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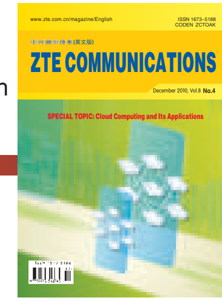

ZTE COMMUNICATIONS
Vol. 8 No.4 (Issue 28)
Quarterly
First Issue Published in 2003

Supervised by:
Anhui Science and Technology Department

Sponsored by:
ZTE Corporation and Anhui Science and Technology Information Research Institute

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Published and Circulated (Home and Abroad) by:
Editorial Office of ZTE COMMUNICATIONS
Printed by:
Hefei Zhongjian Color Printing Company
Publication Date: December 25, 2010
Publication Licenses:
ISSN 1673-5188
CN 34-1294/TN
Advertising License:
皖合工商广字0058号
Annual Subscription Rate:
USD$20

SPECIAL TOPIC: Cloud Computing and Its Applications

RESEARCH PAPER

DEVELOPMENT FIELDS

OPERATIONAL APPLICATION

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ROUNDUP

DEPARTMENTS

Analysis of Hot Topics in Cloud Computing

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Abstract: In the field of cloud computing, topics such as computing resource virtualization, differences between grid and cloud computing, relationship between high-performance computers and cloud computing centers, and cloud security and standards have attracted much research interest. This paper analyzes these topics and highlights that resource virtualization allows information services to be scalable, intensive, and specialized; grid computing involves using many computers for large-scale computing tasks, while cloud computing uses one platform for multiple services; high-performance computers may not be suitable for a cloud computing; security in cloud computing focuses on trust management between service suppliers and users; and based on the existing standards, standardization of cloud computing should focus on interoperability between services.

Key Words: cloud computing; virtualization; grid computing; security of cloud computing; standards of cloud computing

In cloud computing, resources such as processing and storage are offered for public use. Cloud computing adopts a virtualized, dynamically scalable paradigm for organizing, distributing, and using computing resources. In contrast to the traditional paradigm, which relies on desktop resources, computing resources provided in clouds are part of social infrastructure and may have a profound impact on information technologies and their applications. The development of cloud computing is changing software engineering, configuration of resources in network core and terminals, and acquisition of information and knowledge[1].

Since the concept was proposed in 2007, cloud computing has been promoted by academia and industry and has been transitioning from theory into practice. However, the development of cloud computing technologies and their widespread implementation will be a long-term process because of the profound impact that cloud computing services will bring to the public. Important topics such as the technical basis, service models, and commercial operation of cloud computing have already been widely discussed[2-7].

This article analyzes views on resource virtualization, differences between grid computing and cloud computing, relationship between high-performance computers and cloud computing centers, and security and standards of cloud computing.

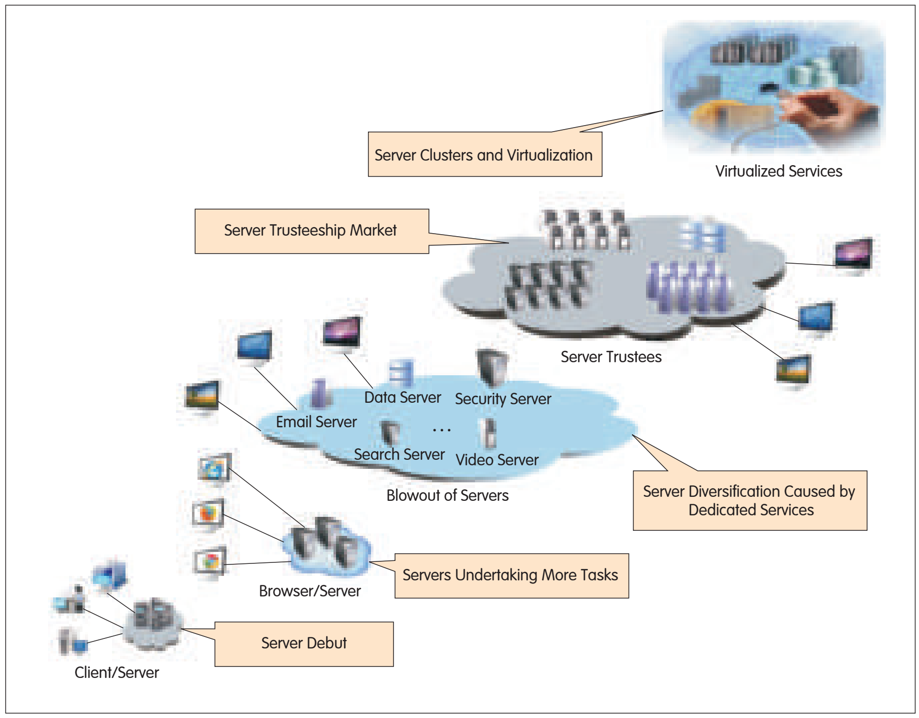
1 Virtualization of Computing Resources

Wikipedia defines virtualization as the "abstraction of computing resources[8]." Virtualization technologies emerged early in the history of technology. An operating system, for example, weakens the dependence of software application environments on hardware platforms, and even completely isolates the two. Middleware also weakens the dependence of application software on software operation. Both are examples of virtualization technology. With the change from stand-alone computers to the Internet, virtualization technologies gave birth to cloud computing. The structure and implementation details of a Web-based email administration system are virtualized when mass emails are sent, received, and managed through browsers. Searches and matches are virtualized when a search engine responds to a personalized search request. Network albums are used for storing and sharing pictures, and dynamic administration of the storage center is virtualized. Online transaction and payment systems are also virtualized.

Computing resources as virtualized objects can be classified according to computing capability, repository capability, and interaction capability. These classifications correspond exactly to CPU, repository, and input/output of a traditional computer. Because of resource virtualization, computing is no longer treated as the main sector. If computing is dominant, the main sector is the computing center; if repository is dominant, the main sector is the repository center. Interactions can also be treated as the main sector, while computing and repository become supporting parts. Virtualization services on the Internet can accommodate mass numbers of users to make highly personalized demands through natural interaction. Users need not consider the specific service model of application software nor whether the service is being simultaneously leased by others. The operating system of the computing platform does not enter into consideration, nor does the physical configuration and administration of bottom-layer resources such as software environment. The geographic position of the computing center is also irrelevant to users. Virtualization services such as Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) provide dynamic and scalable organization, distribution, and utilization of computing resources.

Looking back at the transition of resource configuration on the Internet, as shown in Figure 1, can help in understanding the development of virtualization services. The earliest server appeared using the Client/Server (C/S) structure—which was followed by the Browser/Server (B/S) structure. Client ends became thinner, and applications could be directly accessed through the abstract of B/S browser. Servers then emerged that could perform diverse tasks, and many institutions built servers that could host dedicated applications such as email, data, security, and video. This led to a blowout in diversified servers. Such a large number of servers prompted the creation of server trustees for alleviating the cost burden to owners of maintaining servers. However, trusteeship was not an effective solution to intensive use of servers. If virtualized services could be offered and servers changed into "services," the various kinds of computing resources could be better integrated.

From the evolution of virtualized services it can be seen that a service approach to offering computing resources was inevitable for cloud computing. This transition is similar in nature to that of traditional manufacturing industry from mass



▲Figure 1. Transition of resource configuration on the Internet.

production to intensive, scalable, specialized production during the Industrial Revolution. Today, the information industry is also moving towards being intensive, scalable and specialized. Virtualization of computing resources allows reasonable configuration and use of resources. The actual utilization of a single server is only around 15% whereas utilization of a server cluster can reach to more than 80%. This has direct implications for energy saving, carbon emission reduction, and green computing[9].

2 Differences between Cloud Computing and Grid Computing

Before the emergence of cloud computing, grid computing[10] had been studied for more than 10 years and had attracted widespread attention. In the first two years of cloud computing, general opinion held that cloud computing was hot in the industrial field but cold in the academic field. For grid computing, the boot was on the other foot. What is the main difference between cloud computing and grid computing? Generally, in a grid system multiple computers are networked into a grid to offer specific large-scale computing services—"multiple for one." In cloud computing, intensive and specialized Internet platforms are used to offer scalable services—"one for multiple."

Ian Foster, the father of grid computing, defined it as "a hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to high-end computational capabilities.[10]" Relying on private networks or the Internet, grid computing organizes idle computer resources scattered in different areas and with different capabilities and forms them into a virtual super computer by unified scheduling. In this way, complex tasks—such as scientific tasks requiring mass data handling and processing—can be completed. The basic application scenario of grid computing involves integrating computing resources belonging to different people in different locations in order to gain stronger computing capability.

Cloud computing tends to change powerful computing resources of certain Internet nodes into dynamic and scalable virtual resources. These are then provided as services to mass numbers of users. Cloud computing provides user-driven, on-demand and pay-per-use services that may be dissolved. Its basic application scenario is oriented to the Internet, and a centralized computing resource pool is used to meet the mass and scattered demands of terminal users.

The biggest similarities between grid and cloud computing are resource sharing and virtual computing. Both of these provide users with shared Internet resources through virtualization so that resources are reasonably utilized.

However, they are different in some respects:

(1) Cloud computing is based on cluster computing; nodes in cluster are self-governing and oriented to different service objects. Grid computing is based on parallel computing; cross-area computers are networked and a unified scheduling system is used to distribute tasks to different nodes for handling.

(2) Cloud computing recognizes heterogeneity; that is, heterogeneity in principle, scale, and capability of nodes. Inter-node resource sharing is achieved through the interoperability of the service. Grid computing uses middleware to shield heterogeneous system for the upper layer applications, orienting users to the same environment for resource sharing.

(3) Cloud computing is oriented towards persistent and diverse services, and many cloud computing centers in the Internet usually offer many diverse services for different application fields. Grid computing is primarily used for completing one-off, specific tasks that are pre-set.

(4) Cloud computing is operated commercially, providing best-effort multilease services that are rented for agreed terms or charged on a pay-per-use basis. Grid computing relies on coordinated operation between organizations. Bandwidth and performance are guaranteed, however, there are no obvious commercial models.

(5) Cloud computing is designed to meet the demands of mass numbers of users. People interact and communicate with one another and are involved in computing processes. Semantic handling and uncertainty processing are therefore required. Grid computing is oriented to scientific computing; program input/output is well-defined according to specifications and instructions, and people are not generally part of computing processes.

In short, cloud computing and grid computing are applied in different scenarios and have different goals.

3 Performance of a Cloud Computing Center

A cloud computing center is based on cluster computing. The large number of nodes at a cloud computing center are interoperable and form user-oriented virtual servers. Many institutions have purchased high-performance computers and established computing centers. However, can these high-performance computers be used for cloud computing centers? Is a cloud computing center the same as a high-performance computing center? What is the relationship between high-performance computers and virtual servers of a cloud computing center?

If the largest, most intensive and specialized cloud computing centers (owned by Google, Amazon, and Salesforce) are considered, none of the world's ten most powerful computers have been used in the formation of their service clusters. It is thought that Google's computing center consists of more than 450,000 ordinary computers located in at least 25 places, while the computing centers of Amazon and Salesforce may be running on cluster systems of 100,000 and 1000 ordinary computers respectively[11]. Since cloud computing aims to meet independent demands of mass numbers of users, dependence and intercrossing between server cluster tasks when responding to different requests is greatly reduced. Such loosely coupled tasks even enable computers at the cloud computing center to be fixed "to tall metal racks with Velcro, making it easy to swap them out should they fail[12]." Through cooperation between clusters, a search task involving billions of microprocessor events and the reading of hundreds of megabytes of data can still be completed in several tenths of a second.

High-performance computers are mainly used in science. The world's ten most powerful computers in 2009 were mostly deployed in science research institutes, universities, and national institutions. These include the Oak Ridge National Laboratory, California; the Argonne National Laboratory of the US Department of Energy (DOE); the US National Institute for Computational Sciences; Forschungs Zentrum Juelich (FZJ), Germany; and the National Super Computer Center in Tianjin, China. These high-performance computers are applied in energy, manufacturing, weather forecast, nuclear, hydromechanics, and astronomy[13]. The XT5 (Jaguar) in Oak Ridge is currently the most powerful computer in the world with a performance score of 1.75 PFlops in the Linpack test. It has nearly 250,000 computing cores, with a theoretical peak computing rate of up to 2.3 PFlops. An important goal of high-performance computers is to improve computing speed in order to obtain higher performance parameters in Linpack tests.

Services provided by a cloud computing center are oriented towards the diverse applications of large-scale search, network repository, and network business of mass numbers of users. Therefore, cloud computing centers should be capable of providing high-quality service environments for tens of millions of applications and effectively adapt to user demands and service innovation. Compared to supercomputing centers, cloud computing centers do not follow the traditional task-oriented single computing model but provide service-oriented, scalable, and specialized services. Therefore, high-performance computers deployed in high-performance computing centers are appropriate for scientific problems requiring high concurrency computing but are not necessarily suitable for cloud computing.

4 Cloud Security

Resource sharing within cloud computing centers raises many security issues. Cloud computing is not a new weapon designed to solve security issues. It is a computing paradigm based on the Internet and has some of the same security issues that exist in current information systems. These issues include viruses, malicious attacks, and information disclosure when cloud services are being offered. Therefore, current information security technologies may also be used to secure cloud computing centers while additional security measures are developed for cloud computing. Scalable, intensive, and specialized services change the situation whereby information resources are scattered at end equipment. The development of Security as a Service (SECaaS) is expected to improve Internet security. Intensive and specialized security services may be implemented in cloud computing centers, possibly eliminating the need for end users to install patches and kill viruses. Backup may be treated as a kind of service for implementing specific cloud backup services.

Therefore, the security focus in cloud services will gradually turn to trust management. Traditional information security will develop into trust management between service providers and users. The analogy of a bank deposit can be used to describe the trust relationship between users and cloud service centers. In the past, many people thought it was safest to hide their money away in secret places. However, with the development of banks, people signed service contracts to have their wealth safely stored and managed. Sensitive information is similar to wealth. In the signal computer age and the early days of Internet, leaving sensitive data in network service centers was risky because the centers lacked the management, mechanisms, and technical guarantee of trust. Instead, data was saved in private systems to prevent it being disclosed and to protect privacy. Users themselves were responsible for system security, often installing a firewall and antivirus and backing up data. However, the rapid development of cloud computing will change this picture because users may not choose to keep sensitive data themselves. The core model of cloud computing is service based on the premise that there is a trust relationship between users and service providers. The most basic and important guarantee for establishing this relationship is the bottom-up force created by the democratic nature of the Internet, which cannot be formed by a single person but by interactions in communities. Thus, trust is fulfilled not by one-off testing or a set of fixed indicators but by eliminating untrusted elements during these interactions. This is a quality of cloud computing accumulated during operation. One of the key issues to be solved in trust administration of cloud systems is how to best abstract and apply the trust that emerges during the evolution of a cloud computing system. Society, politics, and technology can jointly promote the establishment, maintenance, and administration of trust in cloud computing.

5 Standardization of Cloud Computing

Cloud computing provides users with many types of services with variable granularity. Interconnection, interworking, and interoperation between these services is a key technical foundation for implementing an open cloud platform. In fact, interconnection, interworking, and interoperation are the basic characteristics of networks in any stage of development. Protocols for Local Area Networks (LAN) and Wide Area Networks (WAN) are used for interworking of computing devices. Transport Control Protocol/Internet Protocol (TCP/IP) enables inter-network connection. In the days of WWW, Hypertext Transfer Protocol (HTTP) and Hypertext Markup Language (HTML) enabled interoperation between terminals and Web sites; Web browsers that use these protocols are able to seamlessly access the WWW. Web services and Service-Oriented Architecture (SOA) opens the door for service computing.

Resources in a cloud computing system exist in the form of services. Many commercial enterprises have built their platforms for cloud computing, offering data and services. However, the grammar and semantic differences between data and services still block effective information sharing and exchanges between them. Cloud computing will not subvert existing standards such as Simple Object Access Protocol (SOAP); Web Services Description Language (WSDL); and Universal Description, Discovery, and Integration (UDDI). However, Cloud computing emphasizes service interoperation based on existing standards. Designing higher level protocols and specifications for openness and interoperation is extremely important in order to facilitate interoperation between clouds and interoperation between services and end users.

The International Standardization Organization ISO/IEC JTC1 SC32 is responsible for the development of ISO/IEC 19763—Metamodel Framework for Interoperability (MFI). MFI is a standard family that provides reference for the model registration, ontology registration, and model mapping of registered information data resources. It promotes interoperation of software services. China participated in the development of ISO/IEC 19763-3 in the standard family. ISO/IEC JTC1 SC7 and ISO/IEC JTC1 SC38 established cloud computing study groups in 2009, with the tasks of developing terminology related to cloud computing and drafting study reports on cloud computing standardization.

Industry organizations such as the Cloud Security Alliance (CSA)[14], Open Cloud Consortium[15], and Cloud Computing Interoperability Forum (CCIF)[16] are taking steps to develop relevant cloud computing standards for virtual machine image distribution, virtual machine deployment and control, communication between virtual machines within a cloud, persistent repository, and safe virtual machine configuration. These organizations are ahead of international standardization organizations in the development of cloud computing standards. The China Cloud Computing Technology and Industry Alliance (CCCTIA) also aims to contribute to the standardization of cloud computing.

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Roundup

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Cheng-Zhong Xu received his BS and MS degrees from Nanjing University in 1986 and 1989, respectively, and Ph.D. degree from the University of Hong Kong in 1993, all in computer science. He is currently a professor in the Department of Electrical and Computer Engineering of Wayne State University, the Director of Cloud and Internet Computing Laboratory, and the Director of Sun Microsystems' Center of Excellence in Open Source Computing and Applications. He also holds a visiting professorship at Shanghai Jiaotong University and Beijing University of Posts and Telecommunications. His research interest is mainly in distributed systems and the Internet, datacenters and cloud computing, and wireless embedded systems, with an emphasis on resource and system management for performance, availability, reliability, energy efficiency, and security. He is currently the principal investigator of five U.S. NSF funded projects in these areas. His research was also supported by other funding agencies like U.S. NASA and NSF of China. He has published more than 160 scientific papers, including over 20 articles in IEEE/ACM transactions. He is the author of "Scalable and Secure Internet Services and Architecture" (Chapman & Hall/CRC Press, 2005) and a co-author of "Load Balancing in Parallel Computers: Theory and Practice" (Kluwer Academic, 1996).

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Introduction to Cloud Manufacturing

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Abstract: Cloud manufacturing is a new, networked and intelligent manufacturing model that is service-oriented, knowledge based, high performance, and energy efficient. In this model, state-of-the-art technologies such as informatized manufacturing, cloud computing, Internet of Things, semantic Web, and high-performance computing are integrated in order to provide secure, reliable, and high quality on-demand services at low prices for those involved in the whole manufacturing lifecycle. As an important part of cloud manufacturing, cloud simulation technology based on the COSIM-CSP platform has primarily been applied in the design of a multidisciplinary virtual prototype of a flight vehicle. This lays the foundation for further research into cloud manufacturing.

Key Words: informatized manufacturing; cloud manufacturing; cloud computing; networked manufacturing

1 Trends of Manufacturing Informatization

The manufacturing industry is an important pillar of China's national economy and security. As detailed in the tenth five-year plan, the Chinese government views manufacturing informatization as a strategic measure for realizing new-era industrialization. Manufacturing Informatization draws together information technology; modeling and simulation; modern management technology; design, production, and experiment technology; system engineering technology; and product-related technology, which is used to integrate and optimize the three factors (people and organization, management, and technology), and the four flows (information flow, material flow, value flow, and knowledge flow) to improve product quality, service, and energy efficiency. Production costs and development time are also reduced.

The goal of manufacturing Informatization is to enhance competitiveness of enterprises in order to accelerate their development[1-2]. The idea of manufacturing in this article encompasses the whole product manufacturing lifecycle—from market analysis to design and production, testing, training, usage, and maintenance; and finally, dismantlement.

Generally, the manufacturing Informatization system is developing toward being integrated, digital, intelligent, agile, networked, green and service-oriented. Service, resource environment and knowledge-based innovation[3] are key factors for enhancing core competitiveness in the manufacturing industry. By 2009, China had become the world's second largest industrial manufacturing country, second only to the U.S. However, it has not yet turned into a high-end manufacturing power. "Made-in-China" is generally considered to be at the low end of the international value chain, because of weak innovation and limited resources. China's manufacturing industry therefore needs to break through these barriers as soon as possible, and transition into a service-oriented[4], green[5] and "created-in-China" manufacturing mindset.

Based on the requirements of manufacturing industry and the rapid development of information technologies, the concept of cloud manufacturing[3] was proposed for promoting the development of manufacturing Informatization. Research into cloud manufacturing technology will accelerate the development of an intelligently networked, service-oriented manufacturing industry in China.

2 Technological Basis of Cloud Manufacturing

Cloud computing is a new service-oriented computing technology that has emerged in recent years[6-7]. In cloud computing, mass, highly virtualized computing resources are organized using a cloud computing platform, and a large-scale resource pool is formed to provide unified services. Individuals and enterprises can access computing resources on-demand through heterogeneous, self-governing Internet services. Professional IT and networking companies—third-party service operators—build computing repositories and service centers in which "clouds" of virtualized resources are stored and offered as services.

This work was funded by the National Basic Research Program of China ("973" Program) under Grant No. 2007CB310900, and the National High Technology Research and Development Program of China ("863" Program) under Grant No. 2007AA04Z153.

When cloud computing resources are replaced with cloud manufacturing resources, cloud computing operation models may offer new ways of achieving networked and informatized manufacturing systems with high efficiency, service-oriented and low energy consumption.

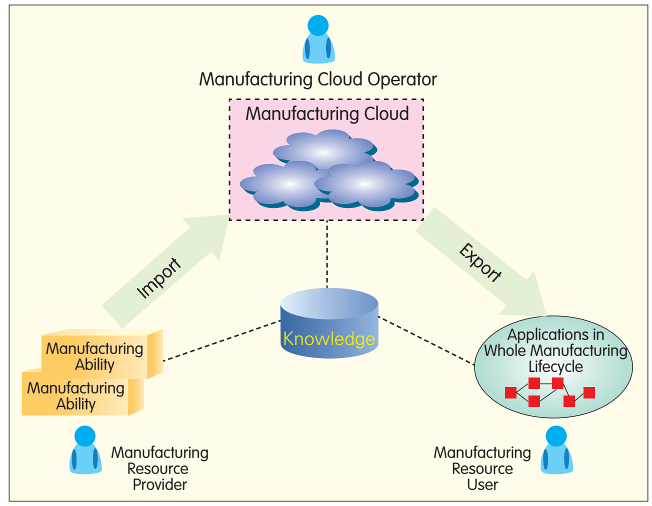
Manufacturing resources include machines, processing centers, and computing equipment used during the whole manufacturing lifecycle. They also include models, data, software, and professional knowledge used during production. Besides cloud computing technology, semantic Web[8], embedded system technology[9], Internet of Things[10], and high-performance computing may be used for virtualization, optimization and scheduling, and collaboration of manufacturing resources. Development of semantic Web technology lays the foundation for knowledge-based intelligent computing, and the rapid development of embedded system technology enables smart access of physical terminal devices. The Internet of Things is quickly growing in line with Radio Frequency Identification (RFID)[11] and sensor technologies and will promote interconnection between things. Development of high-performance computers and high-performance computing technology[12] may provide solutions to complicated manufacturing issues in large-scale collaborative manufacturing.

There is great potential for research and application of cloud manufacturing.

3 Research Progress of Cloud Manufacturing

3.1 Definition of Cloud Manufacturing

Cloud manufacturing is a service-oriented, knowledge-based smart manufacturing system with high efficiency and low energy consumption. In a cloud manufacturing system, state-of-the-art technologies such as informatized manufacturing technology, cloud computing, Internet of Things, semantic Web, high-performance computing, and cloud manufacturing are integrated. By extending and shifting existing manufacturing and service systems[13-14], manufacturing resources and capabilities are virtualized and oriented towards service provision. In cloud manufacturing, pervasive and efficient sharing and coordination of resources and capabilities can be achieved by their unified and centralized intelligent management and operation. Cloud manufacturing provides the whole manufacturing lifecycle with secure, reliable, high quality, and on-demand services at low prices through networked system. The manufacturing lifecycle includes pre-manufacturing (argumentation, design, production and sale), manufacturing (product usage, management and maintenance), and post-manufacturing (dismantling, scrap, and recycling).



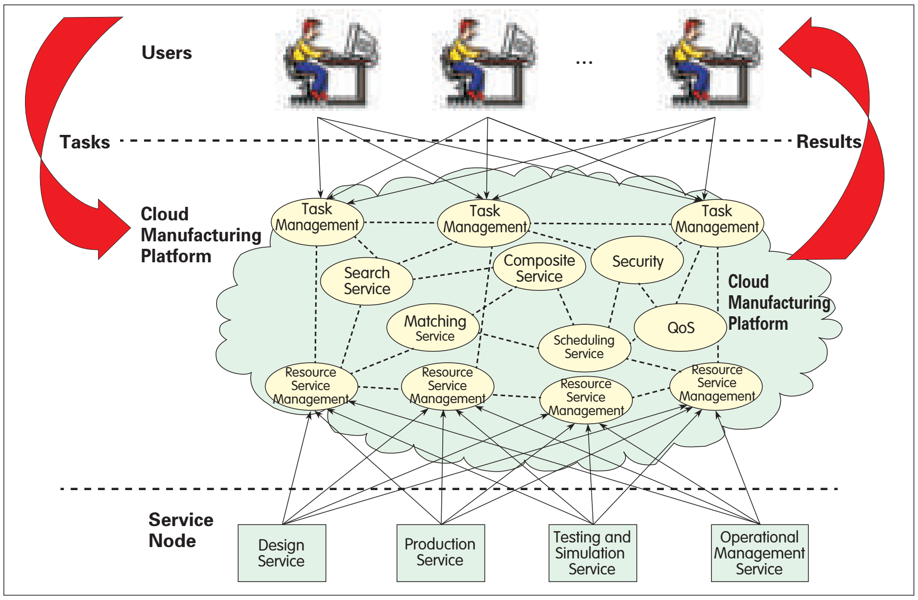
▲Figure 1. Operational principle of cloud manufacturing.

3.2 Operation Model and Key Technologies of Cloud Manufacturing

A cloud manufacturing system consists of manufacturing resources and capabilities, manufacturing cloud, and the whole manufacturing lifecycle applications. It also includes core support (knowledge), two processes (import and export), and three user types—resource providers, cloud operators and resource users. Figure 1 illustrates the operational principle of cloud manufacturing. Manufacturing resources and capabilities are encapsulated as cloud services. This process is called manufacturing resource "import". Depending on different manufacturing requirements, cloud services are combined to form a manufacturing cloud. The cloud provides the whole manufacturing lifecycle applications with diverse services. This process is called "export". Knowledge plays a central role in supporting the entire operating process of cloud manufacturing. It is necessary for intelligent embedding and virtualized encapsulation during import; it assists functions such as intelligent search of cloud services; and it facilitates smart cooperation of cloud services over the whole manufacturing lifecycle. In a cloud manufacturing system, knowledge-based integration across the whole lifecycle is possible.

A cloud manufacturing application model is shown in Figure 2. Users send specific requests to the cloud manufacturing platform. This platform is responsible for the management, operation, and maintenance of manufacturing clouds and service tasks such as import and export. It analyzes and divides service requests, and automatically searches the cloud for best-matched services. By a series of processes including scheduling, optimization and combination, a solution is generated and then sent back to the client. A user does not need to communicate directly with every service node, nor find the specific locations and situations of service nodes. Through the cloud manufacturing platform, manufacturing resources and capabilities can be used in the same way as water, gas, electricity, etc.

Cloud manufacturing architecture has five layers: physical layer, virtualized resource layer, service layer, application layer, and user layer, as



▲Figure 2. Application model of cloud manufacturing.

shown in Figure 3[3].

Figure 4[3] illustrates the key cloud manufacturing technologies including:

- System architecture, operation model, standards, and specifications
- Clouding technologies for resources and capabilities
- Comprehensive management technologies for cloud services
- Cloud security and trusted manufacturing technologies
- Management models and technologies of manufacturing cloud services

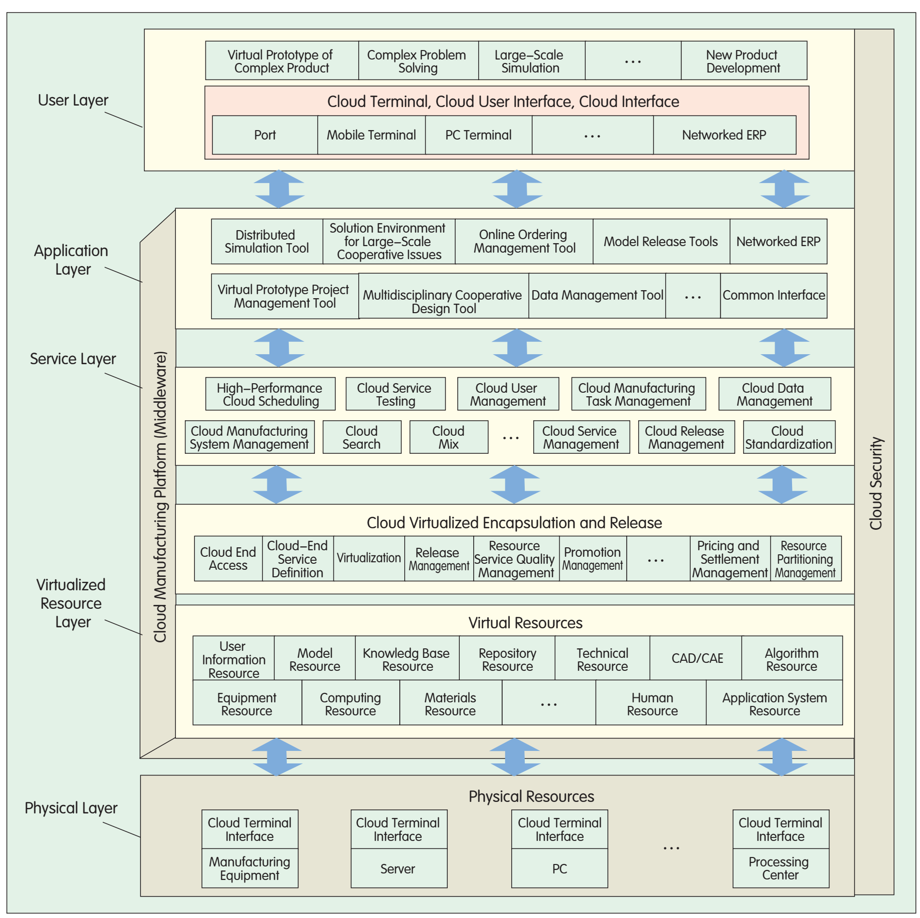
3.3 Primary Research Achievements

To demonstrate the feasibility of the cloud manufacturing concept, our research team developed a typical cloud manufacturing application—cloud simulation technology—based on the COSIM Cloud Simulation Platform (COSIM-CSP)[15]. Cloud simulation technology has primarily been applied in the multidiciplinary design of a virtual flight vehicle prototype. COSIM-CSP uses visual pervasive portal interface technology, project management technology for complex products, simulation resource virtualization, error-tolerance technology, security and trusted mechanism, resource service quality assessment based on semantic knowledge, smart discovery, automatic combination technology, and dynamic scheduling technology. This prototype lays the foundation for further study into cloud manufacturing.

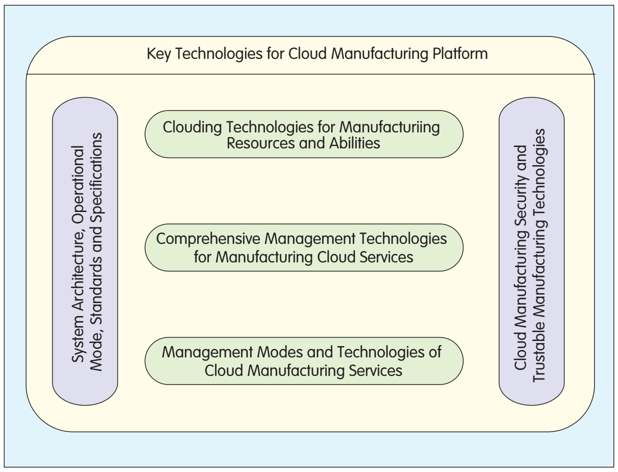
4 Prospects for Cloud Manufacturing

Cloud manufacturing is a new model to manufacturing Informatization and has huge development potential. Research into cloud manufacturing relies on the joint efforts of industry, academia and government. The application of cloud manufacturing will be a gradual, long-term process rather than an overnight project. For the success of cloud manufacturing, enterprises should have good foundation on internal integration of information and processes. Therefore, there is a relative high entrance standard to implement cloud manufacturing for the majority of manufacturing enterprises.

The future development of cloud manufacturing will face many challenges in key technologies.



▲Figure 3. Cloud manufacturing system architecture.



▲Figure 4. Key cloud manufacturing technologies.

Besides the integration technologies of cloud computing, Internet of things, semantic web high performance computing, and embedded systems, several important technical issues must be solved such as knowledge based resource clouding, cloud management engines, collaboration between cloud manufacturing applications, and visualization and user interface in cloud environments.

5 Conclusions

After information and processes have been integrated and inter-enterprise integration has been achieved, manufacturing Informatization technologies focus on core value factors such as service, environment, and knowledge. A new smart manufacturing model—cloud manufacturing was proposed. Further research into cloud manufacturing will accelerate the development of an intelligent, networked, service-oriented, informatized manufacturing industry. This article discussed the technical basis, concept, operation model, architecture, and key technologies of cloud manufacturing. It presented the primary research achievement, and looked into the future of its development.

Acknowledgment: Thanks to Dr. Ren Lei and Dr. Tao Fei from Beihang University, and Dr. Hou Baocun from Beijing Simulation Center for their contributions to this work.

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Service-Oriented Semantic Interoperability Technologies and Standards

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Abstract: Service-Oriented Software Engineering (SOSE) presents new challenges; in particular, how to promote interoperability and cooperation among loosely-coupled service resources. This is critical for service resource sharing and for implementing on-demand services. This paper discusses key technologies of service virtualization, including encapsulation of service interoperability (for available resources); ontology-based Role, Goal, Process, and Service (RGPS) metamodeling (for interoperable aggregation and organization of virtualization services); registration and repository management of Metamodel Framework for Interoperability (MFI) (for virtualization service management); and virtualization service ontology and its represented association with RGPS. Latest progress of the MFI and ISO standards is also discussed.

Key Words: metamodel framework for interoperability; service on demand; service aggregation

Software architecture, as well as its release and use, are undergoing revolutionary changes. Convergence of software and service technologies is progressing at incredible speed, but innovation in theory and methodology lags far behind. On the one hand, information technology has boosted the modern services industry and driven forward social development. On the other, software, hardware, and organization systems in computer and information management still adopt traditional knowledge structures. As yet, there is no formal discipline to fill a gap in the IT field—namely, service[1].

User-centred, on-demand service is the basis of modern Service-Oriented Software Engineering (SOSE)[2]. An increasing number of IT companies are transforming their business models from ones with hardware at their core towards ones with computer software and service at their core. Cloud computing is a scalable platform and business model used by service providers and consumers for delivery of and access to services. Cloud computing aims to allow all parties in the value chain—including consumers, partners, and service providers—to share resources. In Software as a Service (SaaS), Platform as a Service (PaaS), or Infrastructure as a Service (IaaS), cloud computing is actually a service. SOSE is the technical basis of cloud computing, and immediate innovation is needed in both theory and methodology.

In January 2010, the China Computer Federation (CCF) established the Technical Committee of Services Computing (TCSC), and in doing so, demonstrated China's ongoing commitment to research and education in service computing. The technical committee has made good progress in developing software methods for service composition and optimization. However, software engineering still requires extensive systematic study and innovation. This paper draws on research results of projects conducted by the authors. Semantic interoperability is discussed from the perspective of the SaaS model in SOSE.

1 Interoperability Among Loosely-Coupled Services

Autonomously-distributed, heterogeneous services are loosely coupled over the Internet. Reference [3] compares loose coupled services using SaaS and tight coupled message transfer in traditional Object-Oriented (OO) software design. In the latter, local or desktop OO software is tightly coupled with pre-design. Loose

This work was funded by the National Basic Research Program of China ("973" Program) under Grant No. 2007CB310801, the National Natural Science Foundation of China under Grant No. 60970017, 60873083, 60803025, and 60903034, and the Foundation for Distinguished Young Scientists of Hubei Province of China under Grant No. 2008CDB351.

coupling dynamically binds services with asynchronous and remote communications, while tight coupling allows cascaded connections, static binding, and integrated operation. Moreover, loose coupling aims to dynamically obtain and collaborate behaviors; tight coupling aims for seamless connection. Therefore, the functional structure of loosely coupled service software dynamically changes without any definite boundary, whereas tightly coupled OO software has a definite boundary, structure, and functions.

Semantic interoperability[4] is the ability of two service units or systems to communicate data. The information and knowledge in the data must be properly interpreted by the receiver in the sense it was intended by the transmitter. That is to say, information and knowledge can be fully understood, with the result of effective collaboration. Collaborative effectiveness is determined by the two interoperable sides through negotiation.

Semantic interoperability is generally divided into three levels:

(1) Meaning interoperability: Also known as deep or perfect semantic interoperability. It requires both parts to fully understand the agreed semantics.

(2) Partial semantic interoperability: Service entities can only understand part of the agreed semantics.

(3) Non-semantic interoperability: Occurs when partial semantic interoperability between service entities falls below a certain threshold. This level of semantic interoperability includes syntactical (or structural) interoperability.

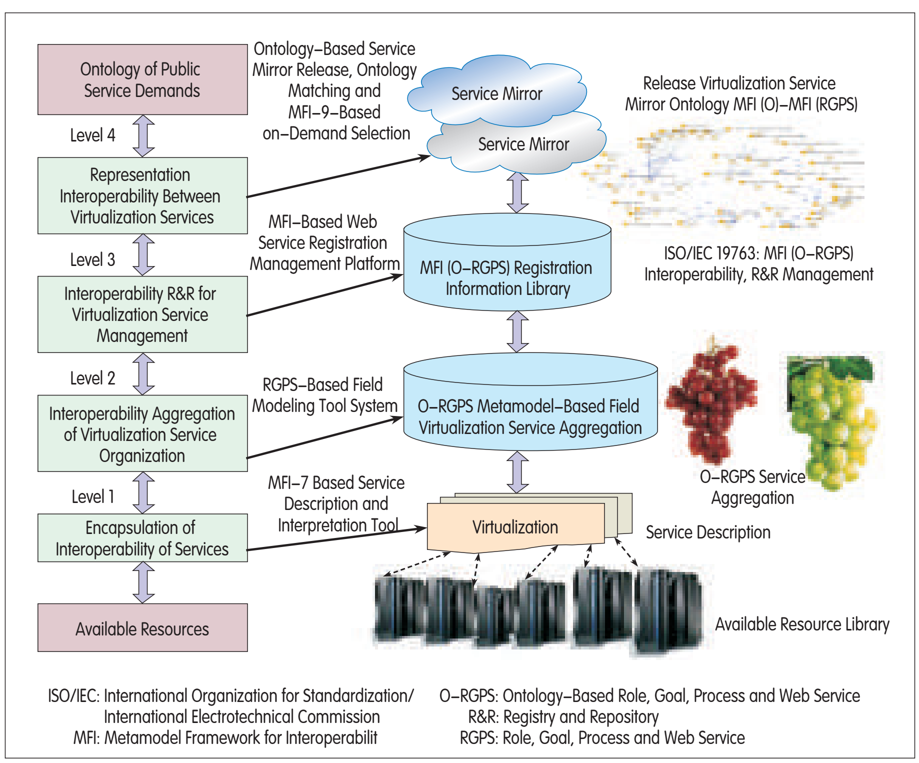
Partial semantic interoperability represents a large gap in current research, and more attention should be paid to describing its theories and methods.

Semantic interoperability between loosely-coupled services poses challenges. A common framework for interaction and interoperability should be studied first. Extensible Markup Language (XML) enables unified information description, but is only a framework for syntactical interaction. To support semantic interaction, the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) have jointly worked out the ISO/IEC 19763 standard. This defines a Metamodel Framework for Interoperability (MFI)[5] , and its core model is semantic interoperability management between loosely-coupled services.

2 Service Aggregation

Service-oriented software adopts a "pay only for satisfactory services" model. In this way, everyone acts as both user and developer. Users may enjoy on-demand services and pay-by-use services, but do not necessarily seek to own services. Providers deliver high-quality, fine-granularity, and flexible services in order to meet users' diverse needs. To realize high Quality of Experience (QoE) user-centred public services, it is necessary to provide not only one or more separate services, but a set of services that are capable of semantic interoperability. Take self-catering for example. Prompt, high-quality service is possible if a store can supply not only the raw foodstuffs but also alternatives to cater for personal preferences and recipes for guiding the user through cooking. On-demand service requires service aggregation.

In the theory of service aggregation, partial semantic interoperability clustering of demand-driven services is studied. A public demand-based Role, Goal, Process, and Service (RGPS) metamodel and its description framework[6-7] is suggested. RGPS metamodel draws together ontology metamodeling theory and methodology, and uses an ontology-based RGPS metamodel to organize service aggregation. The theory, methods, and software tool suite for group demand-oriented service resource aggregation modeling (mass customization of service aggregation) is in this way developed. Aggregation of services with partial semantic interoperability is achieved based on group service ontology, and such aggregation is adjustable and controllable. The hierarchical architecture of service virtualization software is shown in Figure 1. Service aggregation can be vividly described



▲Figure 1. Hierarchical architecture of service virtualization software.

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as a bunch of grapes in which the pedicle is equivalent to users' social roles and service goals, and the stalk is equivalent to the operational process (including supply chain and workflow). As well as being organized in a simple tree structure, the stalks are also organized into complex control structures, such as parallel and cycle. Grapes are equivalent to services or atomic services. The ontology indicates semantic association between RGPSs. One field often has several service functions, which correspond to several service aggregation "grape bunches."

3 Service Virtualization

In 1959, Christopher Strachey et al. proposed virtualization technology for computer hardware that used decoupling. In the 50 years that followed, virtualization technologies, such as computer arrays and servers, have greatly progressed. Traditional software virtualization technologies, such as virtual memory management and virtual job scheduling in the Operating System (OS), have played an important role in the development of computer science and engineering.

Software theories and service virtualization methods are core research areas in SOSE and are critical for high mobilization, in-depth sharing, and on-demand services. One critical problem involves resolving the contradiction between decoupling and interoperable cooperation in a dialectical way. If this contradiction can be resolved, a software service can be worked out that features decoupling of support services from available resources, decoupling of service demand from service resources, dynamic obtaining of behaviors of loosely coupled services via the network, interoperable collaboration among loosely coupled services, interoperable cloud services, and On-Demand Service-Oriented Architecture (ODSOA).

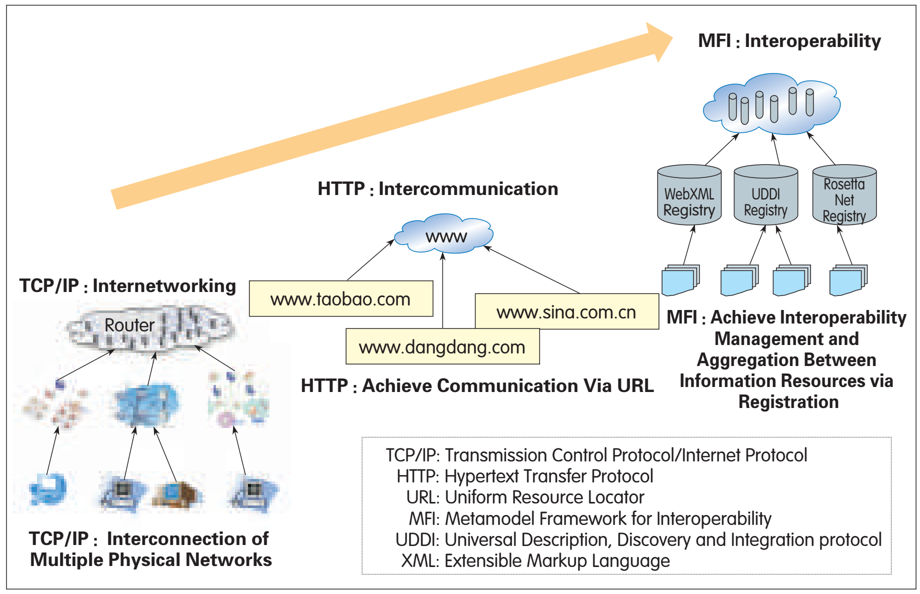
In terms of service virtualization, the following four levels of computing methods and software toolkits have been studied:

(1) Encapsulation of service interoperability between available resources

(2) Ontology-based RGPS metamodeling, used for aggregation of interoperability in virtualization service organization

(3) Interoperability and metamodel framework for Registry and Repository (R&R) management in virtualization service management

(4) Virtualization service ontology and representation of its association with RGPS, generation of public demand-based service ontology, and service ontology matching



▲Figure 2. Basis of interoperability management of information resources: MFI.

4 Metamodel Framework for Interoperability

Internetworking, interconnection, and interoperability are basic features of network technologies. A number of Local Area Network (LAN) and Wide Area Network (WAN) protocols enable computing devices to interconnect with each other; Transmission Control Protocol/Internet Protocol (TCP/IP) makes internetworking possible; and Hypertext Transfer Protocol (HTTP) and Hypertext Markup Language (HTML) protocol are used for interoperability between terminals and websites, allowing users seamless access to the web using a browser that complies with these protocols. Web services and Service-Oriented Architecture (SOA) open the door to service computing. However, in service computing, service-based interoperability poses new challenges. As shown in Figure 2, MFI is the basis of interoperability management of information resources.

Currently, many enterprises, organizations, and individuals use specific syntaxes and formats to create a large number of information resources, store them in various registration libraries using particular registration metamodels, and release them on the Internet in a specific way. Users can access these information resources. With the emergence of new computing models such as cloud computing, network resources are uniformly released as IaaS, PaaS and SaaS. In a network environment, available information resources exist in the form of a service and are provided to users on a pay-by-use basis. It is necessary to manage these distributed, heterogeneous, and autonomous information resources in a centralized way, and to shield details about their physical locations. Public demands tend to be diverse and individual, and may involve knowledge in several fields. Therefore, customization of cross-field/organization resources and services must be implemented by means of interoperability and collaboration. However, data and services provided by enterprises and organizations have different syntax and semantics, which prevents them from effective sharing and exchange. Determining how to use open standards to achieve interoperability between services is a very important issue. Open interoperability standards cannot replace existing standards, but can achieve partial semantic interoperability with them while maintaining independence.

The glossary of the Institute of Electrical and Electronics Engineers (IEEE) defines interoperability as "the ability of two or more systems or components to exchange information and to use the information that has been exchanged." "Exchange" means certain agreements must be reached between these systems for data format, communication protocol, and interface description. "Use" means the two interactive sides can completely understand the meaning of exchanged information. To achieve interoperability between software systems, it is necessary to clearly record the syntaxes and semantics adopted by the exchanged information. This process is called registration. An accurate description of the correspondence between the syntaxes and semantics is needed, and this process is called establishment of syntax and semantics mapping. Registration is also a virtualization aggregation service technology. Therefore, ISO/IEC Joint Technical Committee 1 Subcommittee 32 (JTC1 SC32) are developing a multipart MFI standard, which provides reference for the basic management information—such as model registration, ontology registration, and model mapping—of registered information resources. This standard can facilitate interoperability between software systems to some extent.

In 2003, entrusted by the ISO, the authors began to develop ISO/IEC 19763-3: Metamodel for ontology registration. This was based on ontology metamodeling theories and technologies the authors had developed for semantic interoperability registration and storage management. In March 2008, this part of the MFI standard was released and put into use by the ISO. It provides semantic support for interoperability registration of service resources. Later in 2008, a new proposal[8] was submitted to the ISO, which was subsequently approved in 2009 after expert review. The authors have been entrusted to study and develop the other four parts of the MFI standard: ISO/IEC 19763-5, 7, 8 and 9. The multipart MFI standard can be described according to the following two aspects:

(1) Basic model for interoperability management oriented towards on-demand service selection

MFI-1, 2, 3, 4 and 6 describe the basic models for registry and repository management in semantic interoperability, including Sign-Concept-Instance-Selection (SCIS) core model, semantic-supported ontology registration metamodel, and semantic mapping metamodel. These parts of the MFI standard are primarily designed to create a uniform registration standard for various heterogeneous information resources and services based on the abstract metamodel layer. Semantic and syntactic support can then be provided for interoperability between these resources and services.

- MFI-1: Reference model. This describes the research scope of the standard and the relationship between all parties of the standard.
- MFI-2: Core model. This defines the relationship between the model to be registered, metamodel, and ontology. It serves as the basis for mapping between models, and interoperability between software systems.
- MFI-3: Metamodel for ontology registration. This provides a common registration mechanism for ontologies described in various languages, which can promote interoperability between ontologies and lay the foundation for semantic interoperability between software systems. As information resources and services continuously evolve to meet user demands, future research into MFI-3 will need to take into account the impact of ontology evolution on interoperability between information systems, and evolution information related to ontology registration will need to be extended.
- MFI-4: Metamodel for model mapping. This is primarily used to register and manage mapping information between metamodels or models. It provides support for transformation between metamodels or models that are defined with different languages.
- MFI-6: Model registration procedure. This specifies the procedure that should be adopted in registering various models.

(2) On-demand service-oriented RGPS registration metamodel standard

To be user-centred and provide computing resources as a service, this standard must manage not only data resources, but also service resources, user demands and their association information. In this context, a method that can reasonably describe user demands and services is required. User role, business goal, business process, and service resources are four fundamental elements in such a description[9].

Based on recent research into RGPS, the authors have submitted MFI-5, 7, 8, 9 proposals to ISO/IEC JTC1 SC32. These proposals have been approved by the ISO, and related metamodels are under development: MFI-5 metamodel for process model registration, MFI-7 metamodel for service registration, and MFI-8 metamodel for role and goal registration. These parts of the MFI standard specify standard registration methods for information resources at different levels and of different granularities—such as business processes, services, and goals—and unify the representation of these resources to the public. In addition, MFI-9 provides a complete methodology, detailing the relationship between registration information provided and other parts of the standard. It explains how to use the registration information as well as how to implement multiple iterations of model mapping in order to help in the selection and customization of

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on-demand services.

5 Conclusion

This paper discusses several important issues in the research of theory and methods for services computing, and introduces the progress of related research. SOSE theory and methodology involves many aspects. Its core goal is to promote interoperable collaboration between loosely coupled service resources in the context of Internet, and thus achieve in-depth sharing of service resources and on-demand services. In the future, further study will be undertaken into key technologies and standardization for construction, management, and services for interoperability between cloud services. The authors' ultimate objective is to promote the rapid development of China's software engineering discipline and modern service industry in the era of cloud computing.

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Biographies

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Roundup

ZTE Deploys the World's First Large-Scale Commercial GPON-Based Mobile Backhaul Network for TELKOM Indonesia

ZTE Corporation, a leading global provider of telecommunications equipment and network solutions, announced on November 23, 2010 that it has successfully completed the world's first large-scale commercial GPON-based mobile backhaul network for TELKOM Indonesia, a full-service telecom operator in Indonesia. The project is the first such large-scale commercialization of GPON backhaul technology, and is based on ZTE's mobile network platform.

With Indonesia's strong growth in broadband demand in recent years, TELKOM Indonesia needed to meet traditional voice service demands and its current extensive range of broadband services such as high-speed Internet, IPTV and online games, while also considering the integration of fixed and mobile networks to cater for future bandwidth growth.

Recognizing the need to deploy a GPON based Mobile Backhaul solution to meet the complex networking and bearing requirements involved in business scenarios today, TELKOM Indonesia embarked on the use of GPON technology in 2009. Since the network was put into operation in 2009, users have been able to enjoy improved high-speed internet speeds and service experiences.

The report by Point Topic also made note that the current top 10 fast broadband growth countries are mostly in Asia Pacific and Southeast Asia; including China, Indonesia, Philippines, Vietnam and Pakistan. Alongside this venture with TELKOM Indonesia, ZTE is also implementing projects with China Telecom, Telecom Malaysia and other Asia Pacific operators, to help drive the Asian-Pacific broadband development and deployment into an "accelerated fast lane," so as to achieve "Asia-Pacific FTTx construction mode" according to the report. (ZTE Corporation)

On-Demand Service in Cloud Computing

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Abstract: Cloud computing provides a new paradigm for hardware and software infrastructure design as well as planning and usage of information systems. It offers flexible, efficient, inexpensive, and quality services. This paper proposes an on-demand service system using the cloud computing architecture and analyzes important issues such as organization, management, and monitoring of distributed service resources; context-aware on-demand service modeling, on-demand automated service composition in large-scale networks, and service system analysis based on complex system theory. Continuous Operating Reference Station (CORS) of a geo-spatial information system is taken as an example, and its architecture is analyzed from the perspective of cloud computing. Some fundamental questions are raised about its service.

Key Words: cloud computing; service composition; situation modeling; on-demand service

The cloud computing model aims to change the way traditional computing systems are used and occupied. Computing and communication resources are organized and aggregated through networking, and users are provided with scalable computing resources through virtualization. Therefore, planning, purchasing, occupying, and using a computing system is made more flexible for users[1-3]. As far as users are concerned, services received (rather than computing resources) are the major issue. Providing and using services can therefore be deemed a key issue in cloud computing.

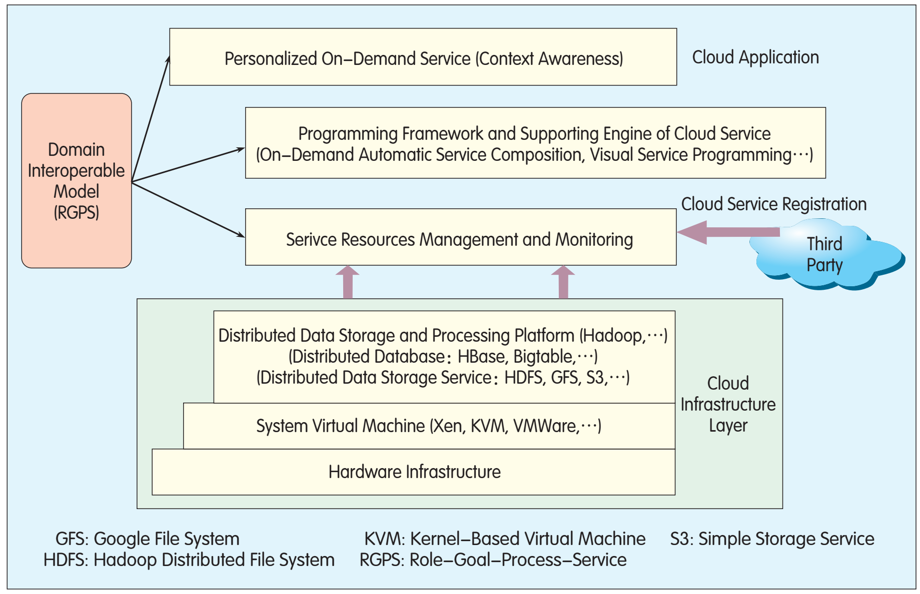
Cloud services are provided using a universal interface and by managing, dispatching, and integrating resources distributed throughout the network. Applications can process information at terabyte scale or even petabyte scale in a very short time, and thus provide super computer processing capability. Services are used on demand and are charged accordingly so that processing, storage, and software becomes a public facility. Two layers exist in cloud computing: infrastructure (hardware, platform, and software), and cloud applications (information service established on the infrastructure).

Fulfilling service demands is critically important. Besides infrastructure services such as Amazon, Google's App Engine, and Windows Azure, distributed data storage and processing platforms such as open source Hadoop[4] provide horizontally scalable services for storing and processing mass data. Developers are starting to develop and deploy cloud services and applications in ever increasing numbers. It is predictable that more and more services will become available on the Internet. Service issues not only encompass user demands but also functions and performance offered by providers. In the eyes of consumers, cloud services should satisfy personalized demands. Domain knowledge from the cloud and user state information can be obtained to provide context awareness that significantly optimizes user experience. On the other hand, for those who maintain the cloud platform, consideration must be given to efficiency in satisfying demand. Issues such as maintaining optimal experience, accommodating as many users as possible, and creating energy-saving platforms must be carefully considered.

Geo-spatial information systems are an important part of information infrastructure. They integrate and apply information such as location, time, and geography obtained from the Earth's surface from space. Technologies used in geo-spatial systems include Global Positioning System (GPS), Geographic Information System (GIS), and Remote Sensing Technology (RS). Continuously Operating Reference Stations (CORS) is a major part of a geo-spatial information system and provides positioning reference and timing. Therefore, various GIS and RS application systems can be

This work was funded by the National Basic Research Program of China ("973" Program) under Grant No. 2007CB310805, and the National High Technology Research and Development Program of China ("863" Program) under Grant No. 2007AA12Z309.

established. CORS typically comprises a reference station that has fixed coordinates and collects satellite signals, a data center used for computing and providing positioning service for users, and user terminals and wide area network used for real time data transmission. From the perspective of cloud computing, CORS has an established resource management and dispatching platform, and can provide services such as space positioning and timing to users. Herein, service issues in cloud computing architecture are discussed as well as the application of cloud computing in CORS system, CORS architecture, and related key technologies.



▲Figure 1. Application architecture of on−demand service in cloud computing.

1 Application Architecture of On−Demand Service in Cloud Computing

The application architecture of on−demand cloud service is shown in Figure 1. It consists of four layers:

(1) Infrastructure Layer

Support for multiple cloud centers involves controllable internal clouds, but also having accesses to third−party cloud resources with related service level protocols. The cloud platform pools these resources to provide unified cloud services for upper−layer system modules and applications. Cloud infrastructure supports numerous resource types including hardware, structured and unstructured data storage, and basic software.

(2) Service Resource Management and Monitoring Layer

Resources provided by the cloud infrastructure layer can be registered into the service resources management system, as can specific service−oriented resources (including resources from third parties). All service resources are used in a unified way. In this layer, resource management attributes in the large−scale distributed environment are dynamically monitored and controlled. Resource management is provided for layer resource scheduling and on−demand services. Depending on different monitoring and management demands, specific resource models, management attributes, and monitoring policies can be defined to ensure scalability in resource management and monitoring.

(3) Programming Framework and Supporting Engine Layer

This layer supports service programming according to the basic platform and service resources. It also provides engine support for service operation. The application of cloud computing in numerous industries is leading to a rapid increase of cloud−based Application Program Interfaces (API) and services. An application demand usually draws on multiple service resources. Therefore, it requires a suitable environment for combining different service resources, and the support of an operating engine. In this layer, predefined service templates, visualized manual service composition, and automatic on−demand service composition for dynamic, large−scale environments is implemented. Efficient and reliable combining of applications for large−scale concurrency is also implemented.

(4) Personalized On−Demand Service Layer

This layer determines how on−demand personalized cloud services are provided to users. It determines:

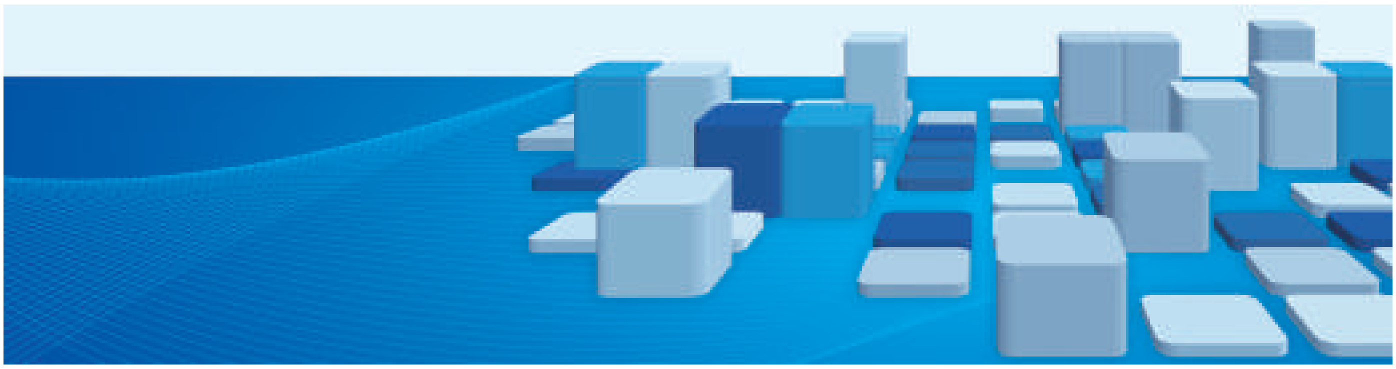
- How to support users in describing their demands accurately so that resources can be accurately identified, recommended, and matched according to these demands;
- Context awareness relating to information such as the state of available resources and user scenarios in order to provide services that are adaptable to information changes.

2 Key Technologies for Implementing On−Demand Services in Cloud Computing

2.1 Distributed Management and Resource Status Monitoring Technologies

Cloud computing not only virtualizes hardware, storage, and network resources, but also various software resources to provide Software as a Service (SaaS). Internet resources are registered and managed on a unified platform; and for high quality SaaS, effective and dynamic monitoring, management, and control of these resources is necessary. In a large−scale distributed environment, important considerations for dynamically monitoring and managing heterogeneous resources include:

- How to address different



management and monitoring demands in order to dynamically configure different resource types and their management attributes;

- How to support easily-scalable monitoring architecture;
- How to best monitor resources and predict status by establishing efficient and flexible monitoring policies and creating as little resource overhead as possible;
- How to efficiently and automatically monitor resource state using smart management technology, and how to diagnose faults so that basic support is provided for high quality services.

As in Reference [5], a cloud computing architecture is proposed that allocates resources according to a market mechanism and Service Level Agreement (SLA). One of the fundamentals of resource allocation according to SLA is effective monitoring of resources of multiple providers. Reference [6] describes a large-scale distributed heterogeneous resource management and monitoring platform called C3 service management. Using this platform, resource registration, management, and automatic monitoring, can be realized.

2.2 Modeling Technology of On-Demand Services with Context Awareness

When resources become abundant on the cloud platform, services with context awareness play a key role in optimizing user experience.

(1) User Demand Modeling Based on Domain Demand

Domain demand models are the basis for modeling users' personalized demands. Semantic interoperable technology uses domain specifications and demand models to create an interoperable semantic base for correctly describing and matching user demands. It also provides underlying support for user-centered demand modeling and automatic service combination. Reference [7] proposes a method of discovering conflicts among multiple inter-organizational service processes. It also provides a solution based on independent amending areas for resolving conflicts. This method is used for assisting and checking user demand modeling during a service process.

(2) A Demand Model that Supports Uncertainty

Another challenge for accurate demand modeling is user uncertainty. In situations where a user may be unspecific, unsure, or provide incomplete information, accurately predicting these demands is a key concern of demand modeling. Uncertainty also lies in service modeling and evaluation. When services are matched with demands, uncertainty requires prediction. Therefore, uncertainty models and speculative technologies such as probability logic, fuzzy logic, and cloud model should be used together.

(3) User Scenario Modeling

User context awareness plays a key role in providing on-demand services that can intuitively fit status changes. Aiming to address modeling demands in uncertain scenarios, Reference [8] suggests a probabilistic-constrained fuzzy logic as well as its speculative method. As opposed to conventional context aware computing, cloud applications deal with resource states, user context awareness, and speculative computing on a large scale. Issues related to scenario identification and speculation must be addressed in a large-scale environment. To solve these issues, efficiency is key. Identification and speculation for a single scenario is not complicated. However, highly effective algorithms are needed for identification and speculation on a large scale.

2.3 Automatic Service Composition Technology on Demand

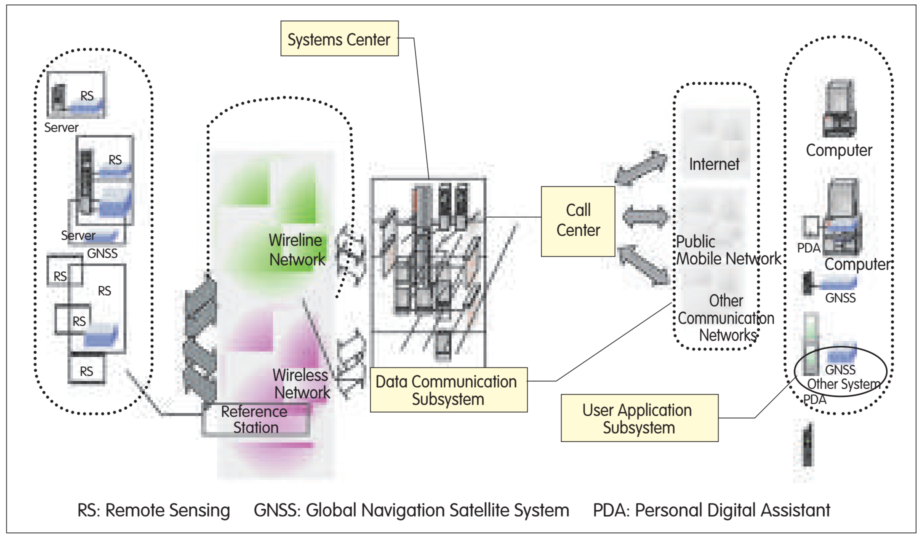
Cloud file systems and concurrent processing models such as Google File System (GFS) and MapReduce are becoming more sophisticated. Large-scale database services are also improving with the emergence of Bigtable, PNUTS, Dynamo, Cassandra, Hbase, and Azure. These open-source or commercial systems lay a solid foundation for the development of cloud-based applications. Using combinatorial modeling and operation mode in current Service Oriented Architecture (SOA), flexible combination modeling can be implemented and operational support for application combinations can be provided using various workflow engines. However, SOA cannot adapt to mass service management and mass concurrent execution request in the cloud computing environment. The conventional method of manually selecting interoperable services for composition modeling cannot be applied when developing cloud-based composition applications because of the massive number of service resources in clouds. Also, a centralized execution engine cannot process hundreds of thousands of concurrent tasks, nor can it meet large-scale monitoring requirements. In the context of cloud computing, on-demand construction and operation of service composition applications is the most important issue to be solved.

(1) Automatic On-Demand Construction of Service Composition Applications

On-demand construction of service composition applications helps developers:

- Retrieve and organize resources automatically or semi-automatically according to coarse-grained user requirements and context;
- Assist users in constructing intricately combined application programs by providing flexible and accessible navigation.

On-demand construction relies on multimode rapid application modeling technology based on automatic service composition. Amazon and SAP have explored automatic service composition technology in modeling using WS-BPEL and various process modeling tools[9-10]. Further research must be done on application grain size and application mode of automatic service in cloud computing. This involves researching location- and time-based search in conjunction with navigation system, and hybrid modeling in conjunction with on-the-fly or interactive recommendation. To help cloud application developers, algorithms for simplifying application configuration[11-12] should be studied. Moreover, reasonable concurrency patterns and distributed processing methods are required to improve



▲Figure 2. CORS architecture.

processing ability and efficiency when configuring on-demand applications.

(2) On-Demand Deployment and Operation of Service Composition Application

When considering on-demand deployment and operation of service composition applications, user Service Level Agreements (SLA) as well as applicable computing, storage, and network facilities must be taken into account to optimize task scheduling, and to make maximum use of distributed resources. This improves the operation of the entire cloud system.

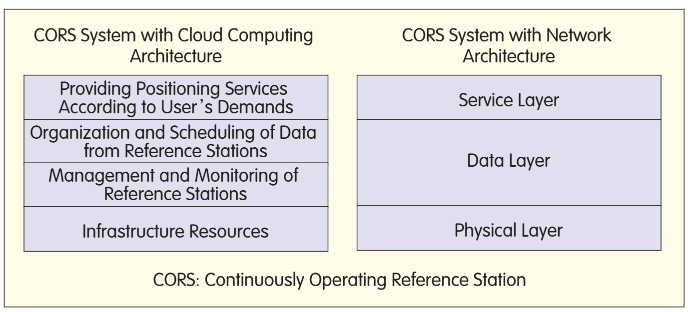
Key technologies include SLA and dynamic selection of service/route of context aware. When a service composition application is operating, the copy of the best Quality of Service (QoS) is selected for local and global optimization[13-14] with reference to the SLA between user and service provider, or to the user's context. In deploying and operating service composition applications, the resource application and SLA constraint should be taken into account for flexible shifting between wholly distributed or sharding structures. In this way, single-point performance bottlenecks can be avoided[15-16].

2.4 On-Demand Service Based on Complex Adaptive System

The cloud computing ecosystem is a typical complex adaptive system, with interactions between different parts of the cloud computing system, and between system parts and the networked cloud-computing environment. The cloud computing network, by self-organization, achieves an orderly state with a specific space-time structure (modal or community structure). The system therefore becomes self-organized, self-adaptive, and is capable of self-study. It can reproduce and develop in the complicated networking environment. If the cloud computing system and its components cannot keep pace with network development, it will be abandoned by consumers. That is why cloud computing must provide on-demand services. The cloud computing system must adjust its operation mechanism to suit the needs of the environment and users. With interactions occuring within the system, and between the system and environment, the cloud computing system is wholly interconnected, interworked, and interoperated in order to provide on-demand services. Compared with traditional computing systems, the networked cloud computing system has more independent composition units, and is capable of on-demand evolution and on-demand service provision with looser coupling and flexible scale. Study into networked cloud computing

▼Table 1. Response time and content of CORS services

Service Name	Service Response Time	Content Description	Type
Spatial Positioning Service	Real−Time	Positioning Service of Centimeter, Decimeter and Meter Grade	High−Level Service
	Rapid−Access	Positioning Service of Centimeter, Decimeter and Meter Grade	High−Level Service
	Afterwards	Positioning Service of Millimeter or Centimeter Grade	High−Level Service
Space Coordinates−Based Service	Afterwards	Providing Consistent Space Coordinates Reference	Basic Service
Satellite Trajectory Service	Afterwards, Rapid−Access	Providing Satellite Precision Orbit Parameter	High−Level Service
Time Service	Afterwards, Rapid−Access	Providing Time Parameter, Time Service	Basic Service
Meteorological Service	Afterwards, Rapid−Access	Providing Atmosphere Humidity, Ionization Layer Information	High−Level Service
Source Data Service	Afterwards, Rapid−Access	Providing GPS Observation Data	Basic Service
Other Services	Rapid−Access, Real−Time	Upon the Requirements	High−Level Service



◀Figure 3. Two CORS architectures.

systems from the perspective of complex adaptive system theory has significant implications for system management, and resource organization and scheduling[17].

3 Application of On−Demand Cloud Computing Framework in Continuously Operating Reference Station

3.1 Overview of Continuously Operating Reference Station

A typical Continuous Operating Reference Station (CORS) is a real−time communication and service system, consisting of reference station, data center, communication network, and user. Each reference station has a consistent and precise three−dimensional coordinate. The system transmits real−time observation data back to the data center, and the latter calculates the data, manages the devices, and provides users with real−time fast positioning services. Figure 2 shows the CORS architecture.

3.2 CORS Applications and Services

In China, CORS is mostly used in surveying and mapping, city planning, transportation and logistics, and hydroelectricity production. CORS services include providing coordinates derived from space, spatial positioning, source data service, and time service. Among these, source data service, space coordinates, and time service are basic CORS services. Spatial positioning, satellite trajectory, meteorological service, and geodynamics parameters are high−level services requiring integration with other information system services. Satellite trajectory is the aggregate of source data services; meteorological service is interdisciplinary, involving source data services and meteorological technology; and atmospheric environmental monitoring is a high−level interdisciplinary service. Table 1 shows the response time and content of these services.

3.3 CORS Architecture Analysis and On−Demand Cloud Computing Structure

When treated as a network, a CORS can be divided into three layers: physical layer, data layer, and application layer. Respectively, these correspond to physical interconnection, data organization and scheduling, and computing and service. From the perspective of on−demand cloud computing, the data layer of CORS can be further divided into a management and monitoring layer for resources (such as reference stations), and an organization and monitoring layer for reference station data.

CORS architecture in cloud computing is shown in Figure 3.

3.4 Key Factors Affecting the Application of Cloud−Computing Model in CORS

Two basic problems must be solved when applying the cloud computing model to CORS:

(1) Organization and Monitoring of Large−Scale Resources

Compared with cloud computing infrastructure, CORS resources are relatively simple: the physical devices are reference stations, data center servers, and communication network resources; and the data resources are initial data from reference stations, coordinates, service data generated by the system, and registered user information. Major problems arise in building a unified platform for cloud computing data and services, developing intelligent resource status management technology, monitoring resources actively and efficiently, and detecting the breakdown of resources.

(2) On−Demand Service Technology for Large−Scale Users

Compared with common Internet−based information service systems, CORS provides simple services with definite semantics and grammar. It generally uses rough user locations to carry out precise, iterative positioning. The difficulty lies in building a cloud computing platform compatible with the existing systems, creating sockets for system access and user login, and service mining and redirection according to the needs of active or inactive users.

4 Conclusions

A cloud computing system includes bottom infrastructure that provides computing ability, upper-layer service software, and users. One of the core problems in cloud computing research and development is services. This paper focuses on services and proposes an architecture of on-demand services in cloud-computing. Modeling of cloud computing services, mass automated service composition, and management and testing technology for distributed service resources is discussed. The architecture and technologies mentioned above will enable cloud developers to design the hardware and structure for different layers; to deploy, manage, and dispatch service resources; and to provide users with a flexible and efficient service system. This paper uses the example of CORS in a geo-spatial information system to analyze service demands, and to highlight two basic issues in providing effective services in the cloud computing architecture.

Acknowledgement: Thanks Researcher Liu Zhiyong and Professor Lü Jinhu for their guidance and assistance in the research and writing of this paper.

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Cloud Computing: Concept, Model, and Key Technologies

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Abstract: Cloud computing is a new network computing paradigm based on IP architecture, and its potential lies in new ICT business applications. For the majority of operators and enterprises, the main task associated with cloud computing is next generation data center transformation. This will ensure cloud computing becomes more widespread among enterprises, institutions, organizations, and operators. Cloud computing not only provides traditional IT resource usage and application services, but also supports full resource usage and application services such as IT, communications, video, mobile, and Internet of Things using a converged network infrastructure. Key cloud computing technologies include unified fabric, unified virtualization, and unified computing system. The formation of an open industry alliance and promotion of open technology standards will be critical for the future development of cloud computing.

Key Words: cloud computing; unified fabrics; unified virtualization; unified computing system

Cloud computing concepts, technologies, and terminologies are continually emerging and being discussed. In particular, interest is growing in the implementation of cloud computing for enterprises. Among industry professionals, there is a general level of understanding of the benefits cloud computing might bring. However, cloud computing is a new concept with a broad definition, and some in the marketing sector have espoused it as an omnipotent technology that includes everything, enables everything, and is ubiquitous. A certain degree of hype surrounds cloud computing, making the concept itself seem like real clouds: scudding and illusory. Unfortunately, marketing hype gives rise to misunderstanding about cloud computing and steers the cloud computing market blindly. This is detrimental to the growth of cloud computing in China. Many introductory articles have been written on cloud computing in China, but there are few papers that analyze its trends rationally. Therefore, a comprehensive clarification of the origin and definition of cloud computing is necessary. This paper seeks to analyze early infrastructure, technology models, and service forms of cloud computing and to summarize advantages and disadvantages so that a breakthrough direction can be ascertained for future cloud computing development.

It should be noted that current discussions on cloud computing in China are focused on the concept, technology, and model in its early days. Cloud computing was initially defined as a dynamic, scalable computing model for offering virtualized IT resources and applications over the Internet. Consumers are not required to have technical expertise, nor are they directly involved in investment, establishment, maintenance, or control in cloud computing. They use cloud services on demand, and pay only for what is used. The essential purpose of early cloud computing technology was to enable consumers to share a common physical resource pool by using virtualization technology. However, virtualization is not all of cloud computing. IT resource components in early cloud computing systems include servers, storage, bandwidth, networks, and security. Data centers are central in supporting and supplying resources and capabilities. Early cloud computing practice integrated virtualization, grid computing, and distributed computing technologies. It represented not only the innovative combining of emerging technologies, but also innovation in service and commercial models. Early cloud computing has influenced development trends in IT technology and IT infrastructure, as well as in IT commercial models, application development, and service deployment and operation.

Well-known and widely introduced, early cloud technology has been commercially deployed, and has achieved some successes. However, the philosophy of early cloud computing still has many limitations. In this paper, these limitations are traced to their source, and the next stage of

development is discussed from an industrial perspective. For the majority of enterprises, data center transformation is the foremost task of cloud computing. Data centre transformation will popularize cloud computing technology and enable widespread application in businesses, institutions, and organizations[1-4]. The early cloud computing concept, technology, and model will be expanded in an all-round way. Services based on traditional IT resources and applications will continue to be provided, but support will also be provided for resources and applications arising from the integration of IT, communications, TV, mobile, and Internet of Things technologies. There is little doubt that cloud computing, as a new technology and new operational model, will profoundly affect IT industrial development in the future.

1 Concept of Cloud Computing

Computer application models have generally developed in the following stages: large computer-based centralized architecture (Data Center 1.0); PC-based client/server distributed computing architecture (Data Center 2.0); virtualization-based Service-Oriented Architecture (SOA), and new-type architecture based on Web2.0 application characteristics (Data Center 3.0). In this context, the architecture and implementation characteristics of cloud computing have developed.

Cloud computing is a popular term, but it is still difficult to conclusively define. Understanding the term as it is most commonly used is necessary for further discussion.

"Computing" generally refers to computing application; that is, any IT application in industry or in the market. Because network technologies are being converged, all applications in information, communication, and video are integrated on a unified platform. Likewise, computing in cloud computing refers to any integrated ICT application. It is a straightforward concept. The key characteristic of cloud computing is not "computing" but "cloud."

The term "cloud" was born quite accidentally. In the early days of the Internet, a cloud was usually drawn to represent the Internet. The inner workings and complex mechanisms of networks were abstracted to simplify discussions of new technologies. The pervasive application of the Internet has fundamentally changed ICT application architectures. In this context, the term "cloud computing" is naturally used to represent new network computing characteristics and technology trends. This is the reason the term has become so popular.

Internet technologies become the basis of ICT applications, and ICT itself requires reconsidering and redesigning in response to new Internet application demands. As the Internet changes, ICT application platforms need to be morphed, and more innovative ICT application implementation and commercial models emerge. These changes may have such a great effect that people may perceive the new characteristics and phenomena of ICT from different perspectives. Despite having many definitions, cloud computing is essentially used for network implementation of ICT applications and services. Cloud computing here is clearly and strictly defined: Based on virtualized resources of integrated infrastructure, cloud computing is the ICT service delivery model for scalable ICT applications over IP networks.

The essence of cloud computing is applications over network; applications are the joint products of IP and IT technologies. The technologies and goals of clouds are continuously evolving. When Web technology emerged, it also had application characteristics of cloud computing and the prototype of a unified interface. As virtualization technology developed on the server application platform and Web-unified interfaces were launched, virtualization and Web were integrated for unified cloud computing over an integrated architecture.

2 Implementation Models of Cloud Computing

If clouds are essentially service implementation models, what do new cloud computing service models look like?

Amazon, Google, and Saleforces.com are well-known contributors to early cloud computing. They have successfully provided cloud services with distinguishable characteristics and using different models.

In Infrastructure as a Service (IaaS), IT infrastructure is used as a service platform to provide cloud services according to duration of use and amount of resources. IaaS consumers can be individuals or enterprises, institutions or organizations. Amazon Elastic Compute Cloud (EC2) is the first IaaS in the industry. Computing, storage, network, and security resources are rented to consumers, who use them with operating systems and application software.

In Platform as a Service (PaaS), application development environments are used as service platforms in order to provide development interfaces and tools for users to create new applications. Services within clouds are implemented by Internet and service providers. PaaS may use both internal and external IaaS. Google's AppEngine software environment provides application developers with PaaS, and developers use AppEngine to develop new applications.

Software as a Service (SaaS) refers to software based on IaaS or PaaS. As opposed to traditional software sets, SaaS implements services by Internet applications. SaaS is available in either internal or external IaaS/PaaS.

Saleforces.com is perhaps the most well-known SaaS operator, offering Enterprise Resource Planning (ERP) application services. SaaS application programs are centralized and managed by SaaS operators; so users are saved from installation, maintenance, upgrade, and management.

A cloud computing system consists of three layers: SaaS on the top, PaaS in the middle, and IaaS on the bottom. Below IaaS are the basic technologies of building block of cloud computing.

Basic characteristics of cloud computing, as observed from operational cases, are:

(1) Dynamical Scalability

Cloud technologies allow users to dynamically scale IT resources up and down according to requirements. Applications are operated on virtual platforms, and no pre-reserved fixed resources are locked. The capacity of a cloud service can be dynamically adjusted over certain periods, for special applications, and in response to a changing number of users.

(2) Very Large Scale Virtualization

Cloud service requirements and use are independent from specific physical resources. IT applications and services are operated on virtual platforms. Cloud computing enables users to access application services with a Web browser of any kind and an Internet connection. All required resources come from very large cloud platforms.

(3) High Availability

Cloud platforms guarantee high availability of services by replicating data for fault tolerance and using interchangeable homogeneous computing nodes. When a fault occurs at a physical resource point, applications on this point will move to other physical resources to keep working. The user knows nothing about this movement. Therefore, cloud computing has a higher availability than other computing means.

(4) Use as Needed and Pay-per-use

Clouds form a huge resource pool. Consumers buy cloud services according to their needs, and pay only for what they actually use—just like public utilities. In the short term and in the long term, commercial models will support pay-for-capacity used.

(5) Multiplexed Resources and Lower Cost

Statistical multiplexing technology is used in cloud computing resources. This greatly improves the utilization of physical resources, and sharply lowers the cost of cloud services.

Early cloud service models share a common characteristic: they use public cloud architecture to offer stand-alone cloud services. A cloud is built and operated by the same operator, and services are made publicly available through the Internet. This cloud is called public cloud. Stand-alone refers to clouds with single vertical applications, such as search application and IT resource application.

The concept of cloud computing was initially proposed for using the Internet to combine cheap computing resources scattered in different locations into a huge virtualized resource pool where stand-alone services could be offered. Cloud computing makes full use of idle resources to complete a great amount of computing. Moreover, it flexibly schedules resource capacity, and responds quickly to changes in resource demand. Cloud computing improves availability and utilization of computing resources, flexibility and scalability of applications, and service manageability. The goal of green and energy efficient computing will also eventually be fulfilled with lower operational costs.

Although the advantages of virtualization are evident in early cloud computing, and successes have been achieved market operation, cloud computing still has some limitations:

- There is no quality service (QoS) guarantee or controllable security mechanism for services, both of which are critically important to most IT applications.
- Implementation of cloud services is based on special private protocols. Therefore, there is a risk that services can be locked by operators.
- Stand-alone clouds limit diversity of cloud service types; that is, not all enterprise IT applications can be implemented in public clouds.

The reason for these limitations is that the public cloud model is built over the Internet, having nothing to do with network infrastructure, and cloud services are implemented using a best-effort model. Since virtualization for early cloud computing is based on private protocols, it is almost impossible for PaaS and SaaS to support cross-operator workload or workload transfer. This significantly restrains the expansion of cloud applications and services. Therefore, early cloud computing technology cannot be used for extensive ICT enterprise services, line services, or public user services, but only for specific stand-alone IT cloud services.

A Rich Media Cloud is a platform supporting multimedia applications such as voice, data, information, video, mobile, and Internet of Things. A user can have all the cloud resources, and be the sole user of the platform. This kind of platform is called Internal Cloud. A Private Cloud can be used and controlled by the user—it can be a cloud owned by the user himself, or a rented part of a public cloud. It may even be a combination of the two.

As a matter of urgency, the focus over the next five years will shift to internal and private clouds required by enterprises, organizations, institutions, and operators. This shift will mark a golden period for cloud computing, with a larger market and extended range of services. Currently, efforts should be focused on grasping the advantages of early clouds; integrating virtualization technologies for computing, application, and network; and offering new cloud computing services that are reliable, have controllable security, and are manageable. Open standards and industry alliances should be promoted so that rich media cloud systems and their operational models can be provided, and data centers and ICT applications transformed.

3 Evolution of Enterprise Data Center Architecture

Both public and private clouds require the support of powerful data centers and IP networks. The emphasis

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of cloud computing development in the next stage will lie on IT and communications applications of enterprises, industries, institutions, and operators. Therefore, further research is needed into requirements of enterprise IT applications, challenges in data centre evolution, and key technologies in the transition from enterprise data centers to internal clouds.

3.1 Challenges Facing Traditional Enterprise IT Applications

Data centers are platforms of traditional enterprise IT applications. They have stack architecture, including IT resources and isolated IT applications. However, as the number of enterprise IT applications grow, traditional data center architecture will no longer be capable of meeting market demands. In past years, the total number of resources—including servers and storage devices—increased by 40%–70% each year, while the average utilization of resources was only 10%–25%. An increase in the number of physical resources leads to increased electricity and cooling costs as a proportion of overall data center costs. This proportion has reached up to 25%–30% in recent years. A large number of physical resources also makes data center deployment more complicated, and increases the risk of data center faults due to human error. Up to 54% of data centre faults involve human error, and this can blow out maintenance costs too. ICT applications are continually emerging, Web2.0 applications are being quickly implemented and deployed, and SOA is developing quickly. Therefore, transition from enterprise data centers to internal clouds will become imperative.

3.2 Implementation of Internal Cloud Architecture

Future cloud computing architecture for enterprise data centers will be designed to improve utilization of physical resources, to enable data centre sharing between multiple users, and to enable dynamic sharing of physical resources by multiuser applications with security isolation. By retaining the advantages of early cloud computing and legacy data centers, future data centers will be safe, reliable, controllable, and manageable. These new data centers will be internal clouds of enterprises, implemented by integration, virtualization, and automation.

(1) Consolidation

In future data center architecture, IT networks should be consolidated.

Bottom–layer functions required by applications should be integrated with bottom–layer facilitates. The service layer should be specialized to efficiency of industrial IT applications rather than to the basic functions of security, reliability, and availability. Evolving the application silo structure towards network–centralized platform architecture is also an important aspect of consolidating data centers. All IT resources connected to application servers in the silo structure should be transitioned into networks. Networks connect various IT resources and basic functions, and become a platform for interchanging virtualized data resources. This platform provides logic services to physical resources, and dynamically deploys services to meet application needs. On such a platform, all types of applications can share computing services offered by virtualized resources.

Generally speaking, an enterprise considers consolidating its data centers once the centers have been proven inefficient, wasteful, and energy intensive. If advanced cloud technologies can be adopted in integration design, enterprise cloud architecture would develop quickly.

(2) Virtualization

Virtualization is a scheduling model of consolidated resources that is independent from physical location, physical presence, and physical status. It is a process of qualitative transition from physical resources to service forms. Virtualization plays a key role in multiplexing physical resources, reducing O&M complexity, and improving equipment utilization. It also lays a foundation for automatic resource scheduling and configuration.

However, even though virtualization is a hot topic, most enterprises do not know how to virtualize their data centers. Consolidation of data centers is a premise for virtualization; in well integrated architecture, virtualization is not difficult.

(3) Automation

With virtualization, intelligent systems can automatically and dynamically schedule and manage bottom–layer resources and functions. The administrator transfers application policy to the intelligent system, and the system schedules related physical resources according to optimal computing and resource configuration. In this way, limited resources are used to the maximum extent for service provision, and faults caused by the administrator are reduced to a minimum. This is an ideal resource scheduling model that conforms to the goal of cloud computing. Automatic deployment is a basic attribute of service–oriented data centers. Dynamic changing of resources, rapid scheduling, and flexible deployment can be fulfilled by automatically deploying resources according to capacity changes of data services.

3.3 Internal Cloud Models

Internal clouds can reduce the costs of establishment and maintenance, improve efficiency in service development and deployment, and provide service–on–demand to end users. Its implementation should take into account the long–term practical experience of data centers of large–scale enterprises. IP/IT architecture should be integrated and unified, and service resources should be flexibly scheduled and shared. For diverse, safe, rich media services that have reliable quality, advanced technologies should be used in internal clouds.

(1) Unified Fabrics

Unified fabrics rely on innovative technologies, represented by 10G Data Center Ethernet (DCE) and Fiber Channel over Ethernet (FCoE).

Switching technology for traditional data centers is generally gigabit. Limited processing capability of servers and low bandwidth I/O interfac restrains the development of high-density high-performance gigabit ports.

DCE is specifically designed for new generation data centers; it improves legacy Ethernet by enabling high performance, low latency, high cost-effectiveness, zero packet loss, and priority flow control mechanism. With support for L2 multipath Ethernet, IEEE DCE standards are not only necessary for lossless Ethernet in super large-scale data centers, but also for simplifying data centers and integrating internal clouds.

Existing data centers include IP local network, fiber storage network, and high-performance computing network. However, these networks have different bridging standards. IP local networks adopt Ethernet; fiber storage networks use optical fiber channels; and high-performance computing networks employ HyperLink. Under these conditions, servers require various I/O cards for network management and backup, and are connected to form a complex structure.

FCoE is used to map and transport optical fiber channel frames over Ethernet. It enables the frames to operate over data center Ethernet without any loss. FCoE enables Optical storage and data Ethernet share the same port, through which both Local Area Network (LAN) and Storage Area Network (SAN) connect to the server. This greatly reduces the number of I/O adapters and cables.

A unified fabric based on DCE and FCoE allows access to all resources in the LAN, SAN, and high-performance network over lossless 10G Ethernet. In such a fabric, physical network resources are consolidated, and the number of devices, network cards, adapters, switches, and cables are reduced. Power and cooling requirements are also reduced, network architecture is optimized, and maintenance and administration is simplified.

(2) Unified Virtualization

Virtualization of computing platform and server enables upper layer applications to schedule CPU, memory, I/O, and application functions on

demand and without regard for physical associations or locations. VMWare's VMotion is the most successful commercial virtualization solution for x86 based servers; Microsoft, Intel, and AMD also provide solutions.

When hardware resources are virtualized by software, and when a server is virtualized into multiple servers, operation, management, and policy of a data center becomes highly complex. Virtualization brings efficiency benefits, but also creates challenges in complexity of management flows, and software consistence, verification, and security.

It is becoming clear that, besides application, host, and operating system, network plays an important role in server virtualization. The network can be used in data processing, but also for a storage or computing. It bridges various resources and facilitates resource virtualization. Cloud computing requires ubiquitous data centers, while server virtualization relies on Virtual Machine (VM) migration technology for resource sharing and multiplexing. VM migration requires a unified cross-VM virtualized network environment.

The network is the basis for guaranteeing QoS and security of rich media cloud services in an enterprise's internal cloud. Therefore, virtualization should be four dimensional; it should be implemented on the computing layer, storage layer, application layer, and network layer. More importantly, it should be end-to-end and integrated. This is the essential difference between internal rich media clouds and early public stand-alone clouds.

Integrating computing virtualization, application virtualization, and network virtualization is very important. Without a unified virtualization platform, monitoring and executing various VM-based network and storage policies is difficult. Internal cloud scalability is also constrained, and cross-network virtualization is difficult to implement when multiple physical machines execute the same application.

VN-link technology has been proposed as a standard. VN-link helps ensure mutual association and communication between network and server with virtualization changes. In this way, the network can distinguish which VM a sent message comes from, and can provide services according to the VM and related policy. An appropriate mechanism for tracking VM migration guarantees service consistency.

(3) Unified Computing System (UCS)

Cloud computing implementations are treated as isolated virtual application islands, with isolated platforms and parts. In cloud computing, virtualization increases complexity; and isolated islands challenge multipoint integration and management, increase maintenance costs and risk, and degrade deployment of applications and services.

Using a unified computing system to integrate and manage computing, network, storage, and virtualization resources is crucial for the implementation of internal enterprise and rich media clouds. Unified systems help reduce ICT infrastructure costs and O&M complexity. They enhance ICT service flexibility, meeting user requirements for future service development.

In a UCS, servers are integrated into the network platform. Intel Nehalem B-series blade servers are required. The patented enhanced memory technology provided by blade servers increases the number of VMs that can be supported by every server. UCS provides unified external interfaces to storage LAN and Network-Attached Storage (NAS) systems. Users can access storage through Ethernet, fiber channels, Ethernet fiber channels, or Internet Small Computer Systems Interface (iSCSI). In this way, UCS provides maximum protection for investment. Only one data center switch is required in UCS, greatly reducing the number of devices, I/O interfaces, and cables, and lowering maintenance cost. Fewer devices mean that an integrated data center is competitively priced, and Total Cost of Ownership (TCO) to clients is greatly reduced.

In UCS, management functions are integrated into all the system components, and the UCS manager provides holistic solutions as a single entity. The UCS manager also provides a Graphical User Interface (GUI), a Command-Line Interface (CLI), and an Application Programming Interface (API). Management capability is the most important component of UCS, and VM management is at the core of management capability.

UCS is representative of the transition of data centers from traditional cloud computing to future cloud computing. It has next generation data center networking concepts and technologies such as data center platform and DCE/FCoE unified fabrics. Using the unified switching platform, applications including large-scale high-performance computing and search engine can be implemented and optimized. Unnecessary switches, network cards, cables, and management modules are discarded so that UCS can implement component-integrated cloud platform architecture with unified network, unified virtualization, unified computing, and unified management.

4 Operators and Cloud Computing

Cloud computing is rewriting the rules in IT, communications, and the Internet. The rapid growth of Internet traffic and the emergence of Internet applications has greatly affected telecom services. Web applications are increasingly visual, community-centered, and personalized, and their operators are concerned with investment return and flexibility of service provision.

Traditionally, when a telecom operator wished to deliver a new service, an individual network was built. Isolated service islands are in this way formed; resource use is not optimized, and O&M is complicated.

Cloud computing creates both challenges and opportunities for telecom operators. With abundant network bandwidth and various hardware and software resources in their large-scale data centers, operators usually have the ability to build internal cloud architecture and to develop competitive rich media services. However, in order to successfully transform their services, they should not only play to traditional strengths but also use advanced technologies.

Existing data or service centers should be integrated into a single new data or service center, and full use should be made of existing next generation networks. A new data or service center and next generation network are IP-based, and further integration creates a powerful and flexible unified service implementation system. This system becomes not only a unified implementation platform for telephone, video, mobile, and data services, but also supports rich media cloud applications and services of the future. In contrast to platforms for traditional services, rich media cloud platforms associate the data center with service transport network in order to provide safer and better quality applications. The introduction of unified rich media cloud platforms will address the important issues of lowering operation costs and speeding up commercialization of services during telecom transformation.

5 The Future of Cloud Computing

The goal of cloud computing is to develop cross-operator services that rely absolutely on open standards. Regardless of whether clouds are stand-alone or rich media, they should be able to randomly migrate from one operator to another. Using common open standards, Inter-cloud is designed for flexible scheduling of cloud applications across different operator clouds. Inter-cloud enables internal cloud applications of enterprises to be replicated into or operated by private operator clouds. Open-cloud aims to meet rich media demands by cross-cloud operation alliances or groups. Open industrial alliance and standards are key in the development of future cloud computing.

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Biography

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Cloud Storage Technology and Its Applications

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Abstract: Cloud storage employs software that interconnects and facilitates collaboration between different types of storage devices. Compared with traditional storage methods, cloud storage poses new challenges in data security, reliability, and management. This paper introduces four layers of cloud storage architecture: data storage layer (connecting multiple storage components), data management layer (providing common support technology for multiple services), data service layer (sustaining multiple storage applications), and user access layer. A typical cloud storage application—Backup Cloud (B-Cloud)—is examined and its software architecture, characteristics, and main research areas are discussed.

Key Words: cloud storage; service; backup cloud

With the rise of cloud computing[1-2] and Software as a Service (SaaS)[3-5], cloud storage has become the focus of attention in information storage. It, unlike traditional storage, comprises not only hardware devices, but is a system of network and storage equipment, server, application software, public access interface, access network, and client programs[6]. Since its introduction, cloud storage has attracted great interest from service providers.

A user's local data can be stored in online spaces provided by a Storage Service Provider (SSP). A user need not build their own data centers but can apply for services from the SSP. In this way, repeated construction of storage platforms can be avoided and expensive investments in hardware and software infrastructure be saved.

1 Cloud Storage

Cloud storage differs from traditional storage in many aspects. In terms of functionality, it is designed to deliver many online storage services, whereas traditional storage systems are primarily designed for high performance computing and transaction processing. In terms of performance, cloud storage places great importance on data security, reliability, and efficiency. With a larger number of users, a wider service range, and a complex and ever-changing network environment, cloud storage systems face greater technical challenges than traditional systems when delivering high-quality services. In terms of data management, cloud storage systems not only offer access to traditional files such as Portable Operating System Interface for Unix (POSIX), but also support mass data management for providing public service support functions, and maintaining data in the background.

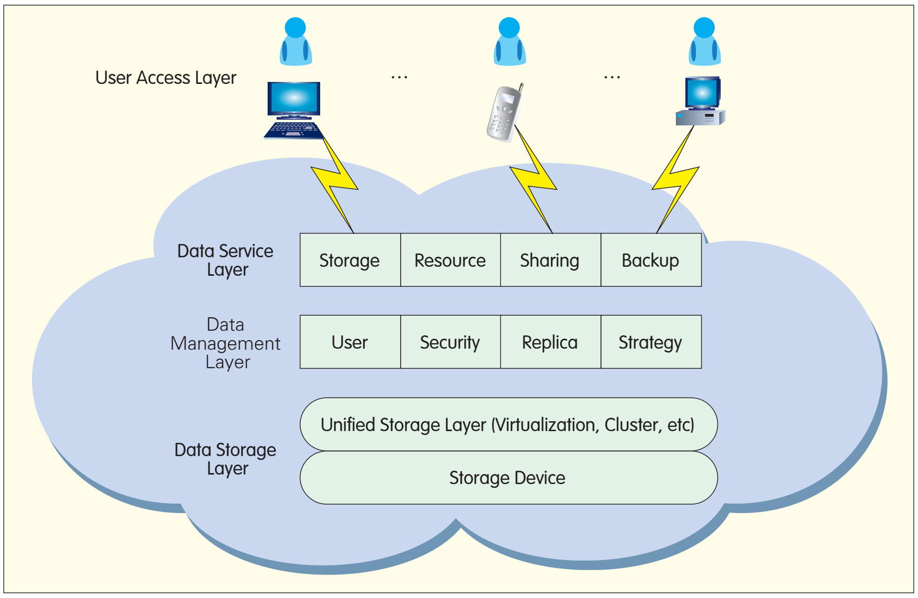
A cloud storage platform can be classified into four layers: data storage layer, data management layer, data service layer, and user access layer. Figure 1 shows the architecture of a cloud storage platform.

(1) Data Storage Layer

A cloud storage system offers diverse storage services, and all data stored in the system forms a massive pool. For efficient storage, this data should be properly organized. Traditional data organization uses a single server and cannot meet throughput and storage capacity requirements of multiple users in a Wide Area Network (WAN)[7]. A Peer-to-Peer (P2P) architecture based organization method requires a large number of nodes and complicated coding algorithm to ensure data reliability[8]. In contrast, using multiple storage servers to organize data better satisfies the requirements of online storage services[9]. Distributed data centers can provide good Quality of Service (QoS) for a large number of users in different geographical regions[10].

By interconnecting different types of storage devices, the data storage layer can manage massive amounts of data in a unified way, and can employ centralized management, status monitoring, and dynamic capacity expansion of storage devices. A cloud storage system is essentially a

This work was funded by the National High Technology Research and Development Program of China ("863" program) under Grant No. 2009AA01A402.



▲Figure 1. Architecture of cloud storage platform.

service-oriented distributed storage system.

(2) Data Management Layer

The data management layer provides the upper layer with a unified public management interface for different services. With functions such as user management, security management, replica management, and strategy management, this layer seamlessly associates upper-layer applications with lower-layer storage services. It also promotes cooperation between storage devices, enabling them to offer diverse and optimized services.

(3) Data Service Layer

The data service layer deals directly with users and can be flexibly expanded. Depending on user demands, different application interfaces can be developed to provide services such as data storage, space leasing, public resource, multi-user data sharing, or data backup.

(4) User Access Layer

In the user access layer, an authorized user can log into the cloud storage platform from any location via a standard public application interface and access cloud storage.

As an alternative to purchasing storage devices and deploying storage software, cloud storage has the following advantages:

(1) Low Cost and Quick Return

In building a storage platform that meets information management demands, purchasing storage devices and deploying software requires heavy initial investment. Software development often involves a long process of feasibility analysis, requirement analysis, software design, coding, and testing. By the time the software is developed, the demands might have been changed so that the software has to be redeveloped. This reduces the Quality of Service (QoS), increases cost, and delays the progress of information management. Enterprises repeatedly invest in traditional low-tech storage approaches; and for an individual enterprise, this means cyclic, high-cost technical upgrades.

Taking the cloud storage approach, terminal devices need only be configured to receive storage services so that heavy investment in platform building is not necessary. Storage services can be purchased according to the number of users and the usage time span, thereby avoiding the risk of heavy initial investment and reducing usage cost. Services can be used immediately and conveniently.

(2) Ease of Management

Traditional storage systems require maintenance to be performed by dedicated IT staff, and this incurs additional cost. Maintenance and upgrade of a cloud storage system, however, is performed by the service provider, so that professional services are provided at the lowest cost.

(3) Flexibility

Traditionally, once an investment has been made into purchasing devices or deploying software, the storage system cannot be dynamically adjusted during its lifetime. As devices are renewed, disposal of the existing outdated hardware platform becomes difficult. Ever-changing business needs may require the software to be constantly updated, upgraded, or even redeveloped. So high maintenance costs are incurred as a necessity and are to some extent beyond control. Cloud storage services are generally charged according to the number of users, usage time, and service items. On-demand services released by an enterprise can be changed anytime according to business needs, personnel changes, or financial status.

2 Application of Cloud Backup

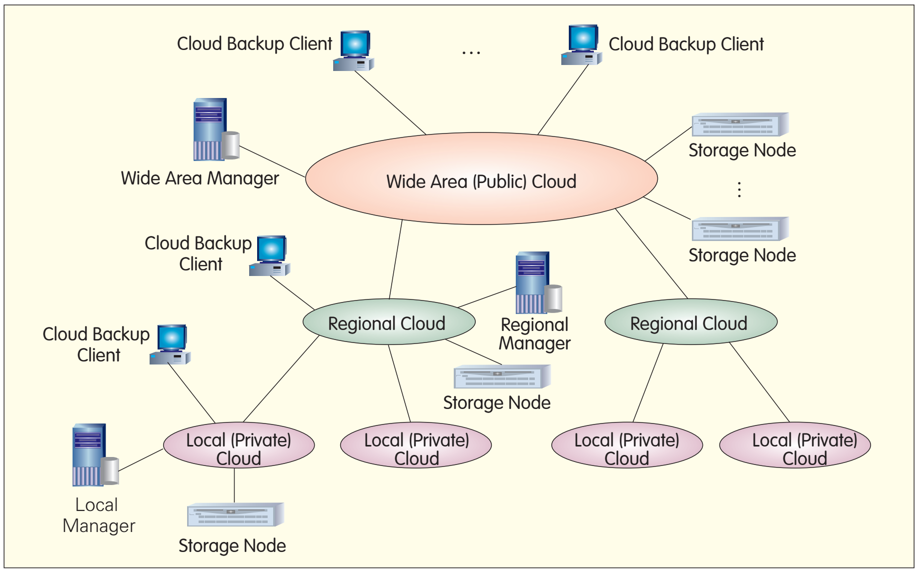
Cloud storage has a variety of applications, including data backup, data sharing, and resource service. It can also provide standardized interfaces for other network services. The following self-developed B-Cloud system is an example of cloud storage technologies and applications.

The deployment structure of B-Cloud is illustrated in Figure 2. It consists of three cloud levels.

The top level is called wide area (public) cloud. It covers all areas that backup clients can access via the WAN. Wide area cloud servers include wide area manager and wide area cloud storage nodes.

The middle level is called regional cloud and usually divided by geographic region (province or prefecture). Similar to wide area cloud, it has service nodes such as regional cloud manager and regional cloud storage servers.

The lowest level is called local (private) cloud. This is divided either by small geographical region or by an



▲Figure 2. Topological structure of B-cloud.

entity such as enterprise, institute, or campus. Local cloud can run on a WAN or Local Area Network (LAN), and its users are only those within the cloud. It has service nodes such as local manager and private cloud storage servers.

Like wide area cloud, regional and private clouds have multiple local storage nodes that serve multiple backup clients.

The topology of the B-Cloud system looks like a tree; the wide area cloud acts as the root node, and regional and local clouds act as branch nodes. Each node has its own manager and storage nodes that perform backup task scheduling and backup data access. All nodes—including wide area cloud, regional clouds, and local clouds—are physically connected. Nodes at any two adjacent levels have a parent-child relationship in which the child node can be viewed as a special user of the parent node. The topological structure is very scalable. Even though only three levels are currently defined in the system, any node can be split into more levels when the number of users grows or the service area expands.

When a new user (or backup client) registers in the system, it first visits the super director server of the system—which is responsible for global user management. The server then assigns the user a backup cloud node according to predefined assignment strategies and user information (such as the segment or region of the user's IP address, organization of the user's email address, or the user's geographic location). User information is maintained by the system's super director server. After registration, the backup client can log onto the system and communicate with the backup manager and storage nodes of the specific cloud to receive a service.

The principle of proximity access dictates that the nearer the client, the higher the data transmission efficiency and the lower the cost. An hierarchical topological structure creates an orderly relationship between multiple scheduling servers and multiple storage servers of the backup system, enabling the system to better serve backup clients in different regions.

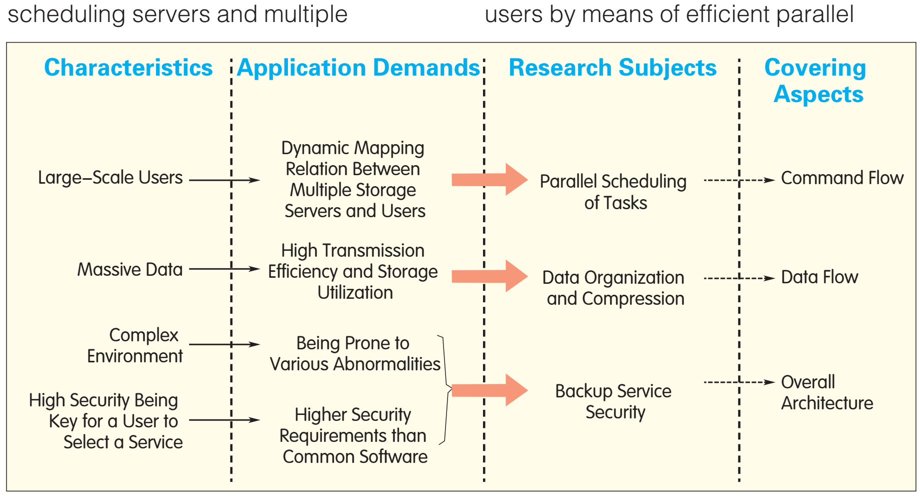
The characteristics of cloud backup determine application requirements, which in turn drive the development of three key backup technologies: parallel task scheduling, data organization and compression, and backup security. These technologies are research subjects of the B-Cloud system, and involve several aspects of cloud backup service architecture. The relationship among them is illustrated in Figure 3.

Cloud backup differs from traditional backup software in the following ways:

(1) Number of Users

Backup software is traditionally used in a LAN or WAN by specific user groups. Because the number of users is small, only a small number of storage servers are usually configured—for ease of deployment, ease of maintenance, and to reduce cost. User access paths to the servers are fixed, and dynamic assignment or adjustment is not required to meet different scenarios.

In contrast, cloud backup is designed for a large number of users in the WAN. As this number grows, the system has to be configured with multiple storage servers to meet scalability requirements. The system should also be capable of processing concurrent access requests from a large number of users, and assigning proper target storage servers to these users by means of efficient parallel



▲Figure 3. Relationship between application requirements and research subjects.

scheduling policy. Load balance and high storage utilization can thus be achieved among all storage servers. The process is completely transparent to users.

(2) Amount of Data

The difference in user numbers between cloud backup and traditional backup software represents a great difference in the amount of data to be processed. Backup data generated by large-scale users in the WAN may easily reach one TB or even one PB. Thus, proper data organization methods and compression algorithms are of great importance to improve the transmission and storage efficiency of massive amounts of data. The ultimate objective of these methods and algorithms is to improve system performance, reduce hardware costs and save energy.

(3) Service Security

Cloud backup must be compatible with heterogeneous data platforms of different backup clients; must ensure data integrity at the block, file and application levels; must adapt to a complex and changing WAN environment; and must guarantee data security.

Cloud backup systems have higher requirements on reliability than common backup software. However, people unconsciously feel it safer to backup critical data on visible devices. Doubts may arise about the security of backing up private data in faraway data centers.

On the one hand, cloud backup is prone to various abnormalities; on the other, users subjectively impose higher security requirements on cloud backup than on backup software. Security is therefore a pressing area of study for cloud backup.

According to the characteristics of cloud backup, the study of cloud backup focuses on:

(1) Command Flow

The B-Cloud system consists of backup clients, manager, and storage servers. The manager is the administrative center of the entire system, responsible for task scheduling, operation management, and status monitoring in the service process.

After receiving a service request from a backup client, the three parts of the system implement bidirectional security certification; and importantly, the manager completes job scheduling to establish a connection between the backup client and the storage server. At this point, the system begins to deliver the backup or recovery service.

(2) Data Flow

The backup or recovery data flow is transmitted between the backup client and the storage server without passing the manager. This method, whereby data goes directly from the source to the destination and does not pass any intermediate node, improves efficiency and also balances the overall load of the system. For data transmission and storage, backup data organization and compression are key.

(3) Service Security

Security of cloud backup involves the security within service platform, modules, and coordination and communication between modules. This issue requires in-depth discussion which is not intended here.

3 Conclusion

This paper introduces cloud storage technology and takes cloud backup as an example to discuss issues to be addressed in cloud storage application.

A trend of technology development is to satisfy requirements with services. Cloud storage conforms to this trend. However, in-depth study is needed into the implementation of cloud storage and its widespread applications.

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Biographies

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Encrypted Storage and Retrieval in Cloud Storage Applications

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Abstract: Problems with data security impede the widespread application of cloud computing. Although data can be protected through encryption, effective retrieval of encrypted data is difficult to achieve using traditional methods. This paper analyzes encrypted storage and retrieval technologies in cloud storage applications. A ranking method based on fully homomorphic encryption is proposed to meet demands of encrypted storage. Results show this method can improve efficiency.

Key words: cloud storage; vector space model; relevance ranking

Cloud computing is an online network service delivery model where users obtain customized, on-demand services from the Internet. It encompasses services delivered over the Internet as well as the hardware and software in datacenters that provide such services[1]. Cloud computing is a kind of distributed computing—an evolution of parallel computing, distributed computing, and grid computing. It can be implemented as Software as a Service (SaaS), utility computing, Platform as a Service (PaaS), or Infrastructure as a Service (IaaS). Current cloud computing applications include GoogleDocs[2] and cloud service infrastructures of Microsoft and Amazon[3-4].

The main goal of cloud computing is to provide efficient computing services. One component of cloud infrastructure is the data center, which provides safe, reliable data services. Storage security, therefore, is a primary issue. A common approach to data protection is to encourage users to store their encrypted data on servers. However, as the amount of encrypted data in the cloud grows, retrieval becomes problematic.

1 Encrypted Storage Technologies in Cloud Storage Applications

Security of cloud storage applications includes authentication, data encryption and storage, security management, and security log and audit.

For authentication, Access Control Service (ACS) employs user identity authentication and authorization to prevent unauthorized access. Operations permitted on a document may be limited by the administrator or document owner, but the administrator does not have access to users' encrypted data and can only carry out management-related operations such as user management, data backup and hotspot migration.

Encrypted storage means saving specified encrypted folders and files. Confidentiality of sensitive data must be ensured during the process of storage and transmission.

Security management involves maintaining user information and authorities, including user account registration and cancellation, authority granting, and reclaiming authority for data recovery in emergency situations.

Security logging and auditing involves recording important security events relating to users and system. This information is monitored and acted upon by the administrator.

Encrypted storage is perhaps the most important storage security service for users. It is fundamental for guaranteeing confidentiality of user data stored on a shared platform.

Networked storage systems and devices have to ensure the confidentiality of sensitive data, and also implement encrypted data sharing technology. The protection of user privacy requires that storage security is fulfilled based on a complete trust in the storage system. Therefore, encrypted storage technologies must be studied, and long-term storage and sharing mechanisms for end-to-end encrypted storage technologies and encryption keys should be supported to guarantee the confidentiality and privacy of user

This work was funded by the National Key Technology R & D Program of China under Grant No. 2008BAH37B07, the National Natural Science Foundation of China under Grant No. 60970148, and the National Basic Research Program of China ("973" Program) under Grant No. 2007CB310806.

data and to improve the security of keys, distribution efficiency and flexibility of encryption policy. Encrypted retrieval plays a critical role in the storage of massive encrypted data; it is also a must-to-be-solved issue for encrypted storage.

2 Encrypted Information Retrieval Technologies

Study in encrypted information retrieval began in 2000. Since then, several algorithms have emerged. Song et al propose practical algorithms for searches on encrypted data[5]; Boneh et al propose public key encryption with keyword search[6]; and Park et al propose public key encryption with conjunctive field keyword search[7].

2.1 Linear Search Algorithm

In the linear search algorithm[5], a symmetric encryption algorithm is used to encrypt the plaintext. For the ciphertext of each keyword under symmetric encryption scheme, a pseudo-random sequence is generated with a length less than that of the ciphertext. Meanwhile, a check sequence is generated based on the pseudo-random sequence and the ciphertext. The sum of the lengths of the pseudo-random sequence and check sequence equals the length of the ciphertext. Finally, the pseudo-random sequence and check sequence are used to encrypt the ciphertext again by modulo 2 addition. When searching, a user submits the ciphertext sequence under symmetric encryption scheme. On the server side, modulo 2 addition with each sequence is performed to each sequence If the results satisfy the checking, the sequence is the encryption of the ciphertext under symmetric encryption; otherwise, the sequence is not the encryption of the ciphertext.

The linear search algorithm is a one-time pad-based retrieval algorithm for encrypting information, so it is strongly resistant to statistical analysis. But it has a fatal flaw in that the ciphertext must be matched each time. It is therefore not applicable to retrieval scenario with large data collection.

2.2 Public Key Encryption with Keyword Search

Boneh et al propose public key encryption with keyword search. This is applicable when storage and computing resources of a user are insufficient, and data is obtained by accessing a remote database. Storage and computing resources are often distributed asymmetrically. That is to say, a user´s computation and storage capacities are not able to meet their needs. In a mobile scenario, demand for data storage and retrieval increases (for example, email service). Hence, it is necessary to protect data privacy. Encrypted data may come from different sources; public key encryption is a good encryption method that works well.

This algorithm generates a public key and private keys, then encrypts the keywords of the plaintext with the public key to generate searchable ciphertext.

2.3 Public Key Encryption with Conjunctive Field Keyword Search

Park et al propose a public key encryption method with conjunctive field keyword search. Such encryption can resist statistical attacks that trouble simpler search methods. The key for each encryption consists of a group of reverse hash sequences generated in advance, and the encrypted index is put into a Bloom filter. During the search process, the reverse hash sequence key is first used to generate multiple trapdoors, then Bloom detection is conducted. The returned encrypted document can then be decrypted.

This algorithm is a good solution for multi-user encrypted information retrieval where new users may join and old users exit. But it involves the generation of many key sequences. As the number of retrievals grows, the computational complexity increases linearly. This cannot be sustained in practice.

Retrieval models of all the above mentioned algorithms are Boolean, so retrieved documents cannot be ranked according to their relevance to query keywords, especially in cloud storage applications where large amounts of data are involved, many documents may contain one query keyword. Obtaining the most relevant documents remains a problem. It is still doubtful whether the classical vector space model can be applied for ranking the relevance of encrypted documents.

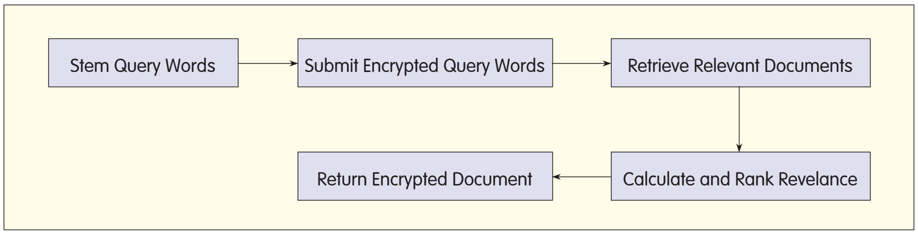
2.4 Confidentiality-Preserving Rank-Ordered Search

Swaminathan et al propose the confidentiality-preserving rank-ordered search[8]. In this algorithm, the frequencies of all keywords in a document are encrypted using the order preserving encryption. When a query is submitted to the server, the server calculates and retrieves the encrypted documents containing the ciphertext of keywords. It then ranks the corresponding ciphertext according to the frequencies of keywords; and finally, returns the encrypted document with the highest evaluation to the user for decryption.

This method can rank encrypted documents in cases where there are multiple relevant documents, and return the most relevant document. However, it is not applicable when the query contains several keywords. Also, it only uses word frequencies of the document and not the document frequency inverse to the keywords. So the vector space model can not be directly applied. A fully homomorphic encryption algorithm[9] can be used to encrypt the word frequency and solve this problem.

3 A Fully Homomorphic Encryption-Based Retrieval Method

Studies in encrypted information retrieval show that ranking of results is an important measure of the performance of a retrieval algorithm. In the scenario of secure cloud storage, the number of encrypted documents will increase exponentially. Accurate ranking is therefore an objective performance requirement for retrieval systems. The main purpose of accurate ranking is to improve retrieval efficiency



▲Figure 1. Fully homomorphic encryption based ranking retrieval.

and Quality of Service (QoS) of retrieval systems. Analyses show existing encrypted information retrieval algorithms can guarantee retrieval in terms of precision and recall, but do not take precision into account.

To address this problem, a fully homomorphic encryption-based retrieval method for cloud storage applications is introduced. The vector space model is used in information retrieval to calculate the relevance of retrieved documents to the query. Terms in a document are encrypted by a given public key scheme while homomorphic encryption is performed on the term frequency and inverted document frequency of keywords. Upon retrieval, the encrypted documents and index entries' ciphertext are uploaded to the server.

Retrieval and ranking based on fully homomorphic encryption is shown in Figure 1. Before a query is submitted, the retrieval statement is split into search words and stems to generate a sequence of keywords in plaintext. The plaintext is then encrypted. When the cloud server retrieves the ciphertext sequence, it submits encrypted query words.

The document is represented by the weight vector of each term. The weight is the normalized product of word frequency and the logarithm of the inverted document frequency. It can be obtained from the term frequency and the inverted document frequency. The document vector can be calculated with Formula (1):

$$Hmp(w_i)=\frac{Hmp(tf_i)\times Hmp(\log(df_i))}{\sqrt{\sum_i[Hmp(tf_i)\times Hmp(\log(df_i))]^2}} \quad (1)$$

The query is represented in the same way. After all relevant documents have been retrieved their relevance to the query words is calculated, as the inner product of the corresponding vectors of both the document and the query. Then the relevance is ranked by the score. Finally, the ranked documents are returned to the user. Upon receiving the encrypted documents, the user decrypts them using his private key.

Plaintext data encrypted with fully homomorphic encryption algorithm can be effectively retrieved without any restoration operation; that is, the most relevant documents are returned to the user. This not only protects the user´s data security, but also improves retrieval performance.

4 Conclusion

This paper analyzes the significance of retrieval technologies over encrypted information in cloud storage applications, and discusses the research status quo and problems of existing encrypted information retrieval technologies. It proposes a fully homomorphic encryption-based retrieval method, and explains its basic principles. Experimental results show this method can improve retrieval efficiency in comparison with other encrypted information retrieval algorithms.

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Cloud Computing Technology and Its Applications

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Abstract: Virtualization and distributed parallel architecture are typical cloud computing technologies. In the area of virtualization technology, this article discusses physical resource pooling, resource pool management and use, cluster fault location and maintenance, resource pool grouping, and construction and application of heterogeneous virtualization platforms. In the area of distributed technology, distributed file system and Key/Value storage engine are discussed. A solution is proposed for the host bottleneck problem, and a standard storage interface is proposed for the distributed file system. A directory-based storage scheme for Key/Value storage engine is also proposed.

Key Words: virtualization; distributed computing; cloud computing management platform; key/value storage engine

Since cloud computing was first introduced by Google, it has scudded swiftly through the Internet community. The number of cloud computing services and platforms has recently mushroomed. Notable examples include Google's File System (GFS), MapReduce, Bigtable, Chubby, and App Engine; Amazon's Dynamo, Elastic Compute Cloud (EC2), Simple Storage Service (S3), Simple Queue Service (SQS), SimpleDB and CloudFront; Microsoft's Azure, SQL, ".Net" and Live service; and VMware's virtualization platform. There are also many open source platforms such as Hadoop Distributed File System (HDFS), Hbase, and Eucalyptus.

1 Core Technologies of Cloud Computing

Cloud computing is based on two core technologies—resource virtualization and distributed parallel architecture—for which there is much open source software available to support users. The software includes Xen, Kernel-Based Virtual Machine (KVM), Lighttpd, Memcached, Nginx, Hadoop, and Eucalyptus. Cloud computing saves hardware investment, development, and maintenance costs for cloud service providers.

Virtualization technology was first introduced and applied by VMware on the X86 CPU. A virtualization platform is used to partition a server into multiple Virtual Machines (VMs) with configurable performance. It monitors and manages all VMs in the cluster system, and based on actual situations, flexibly allocates and schedules resources in a resource pool.

Distributed parallel architecture integrates a large number of computers into a supercomputer to provide mass data storage and processing. Using distributed file system, distributed database, and MapReduce technology, a supercomputer provides programming methods and running environment for mass file storage, mass structured data storage, and unified mass data processing[1-3].

2 Virtualization

Pooling and managing physical resources are primary functions of virtualization technology. Pooling involves partitioning and virtualizing a physical device into multiple minimum resource units with configurable performance. Management involves flexibly allocating and scheduling minimum resource units in a cluster according to resource availability, user requests, and certain policies. In this way, on-demand resource allocation can be achieved[4-7].

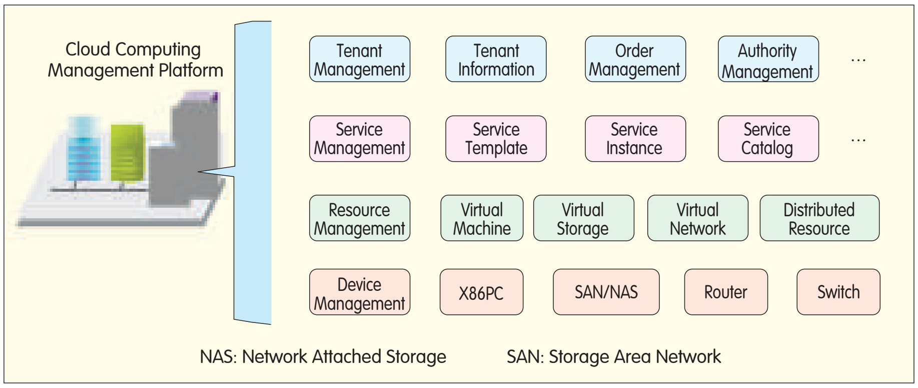
2.1 Pooling Physical Resources

Figure 1 illustrates a cloud computing management platform. Virtualization objects of physical devices include server, storage, network, and security. Different virtualization technologies are developed to solve system problems from different perspectives.

(1) Server Virtualization

Server virtualization involves abstracting the server into virtual resources and then pooling them. Specifically, one server is divided into several homogeneous virtual servers and virtual server resource pools in the cluster are managed.

(2) Storage Virtualization



▲Figure 1. Cloud computing management platform.

Storage virtualization involves making traditional Storage Area Network (SAN) and Network Attached Storage (NAS) devices heterogeneous. All storage resources are collated by type to form a unified large-capacity storage resource. The unified storage resource is then pooled according to the authority of each volume or sub-directory and contains resource management methods. Finally, virtual storage resources for different applications are allocated, or directly assigned to end users.

(3) Network Virtualization

Network virtualization involves partitioning a physical network node into multiple virtual network devices (such as switches and load balancers) and managing these resources. In a cloud computing platform, virtual network devices provide cloud services for applications along with virtual machines and virtual storage space.

2.2 Resource Pool Management

Resource pool management involves not only unified management, scheduling, and monitoring of resource pools, but also proper use and maintenance of the cloud platform. A cloud computing management platform can be divided into four layers: device management, virtual resource management, service management, and tenant management.

(1) Device Management

This layer manages hardware devices on the cloud platform and raises an alarm when there is device abnormality. Specifically, the system administrator uses this layer during daily maintenance to check device performance, and to monitor key indexes such as application server CPU usage, memory usage, hard disk usage, network interface usage, storage space availability, and Input/Output (IO) status. A user can set the monitor threshold for a physical device based on actual configuration. The system then automatically starts monitoring and raises an alarm when the threshold is exceeded.

(2) Virtual Resource Management

The virtual resource management layer implements unified management, allocation, and flexible scheduling of virtual resources for various applications. As in the device management layer, the system administrator checks the performance of each minimum virtual resource during daily maintenance, and monitors key indexes—such as CPU usage, memory usage, hard disk usage, network interface usage, virtual storage (such as Amazon's Elastic Block Storage) availability, and IO status—of virtual machines being used. A user can set the monitor threshold for a virtual resource based on actual configuration. The system then automatically starts monitoring and raises an alarm when the threshold is exceeded.

(3) Service Management

The service management layer manages service templates, service instances, and service catalogs. Based on virtual resources, it promptly provides user-specified operating system and application software to tenants.

(4) Tenant Management

The tenant management layer manages the resource clusters of all tenants. Resource type, quantity, and distribution are managed, as well as tenant lifecycle—from application, examination, and normal operation, to suspension to cancellation.

2.3 Cluster Fault Location and Maintenance

In Google's cluster maintenance approach, maintenance staff push a handcart to the damaged machine, and locate the fault by checking fault indicators on a customized PC. (In Internet data centers, PCs are often used as the computing resource.) At present, all cloud computing management platforms use a machine's IP address, either physical or virtual, as its serial number to monitor or raise alarms. For a physical machine hosting VMs, the IP address of its host OS module is its unique identification in the cluster. The IP address of a machine is often allocated in one of two ways: by enabling Dynamic Host Configuration Protocol (DHCP) to automatically obtain the IP, or by assigning it manually. Since there is usually a large number of machines in a cluster, manual assignment creates a heavy workload. Using DHCP to automatically obtain an IP address is therefore often adopted.

However, if IP addresses are automatically obtained, maintenance personnel cannot specifically locate a faulty machine using the IP address when a physical device fault is found in the management platform. Also, a common PC is not configured with auxiliary fault location functions such as fault indicator. Locating the faulty physical machine is complex and tedious.

In a virtualization cluster, this problem can be solved in a simple and effective way: by configuring a Universal Serial Bus (USB) key for each machine. The key stores location information such as rack number. When a machine starts, it reads the physical location from the USB Key, calculates its IP address using an algorithm, and returns the IP address to the management platform.

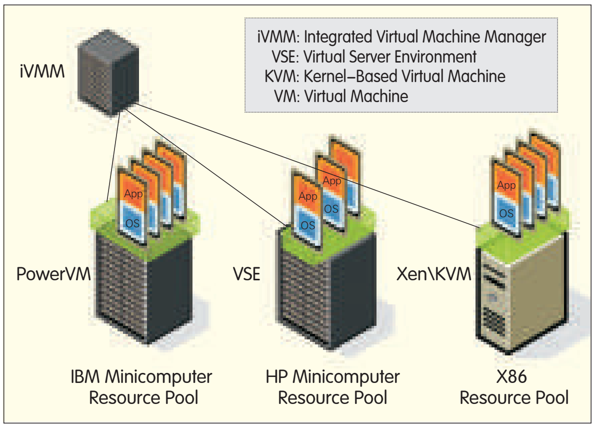


Figure 2. Unified management of heterogeneous resource pools.

The IP address of each machine corresponds to a physical location, and when a fault occurs, maintenance personnel can accurately determine the IP address and location.

2.4 Grouping of Heterogeneous Resource Pools

SUN, IBM and other manufacturers have adopted their own server virtualization architectures for their minicomputers. These virtualization systems are not compatible with others based on X86 architecture (such as Xen and KVM), so resources are wasted.

The heterogeneous resource pool problem in server virtualization can be solved by:

(1) Grouping resource pools by architecture: Servers and minicomputers adopting different architectures are virtualized into VMs, which are then put into different resource pools categorized by architecture. Different applications are allocated VMs according to the VM architecture.

(2) Using a service scheduler to customize services, integrate virtualization platforms of different architectures, and schedule heterogeneous VMs.

Figure 2 illustrates the grouping of heterogeneous resource pools for unified management. IBM's PowerSystems minicomputer cluster, HP's minicomputer cluster, and X86 architecture-based computing resources are virtualized and grouped into different resource pools with virtualization platforms—namely, IBM's PowerVM system, HP's VSE system, and Xen/KVM system. An application can be deployed in a resource pool depending on its service characteristics and operating system. Thus, virtualization of heterogeneous minicomputers is achieved. The resource pools based on X86, PowerSystems, and HP architecture are managed by their respective virtualization management softwares (Virtual Machine Manager (VMM), Integrated Virtualization Manager (IVM), and Global Workload Manager (gWLM)). In the upper layer of VMM, IVM, and gWLM, there is an integrated Virtual Machine Manager (iVMM) configured for unified management of the three computing resource pools.

Figure 3 shows the scheduling of heterogeneous virtual resources for different applications. This method comprises four core components: iVMM, service scheduler, versions (provided by the service system) with the same application functions for different resource pool architectures, and the Oracle C++ Call Interface (OCCI) between iVMM and service scheduler.

In the service application layer, a module for service scheduling is added. This module applies to the iVMM in order to increase or decrease VMs, and to adjust load balancing policies. The service system must also prepare different versions with the same functions for different resource pool architectures. The operational procedure of the OCCI is:

(1) The service scheduler makes a resource request to the cloud computing management platform via the OCCI, providing information such as operating systems supported by the service system, and priorities.

(2) After receiving the request, the management platform allocates resources depending on the availability of resources in the cloud. Meanwhile, it informs the service scheduler (via the OCCI) what resource it has allocated to the service system.

(3) The service scheduler sends information such as the service processor's operating system and service version to the management platform via the OCCI. The management platform then deploys the operating system and service program. Resources are submitted to the service system for use.

3 Distributed Technology

The first inroads into widespread distributed technology were made by

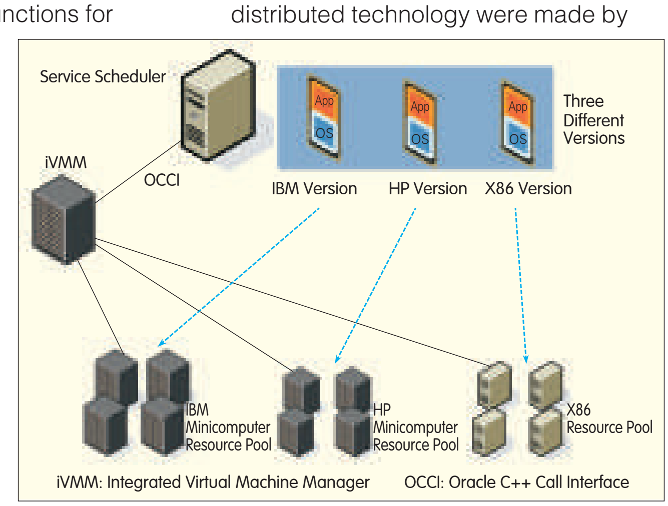


Figure 3. Implementation of heterogeneous applications with cross-resource platform.

Google. Its search services for global users are designed to store massive amounts of data and speed up data processing. Google's distributed architecture allows millions of cheap computers to work together. Mass data is stored in its distributed file system, and using a distributed programming model, MapReduce, major tasks are broken down and performed in parallel on multiple computers. Google's distributed database also stores mass structured data. Many Internet operators are now using Key/Value-based distributed storage engines for quickly storing and accessing a great number of small storage objects.

3.1 Distributed File System

Distributed file systems such as Google's GFS and Hadoop's HDFS are designed for storing massively large files. Such systems are configured with a pair of host computers, and applications can access the system via a dedicated Application Programming Interface (API). However, distributed file systems are not widely applied because the host cannot quickly respond to each application, and access interfaces are not open.

The host is the master node of a distributed file system. All metadata information is stored in the host's memory, so the memory size determines the number of files the whole system can accommodate. Metadata of one million files may occupy nearly 1 GB of memory. But in cloud storage applications, files are often counted in the hundreds of millions. Reading and writing a file requires access to the host, and the host´s response speed can often get slow. Response speed directly impacts Input/Output Operations Per Second (IOPS) of the storage system. Slow responsiveness of the host can be solved by:

(1) Buffering visited metadata information on the client. When an application accesses the file system, it first queries the metadata on the client, and accesses the host only if the query result is not satisfactory. In this way, access to the host is reduced.

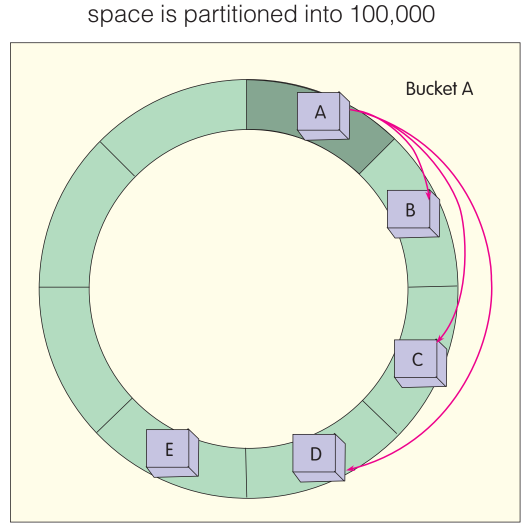
(2) Storing metadata information on the host's hard disk and buffering it in the host's memory. This is applicable where metadata comprising over a hundred million large files must be stored. In addition, to enhance reliability and speed of the hard disk, Solid-State Drives (SSD) can be used which can improve performance by a factor of 10.

(3) Changing the standby work modes of the hosts from 1:1 hot standby to 1:*X* (often 1:4; that is, one host master with 4 standby hosts). The host master is selected by Lock Server. The host master allows the storage system to access the rewritten metadata, and In the case of read-only access, the application's access the metadata is assigned to a standby host with Distributed Hash Table (DHT) algorithm. This stops the host becoming a bottleneck in the system.

In a distributed file system, an external application must go through a dedicated API to access the system. Therefore, the application range of the distributed file system is limited. With a standard Portable Operating System Interface (POSIX) (for Unix), an application can gain access to the system through the process of Filesystem in Userspace (FUSE), but at a cost of 10% to 20% of performance. Network File System (NFS) can be implemented on the basis of the POSIX interface, by directly calling NFS protocol stack of Linux operating system.

3.2 Key/Value Storage Engine

The structure of Key/Value storage engine is shown in Figure 4. Bucket A data are stored in Nodes B, C and D. The biggest problem for the Key/Value engine is the quick redistribution of data after a routing change. To solve the problem, "virtual node" can be introduced. The ring space in which the Key value is mapped is divided into equally-sized Q buckets, each of which corresponds to a virtual node. For Key mapping, Message-Digest algorithm 5 (MD5) is recommended. Each physical node is responsible for data in several buckets, depending on hardware configuration. The data in a bucket can fall into *N* nodes, where *N* is usually 3. Suppose the Q of DCACHE cluster is 100,000; that is, the entire ring space is partitioned into 100,000



▲Figure 4. Key/value storage engine.

buckets. If the maximum capacity of the entire DCACHE cluster is 50 TB, the data in each bucket is only 500 MB, and the migration of 500 MB data between nodes is less than 10 s.

A Key/Value storage engine is a flat storage structure which uses a Hash algorithm to distribute stored contents evenly among all nodes. But in some applications, the service needs batch operations similar to the directory structure. For example, in the Content Delivery Network (CDN), when the website pushes content to CDN nodes, the content is added or deleted based on the directory structure of web pages. A Key/Value storage engine cannot perform that function at the moment. To address the problem, a pair of directory servers can be added in the Key/Value storage engine to store the relationship between Key value and the directory, as well as to operate the directory structure. When an application accesses the Key/Value storage engine, accesses to related nodes is gained in the same way as Hash; but if directory operation is required, the application operates the Key/Value storage engine via directory servers. The directory servers complete the switch from directory operation to Key/Value mode. Since in most projects read operations are the most common type of operation, the need for directory servers to access to Key/Value storage engine is small; and performance bottleneck is avoided.

4 Conclusion

Building a cloud platform is challenging. Two core technologies of cloud computing have been described in detail: virtualization and distributed architecture. In the area of Infrastructure as a Service (IaaS), this article focuses on virtualization technology, discusses the building and application of heterogeneous virtualization platforms, and the functions of the cloud computing management platform. In the area of distributed technology, distributed file system and Key/Value storage engine are discussed and solutions given for some related problems. A solution is proposed for host bottleneck, and a standard storage interface is proposed for the distributed file system. A directory–based storage scheme for Key/Value storage engine is also suggested.

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Heterogeneous Vehicular Communication Architecture and Key Technologies

Abstract: Vehicular networks have traditionally been used in specific scenarios, such as Electronic Toll Collection (ETC). New vehicular networks, however, support communication of safety information between vehicles using self-organized ad-hoc technology. Because of limitations in network architecture, current vehicular networks only provide communication for mobile terminals in a vehicle cluster. Vehicles cannot exchange information with an Intelligent Traffic System (ITS) control center nor can they access broadband wireless networks. This paper proposes a novel heterogeneous vehicular wireless architecture based on Wireless Access in Vehicular Environment (WAVE, IEEE 802.11p) and Worldwide Interoperability for Microwave Access (WiMAX, IEEE 802.16e). A new network infrastructure and system model is introduced, and key technologies are discussed. For WAVE, these technologies include adaptive multichannel coordination mechanism and scheduling algorithm; and for WiMAX, these technologies include group handover scheme and two-level resource allocation algorithm.

Key Words: vehicular networks; multi-channel scheduling; group handover; resource allocation

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With the rapid development and convergence of computers, communications, and microelectronics, a solid foundation has been laid for the application of communications network technologies. In recent years, rapid growth in the number of vehicles on the road has increased demands for communication on the move. This has been the impetus behind installation of communications networks in passenger vehicles. Wireless access in vehicular environments has become a hot research topic worldwide, and such research will promote the development of intelligently networked vehicles in the future.

Traditional vehicular communication networks are closed and designed for specific uses, such as Electronic Toll Collection (ETC). However, vehicular networks are now being designed to support transmission of safety and other information between vehicles. Current vehicular communication systems, with some weaknesses in architecture, can only support data exchange between high-speed vehicles in local areas. New-generation vehicular networks will communicate safety data, information about traffic, and multimedia digital services. Therefore, new-generation vehicular networks must be capable of providing high priority real-time services between vehicles and intelligent transport centers and must also support wireless Internet access for passengers. Real-time services include traffic reports and location-based mapping; multimedia services include news, promotional, and entertainment information. How to best provide these services is an important and emerging topic of research. Vehicular mobile architecture converged with heterogeneous wireless networking is proposed in this paper. Vehicular Ad-Hoc Network (VANET) based on IEEE 802.11p Wireless Access in Vehicular Environments (WAVE) is integrated with broadband wireless access system based on IEEE 802.16e Worldwide Interoperability for Microwave Access (WiMAX). Key technologies used in this the solution are also discussed.

1 Research Progress and Development Trends of Vehicular Communication Networks

Many research organizations have applied advanced communications

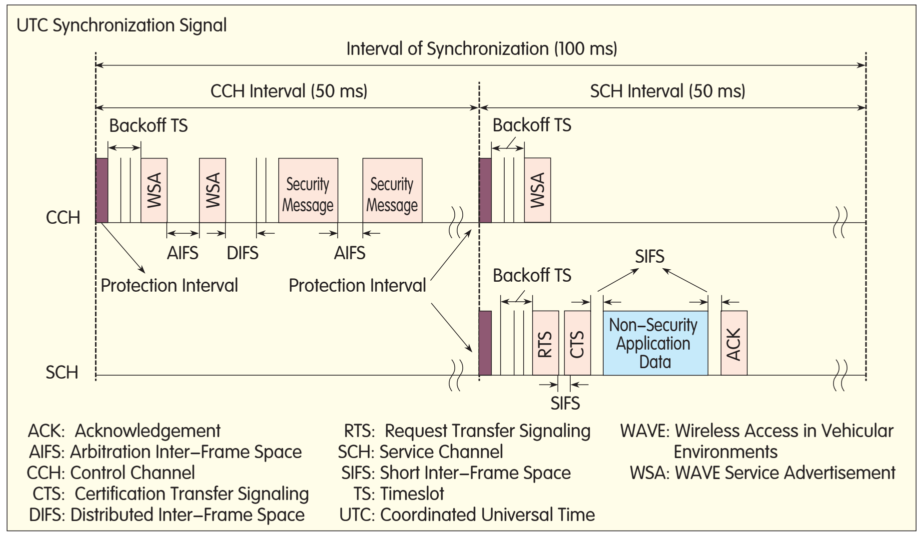
This work was funded by the National High Technology Research and Development Program of China ("863" Program) under Grant No. 2007AA01Z239, and the National Science and Technology Major Projects under Grant No. 2011ZX03001-007-03.

technologies to transportation systems with the aims of improving security, intelligence, and efficiency. VANET can facilitate Vehicle-to-Vehicle (V2V) communications between fast moving vehicles as well as Vehicle-to-Infrastructure (V2I) communications when vehicles are slowly moving or stationary. It provides various safety and non-safety applications.

In developing the specifications for WAVE, the IEEE 802.11p working group—set up in 2004—used the IEEE 1609 standard family as the upper layer protocol, and this has become the basic protocol architecture for vehicular communications[1]. Professor Nitin Vaidya and his team at the University of Illinois, Urbana-Champaign, developed a multichannel wireless mesh testbed, and Professor G. Pau from UCLA proposed Practical Vehicular Routing Protocol (PVRP), setting up a system test platform for verification. Professors Jinhua Guo and Weidong Xiang from the University of Michigan developed a 5.9 GHz WAVE system channel testbed.

In terms of wireless access in vehicular networks, the bulk of research is based on IEEE 802.11. However, IEEE 802.11 has some weaknesses: It has limited coverage, requires frequent handover when a moving vehicle connects to roadside infrastructure, has weak support for Quality of Service (QoS), and has weak support for high-quality multimedia[2-3]. IEEE 802.16 is a solution to these problems. WiMAX (IEEE 802.16) supports wide coverage and guaranteed QoS, and has attracted much attention in recent years.

References [4] and [5] show the first application of WiMAX into vehicular networks for broadband wireless access. This represents the first vehicular communication network that is not based on IEEE 802.11. WiMAX base stations have a reasonable coverage of several kilometers in urban areas, providing higher data rates and wider coverage than IEEE 802.11 systems. The IEEE802.16j working group on Mobile Relay Stations (MRS) was set up in March 2006 with the goal of developing vehicular MRSs for broadband wireless access in moving vehicles[6].

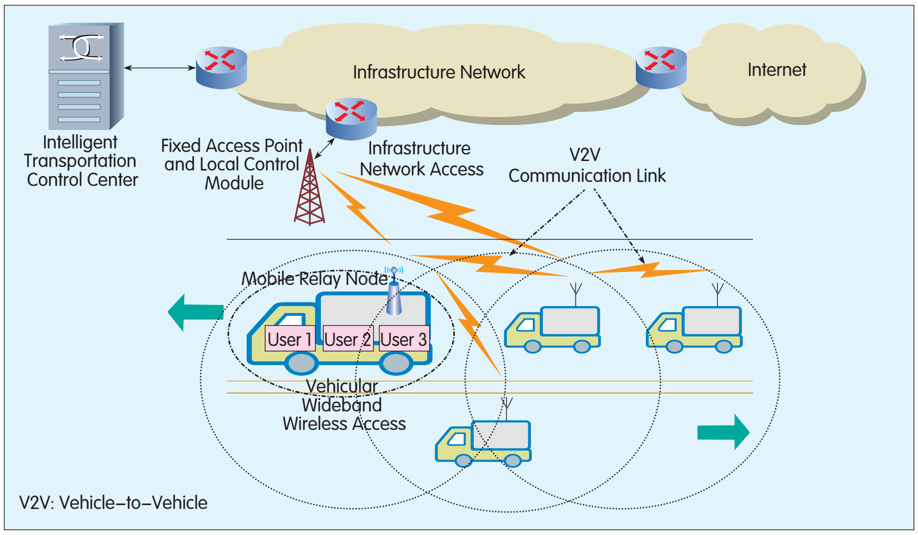


▲Figure 1. Architecture of WAVE-MAC protocol.

Current topics of research in vehicular mobile networks include WAVE (IEEE 802.11p) multichannel coordinated applications and multicast routing management as well as handover and resource scheduling in WiMAX (IEEE 802.16) fixed relay technology.

In VANET, all applications related and unrelated to safety are implemented on the same channel, which makes it difficult to guarantee QoS. Mass data unrelated to safety congests traffic and prevents safety data from being effectively transmitted. This can seriously affect the safety performance of VANET. A direct and effective solution to this issue is multichannel Media Access Control (MAC)[7]. With multichannel MAC, nodes can use different channels to communicate with each other and access is more flexible. A multichannel network has better throughput and less delay than a single-channel network. Timeslot intervals are generally used to alternatively divide time into control intervals and data exchange intervals[8-9]. All nodes negotiate on Control Channel (CCH) within a CCH interval, and then move to other channels to transmit data within a Service Channel (SCH) interval. Figure 1 illustrates a VANET based on multichannel MAC.

The original WAVE routing mechanism is not adaptable to vehicular networks with dynamically changing topologies. Proactive table-driven routing protocol fails to coordinate nodes that cannot be determined in advance in a transport environment. Moreover, frequent topological changes seriously affect the protocol's performance. On the other hand, reactive source-driven routing protocol does not establish a route until a message is being sent, and the route expires after some time. These routing protocols struggle to meet the low-delay requirements of safety applications because an increase in communication hops or vehicle speed causes a longer delay in establishing a route. Therefore, location-based multicast routing technology must be merged[10-11]. The goal of multicast routing is to transfer a message from the source node to all nodes within a Zone of Relevance (ZoR). A vehicular network using multicast routing can be organized into multiple peer units (clusters) in order to improve scalability in mobile environments[12]. The VANET clustering mechanism enables rapid and effective intra-cluster communication of safety messages, and inter-cluster communication for multihop message transmission to far areas. This cluster-based routing mechanism not only enables



▲Figure 2. The proposed heterogeneous vehicular communication architecture.

comprehensive message coverage but also has low delay. Therefore, it can be used to deliver all kinds of messages to moving vehicles. Cluster-based multicast routing will have safety applications in vehicular networks. A cluster header is treated as a coordinator, which collects and delivers real-time safety warning messages in the cluster and transfers processed safety messages to neighboring cluster headers.

Communication between vehicles and roadside infrastructure is possible only when a vehicle is moving slowly or it is static. That is to say, a fast moving vehicle cannot have sustained interaction with roadside infrastructure. Vehicular MRSs are introduced between intra-vehicle user terminals and roadside base stations to facilitate interaction. The concepts of hierarchical scheduling and group mobility emerge from an MRS-based vehicular communication system. MRS acquires allocated resources from base stations and user terminals in vehicles acquire resources from MRS in a process called two-level resource scheduling. If communication links from vehicles belong to the same service type and have similar QoS requirements, MRS will bind the links for centralized handover processing. Group handover reduces the number of signaling interactions between each terminal and the base station.

A two-level resource scheduling mechanism based on fixed relays[13] improves system throughput and decreases packet loss rate and delay. A relay-assisted handover technique using network coding over multihop cellular networks[14] ensures channel QoS parameters and reduces the call drop rate by transferring data through relay nodes. In MRS-based group handover[15], MRS assists vehicles to complete handover to destination base stations, and also reallocates resources during the process so that congestion and delay are reduced and handover is successful.

Within a radius of several hundred meters, WAVE can transmit real-time text and image messages to intersections, gas stations, and parking lots at tens of megabytes per second. It can also provide moving vehicles with pre-collision warning. On the other hand, WiMAX supports communication within a radius of several thousand meters and can be applied in vehicles moving at over 120 km/h. MRS in WiMAX system provides good system gains and facilitates high-rate communication for vehicles. Therefore, a heterogeneous vehicular communication architecture based on converged WiMAX and WAVE is recommended. This architecture is capable of safety communications, transferring transportation data, and wireless broadband multimedia data transmission.

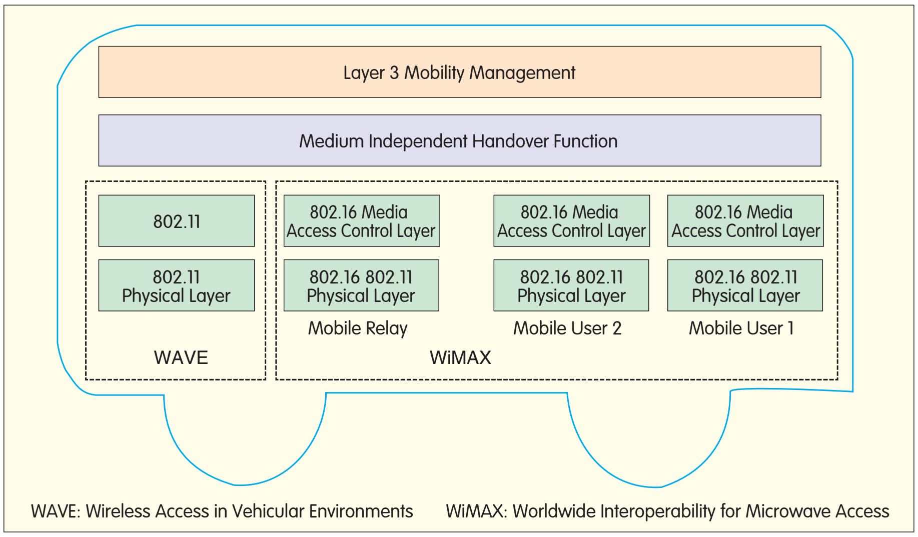
2 Heterogeneous Vehicular Communication Architecture and Its Reference Model

2.1 System Architecture

In the architecture proposed in Figure 2, WAVE facilitates V2V communications and WiMAX facilitates V2I communications. MRS is applied between user terminals in vehicles and roadside infrastructure. This architecture supports emergency V2V communications, guaranteeing proactive vehicular safety. Moreover, MRS also enables broadband wireless access in vehicles. Reliable, real-time data interaction is possible between users and intelligent transport centers, and multimedia data services can be accessed on the Internet. Figure 3 shows the protocol structure of this architecture. V2V communications and transferring of safety data can be reliably carried out using IEEE 802.11p VANET. Vehicular wireless broadband can be accessed over IEEE 802.16 metropolitan networks. Users can upload or download at high speeds, and handover can be conducted as a whole through MRS.

2.2 Communication Protocol Module

A heterogeneous vehicular communication network ensures multimode terminals in moving vehicles receive data services over IEEE 802.11 and IEEE 802.16 networks. However, these two kinds of networks have different MAC and upper-level mobility management protocols. Therefore, in order to offer handover service in the heterogeneous network, a media independent handover technology between L2 and L3 protocols is necessary. In the solution proposed in this article, IEEE 802.21 Media Independent Handover Function (MIHF) module[16] is used. This module enables network discovery and selection, initiates handover, and optimizes power consumption of heterogeneous networks based on 3G, WiMAX, and Wireless Fidelity (Wi-Fi). In a



▲Figure 3. Protocol structure of the heterogeneous vehicular communication network.

heterogeneous vehicular network using the MIHF module, handover delay and packet loss tolerance are greatly improved. Figure 4 shows the layers and modules of the entire network.

2.3 Field Test Platform

Using a laboratory simulation testbed, a field test platform for the heterogeneous vehicular communication network was built around the Jiading Campus of Tongji University and Caoan Road in Shanghai. The V2I and V2V field test schemes have WiMAX vehicular broadband wireless access and WAVE vehicular ad-hoc communications. As shown in Figure 5, the field test platform supports high-speed transmission of V2V safety data. Vehicles can exchange data such as traffic conditions with the intelligent transport center and can access digital multimedia services on the Internet.

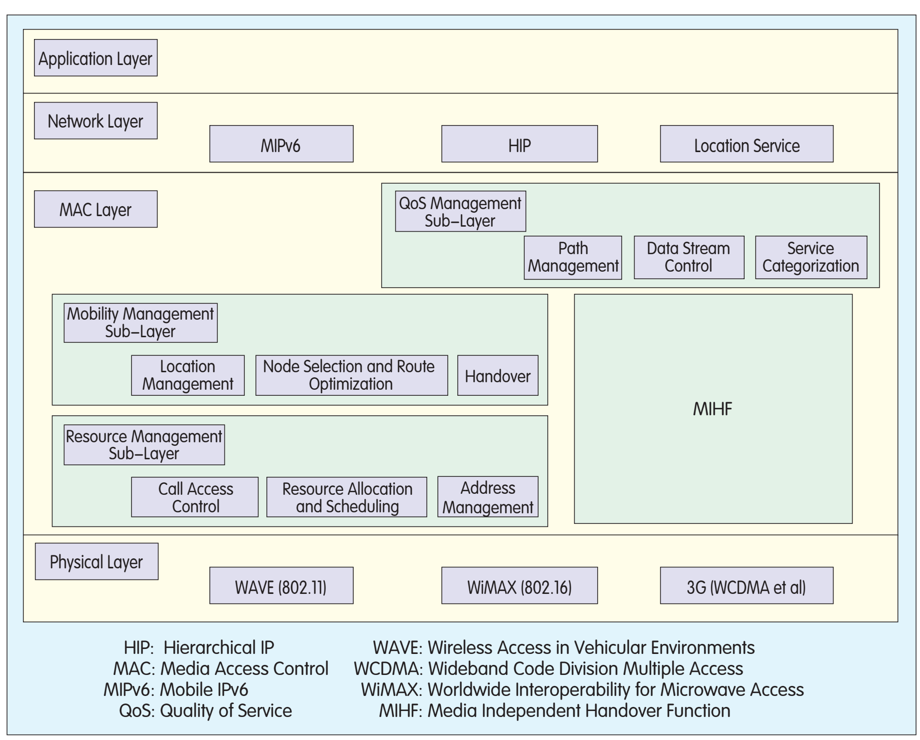
3 Key Technologies in a Heterogeneous Vehicular Communication Network

3.1 Distributed Channel Scheduling and Channel Adaptive Coordination Mechanism Based on Link State

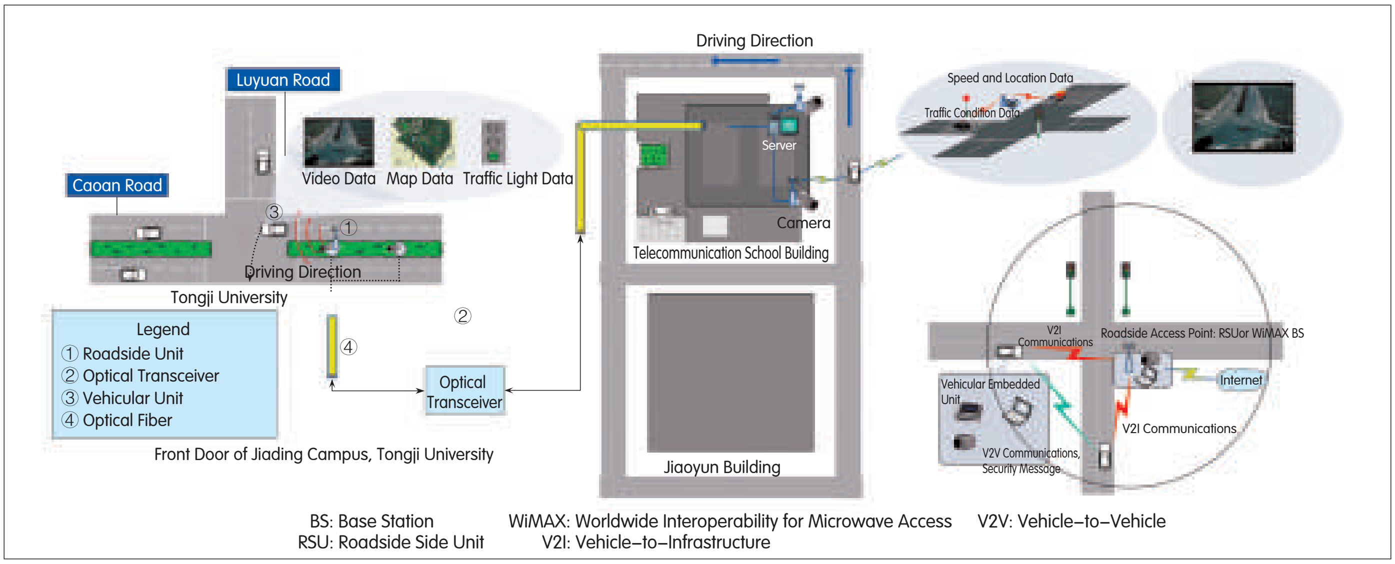
A channel coordination mechanism based on timeslot intervals and Time Division Multiple Access (TDMA) is used to form the basic protocol structure for the proposed architecture. A synchronization interval contains a control window and a data exchange window. Each window is further divided by timeslots. The control window is used for broadcasting safety and control messages, while the data exchange window is used to unicast or locally broadcast messages that are not related to safety. Figure 6 shows the proposed VANET multichannel MAC protocol framework. The channel adaptive coordination mechanism dynamically adjusts control and data exchange window intervals according to traffic load. According to the frequency and time, the distributed channel scheduling algorithm allocates optimal resources to nodes in local areas, improving channel utilization and throughput.

3.2 Location-Based Routing Algorithm

In current vehicular networks, the relative locations of nodes can be acquired by link predication based on which routes are selected. To relieve the burden on the data link layer, Global Positioning System (GPS) equipment can be used to provide location data. Based on mobility predication on moving vehicles and an enhanced cluster-based algorithm, the message broadcasting mechanism guarantees that messages are rapidly and stably transferred in the event of an accident. Therefore, cluster broadcast routing algorithm based on mobility prediction is necessary in the proposed architecture. Also, in order to guarantee QoS and reduce delay for high-speed topology changes frequently, it is



▲Figure 4. Layers and modules of the heterogeneous vehicular communication architecture.



▲Figure 5. Field test platform of the heterogeneous vehicular network.

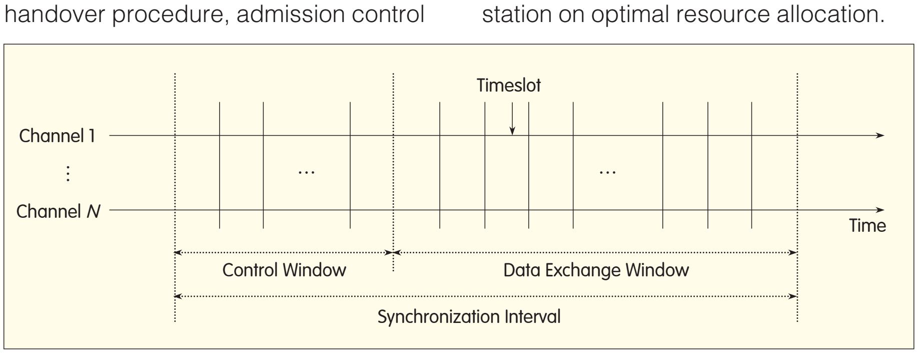
necessary to predict the location, speed, and acceleration of nodes. The connection duration must be estimated, and route discovery process must be initiated before the current route is disconnected.

3.3 MRS-Based Group Handover Mechanism

Group handover refers to simultaneous handover of multiple terminals in a moving vehicle from the serving base station to another base station. During a group handover, resources are reallocated to guarantee QoS at different service levels. Mobile user mobility prediction technology can be used to estimate resource reservation during handover, which helps reduce handover calls admission drop rate and delay. Research into MRS group handover is focused on the design of mobility prediction group handover procedure, admission control strategy for handover based on sub-channel reallocation, and speed adaptive handover algorithms.

3.4 Relay-Based Two-Level Hierarchical Scheduling Algorithm

With the introduction of relay technology into vehicular networks, relay nodes appear in vehicular broadband wireless access systems. Base stations and user terminals signal to each other through relay stations rather than communicate directly. The concept of hierarchical scheduling thus emerges. Hierarchical scheduling uses a central scheduling mechanism for resource scheduling at the base station and relay node. Since a relay node has powerful processing capabilities, such as partial base station function, it can assist base stations to make a schedule mapping from the vehicular terminal to broadband wireless access base station on optimal resource allocation. This reduces the burden on base stations and improves system throughput and data rates. The two-level hierarchical scheduling algorithm follows network environment changes and implements two-level Dynamic Bandwidth Allocation (DBA) under a "vehicle-MRS-roadside base station" three-layer structure. Frequency utilization is thereby improved, and services are provided with QoS guarantees.



▲Figure 6. Basic protocol structure for the heterogeneous vehicular network.

4 Conclusion

Convergence of VANET and broadband wireless access networks is an important component of new-generation wireless broadband mobile networks and a major goal of China's 11th five-year science and technology development plan. The new converged vehicular network is expected to boost QoS in urban intelligent transportation systems, help in the construction of urban broadband wireless information systems, and support digitally networked cities. To these ends, a hybrid vehicular mobile communication architecture based on WAVE and WiMAX is proposed. Its protocol module structure is given, and key technologies are analyzed. These technologies include multichannel coordination and scheduling, multicast routing in VANET and group handover, and hierarchical resource scheduling and allocation. For future heterogeneous vehicular communication networks, further research will be needed into important technologies such as QoS guarantee at high mobile speed and seamless handover of moving vehicles over heterogeneous networks.

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Biographies

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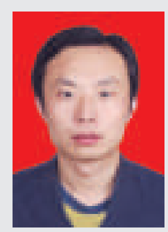
Shan Lianhai



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Roundup

ZTE Wins "Leone D'Oro per la Comunicazione" (Golden Lion for Communications) Award

ZTE Corporation, a leading global provider of telecommunications equipment and network solutions, received the "Leone D'Oro per la Comunicazione" award from the Fondazione Italia Cina in November 2010.

Every year, the Fondazione organizes the "China Awards" with the aim of recognizing Italian companies that operate in China and Chinese organizations that operate in Italy. During the ceremony, prizes are awarded to organizations that have invested in the Chinese and Italian economy, citizens, businesses and services.

In the last two years, ZTE has increasingly invested and leveraged its communications strategy to increase business in Italy. Through partnerships with key carriers and collaborations with qualified local and national consultancies, ZTE has invested in PR and media campaigns, developing co-branded equipment with companies such as Poste Mobile for entry level handset models PM1001, PM1002, PM1005, and with H3G for the MD Touch Mini mobile phone.

ZTE has opened the doors of its headquarters in Shenzhen, China to Italian and international press, inviting business and trade editors to visit the core of the company and its research and development center and to discuss the company's expansion strategy with key executives.

ZTE's business is continuously growing in Italy. The company last December organized a press conference with Telecom Italia to announce the creation of a modern optical fibre network infrastructure for the new houses of the C.A.S.E. (complessi antisismici sostenibili e ecocompatibili) project with the aim of contributing to the reconstruction efforts after the Abruzzo earthquake.

(ZTE Corporation)

A Distributed In–Memory Database Solution for Mass Data Applications

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Abstract: In this paper, a Distributed In–Memory Database (DIMDB) system is proposed to improve processing efficiency in mass data applications. The system uses an enhanced language similar to Structured Query Language (SQL) with a key–value storage schema. The design goals of the DIMDB system is described and its system architecture is discussed. Operation flow and the enhanced SQL–like language are also discussed, and experimental results are used to test the validity of the system.

Key Words: distributed in–memory system; enhanced key–value schema; mass data application

Analyzing and processing mass data is a common function of telecommunications and Internet service applications. As the number of service users increases, traditional on–disk database systems struggle to satisfy demand for mass data processing. Typical service applications include fast querying of large–scale user databases for social networking services, data processing of mass logs, and data analysis and mining of mass databases. In these tasks, response time plays a critical role.

An in–memory database that relies on main memory for computer data storage has been widely used in recent years. In contrast to database management systems, which employ a disk–optimized storage mechanism, main memory databases are faster. Internal optimization algorithms of main memory databases are simpler and execute fewer CPU instructions. Accessing data in the main memory is faster and more predictable than accessing data on disk[1]. Storage services require high availability, good performance, and strong consistency[2]. In–Memory Databases (IMDBs)[3] satisfy these requirements and have emerged as a way of improving the performance of short transactions[4]. Since IMDBs can be accessed directly from the memory, response time is quicker, and transaction throughput is improved when compared to a Disk–Resident Database (DRDB). This is especially important for real–time applications where transactions need to be completed within a specified timeframe[5].

The number service application users is many times higher than in the past. But memory capacity and CPU processing limitations on a single computer means the IMDB system often cannot deal with the mass data in these applications. For example, the main memory in a computer is normally 4 GB to 8 GB, while 100 GB may be needed for a database of 100 million users where every user record needs 1 Kb. In many cases, the IMDB system on a single computer cannot store all the data of certain types of applications. For some applications, logic processing is complicated and processing time is lengthy. So assigning all these processing tasks to one computer is not ideal.

To improve data processing efficiency, a Distributed In–Memory Database (DIMDB) system is proposed. The DIMDB system in this paper supports expanded Structured Query Language (SQL) grammar with a key–value storage schema.

1 Design Goals of DIMDB System

The design of DIMDB has three goals:

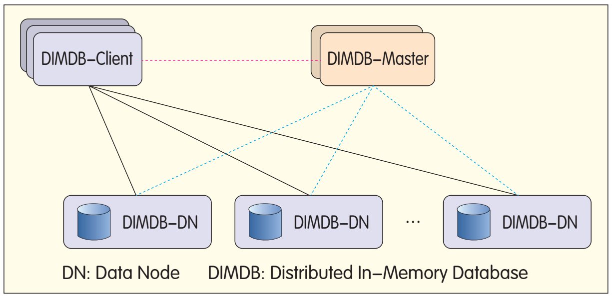
(1) High Performance

A DIMDB system should be capable of high–performance data access and processing. Many current telecom and Internet service applications produce mass data every day, and this data should be easily accessible and efficiently processed. Mass data might include detailed call records of telecommunications systems, user subscription information, web access logs of Internet Service Providers (ISPs), and monitoring data derived from sensor networks. These kinds of mass data could be stored in a DIMDB system for ease of access and high–performance processing.

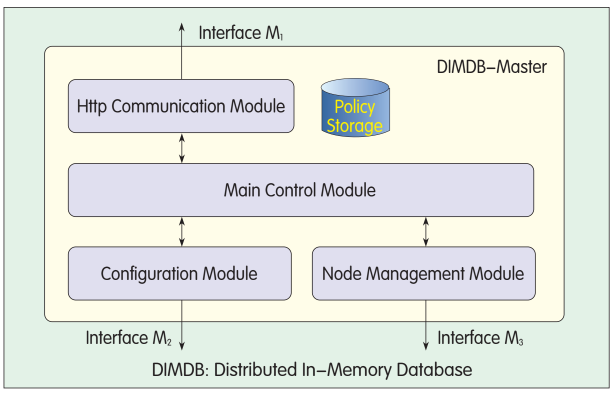
(2) High Scalability

DIMDB is a distributed system with multiple data nodes to accommodate mass data applications. As the amount of data and processing increases, new data nodes can be added online without interrupting the running service. If the DIMDB system has more data nodes than necessary, redundant nodes can be removed.

(3) High Reliability



▲Figure 1. The basic architecture of a DIMDB system.



▲Figure 2. The DIMDB–master functional structure.

Data stored in one node always has one or more duplicate copies in other nodes. If a data node fails, an application can use duplicate data on other nodes. The DIMDB management node is an active–standby system for Home Agent (HA).

2 Architecture of a DIMDB System

Figure 1 shows the basic architecture of a DIMDB system consisting of three elements: DIMDB–Master, DIMDB–Client, and DIMDB–Data Node (DIMDB–DN).

The DIMDB–Client generally receives data processing instructions and access requests from upper–level applications. After analyzing these instructions, it sends the requests to DIMDB–Master for data distribution information, and returns the information according to the data distribution policy. The DIMDB–Client then sends commands to the specific DIMDB–DN for processing and data access.

2.1 DIMDB–Master

The DIMDB–Master:

- Allows applications to configure data distribution policies;
- Allows DIMDB–Client to query configured policies;
- Activates or deactivates DIMDB–DNs and queries the status of DIMDB–DNs.

The functional structure of DIMDB–Master is shown in Figure 2.

There are five modules in DIMDB–Master: main control module, http communication module, configure module, node management module, and policy storage.

The main control module is the key functional module of DIMDB–Master. It interacts with other modules to complete essential functions of DIMDB–Master.

The policy storage is used to save data distribution policies.

The http communication module provides M_1 interface for interaction with DIMDB–Client. M_1 interface is used to receive query requests from DIMDB–Client and to send data distribution information to DIMDB–Client.

The configuration module interacts with the external operation and maintenance platform to configure data distribution policies on each DIMDB–DN through the M_2 interface.

The node management module connects to each DIMDB– DN using M_3 interface. It monitors the status of DIMDB–DNs, and activates or deactivates DIMDB–DNs. Status information includes CPU efficiency, the efficiency and capacity of memory used, and whether the DIMDB–DN is operational or non–operational.

2.2 DIMDB–Client

The functional modules of DIMDB–Client are shown in Figure 3.

The API module in DIMDB–Client is used by upper–level applications to call the data operation functions of DIMDB–Client.

The statement parser is used to transform received SQL–like statements into two parts: database operation statement and input condition (used for requesting data distribution information).

The execution engine is a dynamic link library connected to DIMDB–ND. It is provided by the database management system on a data node, and is used to bring the statement into operation.

The policy acquisition module is used to obtain the data distribution policy from DIMDB–Master according to the input condition.

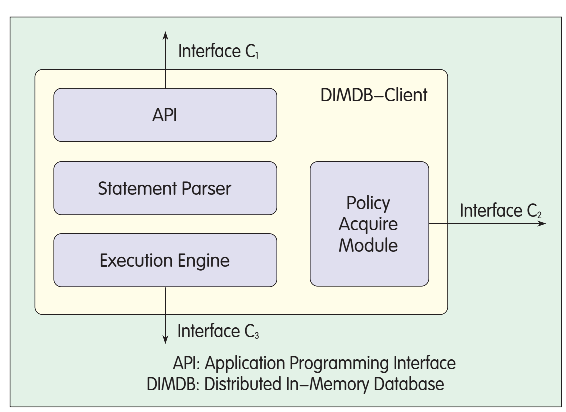
2.3 DIMDB–DN

DIMDB–DN is a conventional in–memory database used for data storage. It is a stable and efficient database management system supporting Open Database Connectivity (ODBC) and Java Database Connectivity (JDBC) interfaces.

3 Enhanced SQL–Like Language and Operation Flows

3.1 Enhanced SQL–Like Language

Data operation and query in the proposed system is carried out using an enhanced SQL–like language. This language mimics SQL syntax for



▲Figure 3. DIMDB–client functional structure.

creating tables, loading data into tables, and querying tables. Enhanced SQL-like language also allows data distribution information to be embedded into statements. When the DIMDB-Client receives an SQL-like statement, the statement parser transforms it into a normal SQL statement and input condition. The input condition is a kind of key-value range pair. The policy acquisition module then sends the condition to DIMDB-Master, and receives data distribution DIMDB-DN information through C_2 interface. This information includes node IP addresses and ports oriented to each key-value sub-range pair. According to the information received, DIMDB-Client rewrites the SQL statement and divides it into sub-statements. DIMDB-Client connects to DIMDB-DNs, executes the statements through the execution engine, and collects the data operation results.

Enhanced SQL-like language used in the proposed system includes the condition for data distribution information. For example, the following statement creates a TABLE t1 with additional conditions:

CREATE TABLE t1(Index int not null, Name char(50) not null, Age int, Height float){Key=Index} (1)

The following statement inserts a record into TABLE t1:

INSERT INTO t1 (Index, Name, Age, Height) values (1001, "Tom", 20, 1.72) {Key=Index} (2)

When receiving statements (1) and (2), DIMDB-Client abstracts and sends the key-value pair to DIMDB-Master, which returns the data node information according to the key-value pair. Then DIMDB-Client performs the data operations on DIMDB-DNs according to the received data node information.

If the application needs to query data in TABLE t1, a statement is sent to DIMDB-Client as follows:

SELECT ·FROM t1 WHERE Age=25 {Key=Index, Minvalue=1001, Maxvalue=1100} (3)

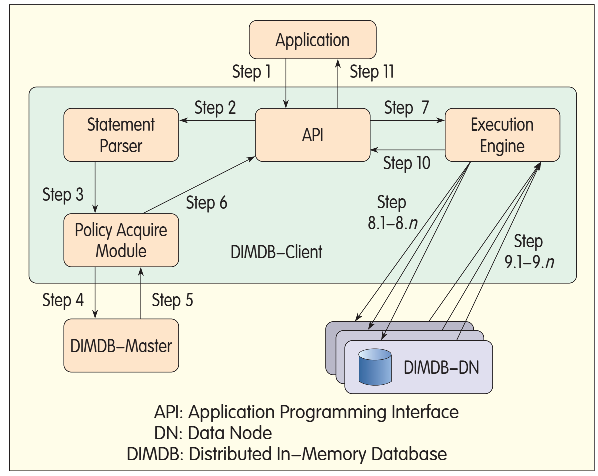
After receiving query statement (3), DIMDB-Client abstracts the key-value pair Key=Index, Minvalue=1001, Maxvalue=1100 and sends it to DIMDB-Master. DIMDB-Master then returns the data node information DIMDB-ND_1 and DIMDB-ND_2, and corresponding key-value sub-range pairs Key= Index, Minvalue=1001, Maxvalue=1050; and Key= Index, Minvalue=1051, Maxvalue=1100. Then DIMDB-Client divides and rewrites the query statement according to the received data node information. The first sent to DIMDB-ND_1 is:

SELECT ·FROM t1 WHERE Age=25 and (Index>=1001 and Index<1050) (4)

And the second sent to DIMDB_ND_2 is:

SELECT ·FROM t1 WHERE Age=25 and (Index>=1050 and Index<=1100) (5)

After obtaining query results from the two DIMDB-DNs, DIMDB-Client combines the results and returns them to the application.



▲Figure 4. The DIMDB system operation flow.

3.2 Operation Flows

The operation flow of the DIMDB system is shown in Figure 4.

Step 1: The application calls the API interface in DIMDB-Client with the parameter of an enhanced SQL-like statement.

Step 2: The statement is sent to the statement parser module.

Step 3: After being analyzed, the normal SQL statement is saved, and the key-value range pair is sent to the policy acquisition module.

Steps 4 and 5: The policy acquisition module interacts with DIMDB-Master to obtain the data distribution information. The input is the key-value range pair, and the output is the IP addresses and ports of DIMDB-DN for each divided key-value sub-range pair.

Step 6: The data distribution information is sent to API.

Step 7: The API composes multiple SQL statements and calls the function of the execution engine with the parameters of new statements and data node information.

Step 8.1-8.*n*: The execution engine connects to multiple DIMDB-DNs and executes the SQL statements.

Step 9.1-9.*n*: The execution engine obtains the data results.

Step 10: The execution engine sends the data results to API.

Step 11: API combines the all data results and returns them to the application.

With these 11 steps, the operation is finished.

4 Experiments

In this section, some experiments are provided to evaluate the performance and scalability of the DIMDB system.

4.1 Experiment Environment

The configuration of the experiment environment is listed in Table I.

4.2 Experimental Results

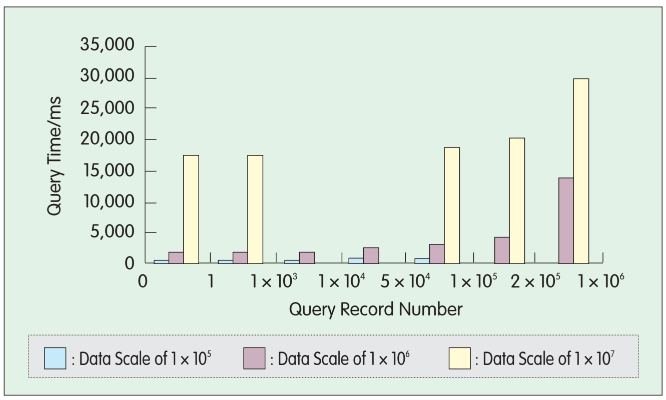
The bar chart in Figure 5 shows the query time for different total data scales, being 100 k, 1 M and 10 M records in the databases of all DIMDB-DNs. Different colored columns denote different scales. The query efficiency for large-scale data in the DIMDB system is notably better than in traditional databases.

As shown in Figure 6, query time for different DIMDB-DNs in the system is different. The query time for DIMDB-DN 3 is notably shorter than that for DIMDB-DNs 1 and 2. When the scale of data is increased, more

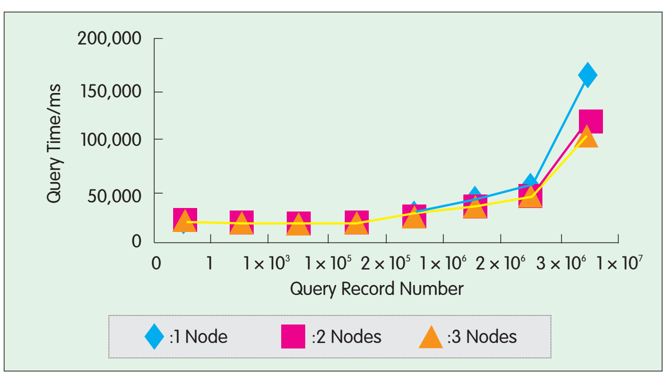
▼Table I. Configuration of experiment environment

Functional Module	Number	Configuration	Operating System
DIMDB–Master	1	HP PC Server/8 core Xeon 2G CPU/4G Memory	RedHat Enterprise 5.4
DIMDB–Client	1	HP PC Server/8 core Xeon 2G CPU/4G Memory	RedHat Enterprise 5.4
DIMDB–DN	3	HP PC Server/8 core Xeon 2G CPU/4G Memory	RedHat Enterprise 5.4
Switch (Routing Funciton)	1	ZXR 2826S/100M	Not Available

DN: Data Node DIMDB: Distributed In–Memory Database



◀Figure 5. Query time for different total data scales.



◀Figure 6. Comparison of query time for different DIMDB–DNs in the system.

DIMDB–DNs should be added to the system.

The above illustrates the effectiveness of the prototype in this paper. Efficiency of the DIMDB system is expected to improve with optimizations such as table indexing, and more reasonable data distribution policies. When expanded to hundreds of data nodes, the DIMDB system could be used in telecommunications and Internet applications requiring mass data processing.

5 Conclusion

In this paper, limitations of current in–memory database systems are analyzed, and an a DIMDB system is proposed to improve data processing ability in mass data applications. An enhanced language similar to SQL is used, which has the advantage of a key–value storage schema. DIMDB could be widely used in applications that require mass data processing. Future research will need to be conducted into optimizing data distribution policies and table dividing schemas, and improving overall stability of the system.

Acknowledgment: Thank you to Tang Jue for his support and patient guidance, and to Wang Zhiping, Zhou Yang, Ye Xiaowei and Lin Xiangdong for their contributions to this work.

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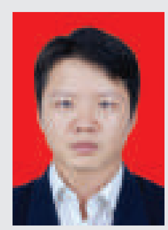
Biographies

Dong Hao



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Soft Base Station Technology in Wireless Communication Systems

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Abstract: With the rapid development of wireless communications systems, different system standards are being merged. Operators take stringent measures to reduce Operational Expenditure (OPEX) and Capital Expenditure (CAPEX); and as a result, soft base stations supporting multiple standards become the evolutionary tend of wireless base stations. This paper introduces the background of soft base stations and analyzes their architecture design, system modules. The key technologies in system implementation and future directions are also presented.

Key Words: wireless communications; soft base station; multimode base station

1 Background

Nowadays, mobile networks are rapidly migrating to all-IP networks. Many international standardization organizations, such as 3GPP, 3GPP2 and IEEE, have proposed all-IP network architectures. During the evolution towards 4G, the flat architecture is employed, that is, the aggregation node in Radio Access Networks (RAN) is removed from the network architecture and instead the NodeB directly connects to the core network. In order to support the coexistence of multiple standards and network convergence, the Iur-g interface is defined for the Radio Network Controller and Base Station Controller (RNC/BSC)[1]. The interfaces between NodeB and RNC and within the NodeB itself become standardized and open. The previous proprietary Abis, Iub, and baseband Radio Frequency (RF) interfaces are transformed into open standards.

Moreover, RAN actively adopts the IP and technologies such as distributed database, Point to Point (P2P), virtualization, and cloud computing from IT industry. These technologies were originally designed for the load-balanced data storage, interaction, and processing in large servers or the Internet. Applying these technologies to the telecom field has resulted in the convergence of telecom and IT networks.

Both the telecom and IT industries embrace the openness of standards. Therefore, many standards organizations have been founded to establish completely or partially open and standard architecture. Open Base Station Architecture Initiative (OBSAI)[2], Micro Telecommunications Computing Architecture (MicroTCA)[3-4], and Common Public Radio Interface (CPRI)[5] are three typical open architectures and standards.

OBSAI is an open base station architecture, jointly developed by a number of manufacturers. It defines all sets of base station structure, architecture, and interface. However, from the perspective of implementation, the structure is not easy to scale down and the architecture is not compact. Therefore, it is not practically used by equipment manufacturers. Though the OBSAI RP03 interface[6] (the interface between radio frequency and the baseband) provides more flexibility for various systems and higher rate, only a few manufacturers currently use this interface due to its complexity in implementation and low bearing efficiency—the effective bandwidth is only 84%.

MicroTCA is an open computing architecture defined by the PCI Industrial Computer Manufacturers Group (PICMG). The focus of MicroTCA is to define implementation technology and schemes in terms of structure size, power architecture, chassis management, and switch fabric. MicroTCA architecture can be used in high-performance embedded computing, communications, and physics. However, the standard is complicated and its implementation is difficult. There is still much room for improvement in applicability and configuration cost for the telecom field. ZTE's soft base station system is based on the MicroTCA architecture with a lot of key technology improvements during implementation.

CPRI is a specification defined for the baseband RF interface; most manufacturers use the CPRI specification. Based on CPRI, Next Generation Mobile Network (NGMN) defines the Open Baseband Radio Interface (OBRI), which further defines the frame format and realizes the unified software interface.

All these architectures and standards target to realize unified architecture. However, there is still a gap between

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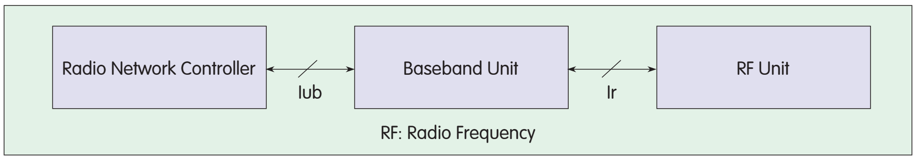


▲Figure 1. Composition of a radio base station.

these architectures and standards and the implementation of multimode soft base stations.

On the other hand, the rapid development of semiconductors and software technologies has made possible the commercial implementation of soft base station. Field Programmable Gate Array (FPGA) and Digital Signal Processing (DSP) make the concept of soft baseband feasible; the architecture design is no longer constrained by the processing power. The bus Serializer/Deserializer (SERDES) also provides high bandwidth in limited connections and simplifies system architecture; the unified clock system may benefit from the high-performance phase-locked loop technology.

As to the software aspect, the open and standard protocols accelerate the convergence of architectures and interfaces that use different standards; virtualization technology separates equipment management from wireless services so that services from different systems easily coexist and isolated; distributed technologies such as cloud computing improve software configurability.

2 Architecture of Soft Base Stations

In order to support multiple systems and the smooth evolution, various product implementations should be highly abstracted and summarized. The common parts are extracted for the design of universal architecture. The composition of a radio base station is shown in Figure 1.

Generally, the soft base stations require the Baseband Unit (BBU) and RF Unit (RU) be compatible with the services from multiple systems with different standards. At the same time, the Iub (Abis) and Ir interface should be standardized to shield the differences of multiple systems.

The Iub interface has already been standardized, and the channelized E1 is gradually replaced by IP transmission. In this way, 2G and 3G base stations can be unified at the Iub/Abis interface. The Ir interface may also comply with CPRI and OBSAI standards. Therefore, from the macro view, these interfaces can be unified. The technical problem lies in the implementation of different scenarios for different systems.

BBU can be divided into four parts, as shown in Figure 2.

The architecture of BBU can be divided into three planes: public resource plane, service switching plane, and I/Q switching plane, as shown in Figure 3.

The aforementioned plances are only roughly divided. The boundary between different planes may be vague. However, they are adequate for the BBU architecture analysis.

According to the functional modules of BBU, transmission can be shared by multiple systems using different standards, and can therefore be regarded as unrelated to standards.

The control, clock, power are independent of any specific standards. However, the baseband processing and RF interface involve different standards. For implementing soft base stations, the standard-involved function modules should be divided into finer granularity in order to find the standard independent part; for the standard dependent part, the encapsulation is at least required to shield the differences between standards.

Classification of planes has the following features:

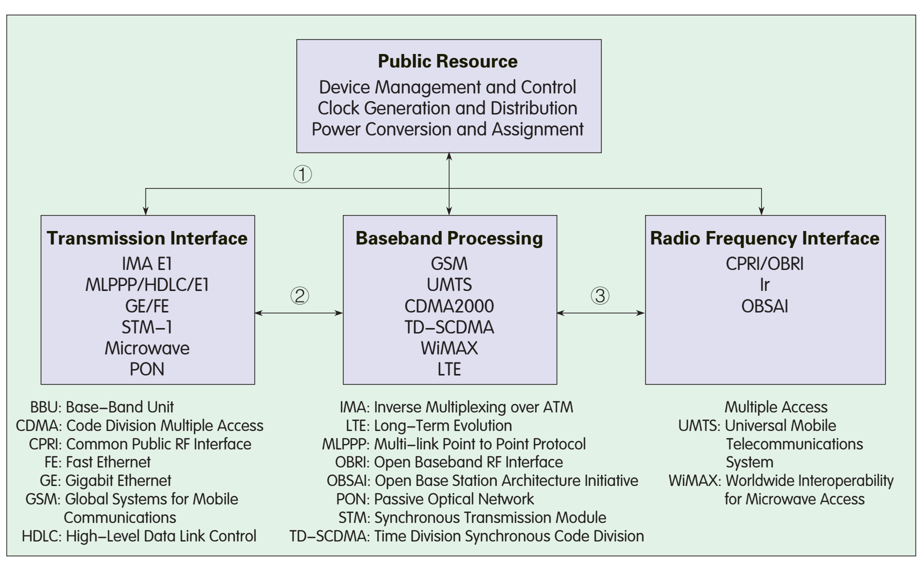
(1) Different standards have different clock requirements. This is the major difference between standards.

(2) A unified switching plane may be formed by using the GE/FE switching plane and internal protocols through software.

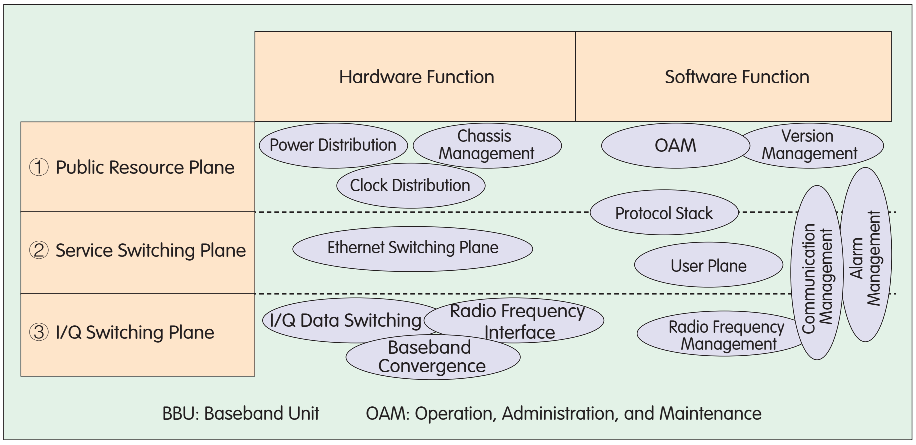
(3) SERDES can be used to remove differences within standards from the architecture point of view. However, since the I/Q data rates vary according to different standard, the encapsulation is required to shield the differences in standards so as to achieve the multimode configuration.

3 Public Resources

The key challenge in implementing soft base stations is how to isolate the public resource management from wireless service. The isolation allows



▲Figure 2. Functional modules of BBU.



▲Figure 3. Three public planes of BBU.

base stations to support multiple standards and smoothly evolve through software configuration.

In this paper, this challenge is addressed through the hardware and software design. As to the hardware, the major problem for base station is that different standard systems have different clocks. The chip rates differ from 1.2288 MHz to 3.84 MHz, 13 MHz, or 44.8 MHz (besides frequency multiplication or frequency dividing). In our design, the public frequency of 122.88 MHz is selected, which facilitate the usage of digital phase locked loop on each baseband unit and the generation of various frequencies. In this way, differences in standards on the public hardware resource can be shielded. As to the software, soft base stations require smooth evolution, coexistence, and non-interference among multiple systems using different standards. They should support the backup capability for transmission links and main control/clock. The software should be configurable and support flexible installation/uninstallation of systems for specific standard. ZTE applies pseudo-virtualization and operating system virtualization technology in embedded systems[7], and proposes a software-configurable soft base system.

Virtualization is a popular technology in the IT industry, and one of the foundations of cloud computing. It enables users to install multiple operating systems (virtual machines) on a computer and process multiple tasks. This saves IT budget and supports high-speed task processing. Virtualization supports dynamic resource deployment and re-configuration for the purpose of service expansion. Virtualization also helps in service isolation and division and provides controllable and secure access to data and services. In addition, virtualization could provide the interface of virtualized resources that are independent of physical resources and protocol compatibility.

In traditional base stations, wireless service, database management, device management, alarm management, version management, and transmission management are mutually coupled with control modules. However, this leads to restrictions and conflicts where multiple systems coexist with different standards. By establishing a virtualized device management layer, wireless services, on the one hand, can be decoupled from device management, thus the public device management of the base station can be shielded from wireless services and the unified device management of the base station can be achieved. On the other hand, when services with different standards are running in independent virtual spaces, one service is not aware the existence of other services with different standards. Therefore, any standard can be flexibly added or removed. In this way, management of a multimode base station is unified, and services can be independently upgraded and maintained, which enable the flexible standard scalability.

4 Transmission

Access and transmission networks are tending to be rapidly merged. Base stations are required to support L3 routing protocol and Ethernet management protocol. In wireless network clouds, access devices are gradually responsible for the transmission interface bearing, protocol termination, route conversion, internal node management, and even multi-node network management. The intelligent technologies, such as self-discovery and self-configuration, have also emerged.

With the rapid growth of data service and the development of open networks, wireless base stations take on more roles than traditional base stations, that is, they provide users with voice and data services, but also serve as transmission routing nodes and aggregation nodes to provide transmission for multiple stations.

To handle complicated transmission networking and protocols, soft base stations should have the following capabilities:

(1) Diversified Embedded Transmission Capability

The sites for base station deployment are generally limited and have to adapt to the legacy transmission modes of operator's network. Soft base stations should be embedded with diverse transmission capabilities—such as microwave, Passive Optical Network (PON), E1/T1, Synchronous Transmission Module 1 (STM-1), and Ethernet—and also support flexible networking. In addition, base stations should divide transmission into multiple transmission media, for example, the Ethernet is used to carry data and E1 used to carry voice.

(2) Standard Transmission Protocol Stacks

The network protocol suites opened up by standards organizations, such as IETF, provide standardized high-level protocols that are independent of network hardware environments. They meet the requirements of co-existence and interconnection between multiple systems. ZTE initiated the research and development of all-IP wireless base stations in 2002, and has since proposed a transitive networking mode of IP over E1 as well as FE access to Multi-Service Transport Platform (MSTP) Resilient Packet Ring (RPR). In open network architecture, soft base station should pay more attention to transmission management and security, and provide the Internet Protocol Security (IPSec) (digital certificate management and deployment) and IPv6 solutions. Soft base stations should also provide Ethernet management protocols such as 802.3ah.

(3) Unified Management of Transmission Resources

In multimode base stations, transmission resource is shared by services using any standard. Soft base station should support the co-existence of multiple transmission modes and the interworking between them. The QoS scheduling and traffic control of different service flow should also be implemented for different services sharing the same transmission.

(4) Convergence of Access and Transmission Networks

With the development of 4G networks, base stations migrate from the L2 switching protocols towards L3 routing protocols in order to meet the increasingly complicated networking requirements. Base stations should not only serve as edge transmission nodes, but also integrate the route management and protocol termination nodes. In addition, the base station should partially replace Multiple Protocol Label Switching (MPLS) edge routers to reduce deployment costs across the network.

5 Soft Baseband

Among various standard systems, the CDMA 2000 core technology is monopolized (by Qualcomm), which generally use the Application-Specific Integrated Circuit (ASIC) for baseband modulation/demodulation. For other standard systems, the baseband implementations of equipment manufactures are diverse, including ASIC, Digital Signal Processing (DSP), DSP+ASIC, and DSP+ Field-Programmable Gate Array (FPGA). All these methods have their own strengths and weaknesses.

With the development of FPGA, DSP, and baseband processing technology, the replacement of software (including the FPAG network table) and standard system in soft base station is not longer a dream. Hardware accelerators in FPAG, complicated algorithms in DSP arrays, and the high-speed Serial Rapid IO (SRIO) switching fabric to support the interworking between DSP array and FPGA all contribute to the powerful baseband processing capability for multi-standard systems. The main constraint for the application of soft baseband technology into various standard systems is cost. For example, GSM is a mature and cost-sensitive system with low baseband processing capability. Therefore, applying baseband hardware suitable for Long Term Evolution (LTE) services into a GSM system is a waste of resources. Other issues are how to flexibly allocate the processing power from a large, unified baseband processing resource pool to different standard systems and how to realize flexible resource expansion.

Driven by the cost pressure, equipment manufacturers may migrate from full softband to semi-softband and ASIC. However, the ASIC solution may lose the evolution capability with standards and flexibility of service migration.

6 Baseband RF Interface

Among baseband RF interface standards, CPRI is widely adopted because of its simple implementation, cost-effectiveness and efficient use of bandwidth. Both the OBRI and ETSI Open Radio equipment Interface (ORI) borrows the bottom layer definition of the CPRI.

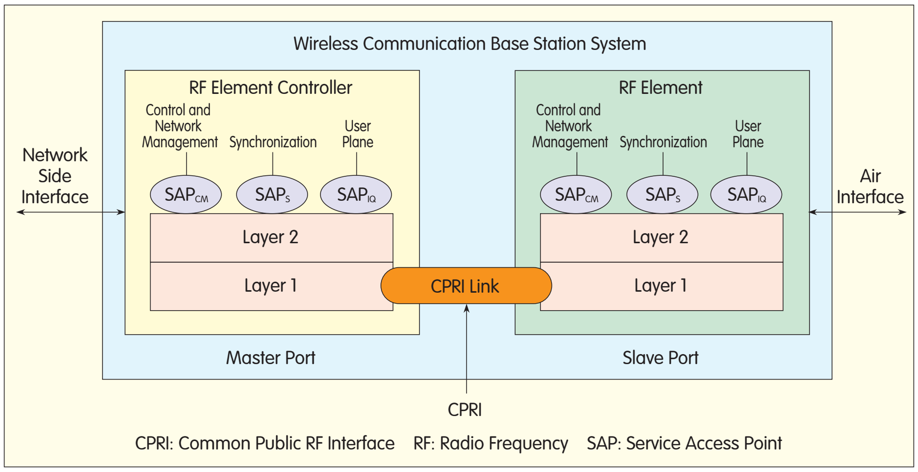
CPRI protocol is divided into two layers, as shown in Figure 4. Layer 1 includes the physical-layer transmission and I/Q data Time Division Multiplexing (TDM) mapping, and Layer 2 includes specifications for control signaling. CPRI organization specifies the I/Q formats of Universal Mobile Telecommunications System (UMTS)/LTE, but does not define those of GSM and CDMA 2000—possibly because of the chip rate. In principle, this protocol division can support multiple services; however, the detailed definition in Layer 1 is not beneficial to fulfill the requirements of multimode soft base stations. Compared with CPRI, the four-layer structure of OBSAI RP03 is more practical. As shown in Table 1, the protocols for guaranteeing point-to-point transmission in OBSAI RP03 are independent of system standards.

CPRI should adopt hierarchical architecture to support the transmission of multiple standard systems. Moreover, when defining the size of AxC (Antenna Carrier) at the bottom CPRI layer, the size should adapt to the I/Q data capacity and should be independent of the system standards. During transmission, only the AxC transmission independent of system standards is taken into consideration, other issues, such as the mapping mode, standard and sampling information when mapping the I/Q data to AxC are ignored. The difference between standards cannot be ignored in baseband modulation/demodulation and intermediate frequency processing, so the data from different standard systems are different. This may sacrifice the efficiency and bring complexity. However, such costs may be worthwhile for flexibility and wireless product evolution.

7 Future Direction of Soft Base Stations

Soft base station architecture is developing towards a flat, multimode structure. The multimode soft base stations should provide rich software services. Software services change from pure traditional base station services into integrated transmission, integrated controllers, and integrated routers. In addition, fixed services will turn to the configurable and customizable ones.

The hardware architecture of soft



▲Figure 4. CPRI protocol architecture.

▼Table 1. OBSAI RP03 hierarchical architecture

Layer 4: Application Layer	Mapping Different Types of Data to Message Payload	Dependent of the System Standards
Layer 3: Transmission Layer	Ensuring Point-to-Point Message Transmission	Independent of the System Standards
Layer 2: Link Layer	Link Synchronization; Frames and Messages Framing	
Layer 1: Physical Layer	Line Coding and Electrical Transmission	

base stations currently meets co-existence requirements of multi-services. Future soft base stations should support higher levels of integration, lower cost, and power efficiency. They will support more flexible baseband resource scheduling and more transmission modes.

The futures software technology will be based on IP and IT, and base stations will use more open standards. When base stations are connected to open networks, the security issue in future IP networks will become a hot topic. Future soft base stations will support more intelligent, distributed, and virtualization technologies. These technologies will enable flexible combination of base station functions and balance the load of base stations.

Self Organizing Network (SON) technology is an innovation of the base station management mode. Self-discovery, self-download, and self-configuration enable the access network to add or delete network nodes smoothly and this allows automatic network optimization. With the improvement of related standards and technology implementation in base station equipment, intelligence of soft base stations will be improved greatly.

Distributed data processing and technology can solve bottlenecks of storage space and processing resources that plague traditional base stations. With new technology, unbalanced services can be more reasonably distributed. A popular technology, cloud computing, is also evolved from distributed computing, parallel computing, and grid computing[8]. Cloud services are offered through centralized large-scale servers, and the concept has been put into commercial use. Although there is still a long way to go for cloud services, the basic theory of cloud computing can be incorporated into base station technology.

Virtualization can further abstract the dividing of functions in a base station, creating a simplified dual layer structure consisting of processor resource pool and data processing pool. Each function can be dynamically assigned to a board that is in idle, and even distributed processing across base stations can be supported. Therefore, using virtualization technology, resource allocation can be optimized, power consumption can be reduced, and the goal of green base stations can be achieved.

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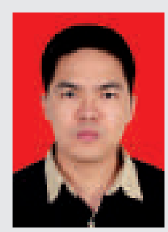
Biographies

Wang Xiyu



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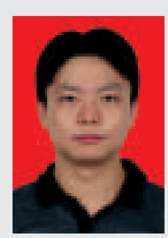

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An Approach for Telecom Operators to Achieve Converged Telecom and Internet Services

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Abstract: This article discusses a possible approach for telecom operators to achieve converged telecom and Internet services. It involves integrally developing telecom networks and Internet businesses through the convergence of their instant news and social networking services. Some background, benefits for telecom operators, and possible challenges are analyzed. A new service convergence approach such as this can also facilitate triple-screen and multi-screen convergence in the future.

Key Words: social network service; convergence; triple-screens convergence

The openness of the Internet lowers the threshold for enterprises and individuals to start new businesses. This, in turn, promotes the flourishing of Internet services. Although Internet enterprises are sometimes criticized for existing on advertising and capital, two things cannot be denied: Internet enterprises have excellent service innovation, and they have made breakthroughs in profit-making models. Internet enterprises provide services such as map, search engine, instant messaging, music, and streaming media that have large user groups and strong user stickiness. With new profit models, companies such as Google, Baidu, Alibaba, and Tencent have become highly profitable. Now most telecom operators are questioning whether they can enjoy a share of the profits from Internet services and improve their user stickiness in order to meet direct and indirect competition from other telecom operators.

Because wireless access is usually mobile broadband, the number of mobile Internet users has increased rapidly. Almost all parties in the industrial chain are transforming their businesses or trying to expand outside their core businesses. Companies such as Nokia, Apple, Google, and Microsoft are trying to expand into each other's fields in the hope of taking a dominant position in the chain. As a result, in addition to indirect competition from other operators, telecom companies must also resist direct competition from operators expanding outside their fields in order to keep themselves from becoming a dump pipe. Operators have no choice but to counter all challenges. As Internet services increase in popularity, operator demand for them has also increased. Convergence of telecom and Internet services can more fully satisfy user demands, attract more users, and drive the development of both services. Hence, converged services have become an important focus of attention.

A number of measures can be taken to meet challenges, and each may work out its own solution. A common approach involves expanding into the Internet industry and running Internet services to deliver converged telecom and Internet services. By means of convergence, an operator can attract more users, enhance user stickiness, and profit from the Internet services, as well as resist incursion from other competitors, and reduce the risk of becoming a dump pipe.

How, then, should convergence begin, and which route should be followed?

1 Route for Service Convergence

A telecom operator may take several steps to achieve convergence of telecom and Internet services:

(1) Internet services such as mailbox or instant messaging are initially provided. Instant messaging is the likliest choice as it is highly popular and has a large user group. It can exploit the advantages of service interconnection to attract more users, and may promote the development of broad access services.

Instant messaging can be enhanced in many ways. For example, an operator can offer the service free of charge or at an attractive rate, provide flexible service packages, or bind the service with its existing telecom services. Such promotions are aimed at attracting users and cultivating a user group.

(2) After a user group has been formed, instant messaging can be bound into social networking services such as blog space, friend management, forum, and news and reading to create an all encompassing online lifestyle. The contents in blog space and forum enable an operator to

run content operation at low cost, while reading services allows transition into the online reading market.

Operators may also venture into advertising by placing banner advertisements on Internet web pages or publishing blind advertisements in forums. A food forum, for example, could be created and resturants charged an advertising fee for being introduced to participants.

(3) Within the social network, an operator can provide additional telecom and Internet services including mailbox, Multimedia Messaging Service (MMS), and directory management, as well as expanding the functions of the social network.

Mailbox can be combined with other services; for instance, an operator can provide Short Message Service (SMS) notification service and push mail service while charging users a fixed monthly rate.

MMS is mainly provided to instant messaging users and offline terminals. With the powerful input capability and large storage capacity of computers, MMS can be further extended and MMS user groups cultivated. Moreover, this service enables users to access via the Internet.

Social networking services can also be expanded. A network can include functions such as media sharing, music recommendation, and videos in blog space.

(4) An operator may include social network services on its customized handsets and optimize the functions of these handsets according to specific situations.

Handsets can be customized or optimized in several ways. Operating systems, for example, can be unified to solve service deployment and provision problems arising from multiple operating systems. Widget platforms can also be unified. Because it may take a long time to unify operating systems, the widget platform can be unified first. Such a platform would enable operators to deliver services encapsulated as microware, and also reduce problems arising from multiple operating systems. Operators can build social networking services into handsets so that directories and contact lists can be synchronized to update with friends lists in the social network. In the handset's media functions, one-key operations can be introduced for access to social network services; functions of social networks can be made into microware and integrated into the handset; and the links of social networks can be directly added[1].

By developing its own Internet services, an operator can gain more control over how its terminals are used. This facilitates deployment of services in the future.

(5) Boss function is introduced into the social network to expand its advantages and attract more users. Users can easily manage and recharge their accounts online by logging onto the social network.

(6) More telecom services are aggregated into the social network so that users can manage their own Call Detailed Records (CDRs), voice mails, and SMS and MMS records as well as replacing private ring back tones.

The operator's social network acts as a content center; with a large user group, the center boosts content service operation.

(7) Family services and enterprise services are aggregated into the social network, expanding it into a release center, a shopping center, and a center offering diverse services. Services can easily be released through the social network, while users conveniently do their shopping.

Due to IP and Web technologies, Internet services are not affected by differences between terminals; any terminal capable of IP access and Web technology support can facilitate Internet services. Moreover, as the end-to-end feature of Internet services becomes independent from access, an operator need not consider the roaming and interconnection capabilities of services. Therefore, it is possible to achieve convergence over a broader scope—for example, triple-screen convergence or even multi-screen convergence[2]. Triple-screen convergence here refers to convergence of telecom, Internet and enterprise network services. It is more significant and covers a broader range than commonly-recognized triple-screen convergence, where the media content of handsets, TVs and computers are accessed via a unified interface and continuously served.

2 Strengths of Telecom Operators

Telecom operators may be hesitant to enter the Internet industry, but they have many advantages in Internet service operation as well as convergence of telecom and Internet services. The advantages are:

(1) User Groups

Telecom operators already have large user groups, which are potential customers for their Internet services. By retaining the groups, they can easily enhance their stickiness.

(2) Services

In the initial stages, an operator can attract users by binding Internet services to existing services and by integrating telecom services into social networking to deliver convenient one-stop services. Then, with integrated telecom and Internet services, both are pushed forward at the same time.

(3) Service Offerings and Charges

By offering various packages and favorable charges, an operator can attract more users and rapidly create its own user groups. With a widespread service network, better services can be delivered.

(4) User Directory

User telephone directories can be accessed and CDRs retained to reflect real social relationships between users. Through directory management and friend recommendation, an operator can accelerate the development of social networks to increase its users.

(5) Terminals

Internet services can be driven by customizing terminals and building Internet services into terminals.

3 Challenges Facing Telecom Operators

Despite the sizeable advantages of

delivering Internet services, telecom operators are confronted with some challenges:

(1) They lack experience in Internet operation. A service provider's capability plays an important role in Internet services operation. For example, 5460.net is a well-known alumni website in China. Although it provides a sought-after service of linking alumni, and has a large user group with great consumption potential, it does not operate as successfully as kaixin.com.

(2) The introduction of Internet services may reduce operator revenue in existing telecom services. If free Internet services are delivered in conjunction with telecom services, they may impact SMS and MMS markets. As a result, an operator may be cautious about taking such an approach.

(3) Existing platforms do not support all Internet services. Although many Internet functions such as SMS, MMS, mailbox, and Boss, are easy to transfer, some—especially family and enterprise services—are difficult to transfer onto existing platforms.

4 Conclusion

Telecom operators can capitalize on their advantages to gradually develop their own Internet services and transfer their telecom services onto Internet platforms. In providing Internet services, they can promote the development of both telecom and Internet services and gain control over their terminals. Further along the route of service convergence, telecom operators may work towards Internet platform based triple-screen convergence or multi-screen convergence. This approach can help operators deliver telecom services, Internet services, and converged services in order to avoid becoming a dump pipe and to meet competition head on.

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Biography

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Xing Xiaojiang holds a master's degree from Nanjing University of Science and Technology. He is a project manager at the Standard Development and Industry Relations Department of ZTE Corporation, and deputy head of Workgroup 1 of Technical Committee 2 of China Communications Standards Association (CCSA TC2 WG1). He is engaged in researching service standardization, and has research interests in mobile Internet, Internet of Things, and ubiquitous networking. He has published two papers, and has been granted several patents. A number of his papers have been accepted by Open Mobile Alliance (OMA).

Roundup

ZTE Showcases World's First VoLTE Call Based on IMS with Existing Mobile Networks at Mobile Asia Congress 2010

ZTE Corporation, a leading global provider of telecommunications equipment and network solutions, demonstrated successful IMS based Voice over LTE (VoLTE) calls on CSL Limited (CSL)'s LTE network and its existing mobile networks at Mobile Asia Congress 2010 (MAC 2010). The calls finished between IMS clients as well as IMS client and conventional 2G/3G handsets. This is the first time VoLTE calls are made to the industry based on the inter-operability of LTE network and existing 2G/3G networks. In addition, supplementary services such as call forwarding, call waiting were demonstrated.

VoLTE is the next step in developing a standard way of delivering voice for LTE. Through the use of its IMS-based solutions and LTE expertise, ZTE is able to demonstrate how voice will work seamlessly in the future. The successful VoLTE showcase at MAC 2010 builds on the deep relations between ZTE and CSL. In July this year, ZTE and CSL began deployment of the world's first 1800 MHz/2600 MHz dual-band LTE network as well as the upgrade of CSL's existing 3G network with Dual Cell technology. The dual-band LTE network takes advantage of CSL's spectrum position to provide customers with better coverage and enhanced penetration, for a more satisfying communications experience. CSL is one of the first operators in the world to introduce LTE technology into its network infrastructure.

ZTE provided Uni-CORE solutions for CSL to build an intelligent, convergent and high-performance core network, achieving 2G/3G/4G full convergence. CSL's network will support accurate service control and content-based billing. It provides powerful data throughput to ensure that the network can deal with the challenges from the explosive growth of data traffic as well as an increasingly complex services.

ZTE is the provider of core network equipment and solutions supporting all access technologies. ZTE's all-IP Uni-CORE solutions cover fixed network softswitch, mobile softswitch and IMS. Recently, ZTE launched its IMS-based zMILE (ZTE's Multimedia Integrated Life Experience) solution, including IMS core network, RCS-compliant APP, and the 7 inch touch-screen ZTE Light multimedia tablet terminal with inbuilt an IMS client. The zMILE solution is a carrier-class multimedia solution, enabling a breakthrough in delivering a true multimedia experience to legacy end users over fixed and/or mobile networks, including LTE network. As of Q3 2010, ZTE core network globally served 1.34 billion subscribers around 110 countries.

(ZTE Corporation)

Cloud Computing (4)

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Editor's Desk:
The first three parts of this series discussed cloud computing in terms of basic concept, applications, architecture, and computing model, and a comparison was made with other distributed computing technologies. In the final of this series, three cases are examined to determine key factors for success in cloud computing. Several economic and technical issues associated with cloud computing—including business model, reliability, security, privacy and developing trends—are discussed.

8 Case Study

Cloud computing is still a new phenomenon. Although many IT giants are developing their own cloud computing infrastructures, platforms, software, and services, few have really succeeded in becoming cloud computing providers. Enterprises and research institutes have mostly been engaged in building their own experimental platforms. To help identify success factors in cloud computing operation, three cases can be examined[1-3].

8.1 Google

Google was the first to initiate cloud computing, and its success can be attributed to its applications. To meet demands associated with its search engine, Google developed a unique large-scale distributed computing platform—a cloud computing platform—which can powerfully analyze mass data. It is this powerful platform and analysis algorithm that propelled Google to dominance in the search engine field.

Google's infrastructure can be divided into three layers:

- Products: search, ads, mail, map, video, chat, and blog
- Distributed system infrastructure: Google File System (GFS), MapReduce, and BigTable
- Computing platform: a large number of computers in many data centers.

On March 9, 2010, Google opened its Google Apps Marketplace, thus introducing the concept of an "Apps Marketplace" to cloud computing. Its well-known applications Gmail, Docs, Sites, and Calendar gave Google the advantage of a large existing user group. Google Apps Marketplace is designed to deliver a variety of products and services to users, including applications that can be installed and synchronized with Google Apps. These are generally easy to use, supporting single sign-on, Google's general navigation, and can be integrated with a user's own data.

Google Apps now features some novel cloud applications for enterprise. Intuit Online Payroll for Google Apps is one such application, which integrates the online payroll application of Intuit—a financial software developer—with Google. An employee need only click an icon in Google Calendar to download the payroll. Manymoon is another eye-catching application, integrated with Google account and Google Apps engine. It includes functions such as status message display and document editing and achieves fully socialized project collaboration. The operation model of Google Apps involves leveraging its large user group to attract developers to create applications on its platform. Profits are then shared with developers. A three-way win is realized for Google, developers, and end users.

8.2 Amazon

Amazon Elastic Compute Cloud (EC2) allows users to lease computers to run their own applications. Through an EC2 web service interface, a user can create a virtual machine, called an "instance," to run software. Scalable deployment of applications is thus achieved. A user can create, launch and terminate server instances as needed, paying by the hour for active servers. Such flexibility gives rise to the term "elastic."

As well as allowing for flexible configuration, Amazon's cloud computing platform differs from Google's in its operation model. Users are not only provided with bare machine (a virtual machine) on which to configure static IP addresses, but also absolute control over these so they can run their own application programs. Moreover, Amazon's EC2 can be easily integrated with other Amazon web services, such as Simple Storage Service (S3) and SimpleDB. By configuring firewalls, Amazon EC2 controls network access between instances. A user can create an Amazon Virtual Private Cloud (VPC) and connect it to an enterprise's IT infrastructure.

Amazon's success in cloud computing lies in its advanced network service technologies. Although it could never have foreseen itself as a cloud computing provider at the beginning, Amazon can now provide users with access to its enormous idle resources (used for e-commerce) through advanced network service technologies. Consequently, its cloud computing platform has been developed. Amazon's cloud computing technology is developed on the basis of network computing services.

8.3 Salesforce

Salesforce.com is a Software as a Service (SaaS) company that distributes business software and provides services for a monthly subscription fee. Its best-known product is Customer Relationship Management (CRM), which delivers services via the Internet using the SaaS model. CRM services cover all aspects of customer relationship management—from common contact management, catalog and order management, and opportunity management, to sales management. In 2009, Salesforce was voted by Forbes magazine as one of the fastest growing technology companies, second only to Google. It is the first cloud computing company with annual revenue of 1 billion U.S. dollars. At present, SalesforceCRM has 7.5 million users worldwide, including Google, Cisco, Starbucks, and Deutsche Bank's Prestitempo Division. Two important platforms of Salesforce are Sales Cloud and Force.com.

(1) Sales Cloud: The World's Leading Sales Application

Sales Cloud gives sales reps everything they need to complete their tasks, saving time spent on administration and leaving more time open for selling. It also provides sales managers with real-time visibility into a team's sales activities. Service Cloud is a modern customer service platform, providing efficient and responsive services through channels as diverse as call centers and social networks.

(2) Force.com: Cloud Platform for CRM

Each enterprise has its own CRM solution, but force.com is a perfect CRM cloud platform. Because it resides within the cloud, CRM applications are never limited by underlying technology and can be customized in real-time depending on business conditions. Force.com AppExchange is an application directory created for Salesforce by third-party developers. Users can buy applications and add them to their Salesforce environment. In 2009, a total of 100,000 applications had been developed by more than 124,000 developers. Applications on Force.com can also be integrated with services delivered by providers such as Google.

The key to Salesforce's success is its top sales application, which is highly regarded by many enterprises, and a cloud computing platform that helps Salesforce pack its applications into services and release them on the Internet. The cloud computing platform has contributed to the widespread success of Salesforce.

9 Some Issues Concerning Cloud Computing

More than three years have passed since cloud computing was first introduced, and many enterprises, including IT giants, have begun deploying cloud computing environments, platforms, and services. On the one hand, cloud computing is developing rapidly, like a scudding cloud. On the other, debates about cloud computing are raging. Some questions need to be clarified. For instance, what exactly *is* the cloud? Compared with existing distribution technologies, what new features does cloud computing bring? What does the future of cloud computing look like?

In this chapter, we will discuss issues concerning cloud computing as well as some perspectives on cloud computing development trends.

9.1 The Name "Cloud"

Academia and enterprise view cloud computing from slightly different angles. It is interesting to note that China's Cloud Computing Experts Association[4] is established under the Chinese Institute of Electronics (CIE) rather than the China Computer Federation (CCF). According to Ian Foster, cloud computing and grid computing are identical in terms of vision, architecture, and technology, but differ in terms of security, programming model, business model, computing model, data model, application, and abstraction[5-6]. Some Chinese scholars have coined the term "gloud" for cloud grid, in an attempt to integrate cloud and grid computing. In the cloud-grid, cloud computing services are provided in a grid environment[7-8].

As the technology develops, more names are likely to be coined. However, attention should not be paid to the definition of cloud computing or its features. Instead, the focus should be on whether a cloud computing environment can solve real computing problems, no matter what technologies or operational model is adopted. We should grasp the essence and forget the dross, as the Chinese story "Jiufang Gao Judges Horses" goes. In the warring states of China, Duke Mu of Qin sent Jiufang Gao in search of a swift horse. Three months later, Jiufang Gao reported that a swift horse had been found, a yellow mare in the dunes. However, a black stallion was sent back. The Duke was not satisfied. But Bo Le, a horse connoisseur, sighed and said: "What Jiufang Gao observes! He sees the essence but ignores the appearance." The horse was proven unparalleled.

9.2 Business Model

Advocators of cloud computing claim the pay-per-use business model is its biggest highlight. A user pays for a service based on how much of the resource is used. But this business model does not define what cloud is, and does not directly relate to the cloud computing system. Two important concepts in telecommunications network operation are Operations Support System (OSS) and Business Support System (BSS). Only BSS is related to the business model. Therefore, a pay-per-use business model does not involve cloud computing. Any system can adopt this business model as long as it can measure the resources consumed by each user. If the grid system is put into commercial operation, a pay-per-use business model can also be used.

Popular opinion is favorable about cloud computing, and many research institutes and enterprises are in the process of building their own cloud computing platforms. However, some critics do not recognize private cloud and believe it does not exist. The reasoning is simple: If a user still has to buy, build, and manage a private cloud, it does not lower front-end investment and reduce management, which conflicts with claims made about the pay-per-use model[9].

The pay-per-use business model is not the only success story. With its innovative user interface, Apple's iPhone mobile has become popular. Users can purchase applications in Apple's application store, called App Store. This model has also proven to be a successful business model. Google Apps Marketplace now adopts the same model as Gmail´s extensive user group.

9.3 Cloud Service Provider

Another issue to be considered by cloud service providers is the profit-making model. Cloud computing has always been said to save user investment; but to date, no one has really figured out how cloud service providers should make profit. Again, a success story may prove useful in determining how to make a profit.

Google developed GFS and BigTable for storing mass data generated by its search engine. The MapReduce framework was developed for fast computing during the search process. Google's profits are derived from huge advertising revenue generated by its search engine business. Google has also located its data center next to a hydropower station to save energy costs. Amazon purchased many computers during the construction of its e-commerce platform, but later found that it did not need so many computers. To make full use of those idle devices and avoid waste, it packaged these devices into services by means of virtualization technology and provided them to users. Tencent is rumored to pay almost one hundred million US dollars in electricity per year.

The success of Salesforce depends entirely on its sales application, which leads the world and is highly valued by customers. The story of Salesforce tells us that an enterprise should have a competitive product before it becomes a cloud service provider. In March 2010, Alibaba announced the close of its Internet platform, alisoft.com, and the termination of related services. Some critics question how long free SaaS can continue. In response to this question, it may be asked: Is CRM software good enough? Providing free services is obviously a fishing strategy. A service provider first gives certain benefits, and when users rely on these benefits, the service is charged. Of course, two premises are required: the software must be good enough, and the price must be reasonable. The former implies the software should improve business capability and profit enterprise. Otherwise, even if the software is free, it will not be widely adopted. The latter requires consideration of a user's profit margin to determine whether it is being shrunk, and whether the service fee is bearable.

IBM established the first Chinese cloud computing center in Wuxi, Tai Hu New Town Science and Education Industrial Park. So far, no enterprise is known to be seeking storage services from the cloud computing center. This demonstrates that caution should be exercised if an enterprise or institute wants to become a cloud computing operator. As well as having an advanced distributed computing platform and excellent service software, it must limit operating cost in order to provide users with high-quality low-priced cloud services. Seeking quick success or windfall profits is detrimental to the development of Internet applications.

9.4 Reliability, Security and Privacy

According to a news report in 2008, Amazon's S3 became unavailable due to authentication service overload—a failure that lasted for two hours. Later, a Gossip protocol blowup led to an outage of S3 for almost eight hours. Gmail and Google Apps once suffered downtime of several hours due to contact system failure and program errors. When users find the cloud has disappeared, their businesses are inevitably affected. Such failures also occur in common computing from time to time. Reliability and availability problems are not confined to cloud computing. On the contrary, in a cloud computing environment, redundancy is an important feature that greatly improves reliability and availability.

All security information technologies can be used in the cloud computing environment. The cloud computing environment is no less safe than common computing systems. Like money-keeping, it is safer to deposit money in the bank than to keep it under the pillow. When people talk about network security, they are especially concerned about privacy. Americans, among others, are concerned their private data may be seized by the government by means of a court order if that data is stored in a cloud. One solution to this problem involves building an InterCloud containing clouds of all operators as well as private clouds of other enterprises. When data is stored in the large cloud, others do not know which storage devices are used or the clouds in which the data is stored. Chinese companies may be more concerned with data confidentiality than privacy and are perhaps reluctant to save their data in clouds of service providers. This is actually a trust problem. If you have no trust in the bank, you can do nothing but put your money under the pillow. Security technologies are designed to prevent attacks from hackers, and solving the trust problem requires everyone to work together to build a healthy business environment.

9.5 Future Cloud Computing

Computing as a utility has been a long-held dream. Cloud computing aims to make this dream come true. Before discussing the development trends of cloud computing, a look at Google's future objectives might be insightful:

- To support geographically distributed clusters.
- To create a globally unique name space for data. Currently, data is isolated by clusters.
- To provide more and better automated migration of data and computation.
- To solve the consistency problem that occurs in coupling data copies split by wide area networking, and to ensure services are delivered normally even when a cluster is down due to maintenance or other reasons.

From these objectives, it can be seen that building large-scale geographically distributed infrastructure is still important in the field of cloud computing. However, Google's MapReduce framework still has some limitations. Although the map and reduce functions are very suitable for large-scale parallel computing, not all computing can be easily converted into a MapReduce framework. As a result, parallel computing algorithm for general problems remains a major challenge[10].

The success of Salesforce demonstrates that users really want solid applications that can solve practical problems. Therefore, one development trend of cloud computing is to develop new cloud computing applications, such as Facebook, that can provide users with rich experience. Another area of interest is the integration of diverse services with a cloud computing infrastructure platform.

From the perspective of cloud providers, using commercial computing, storage, and network facilities to build a large-scale data center and then to sell these resources using a pay-per-use model may cost less but be more profitable than building a medium-sized data center. This is because a large data center can be shared by large user groups during different periods. From a user's point of view, new software companies can use cloud infrastructure as a starting point to build their own data centers. Overload or insufficiency risks suffered by traditional service methods can be avoided, where internal data centers are used to provide services. Other companies or organizations also benefit from the "elasticity" of cloud computing.

Cloud exchange and market infrastructure may be the most suitable option for the future of cloud computing. In such an infrastructure, an enterprise or organization is not just a cloud computing provider or user. It builds its own cloud computing platform (private cloud) based on its average computing services in order to drive the development of its own business. But it also merges this private cloud into the global cloud to form a large Internet cloud. This mode of development is similar to the Internet: As network technology arose, many enterprises built their own networks. Later, with the introduction of Transmission Control Protocol/Internet Protocol (TCP/IP), those isolated networks were interconnected to form the Internet. In this development mode, an enterprise may use other cloud resources in the Internet when its own computing resources are overloaded. It can also open its idle resources to other users. The resource can be priced according to a market mechanism. An enterprise pays others to use resources, and in turn, gets paid by providing its resources. Another benefit of Internet cloud is the prevention of monopolistic behavior due to over-dependence on a provider. Only a win-win philosophy can make cloud computing a success.

In summary, cloud computing involves integrating all resources, including hardware, software, platforms, applications, and services. Simple interfaces must be provided for easy use of cloud resources.

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Biographies

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Abbreviation Index

A

ACK: Acknowledgement
ACS: Access Control Service
AIFS: Arbitration Inter-Frame Space
API: Application Program Interfaces
ASIC: Application-Specific Integrated Circuit

B

B/S: Browser/Server
BBU: Baseband Unit
BCH: Broadcast Channel
B-Cloud: Backup Cloud
BLER: Block Error Rate
BSC: Base Station Controller
BSS: Business Support System

C

C/S: Client/Server
CAPEX: Capital Expenditure
CCCTIA: China Cloud Computing Technology and Industry Alliance
CCF: China Computer Federation
CCH: Control Channel
CCIF: Cloud Computing Interoperability Forum
CDMA: Code Division Multiple Access
CDN: Content Delivery Network
CDR: Call Detailed Record
CIE: Chinese Institute of Electronics
CLI: Command-Line Interface
CORS: Continuous Operating Reference Station
CPRI: Common Public RF Interface
CRM: Customer Relationship Management
CSA: Cloud Security Alliance
CSP: Cloud Simulation Platform
CTS: Certification Transfer Signaling

D

DCE: Data Center Ethernet
DHCP: Dynamic Host Configuration Protocol
DHT: Distributed Hash Table
DIFS: Distributed Inter-Frame Space
DIMDB: Distributed In-Memory Database
DN: Data Node
DOE: Department of Energy
DRDB: Disk-Resident Database
DSP: Digital Signal Processing

E

EBS: Elastic Block Storage
EC2: Elastic Compute Cloud
ERP: Enterprise Resource Planning
ETC: Electronic Toll Collection

F

FACH: Forward Access Channel
FCoE: Fiber Channel over Ethernet
FDMA: Frequency Division Multiple Access
FE: Fast Ethernet
FPGA: Field Programmable Gate Array
FUSE: Filesystem in Userspace
FZJ: Forschungs Zentrum Juelich

G

GE: Gigabit Ethernet
GFS: Google File System
GIS: Geographic Information System
GNSS: Global Navigation Satellite System
GPS: Global Positioning System
GSM: Global Systems for Mobile Communications
GUI: Graphical User Interface
gWLM: Global Workload Manager

H

HA: Home Agent
HDFS: Hadoop Distributed File System
HDLC: High-Level Data Link Control
HIP: Hierarchical IP
HTML: Hypertext Markup Language
HTTP: Hypertext Transfer Protocol

I

IaaS: Infrastructure as a Service
IDC: International Data Corporation
IEC: International Electrotechnical Commission
IEEE: Institute of Electrical and Electronics Engineers
IETF: Internet Engineering Task Force
IMA: Inverse Multiplexing over ATM
IMDB: In-Memory Database
IO: Input/Output
IOPS: Input/Output Operations Per Second
IP: Internet Protocol
IPSec: Internet Protocol Security
ISCP: Interferencing Signal Code Power
iSCSI: Internet Small Computer Systems Interface
ISO: International Organization for Standardization
ISP: Internet Service Provider
ITS: Intelligent Traffic System
IVM: Integrated Virtualization Manager
iVMM: Integrated Virtual Machine Manager

J

JDBC: Java Database Connectivity

K

KVM: Kernel-Based Virtual Machine

L

LAN: Local Area Network
LTE: Long Term Evolution

M

MAC: Media Access Control
MD5: Message-Digest Algorithm 5

MFI: Metamodel Framework for Interoperability
MicroTCA: Micro Telecommunications Computing Architecture
MIHF: Media Independent Handover Function
MIPv6: Mobile IPv6
MLPPP: Multi-Link Point to Point Protocol
MMS: Multimedia Messaging Service
MPLS: Multiple Protocol Label Switching
MRS: Mobile Relay Station
MSTP: Multi-Service Transport Platform

N

NAS: Network Attached Storage
NFS: Network File System

O

OAM: Operation, Administration, and Maintenance
OBRI: Open Baseband Radio Interface
OBSAI: Open Base Station Architecture Initiative
OCCI: Oracle C++ Call Interface
ODBC: Open Database Connectivity
ODSOA: On-Demand Service-Oriented Architecture
OO: Object-Oriented
OPEX: Operational Expenditure
O-RGPS: Ontology-Based Role, Goal, Process and Web Service
ORI: Open Radio Equipment Interface
OS: Operating System
OSS: Operations Support System

P

P2P: Peer to Peer
P2P: Point to Point
PaaS: Platform as a Service
PB: Petabyte
PCH: Paging Channel
PDA: Personal Digital Assistant
PICMG: PCI Industrial Computer Manufacturers Group
PON: Passive Optical Network
POSIX: Portable Operating System Interface for Unix
PVRP: Practical Vehicular Routing Protocol

Q

QoE: Quality of Experience
QoS: Quality of Service

R

R&R: Registry and Repository
RAN: Radio Access Networks
RF: Radio Frequency
RFID: Radio Frequency Identification
RGPS: Role, Goal, Process, and Service
RNC: Radio Network Controller
RPR: Resilient Packet Ring
RS: Remote Sensing
RS: Remote Sensing Technology
RSU: Rate Sensor Unit
RTS: Request Transfer Signaling
RU: RF Unit

S

S3: Simple Storage Service
SaaS: Software as a Service
SAN: Storage Area Network
SAP: Service Access Point
SCH: Service Channel
SCIS: Sign-Concept-Instance-Selection
SDMA: Space Division Multiple Access
SECaaS: Security as a Service
SIFS: Short Inter-Frame Space
SLA: Service Level Agreement
SMS: Short Message Service
SOA: Service-Oriented Architecture
SOAP: Simple Object Access Protocol
SON: Self Organizing Network
SOSE: Service-Oriented Software Engineering
SQL: Structured Query Language
SQS: Simple Queue Service
SRIO: Serial Rapid IO
SSD: Solid-State Drives
SSP: Storage Service Provider
STM: Synchronous Transmission Module

T

TB: Terabyte
TCO: Total Cost of Ownership
TCP: Transmission Control Protocol
TCSC: Technical Committee of Services Computing
TDD: Time Division Duplex
TDMA: Time Division Multiple Access
TD-SCDMA: Time Division-Synchronous Code Division Multiple Access

U

UCS: Unified Computing System,
UDDI: Universal Description, Discovery, and Integration protocol
UMTS: Universal Mobile Telecommunications System
URL: Uniform Resource Locator
USB: Universal Serial Bus
UTC: Coordinated Universal Time

V

V2I: Vehicle-to-Infrastructure
V2V: Vehicle-to-Vehicle
VANET: Vehicular Ad-Hoc Network
VM: Virtual Machine
VMM: Virtual Machine Manager
VMs: Virtual Machines
VPC: Virtual Private Cloud
VSE: Virtual Server Environment

W

WAN: Wide Area Networks
WAVE: Wireless Access in the Vehicular Environment
WCDMA: Wideband Code Division Multiple Access
Wi-Fi: Wireless Fidelity
WiMAX: Worldwide Interoperability for Microwave Access
WSA: WAVE Service Advertisement
WSDL: Web Services Description Language

X

XML: Extensible Markup Language

Z

ZoR: Zone of Relevance

ZTE Communications

Table of Contents for Volume 8, Numbers 1–4, 2010

ZTE Communications
Table of Contents for Volume 8, Numbers 1–4, 2010