Application-Layer "Cloud Computing" Post-print Supporting Cross-Domain Information Sharing and Application Collaboration

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Abstract

Data centers are commonly regarded as the principal vehicles for cloud computing. Despite their designation as "data centers," historical emphasis has been placed predominantly on the hardware environment. Presently, it is recognized that content and services, encompassing data and applications, are of critical importance. In response to the widespread issue in contemporary cloud computing-related data center construction of "overemphasizing hardware and platforms while undervaluing content and applications," this paper advocates for the establishment of a "cloud resource center" focused on content and services, and underscores the role of services as a "bridge" between cloud infrastructure capabilities and resources and user experience. Within this paper, we designate the work pertaining to the construction, operation and maintenance, and effective utilization of the aforementioned cloud resource center as application-layer cloud computing. The paper will examine select technical challenges and solution pathways, and present a targeted overview of the VINCA-TARC cloud resource center service software developed by the Institute of Computing Technology.

Full Text

Preamble

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Application-Layer "Cloud Computing"for Supporting Cross-Domain Information Sharing and Application Collaboration: The VINCA-TARC Cloud Resource Center Service Software
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Abstract

Data centers are often regarded as the primary carriers of cloud computing. Although called "data centers," past focus has been primarily on hardware infrastructure. Today, it is recognized that content and services, including data and applications, are crucial. Addressing the prevalent problem in current cloud computing-related data center construction of "emphasizing hardware and platforms while neglecting content and applications," this paper advocates building "cloud resource centers" that prioritize content and services, highlighting the role of services as the "bond" between cloud infrastructure capabilities/resources and user experience. The work related to the construction, operation, and effective utilization of such cloud resource centers is referred to in this paper as application-layer cloud computing. The paper explores some of the technical challenges and solution approaches in this domain, and as a targeted case study, introduces the Institute of Computing Technology' s VINCA-TARC cloud resource center service software.

Keywords: cloud computing, cloud resource center, information sharing, application collaboration

1. Introduction

Cloud computing is an Internet-based open computing paradigm that emphasizes establishing information processing infrastructure relying on the Internet, and then supporting application construction and operation, data and computing capability sharing, and information processing capability outsourcing in a multi-tenant manner based on such infrastructure. Its benefits include not only supporting social division of labor specialization, improving resource utilization and work efficiency, and reducing system construction and operation costs, but also providing new avenues for promoting resource sharing and application collaboration. From the perspective of deployment and ownership, application systems themselves have become virtualized—their deployment involves multiple network nodes across multiple administrative domains, and system owners are not necessarily the natural owners of system components. Users typically face an open virtual application system. This Internet-based computing model and corresponding business model have overturned many traditional fundamental assumptions, bringing impact and challenges to disciplinary foundations, industry, and applications.

Currently, cloud computing has two main approaches: one is the common Internet company model, which involves "staking out territory" in Internet-based virtual space (the "public cloud"), establishing data centers, aggregating and controlling certain resources, and profiting through value-added services built upon them; the other corresponds to the information processing infrastructure transformation and application upgrading of traditional industry applications or enterprise applications (forming "private cloud"). Data centers are often seen as the primary carriers of cloud computing today. In fact, the connotation and extension of data centers are also evolving. Early data centers focused more on hardware environments, while today' s data centers attach greater importance to content and have evolved into "resource centers" for data and applications. Cloud computing-related practical work thus has different emphases: one is the continuation of traditional data center thinking, namely centralized utilization and virtualization of IT hardware resources to support flexible scaling and improved equipment utilization; the other is the aforementioned "resource center" approach, which not only leverages Internet-based information processing infrastructure to better achieve multi-tenant resource sharing and application collaboration, but also optimizes social division of labor and the software industry chain. In recent years, multiple cloud computing centers have been built in China, most focusing on the first level of issues and emphasizing the construction of data center hardware and virtualization environments, inevitably resulting in problems and risks such as unclear effectiveness and insufficient applications (often metaphorically described as "roads without vehicles," "parks without visitors," or "stages without performances"). Content, including data and applications, has become an obvious bottleneck. This paper focuses on the construction, operation, and effective utilization of content and service-centric cloud resource centers, collectively referring to these efforts as application-layer cloud computing.

Early service computing, as a technical system for system construction and application integration, emphasized principles such as decoupling, open standards-based interoperability, large-granularity reuse, and support for dynamic extension, pursuing reuse effectiveness, flexibility, low cost, and rapid development capabilities. Around 2005, the first wave of service computing emerged. The benefits brought by the service-oriented paradigm began to be recognized, and people attempted to build or reconstruct enterprise application integration and other comprehensive integration application systems based on service-oriented architecture (SOA) principles and Web services technology. With the rise of cloud computing, service computing is approaching its second development peak (see Figure 1 [Figure 1: see original paper]). Against the backdrop of rapidly developing cloud infrastructure, software becoming services is the general trend. Consumers no longer need to install and deploy all software locally; software capabilities and resources are gradually moving into the cloud, forming infrastructure capabilities. The "Anything as a Service (XaaS)" software usage and operation model will support users in consuming and utilizing ICT resources through a "use without ownership" approach. Services play the role of "bond" and "glue" between infrastructure capabilities and ubiquitous user experience, becoming an important source of IT technology innovation. In this context, service computing will become a methodology and important technical means for supporting industry and social informatization in the network era, playing a key role in the transformation and chain optimization of the information industry.

Currently, under the broad concept of cloud computing, there exist works at different levels and from different perspectives. We have identified two typical perspectives: one is the industry informatization perspective, corresponding to the concept of private or industry cloud, which represents the upgrading and evolution of traditional enterprise application integration systems in the cloud context; the other is establishing various public infrastructures on the Internet to serve individual users and small-to-medium enterprises. From the enterprise application integration system upgrading perspective, the usual approach to solving data resource sharing and application collaboration problems is to establish a logically integrated virtual layer over a distributed and autonomous resource collection, pursuing more powerful, standardized, convenient, efficient, reliable, high-quality, and cost-effective resource sharing and collaborative services through technical means. Figure 2 [Figure 2: see original paper] illustrates this approach. Around these pursuits, many concepts have been or are becoming popular (such as utility computing, grid computing, cloud computing, and Software as a Service). This paper focuses on core technologies, methods, frameworks, and software tools related to network resource servitization, appropriate service abstraction and modeling, service asset modeling and virtualization, effective service organization and management, on-demand composition and personalized customization, service semantics and interoperability, trusted services and system survivability, and system evolution and reconstruction. The paper focuses on resource integration and management issues in cloud environments and, as a case study, introduces the VINCA-TARC (Third-party-operable Aggregative Resource Center) cloud resource center software developed by the Institute of Computing Technology, Chinese Academy of Sciences (see http://sigsit.ict.ac.cn).

As software and resources move into the cloud, services embody value and emergent intelligence, giving rise to new forms of Internet services. Real-time perception, autonomous collaboration, high concurrency, unpredictability, multi-dimensional dynamic optimization, human-computer integration, and emergent effects will become the basic characteristics of emerging Internet applications, which will also drive new developments in service computing.

2. Cloud Resource Center Supporting Information Sharing and Application Collaboration

As previously mentioned, the cloud resource center proposed from the industry informatization perspective emphasizes providing support for industry business-related specific content (including data, applications, and services) on top of current hardware virtualization-centric cloud infrastructure. Beyond leveraging cloud infrastructure for reduced hardware resource costs, it more importantly enhances IT' s responsiveness and support capability for dynamic business needs through support for information sharing and application collaboration. Therefore, cloud resource centers mainly have the following characteristics:

First, logically integrating and centrally hosting various resources, that is, using cloud infrastructure to achieve logical or physical centralized hosting of resources at different levels, especially industry business content-related resources such as data, applications, and services, with unified operation and maintenance by third parties to reduce resource construction and provision costs. Specifically, it is necessary to establish a hosting support environment for data and application resources on existing cloud infrastructure that primarily focuses on computing and storage resource virtualization, which presents evolutionary requirements for current cloud infrastructure.

Second, infrastructure becomes cloud services, that is, intensively operated resources can be provided externally in standardized service forms of different granularities when permitted, promoting resource sharing and comprehensive utilization and making it easier to meet diverse business collaboration needs. In cloud resource centers, service computing gradually becomes the core concept and foundational technology of information processing platforms in the cloud computing context, rather than merely a technical means for implementing application integration projects. This also generates many challenging requirements in service infrastructure runtime environments, service application development methods, and service management and assurance.

Third, effectively utilizing cloud resource centers and cloud services in a multi-tenant manner, that is, supporting users to consume and utilize resources in cloud environments through a "use without ownership," "on-demand," and "ubiquitous" approach. While enjoying the benefits of centralized economies of scale, how to enable users to effectively utilize cloud infrastructure while maintaining autonomous control capabilities such as personalized application customization, diverse terminal utilization, and private data protection has become a research hotspot.

Correspondingly, to address the construction needs of cloud resource centers with the above characteristics, three levels of content need to be prioritized (as shown in Figure 2 [Figure 2: see original paper]):

Infrastructure layer upward extension: Incorporate data and applications, which are fundamental to industry informatization, into the infrastructure layer, providing a transparent hosting support environment for data and applications, and achieving integration with existing IaaS (Infrastructure as a Service) environments that primarily focus on computing, storage, and network hardware resources to establish cloud application infrastructure supporting industry-wide information sharing and application collaboration. A key issue here is how to effectively integrate legacy systems while maintaining compatibility with mainstream existing application-layer technologies to avoid a "two separate systems" phenomenon between old and new systems.

Services as core elements of cloud applications: Services will become the basic abstraction form for different levels of cloud application resources, including data, applications, business functions, and hardware devices. Through cross-domain, layered service management (including support for service description, service monitoring, service access, and service application execution) and data services and business process services oriented toward data-intensive and business collaboration applications respectively, a service-centric platform is provided for cloud applications.

User-centric application models: Addressing the characteristics of future industry informatization applications supporting information sharing and business collaboration, such as large quantity, rapid growth, and strong immediacy, provide end-user-oriented, model-driven service application programming methods and usage environments for two typical business needs—information integration and process collaboration—to establish a new type of cloud application client.

3. Introduction to VINCA-TARC Service Software for Industry Cloud Resource Centers

The cloud resource center implies a new type of industry informatization architecture and corresponding application model. To provide tool support for cloud resource center construction, we designed the VINCA-TARC (TARC: Third-party-operable Aggregative Resource Center) cloud resource center service software. Its design philosophy mainly includes three aspects:

- At the infrastructure layer, the focus is on achieving decoupling between data, legacy applications, and other resources and new integration and collaborative applications on hardware resource virtualization-centric cloud infrastructure. Middleware such as database servers and application servers, and even data and application component resources, will no longer be oriented solely toward single application systems but can become shared resources on demand.
- At the service layer, achieve abstraction of data and application resources in service form and support service governance and management. In cloud computing, services have become a widely adopted form of resource provision, while the different levels and types of services generated in cloud computing environments also place higher demands on service management.
- At the application layer, provide user-centric cloud application development methods and usage environments. VINCA-TARC aims to support the construction of comprehensive integration application systems, which often exhibit dynamic and strong immediacy characteristics, thus creating strong demand for user-centric service application development methods and environments.

Based on the above design philosophy, as shown in Figure 3 [Figure 3: see original paper], VINCA-TARC mainly consists of the following three components:

1. Multi-Tenant Third-Party Service Hosting Facility

In traditional service environments, service providers need to establish their own infrastructure for service deployment and operation while bearing operation and maintenance responsibilities. However, due to the uncertainty and unpredictability of service usage and requests in service environments, service providers find it difficult to cope alone. VINCA-TARC aims to provide common infrastructure for different service providers, thereby reducing the technical costs and operation responsibilities of service provision, making service providers willing and able to provide services.

To achieve this goal, VINCA-TARC has developed a multi-tenant third-party service hosting facility, including the following key technologies:

Service data management: The multi-tenant hosting mode achieves separation between data and applications, which is beneficial for further data sharing and integration but also places higher standards on metadata management, requiring the ability to describe data sources, application scope, data schemas, semantics, etc. Therefore, it is necessary to establish a metadata-based multi-tenant data organization and management model.

Data service generation: Establishing a virtual data layer is an effective way to meet the needs of integrating data from different sources. In a data hosting environment, a virtual data layer can be implemented by generating data services at different levels, granularities, and for different needs. Automatic or semi-automatic generation of data services becomes a key issue.

Service infrastructure resource optimization: Due to the uncertainty of pressure and load on service runtime environments during service usage, optimization metrics in service hosting environments are not limited to computing performance and storage space utilization but also need to comprehensively consider service deployment, usage, and request requirements to provide flexible, multi-dimensional service infrastructure resource optimization mechanisms.

Multi-engine execution environment: Provide a scalable execution environment for service applications that can dynamically increase or decrease engine servers based on the load of service application execution requests. When an engine server fails, application execution instances on it can be migrated to normal servers within a short time to continue execution, thereby ensuring business continuity for users.

2. Service Community Tools for XaaS Environment Governance

As an abstraction of various resources at different levels, services mainly include IT services that are business-agnostic and business services supported by IT, featuring diversity, dynamism, interaction complexity, and business relevance. At the same time, services will be the foundation for collaborative work among a large number of applications in the future, thus imposing requirements on usability, availability, and service quality. Therefore, how to provide guaranteed services to users in an uncertain "everything as a service" environment is key to promoting the sustainable and stable development of service environments. From the perspective of service management and maintenance, VINCA-TARC provides service community tools that can provide the following support:

Business-level service abstraction: Due to their high level of abstraction, services are considered effective means of bridging business and IT domains. In the context of the Internet of Services, the proportion of services representing real-world business functions will increase significantly. Therefore, based on research into business-level service abstraction methods, service community tools support the characterization, organization, discovery, and evaluation of services from a business perspective based on a unified service meta-model.

Dynamic service organization: To realize third-party operation and maintenance and support resource centers for wide application collaboration, service community tools support organizing related services from different perspectives according to different application needs, establishing context-related service organization management units, and providing personalized service catalogs and service views to meet diverse service development and utilization needs.

Service monitoring: Due to the decentralized and interactive nature of service systems, service systems have different system metrics from traditional application systems, and the system complexity generated by this decentralized interaction exceeds the control capabilities of system developers. To this end, service community tools provide customization functions for key indicator systems of service systems and adopt monitoring, evaluation, and other means to achieve runtime monitoring and feedback of service systems to support the execution of corresponding governance strategies triggered according to service system operation conditions and predetermined conditions.

Service relationship analysis: Due to the layered and composable nature of services, interactions between services are often interdependent and mutually influential. This distributed dependency relationship brought by service composition and runtime behavior of service systems makes reliability assurance of service systems more difficult. To address this challenge, service community tools provide effective modeling and analysis means for service interaction, dependency, and collaboration relationships to achieve unified management of such complex service relationships in Internet service environments.

3. User-Centric Service Application Development and Usage Environment

Current information sharing and application collaboration needs in industry informatization exhibit characteristics such as large quantity, strong immediacy, short lifecycle, and continuous evolution, which determine that the development model for such cloud applications will differ from existing software systems. This requires further raising the abstraction level of software development and reducing software development costs. Model-driven software development is a main approach to raising the abstraction level of software development. Therefore, in terms of cloud application development and usage environments, VINCA-TARC mainly provides support for user-centric service application construction from the perspectives of business process modeling, information aggregation modeling, and service composition modeling, including:

End-user-oriented cloud client software: VINCA-TARC adopts a client-centric computing model that considers the diversity of client devices and environments. The client serves as the control center for cloud application scheduling and execution, supporting comprehensive utilization of both client-local and network resources through end-user service composition, and coordinating the operation of client resources and cloud services, thereby achieving client-side control and private data protection functions.

Data-centric application integration tools: To better support data resource sharing and application collaboration and address the neglect of data sharing and data flow in traditional service computing research, VINCA-TARC provides functions for data resource access in cloud computing environments, user-centric data resource integration, and data-driven business collaboration, supporting logical integration and information sharing of multiple information systems across management domains, extraction, visualization, and real-time presentation of characteristic data for comprehensive integration systems.

SaaS business process system: Addressing the large number of business process modeling and management needs, VINCA-TARC provides a multi-tenant SaaS business process system that emphasizes utilizing cloud infrastructure capabilities to provide hosting and runtime support for process applications, offering users an on-demand rentable process service (BPM-as-a-Service). While various tenants share the same process service instance, it ensures effective isolation and privacy protection of data between tenants.

In summary, VINCA-TARC, on the one hand, supports the transparent construction of industry information applications on top of cloud infrastructure to obtain benefits such as optimized IT resource utilization from cloud computing. On the other hand, and more importantly, it can provide a public service platform for future industry informatization that is primarily driven by information integration and application collaboration needs, enabling diverse industry data and applications to be provided in the cloud in service form, thereby facilitating more convenient integration, collaboration, and consolidation within and even across industries. Additionally, VINCA-TARC is also a research exploration we have conducted from the perspective of service computing combined with cloud computing development, targeting typical information sharing and application collaboration needs in future industry informatization. This work expands the research scope of service computing, can promote the integration and development of service computing and cloud computing, and also has certain reference significance for future cloud application system architectures and operational principles.

4. Summary

The basic concepts, ideas, and goals of cloud computing meet the needs of industry informatization and have gained industry support. However, why hasn' t it been widely adopted in actual environments? Why are utilization rates of built cloud computing centers generally low? The authors believe that content and applications are the current bottlenecks in cloud computing development. The transition from traditional data centers to content-centric resource centers is an important attempt to break through these bottlenecks. This paper presents some preliminary understanding and introduces the VINCA-TARC cloud resource center service software. The following three articles in this issue will discuss specific issues in VINCA-TARC, including cross-domain service management, business process services, and cloud clients. Furthermore, traditional service computing research often neglects data sharing and data flow, while this paper emphasizes that content is one of the bottlenecks in cloud computing development. The final article in this series will specifically discuss data-centric application integration issues. Our next main work is to apply VINCA-TARC to solving practical industry informatization problems. We welcome potential users and interested industry partners to contact us.

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Note: Figure translations are in progress. See original paper for figures.