all, there is a need in the business community, exposed to ever increasing uncertainty, that business organizations must transform themselves into more flexible and adaptable forms, enabling them to instantly cope with radical environmental changes. These requirements promote fluidization of resources at hand, including human resources, and a trend toward the service economy (i.e. simple delivery of goods is being replaced by the comprehensive provisions of services that include delivery of goods as a part of it). Information resources have to become more fluid to provide uninterrupted support for these trends. The Cloud offers an information platform to transform the nerve system of businesses (information system) into a more agile system that can conform promptly to the changes in the external world.

Secondly, there is a need to cope with globalization. The Cloud raises expectations because of its huge scalability that enables providing services to billions of users across the world. Thirdly, there is demand for environmental protection (e.g. the reduction of CO_2 emission) and energy consumption reduction.

Fourthly, there are demands to cope with a variety of new forms of information processing that came into existence accompanying the introduction of such subjects as e-Science, e-Government and smart meters.

2-2-2 Technology Infrastructure Elements

Technical infrastructure elements that support the Cloud include virtualization, the Internet, and ever-increasing sophistication and price reduction of electronic devices driven by Moore's Law.

The origin of virtualization technology dates back to the 1960s, when Virtual Machine (VM) technology was installed on the IBM360 series of computers. The virtual machines back in those days were developed for shared use of highly expensive mainframe computers. Today's virtualization has developed into technology that enables the offering of virtual systems, that run on a vast numbers of (i.e. tens of thousands of) mutually connected processors, to a great number of users.

Among the technology elements that support today's Cloud, system management that controls virtualization is the function most appealing to system users. In a cloud center that consists of a huge number of systems, it is customary that some of the systems are out of order at any time. Although some systems are under repair at any time, the center as a whole is managed to provide general users with sufficient and stable performance so that they rarely feel inconveniences (as affairs now stand, 99.9% availability is the operational target). Still, the cost required for system management is less expensive than that for dedicated systems that pursue extremely high availability.

It is apparent that the Internet and the underlying network technologies are essential to support the Cloud. Utilization of the network is an indispensable portion of Cloud usage. For enhanced security and convenience of the Cloud, efforts for further sophistication of the network and for optimum allocation of networks from a global point of view are essential now and will continue to be in the future.

As described below, higher functionality and lower price have to the proliferation of cloud centers. In view of the future of processor technology, the mainstream of development efforts aims at integrating more processor-cores on a single chip (many-core architecture). It is predicted that, sometime in the future, the system management technology currently applied to the assembly of a huge number of systems (i.e. the Cloud) will also be used to manage a computer with a many-core processor in it.[5,6]

2-2-3 Cloud Data Centre Technology

Among the Cloud related artefacts, the cloud data center (hereafter referred to as "cloud center") is the most easily comprehensible one. The cloud center, where a huge number - a few thousand to a few tens

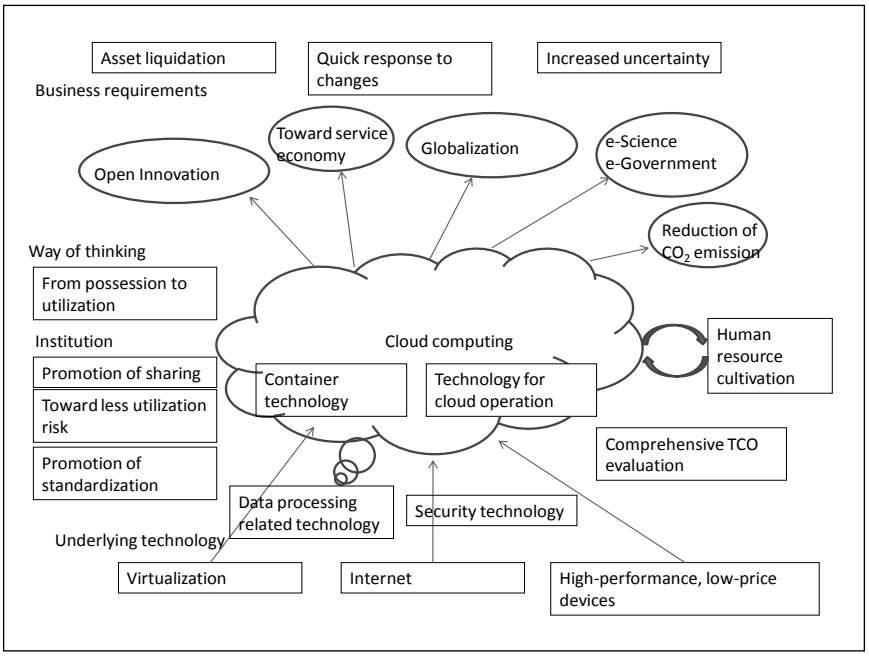

Figure 4 : Environment Surrounding Cloud Computing and Underlying Technologies

Prepared by the STFC

of thousands - of computing resources are centrally controlled, provides cloud functions to users across the world.

The cloud center is an extended form of a data center where all the computing resources are concentrated. However, it has evolved into something different not only in terms of scale expansion, but also in terms of policy and technology.

One of the basic policies is the reduction of TCO (Total Cost of Ownership) in a comprehensive framework. The "comprehensive" TOC differs from conventional TCO in its policy to try to reduce costs involved in all aspects of data center management - including power sources, air conditioning, labor costs, and CO_2 emission. In contrast, conventional TCO has focused basically on the costs involved in system hardware, software, and networks. The provision of computing power at a drastically reduced cost is one of the important factors supporting the growth of "change-free business"[7] innovation.

The container technology[8] – utilization of conventional containers packed with a number of computing systems - has recently gathered attention as one of the technologies applicable to efficient design of a cloud center. In this approach, the standardized container for international logistics is used as a unit to organize a cloud center. The modern containers have built-in features that allow naturally-cooled operation, enabling a substantial cost reduction in cloud center construction. Concentrated arrangement of these containers and proliferation on an as-needed basis provides a quick and cost-effective way to cope with the huge demand for information processing.

New operational strategies, that have no history in conventional data centers, have also been introduced. For example, as the hardware cost of data centers such as elemental equipments, processors, disks (including flash memory type) and routers, as well as power consumption, keeps going down according to Moore's Law, total replacement of these elements, say, in three years time, will become more favorable from the point of view of comprehensive TCO reduction. The fixing plan for failed system elements has also been changed: they are not replaced on an as-detected basis, but replaced collectively on a regular inspection round basis, as these failures have little adverse effect, even if they are left untreated, on the overall computing power efficiency. These operational approaches have a substantial effect on comprehensive TCO reduction.

2-2-4 Data Related Technologies

In terms of data and its management, data portability for the users and the related management schemes are gathering attention. The commercially operated Cloud, at present, does not guarantee the portability of user data, and from an institutional point of view, the policing and judicial system applied to the data depends on the region where it is thought to reside physically. This is not a reasonable judicial system for the users accessing the Cloud from different regions of the world.

Large-scale parallel processing technology, one of the major capacities of the Cloud, has been receiving attention. Although the core of this technology resides in virtualization and system management techniques, basic policies on database processing and transactions, or the aspects near the application-side, are also poised for radical changes. In database and transaction processing, integrity and consistency have been considered to be the properties of utmost importance. The newly developed technology in the framework of the Cloud, however, places the priority for the high-speed processing base on the scale-out capability of parallel processing rather than on integrity and consistency. In particular, a database is processed based on the key-value pair scheme, not on the conventional relational database model, to enable high-speed parallel processing of a vast amount of data. In transaction processing, a new technology called "eventual consistency"[9] have been implemented: this approach does not employ techniques that guarantee consistency at all times (e.g. two-phase commit) and confirms consistency once a parallel transaction of a vast amount of data has been completed. Furthermore, the generalized concept of such calculation technique ("failure-oblivious computing"[22]) has been propounded. This approach does not take corrective action against consistency errors on an as-detected basis, and continues processing only logging the occurrence of the error. The adoption of "eventual consistency" and "failure oblivious" applications for database/transaction processing means that business places priority on higher speed and scale-out of business transactions as a whole, even with some penalty of integrity and consistency. The new business models based on the Cloud may trace a different route from the extension of conventional businesses. These new breeds of business models include the Google search engine and Amazon's recommendation system.

The setup of "cost-free" businesses described earlier is considered in line with this trend.

2-2-5 Security Technology

Security is regarded as the weak underbelly of the Cloud: technology development is proactively pushed forward to overcome this problem. As one of the new schemes, "Virtual Private Cloud (VPC)"[23] has been introduced. The provision of a security-tight virtual environment is a possible option, and other options have also been proposed, one of which tries to turn the aspect of the Cloud generally considered as a weak point into an advantage (e.g. concealment of physical location of data), and avoid attacks and data leak by actively dispersing the data.[10]

Protection of general users against fraudulent practices and service providers against malicious attacks such as DOS (Denial of Service) is an important challenge: there is effort afoot to secure network security by eliminating malicious users at the network connection level.

Various methods are being deliberated to cope with this problem while paying due account to such factors as security, risk, and the reality of actual network operation. In line with this, upgrading the framework and standardization of network operation, including the modification of international law systems, are being discussed. This issue involves the scope of legal liability the Cloud undertaker should shoulder, and how to assure the safety of information. Concerns over information security from the viewpoint of the nation also seem imperative (see Chapter 6 "Cloud Centers in Japan").

On the other hand, with the ever-increasing prevalence of the Cloud, the general attitude toward security itself has been changing. The younger generation, often called "Digital Natives",[20] has a tendency to openly discuss things that older generations would consider private and that one should not present in open media, using such vehicles as Twitter and SNS. As private sessions on the network become an everyday affair, the challenge for the future is shifting more toward protection of the arena against malicious outsiders, rather than piece-by-piece security protection. In business communities also, the involvement of information exchange using Twitter and its relation to formal public relation activities are being discussed from the point of view of corporate jurisdiction. Interdependencies among these factors, including personal elements, have been under evaluation from the perspectives of cost and efficiency.

3 Possible Changes Cloud Computing Can Bring About

We consider the impact that cloud computing may have on the world in which we live from three perspectives: society, business, and personal life. As already pointed out in the report "PC Grid Computing," 2005,[17] CPU power is considered to be over-deployed, i.e. the total of CPU power deployed in the world has already exceeded the level actually required by businesses and services. Still, proliferation of cloud centers, for the promotion of cloud computing, do not show any sign of ceasing. In the background of this trend, there seem to be changes in the underlying environment including: (a) the growth of new application areas such as YouTube (posting and sharing of movies) and iPads (electronic browsing of printed media), which were previously positioned out of the computing community, (b) mushrooming of new business models, such as "change-free" businesses, that presupposes an affluent supply of cheap computing resources.

3-1 Prospects in Social Changes

The Cloud represents a variety of possibilities for alleviating computation (information processing) related burdens in many aspects of our society. The reduction of burdens can be achieved by centralized management and sharing of dispersed computing resources, and through standardization of ICT services. For example, in view of the latest trend of global environmental protection and reduction of CO_2 emission, the shift to cloud computing can help reduce CO_2 emission from information processing related activities. Consolidation of computing power, hitherto scattered in diverse locations, in a cloud center has a straightforward effect of reducing electric power and water usage as a whole,[11] and it also has an indirect consequence of helping people work at home utilizing cloud computing. The reduction of social burden includes work reduction for constructing computing environments and for providing ICT-based services, and shortening of hours for installation. Looking at the same effect from another viewpoint, the consolidation effort also means that the huge

workforce engaged in the development and service provision in the information processing sector will become redundant.[12]

Reduction of ICT cost with inexpensive ICT facility means reducing the burden of ICT system construction in terms of development labor and time. The reduction of ICT cost may have wider repercussions such as the replacement of existing services with cheaper ones using ICT, and the invention and introduction of new services that will fully take advantage of ICT will be facilitated. The trend will provide a possibility to accelerate the evolution of social systems and enhance the benefits of our society as a whole. On the other hand, heavier dependence of social activities on ICT may create such problems as widening disparity between ICT knowledgeable and ICT illiterates, and increased risk of ICT security.

3-2 Prospects in Business Changes

In the business community, the beneficial effect described above can be enjoyed by each group of enterprises including: reduction of burden, reduction of ICT cost and shortening of development period, and reduction of development burdens of new products and services in terms of cost and time. Utilization of the cloud renders it possible to make contact to all of the four billion Internet users (cloud users), giving a chance to even a small-sized company to directly access the huge market. The promotion of sharing resources, a typical characteristic of the cloud, will facilitate the proliferation of open innovations. This also facilitates the strengthening of inter-enterprise links: incorporation of a service provided by a company whose activities lie in a different area, and vice versa.

In Japan, installation of thin clients (a terminal used for connecting the in-house cloud with the outside world and inside the company) is under way as a measure against security hazards such as information leak. Some of the major companies have already removed mass storage (e.g. hard disks) from desktop PCs, and place all of the application software (word processing, mailing, etc.) on the cloud. The cloud terminals such as smart phones are considered to be used more widely within companies.

On the other hand, the widening of the accessible market will create increasingly fierce competition on a global scale, and there will be increasingly many cases where an unexpected competitor comes in out of the blue. Realignment of coalitions with other companies will become necessary more often, and this may lead to an increased number of critics and claims from customers. This may also lead to an oligopoly of services, increasing the uncertainty surrounding business operations.

3-3 Prospects in Personal Changes

A personal user cannot normally distinguish whether he/she is using cloud computing or simply using other Internet services, except when he/she is using PaaS or IaaS directly on a personal basis. For example, Gmail, one of the typical existing applications, may not be distinguished from the conventional free-of-charge Internet mail services, except for the capacity allocated and the number of related services. The following descriptions, therefore, overlap with many of the aspects surrounding an individual when "ubiquitous telecommunication" is realized.

Terminals, called a cloud devices,[13] will be available all over the world and play a major role in telecommunications. Cloud devices can be thought of as an enhanced form of ICT terminal such as the Notebook PC and Smartphone as we see today. Two types of cloud devices are expected to become prevalent: a mobile type which an individual carries with him/her, and a desktop/wall type installed in homes, offices, and public places. Both are equipped with multiple input/output functions such as voice, gestures and keyboard.

Personal information required for carrying out social life is stored and managed on the cloud. The cloud provides, through cloud devices, various procedures on a 24/7 basis and does not require special skill. On the other hand, cyber-crimes are expected to grow steadily, with criminals trying to get hold of valuable information on the cloud. Each individual will have to check the integrity of his/her information on a regular basis.

The prevalence of the cloud will give more entrepreneurial chances to an individual, as well as more chances for employment and more learning opportunities. On the negative side, however, the frequency of losing jobs is expected to rise, because enterprises/organizations will have to modify their organizations more often.

4 From Possession to Utilization

The truly revolutionary character of the cloud lies in the fact that it triggers a paradigm shift in information processing engines, i.e. "from possession to utilization." The people of older generations, say people over sixty, may feel as if this age harkens back to more than thirty years, from the point of view of computer utilization, when the sharing of mainframe computer centers was the mainstream. In those days, as computers were very expensive, shared use of a computer was the common practice, and proprietary possession of it by an individual or a company was exceptional. Subsequently, the dramatic increase of the performance-cost ratio of computing devices and drastic reduction of prices (Moore's Law) enabled possession of computers on an individual or a company basis. Although this is a rare and exceptional case, Microsoft distributed a laptop computer free-of-charge to each of the thousands of participants to the convention hosted by Microsoft (San Francisco, December 2009).[14]

The important factors that change the form of computer utilization – from proprietary possession to share use, i.e. the cloud – include the change of the underlying sense of values as well as the pursuit of cost reduction, enhanced convenience, and a wealth of applications. As exemplified by the prevalence of the Internet, information processing has become a day-to-day practice in all aspects of personal life, and we all now consider such an environment as a matter of course. The use of information technology is not any more limited to businesses and governmental organizations. The cost associated with the use of a computer has dramatically come down, owing to the prevalence, performance enhancement and much higher reliability of telecommunications infrastructure (typically, the Internet and cell-phones). The entry of ICT into almost all aspects of our lives, as well as the progress of standardization, made the use of ICT much less troublesome than before. Wireless networks, underlying the Internet and cell-phones, have become increasingly ubiquitous and faster, raising the level of convenience of usage to an unprecedentedly high level. Applications such as SNS and GPS, quite unthinkable in the conventional computing environment, have come into practical use, and they can be used freely from mobile terminals. Looking at the sheer number of people connected to the network, the billions of cell-phone users across the world are coming into view of these applications; a huge market is in the process of being made.

The concept of "sharing" as pushed forward by the cloud does not mean the reversion to "shared use of a computer center," which was necessitated by the inability to own a computer. It rather means to save the time and effort associated with personally owning a computer. Or, the utilization style can be expressed as "virtual possession." The situation is similar to the car sharing system: car sharing has been introduced not because cars are expensive, but to save the trouble associated with car ownership, as well as to be friendlier to the environment.

In cloud computing, the user can select an application freely from among the huge array of computing resources to fit his needs, and perform input and output from anywhere at any time using a cloud device at his/her fingers. This environment may give the user an illusion as if a colossal computer is behind the cloud device held in his/her hand.

In addition, the shift of the way of thinking – from proprietary ownership to shared utilization – will pave the way to a new realm of simultaneous sharing of applications and knowledge with others, and the development of open innovation to new directions hitherto unthinkable.

5 Areas Where Broad Innovative Changes Are Forthcoming

5-1 Innovation in Research and Development

Research and development of the Cloud has been largely driven by the pressing needs of business strategy, rather than the traditional buildup approach starting from the R&D of generic technology.

Google and Amazon first decided what types of services they would provide to customers based on their business strategies, and then designed the business processes and the infrastructures including IT, the enabler of the business process, in view of obtaining the optimum method to deliver these services. In the construction of IT infrastructure, they did not develop new computers to their purposes, but constructed a large assembly of conventional computers, taking into account the balance of cost and efficiency. Thus, giving priority to business, they started service delivery utilizing conventional

technologies. Once the service was started, however, basic research challenges came into view to process a huge number of transactions. These research challenges included such items as data consistency[15] and development of a distributed file system (Amazon S3). The former challenge gave birth to a new transaction technology,[15] or BASE (Basically Availability, Soft State, and Eventual Consistency), which is an extension of the conventional data consistency concept of "eventual consistency." This represents a typical example of a business strategy driven (or solution-driven) approach, in contrast to the build-up approach where step-wise developments starting from basic research finally lead to commercialization of a product. To provide excellent IT services, while avoiding wasteful investment, a good methodology is required to lead the solution-driven research and development to a good result. Successful execution of the solution-driven development is the key for the development of Internet technologies.

5-2 Innovation in Business Process and Business Infrastructure

The prevalence of the Cloud and its underlying concept, "from possession to utilization," will trigger a major break in business processes and business infrastructures. Many of the businesses today handle information explicitly as a capital part of their business. The transition of infrastructure morphology, from proprietary to sharing, will surely affect many aspects of a business process.

Usage of a shared Cloud can take various patterns: an in-house Cloud that integrates the servers deployed within an enterprise on a section-by-section basis, a group Cloud that consolidates group businesses, and a commercial Cloud that serves unknown and anonymous users. The extent of innovation that will take place may vary depending on the environment and circumstances, but innovation is considered to progress both in static aspects (represented in terms of openness, visualization, and standardization) and dynamic aspects (represented in terms of swiftness, elasticity, and quick response to changes).

The business environment has been such that a business tries to gain an upper hand over others by taking sole possession of the business process and limiting information to its own use. The static aspects (openness, visualization, standardization) above represent the business attitude to open up the proprietary process, or replace it with a standardized one, to achieve a visualized and shared process for construction of a win-win relation among all those involved. Activities of APEC to visualize international logistics, and the move toward adoption of the International Financial Reporting Standards are considered in line with this trend.

The dynamic aspects – swiftness, elasticity, and quick response to changes – represent the concerns of business entities for elastic operation of business processes and business infrastructure, coping with the uncertainty they are facing. The flexibility obtainable from adopting the Cloud makes even an originally seasonal business become available throughout the year. Webpo, an online delivery service of New Year greeting cards, is an example of new breeds of businesses along this line. Many of the "cost-free" businesses have become a reality by converting fixed costs and expenses into variable expenses, where the flexibility of the infrastructure plays an essential part.

The Cloud not only helps innovating the above-described static aspects by realizing data and process sharing, but also the dynamic aspects by flexible provision of information processing resources.

5-3 Structural Innovation in Information Industry

The Cloud has the potential for triggering all-industry-wide innovative changes, leading to industrial restructuring. As described in 3-2, the Cloud helps in streamlining each of the industrial sectors by jettisoning redundant properties, as well as promoting active inter-business coalitions. As a result, rather than a scale expansion in the conventional ways of thinking, the ability to specialize in one's core business and to link with other businesses in an alert and agile way will be highly regarded.

In particular, the Cloud has the potential to bring about the following changes to the ICT industry, which is in direct contact with information processing.[12]

- Sales of computers to general users will be rendered obsolete by the introduction of cheap Cloud devices that provide the functionalities of wide range or computers including PC and cell-phone.
- Standardization of ICT related products and business moves further forward.
- Customization of information processing services such as system development/integration tailored to

the needs of the user will be rendered obsolete, and instead, the users will select one from multitude of applications, or combine them to suit their needs by themselves.

- As a result of these changes, workers involved in the conventional computer industry and information processing services will face the need to drastically change their business contents.
- Such activities as sales, lease, and outsourcing of a hardware/software service belong to a business model that carries meaning only in a market predicated on possession of goods (including possession only through a fixed period of time). Therefore, as the wheels of commerce change from possession to utilization, the business models of ICT enterprises will shift to the on-demand provision of component "functions" on the always-on network environment, and theses components will be selected or refused by the users.

6 Cloud Centers in Japan

Japan provides an ideal environment for cloud computing: it has well-developed Internet and cell-phone networks, whose prevalence, availability and reliability are counted as one of the highest in the world.

However, at present, there is no world-class cloud center in Japan. As described above, technology development for container type cloud centers has been well under progress overseas. In contrast to this, Japan is in a stage that a company (i.e. IIJ) has just begun a demonstration experiment.

As described in 2-2, the prices of the element components used for the construction of a cloud center have kept falling, and price-busting has become a day-to-day occurrence. The levels of service prices are also expected to fall in years to come, producing a fear to press on the management of small-sized ICT data center businesses as the investment recovery from existing facilities will become increasingly difficult. The advanced, large-scale cloud center businesses, on the other hand, may be able to enjoy this situation: they can keep a competitive advantage by lowering service prices supported by the benefits of comprehensive TCO reduction. New entry to this cloud center business sector may become increasingly difficult in the future.

Many factors are cited to explain why a world-class cloud center has not been constructed in Japan including the limited availability of land, geopolitical location (i.e. Japan is located in the far-east part of Asia), high risk from natural hazards (e.g. an earthquake), high cost (land, electricity, water, and labor), deficiency of human resources, and the lack of a preferential taxation system. Additionally, the inflexible and rigid law system has been pointed out. In view of the moves afoot to set up a cloud center in such areas as Singapore and Hong Kong, narrowness of land and high cost seem to lack persuasiveness. Rather, the institution of law may be a greater impediment. For example, the container-type cloud center constructed in the USA, as is, cannot be installed in Japan, where discrepancies with Japanese laws (Building Standard Act, Fire Service Act, etc.) are said to pose major barriers. This reminds us of the situation where, in the 1990s, Japan lagged behind in the development of search engines hindered by the lack of operational transparency of Japanese copyright law, resulting in the delayed start of search services business.

Given the perspective that many sectors of industries and services will depend on the cloud infrastructure, and if the situation in Japan continues as it is, Japanese users will have to rely on the cloud infrastructures and services provided by overseas enterprises and will have to keep paying the charges accordingly. Self-sufficiency and safety assurance in terms of energy and food has been a subject of continued debate. Discussion also seems necessary on how to maintain self-sufficiency and safety assurance in terms of information and its management.

7 Trends of Foreign Countries

In the United States, the most advanced nation in cloud computing, the government, under the leadership of GSA (General Services Administration) and other organizations, is actively promoting the use of cloud – IaaS, PaaS, and other services. For example, GSA's website has already begun providing computers and storage through the Cloud.[18] In Europe, as the EU directives forbid government organizations from using data centers located outside the EU area, data centers have been constructed in Ireland and other European countries. A cloud computing trade organization, EuroCloud, was established in October 2009. In Asia, cloud centers have been constructed,

or are planned to be constructed in the near future, in China, Singapore, Vietnam, India, and Dubai. In Taiwan, the Taiwan Cloud Computing Consortium was established in April 2010, under the initiative of the Taiwan government.[19]

8 Human Resource Development for Cloud Computing

As is the case with all other technologies, development of human resources to support and utilize the Cloud is of utmost importance. In the United States, an industry-government-academia program (the Academic Cluster Computing Initiative[16]) is under way, and universities outside the United States, including Kyushu University from Japan, have joined the program. As well as the cultivation of human resources for technical aspects of the cloud, Japan urgently needs human resources capable of bringing about social and economical reforms utilizing cloud technology.

One method in this direction might be the establishment of an international internship program in collaboration with leading international companies in this business such as Google and Amazon. Firsthand experience on how an innovative idea, notion, or strategy is born and develops is an important factor that enables cultivation of a substantial number of "thought leaders" in Japanese society. This is not an issue for which we can rely only on the efforts of each company in the private sector; our society as a whole should tackle this issue.

Japan as well seems to be lagging behind in the development of human resources that support and utilize the cloud. Japan is also behind the other advanced countries in terms of the fostering of an ICT service industry, partly affected by the continued sluggishness of this sector that started already before the beginning of the cloud age. Thus, lifting up this industrial sector to a level capable of competing in the world is another challenge for Japan.

Turning our eye to the activities inside Japan, the Ministry of Internal Affairs and Communications (MIC) and the Ministry of Economy, Trade and Industry (METI) has set up a study group regarding cloud computing, and other plans such as the Kasumigaseki Cloud are under way. The Ministry of Education, Culture, Sports, Science and Technology (MEXT) is also sponsoring human resource cultivation projects for the cloud, but these measures seem far from sufficient.

9 Conclusion

This report overviewed the change in the way of thinking – i.e. from possession to utilization – toward the expanded scalability to enable embracing four billion Internet users across the world, whereby the authors called for the needs of Cloud utilization and improvement of the development environment.

The most immediate motivation for Japanese enterprises to introduce the Cloud, at least at present, seems to be the cost reduction. However, it should be understood to be a vehicle to trigger the transition from an possession-based to utilization-based economy.[24] The cloud, and the cloud center that supports it, represents a platform to realize such changes. In other words, the development of future cloud center technology serves as the central machine of the future industry. This technology development bears so much importance that it deserves all possible measures toward effective and flexible application of the legal system (e.g. establishment of a special economic zone).

Grid computing,[21] much discussed up until several years ago, has a common aspect with the cloud center in that both use huge computing resources, but the former provides services to only a limited range of the users, having made the discussion of its social implications slip away from attention. Accompanied by the rapid repletion of communication infrastructure in these several years, the cloud can now have a huge impact on society, especially on industries in general, so that the information industry sees its evolution both with huge expectations and full of concerns. It is not going too far to say that the fate of an enterprise in the information industry depends on how well it takes advantage of this opportunity. The cloud computing involves drastic changes in the business models used in a variety of sectors, which seems to trigger a tipping point to Japan's information and telecommunication industry.

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