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Cloud-Instigated IT Transformations!

INTRODUCTION

Designing enterprise architecture (EA) presents a bigger challenge in the cloud era. With the gripping cloud idea, the business and IT landscapes are solidly expanding further and farther. Therefore, enterprise architects' roles and responsibilities are becoming diversified and complicated. To moderate the rising complexity, EA is increasingly being splintered into a bunch of smaller projects. That is, here too, the acts of decomposition and composition gain prominence. Toward the end, the aggregate of all of them is created and concluded. The impacts of the cloud in business goals, operations, service offerings, processes, and partnerships need to be fully understood in order to arrive at a comprehensive and convincing business strategy and architecture. Secondly, the IT improvements need to be taken into acute and astute consideration as it is being pronounced widely in world media that there are several incisive and decisive advancements out of embracing the cloud.

There are a series of promising and potential optimizations on IT infrastructure. Cloud infrastructures are being portrayed and presented as the next-generation service, on-demand, autonomic, elastic, and utility computing infrastructures. All kinds of development, deployment, testing, production, and management platforms for futuristic enterprise IT are also being incrementally laid on cloud infrastructures. Finally, all kinds of personal and professional services and applications are being sent to cloud platforms. Thus, with the aggressive adoption of the ever-shining cloud across the industry, there is a palpable and strategic shift in any IT environment. As discussed in Chapter 2, there are pioneering deployment, delivery, management, pricing, and consumption models emerging and evolving continuously. These business-centric models are being supported with the corresponding empowerment in IT infrastructures.

In short, the cloud idea bridges and blends the business and IT environments together to accomplish more and better things for humanity.

The domineering trend is that all sorts of IT products and solutions are becoming cloud-based services to be provisioned to millions of users simultaneously across the globe. In a nutshell, the stability of cloud facilitates the vision of "IT as a service." Cloud computing has become such a path-breaking and premium technology. All tangible modules of IT are being touched upon in an exemplary fashion. If there is not a well-intended and defined EA in place to spell out which cloud solution has to be used, what technologies are required, how they have to be approached and accomplished in the cloud context, and how it all fits into the big picture, eventually the enterprise is bound to suffer. The long-term perspective will be sorely missed.

The good news is that the shift to cloud services will actually simplify and sensitize IT to operate more systematically and successfully. Whether there is a different group of professionals responsible for managing and overseeing it, or it is built into the group's DNA, EA will be one of the prime enablers and exponents of IT in this modern world. From the cloud's ongoing journey, it can be inferred that the versatile idea of the cloud is to take enterprise architecture to the next level. That is, cloud architecture is all set to become an inseparable and indistinguishable part of EA. As cloud computing matures, it materially and mesmerizingly influences any organization that is hell-bent on leveraging the cloud's unique concepts and capabilities. Cloud adoption is bound to bring in a number of significant and delectable modifications in enterprise analysis, planning, strategy, execution, and enhancement. It is obligatory to seamlessly enable the smooth integration of enterprise procedures, processes, patterns, platforms, and practices into the cloud paradigm. Prominently, there will be several domains that get attracted and altered by the convergence of EA with the exploding and expanding cloud domain. Ultimately, the brewing IT trend is toward the realization of cloud-centric enterprises.

EXPLAINING CLOUD INFRASTRUCTURES

Cloud infrastructures can be segmented into a few major types: computing, communication, and storage infrastructures. Let us take a deeper and more detailed look at these in the following sections.

Cloud Computing Infrastructure

Apart from a series of groundbreaking innovations in introducing newer and nimbler business models, the doughty cloud idea has laid the stimulating and scintillating foundation for next-generation IT infrastructure, which is the most crucial and critical component for cloud-centric enterprises [1,4–7]. Cloud infrastructure is a dynamic pool of consolidated, virtualized, and automated server systems. With federated clouds emerging fast, federation has become a key enabler. These unique features, in association with the auto-provisioning and deprovisioning capabilities, enable and ensure unprecedented IT optimization. The utilization rate has gone up considerably. That is, several heterogeneous applications are being deployed, delivered, and managed in a single physical server through the partitioning and provisioning of multiple VMs.

IT portability and flexibility are on the rise with the clear separation of hardware and software components. That is, any software runs perfectly on any virtualized environment. As promoted by Sun Microsystems, Java technology has achieved platform portability whereas the .NET framework facilitates the language portability requirement. In a virtualized setup, any software coded using any language runs on any platform without any hitch. In a virtualized environment, all the IT resources are being controlled with better and deeper visibility. That is, memory, processing, and storage modules can be operated in a finely grained fashion. Allocation and deallocation of computing resources are being simplified using automated tools. Live-in migration of VMs is becoming a reality. Thus, in short, the virtualization seed has sprouted a number of fresh possibilities and opportunities as well. The end product is on-demand, lean, utility-like, green, affordable, and available IT infrastructure. The cloud technology has a stunning and soothing effect on power-hungry, mammoth, silo-like, closed, costly, and complicated data centers and server farms. Green activists are enthused by the lower electricity consumption and lesser heat dissipation from cloud centers. That is, the cloud idea has emerged as the most influential element for arresting climate change; thus, the goal of environmental sustainability through the reduced outpour of greenhouse gases will see the dazzling light at the end of the long tunnel.

There are several options such as public, private, hybrid, and community clouds. There are specific clouds such as science, knowledge, storage, government, information, service, and mobile clouds. However, the

clouds of the future are federated clouds, which ultimately lead to the intercloud. As a first step, enterprises are building their own cloud. We are going to see how enterprise clouds are fully supporting various business operations and offerings of enterprises. Before that, a brief digression.

Cloud Communications Infrastructure

Enterprise architects focus not only on the computing front but also on the communication space in order to frame and formulate a comprehensive enterprise strategy [16–19]. There are both evolutionary and revolutionary movements in the hot communication field. Cutting-edge technologies and state-of-the-art infrastructures contribute immensely to making communication. Enterprise communication has also been through several remarkable and radical changes in the last decade, and the same is expected in the years to come. In the communication space, the often presented and pronounced buzzwords are ambient communication, autonomic communication, and unified communication (UC). The communication landscape is quite rewarding and pregnant with powerful technologies. Communication service providers; connectivity solution vendors; content, application, and service providers; standards consortiums; service integrators; and other important stakeholders are cognitively and collaboratively working tirelessly in producing new-generation and people-centric communication services to maintain revenue flows.

Now with the game-changing cloud technology sweeping the entire the ICT industry, there are more sophisticated, situation-aware, and premium services from cloud-enabled communication providers. Multifaceted mobile applications and services are increasingly stocked up and served from highly specific and smart cloud environments. For example, Apple has introduced a new mobile cloud "iCloud" for their iPhone and iPad users. The mobile space is already crowded with a wider variety of service providers and is buzzing with attractive and appealing services to keep mobile users happy. These mobile clouds decimate all sorts of media differences. Further on, all kinds of base services are seamlessly aggregated and composite services are produced on the fly to be made available according to users' locations and device capabilities via centralized cloud. The latest Forrester report [4] on enterprise communications insists on cloud-based multimodal services that directly provide much-needed multimodal communication and collaboration facilities.

Businesses have been asking for a bevy of deft and disruptive technologies to gain real-time connectivity and collaboration capabilities for their workers to sharply enhance their productivity while fulfilling real-time delivery within reasonable cost. The other critical segment is end users, who aspire for context-aware services. Technology advancements include innovative applications based on session initiation protocol (SIP), multimodal devices that displace landline phones, increased adoption of open source software, widespread video usage, and mobile business intelligence (BI) and UC for contextual collaboration. Social networking sites supply more relevant content and information for workers.

There is a rapid expansion of SIP for services and applications. Devices will provide greater functionality to replace or coexist with desktop phones. The growth of working remotely and telecommuting, which will create demand for secure mobile applications, will be facilitated by SIP. Video usage will become common and casual and promotes conversations and collaboration across enterprise. Video-based surveillance, security, and safety will get a strong boost in the days ahead. These changes will create and sustain an integrated workplace environment that facilitates real-time and purposeful collaboration to fulfill business goals and to assist in forming and firming up aware and aligned processes. Videoconferencing solutions will expand steadily and capture more market segments as they are inexpensive, and will open up a number of not-yet-envisioned options. Physical meetings will gradually become cyber as companies start to embrace hugely cost-effective video solutions for internal meetings and to engage with their customers over audio and video communication over the web. Video solutions will expand upward into large telepresence conference rooms and downward to individual desktops. The cost savings achieved on the reduction of travel costs often support the business case for video market expansion.

Other noteworthy trends include the much-maligned convergence in the mobile space. Computers are becoming communicators, whereas communicators tend to be computers. Cell phones are transitioning to smartphones with the smooth synchronization of mobile phones and personal digital assistant (PDA) functionalities. Miniaturization technologies superbly contribute for very large scale integration of multiple digital modules that work cohesively together within a phone. This terrific transformation helps mobile phones to be actively involved in business transactions. Professionals on the move benefit exceedingly

from this great evolution. Wireless and mobile devices seamlessly bring together voice, the Internet, and video to support business communication. Integration with UC software allows workers to use their mobile devices for contextual and content-based collaboration and enables access to features that indicate a coworker's availability and location. Mobile BI and mobile-based commercial and financial transactions will flourish and proceed at a feverish pace. There will be a huge precipitation in mobile services. The mobile web will see a flurry of activity. Mobile governance, retail, banking, commerce, ticketing, games, and so on will become simpler and ubiquitous.

Virtualization for the Communication Industry

Of late, virtualization has become a highly impactful and insightful technology. Virtualization enables partitioning of any IT resource into a collection of independently composable and manageable modules. This makes the handling and usage of modules simpler, wastage of resources gets substantially reduced, energy costs crash down, complexity gets minimized, utilization goes up, innovation is facilitated, and so on. All communications activity needs to be capable of being virtualized, just like any other application. Communications servers and applications need to be virtualized and capable of being deployed over any thin clients including virtual desktops. The ultimate business benefit is not only to reduce costs but also to facilitate novel and flexible working models. With virtualization, enterprise managers and knowledge workers become less interested in where their platforms and applications are being hosted and run as long as their computing needs are being fulfilled in time and within the agreed cost. Centralized systems connected to remote locations using high-speed networks allow services to be produced and provided quickly. Centralization brings cost savings and effective management leading to new utility pricing and deployment models.

The Cloud Inspires the UC Paradigm

The emerging UC concept is definitely appealing and compelling. UC is all about the seamless and spontaneous convergence of all kinds of connectivity and communication methods between two or more people, from any application, using any device, at any location, via the most appropriate route, enabling effective and real-time collaboration with business-grade security.

With UC, IT departments can offer streamlined communication solutions and advanced productivity-enhancing applications throughout the network. Because of the facets it implicitly incorporates and combines, UC is a definite and decisive value-add for corporations focusing on communication-related services. UC is a powerful entity, capable of creating ample and accelerated business opportunities. Advanced UC applications, for example, provide the real-time status and availability of other staff, including preferred methods of contact and communication.

With this level of presence, employees can quickly determine who is accessible and where. Time and context will become critical deciding factors for crafting next-generation applications. Mobility solutions further extend the unprecedented capabilities of communications network beyond the confines of organization environments. Regardless of the location, mobility can provide presence and voice communications via smartphones as if the employee were physically in the office. Video communications and desktop collaboration have also emerged as promising UC solutions. Both can provide tremendous benefits. Around 90% of human communication is based on visual cues, so video serves as a logical extension of the UC network. With the addition of the brewing functionalities of desktop collaboration, such as the ability to share documents, presentations, and any stored media, UC is all set to become the dominant force in the days to come. That is, UC becomes not only completely versatile but increasingly indispensable in today's fast-expanding communication space.

Communication as a Service

The transformational cloud technology permeates into the money-spinning communication domain. Providing communication services from the cloud will turn the current communication landscape upside down. Communication as a service (CaaS), an offshoot of cloud enablement of communication services, is being projected as the next-generation communication method. Cloud empowerment brings the celebrated centralized service delivery into the communication landscape. Although currently an emerging market, CaaS offers greater accessibility for UC applications and services. Network service providers will offer communication and collaboration solutions to companies as a fee-based service offering, which incorporates the Web 2.0 technology stack with solutions from traditional premise-based providers.

CaaS eliminates the need for acquiring and operating on-premise telephone equipment and does away with the need for voice applications. Rather than overinvesting, companies can focus on their competencies such as adding novel communication applications. The adoption of integrated applications allows workers to use advanced applications. Integration will support a connected and well-knit workforce and reduce business delays due to existing limitations of current applications. Information workers can quickly launch conferencing and collaboration sessions with their peers, partners, and people, and accelerate decision making. It is all about efficiency and reducing waste.

In summary, it is very clear that cloud technology will have a deep impact on the communication industry. Communication will become pervasive, easily consumable, and affordable through a neat and nice integration and cooperation among computing and communication methods.

We all know that the impact of the cloud paradigm on IT infrastructures is really tremendous and trend setting. A number of strategic transformations are bound to occur and recur in the infrastructure domain and discipline with the exploitation of inventive cloud concepts. In the subsequent sections, we will discuss the futuristic cloud-based services and their refreshing features.

A BRIEFING ON NEXT-GENERATION SERVICES

All kinds of enterprise services and applications are being modernized and migrated to and managed in converged, cohesive, and highly automated cloud infrastructures and platforms [6,12–14]. Web-based services are being deployed in highly optimized cloud servers to be delivered and consumed via the public and open Internet. With the unmatched advancements in the device space (fixed, portable, nomadic, mobile, wireless, handheld, pocketable, implantable, wearable, etc.), the aura of device services performing and providing information, commercial, convenient, comforting, caring, financial, and even physical services is gaining ground.

In the recent past, device services are also being moved to clouds in order to reap the unique advantages being offered by the cloud paradigm. Sensors and devices-to-cloud integration frameworks middleware,

services, and software packages are being given thrust in academic as well as in corporate circles in order to make the cloud the most natural choice not only for enterprise but also for embedded IT solutions. In short, future IT solutions will be mostly cloud centric. Traditional IT products will be methodically switched over to service-oriented and cloud-based methods.

There are several established as well as start-up companies offering lean, green, and special-purpose cloud infrastructures in order to capture and capitalize on the technology-sponsored and business-driven changes. Platform providers are also enthusiastically hyperactive in this growing space. Newer deployment and delivery models have erupted in the recent past and are being consciously supported to reach greater heights. In a nutshell, it is all about distributed and decentralized cloud centers taking care of the growing array of diverse services, applications, and data (personal as well as professional). This induces and inspires the need for reflective and introspective cloud brokers (a kind of software middleware for connecting, integrating, and composing people-centric and context-aware cloud services) and brokerage service firms. Primarily, brokerage services include discovery, negotiation, intermediation, and aggregation, arbitration, and collaboration services. Frankly speaking, cloud brokerage firms help cloud consumers in identifying and tying up with the best cloud providers. In this process, cloud providers also gain bigger market share.

As per Gartner's latest market research and analysis report on cloud computing, there is a huge market out there for cloud brokerage services. Novel services and applications can be built by professionals with the solitary goal of supplying them to the world from clouds. As the acceptability, accessibility, affordability, agility, adaptability, availability, and accountability of cloud services, platforms, and infrastructures are on the rise, there is a new group of companies and corporations emerging and establishing to act as viable and valuable mediators, auditors, procurers, arbitrators, and decision makers for the cloud era.

Emerging Cloud Types

We have a good understanding about public, private, hybrid, and community clouds. Besides these generic types, there are several domain- and purpose-specific clouds being unveiled. There are service, mobile, storage,

knowledge, sensor, device, and high-performance clouds. Due to the diversity and multiplicity of infrastructure clouds, viable methods and mechanisms for federated clouds are being formulated. Ultimately, the intercloud is the vision.

Innovations are flourishing in the cloud space. The cloud-induced possibilities seem to be limitless, and there are a lot of refreshing opportunities available that are ready to be taken advantage of. These novel clouds enable visionaries and bright minds to visualize and articulate highly complicated and composite services that are multitenant, multipurpose, multidevice, multichannel, and even multienterprise. Self-, surroundings-, and situation-awareness and self-managing capabilities define new-generation services. Dynamism, modularity, openness, ubiquity, knowledge driven, transparency, utility, and so on are the preferred and profound qualities of services for the forthcoming knowledge era. In a nutshell, service orientation inculcates fresh air into the arena of software engineering in producing and preserving sophisticated and smart services. We need optimized and adaptive platforms and infrastructures to produce, deploy, and deliver these types of high-quality and state-of-the-art services. The cloud is the highly competent and efficient infrastructure for next-generation services.

Currently, server virtualization is being accomplished through the availability of multifaceted virtualization solutions (hypervisors) and hence server machines form the base and fulcrum for clouds. With the maturity and stability of desktop, embedded, and mobile virtualization technologies and solutions (microvisors), personal computers (PCs) and embedded devices will also ultimately join and jump on to the raging cloud bandwagon.

Ambient Cloud

This is the new buzzword in the cloud era. It is estimated that there will be two billion PCs in the year 2015. That is going to be a giant reservoir of unparalleled computing power as every new PC is being stuffed with powerful processer(s), gigabytes (GBs) of memory, and terabytes (TBs) of hard disk space. Each processor in turn comprises several cores (multicore computing). The prediction for smaller cousins such as laptops, tablets, and smartphones is still more fascinating. It is plausible to assume that the total number of mobile phones in use today will be roughly equivalent to the number of people on the earth. Smartphones are roughly half of that

number at this point in time and are projected to grow faster than any other computational devices on the planet.

Typically, smartphones come out with 1 GHz processor, 512 MB RAM, and 32 GB storage capacities. As per the trend, smartphones will soon catch up with PCs. As days go by, smartphones will be powered with multicore processors. More cores means more computing power. Therein lies a lot of opportunity. Memory size will be truly stunning. Smartphones will become the universal and unified instrument for computing, communication, sensing the surroundings and situation, controlling all kinds of electronic devices in the vicinity, even remote monitoring and management of household items, delivering people-centric service unobtrusively, knowledge exchange, formation of digital communities, social networking, and so on. The possibilities are really staggering.

But all the exciting computing power in the world is of little use if the devices do not connect and collaborate with one another. Networking (wired as well as wireless) has to be seamless, and the data transfer has to occur at furious speeds. Zero latency has to be aimed at and achieved. We have 3G mobile connectivity these days and in the near future, and 4G communication based on Long Term Evolution (LTE) will become common. The research on 5G communication has already begun.

Within data centers using high bandwidth 1–100 Gbps interconnects, the latency is less than 1 ms within a rack and less than 5 ms across a data center. Between data centers, the bandwidth is far less at 10 Mbps–1 Gbps, and latency is in the hundreds of milliseconds realm. Current bandwidth rates and latencies for cell networks might not be sufficient to build and operate clouds. However, with faster evolution and the occasional revolution in the communication space, future clouds will definitely be based out of smartphones.

True high-performance computing (HPC) and low-latency-interconnect applications will not find a cell-based cloud attractive at all. But for applications that need to be highly parallel and manageable with short latencies, cell-based clouds present a very appealing phenomenon. Energy efficiency is another challenging arena for the device world. Besides device clouds, the sensor clouds will become ubiquitous. With these advancements, there will be mind-boggling real-world and real-time applications. The way we work, decide, interact, and so on will dramatically change.

In summary, as indicated in Chapter 1, firstly, the casual and common things in our everyday environments will become smart (scores of digitalization and implantation technologies will enable enhancements in computation, communication, sensing, and displays). Secondly, our working, walking, and wandering environments will become smarter, and our decision making will be the smartest. Ubiquitous computing (computing everywhere and every time) and AmI (intelligence everywhere) will become reality as the Internet of things (IoT) and cyber-physical system (CPS) technologies and solutions are quickly maturing. D2D, device-to-enterprise (D2E), and sensor-to-cloud integration and wireless machine-to-machine (M2M) interaction frameworks, platforms, and technologies are rapidly becoming stable. Thus, with technological convergence and clustering, the path for ambient clouds becomes smoother.

SERVICE INFRASTRUCTURES

We need robust, resilient, and reliable infrastructures and platforms for dependably hosting, delivering, monitoring, regulating, substituting, and retiring new-generation cloud services and applications. When the service paradigm was sweeping the entire IT industry, there was a push for switching over to SOI. That is, every tangible IT resource gets service enabled so that they can find one another dynamically, and interact toward business goals. Service enablement is the leading cause for achieving higher infrastructure flexibility, utility, usability, and visibility. Public discoverability, network accessibility, remote manageability and serviceability, and so on are the key business and technical cases for enterprises to join in the service bandwagon. Thus, a wider variety of service infrastructures and platforms have been conceived and brought out in plenty by open source communities as well as by leading IT vendors. In short, the service science, engineering, and management disciplines have been receiving a lot of attention.

There is informative and inspiring literature on service platforms and their features and functionalities. Recently, there is a new product category called the service delivery platform (SDP). The telecommunication industry first incorporated the SDP as the foremost infrastructural element for facilitating service delivery, and today there is a greater awareness and articulation across industries about the significance of SDPs.

There are competent software solutions for simplifying and streamlining service modeling, design, construction, inspection, performance, and so on. Services intrinsically support composition and choreography. Therefore, service orchestration engines, service collaboration platforms, service security and privacy solutions, and so on have become mandatory software packages in any generic service infrastructure. Today any reasonably established enterprise boasts about creative and compact solutions for event processing, rule/policy management, business process management, enterprise service bus (ESB), data services, portal, and so on.

With the additional complexity of enabling each service to find and communicate with one another, service virtualization has become an important topic. Thus, service registry repository, governance, and virtualization solutions are the other important constituents of the service infrastructure. Finally, for any organization with a growing array of business and technical services, service management becomes an essential ingredient for establishing a sort of interaction control and visibility in any service environment.

Further on, the network connectivity tier comprises routers, security solutions, load balancers, switches, gateways, proxies, and so on. As usual, enterprise services would run behind firewalls. Building a data center to support enterprise-class and -wide SOA is prohibitively expensive. It is nearly impossible for small to medium enterprises. For larger enterprises, the process of developing and sustaining data centers is beset with a number of practical difficulties, as the business processes are generally more diverse, distributed, and decentralised. Further, an enterprise has to connect data centers, since it has to connect and collaborate dynamically with its business partners, retailers, suppliers, customers, and other stakeholders. Moreover, many racks of servers in any large data center are sitting idle or passive, especially during the nonpeak hours, and resources are usually overprovisioned to meet any unexpected spike or surge in resource usage, resulting in huge cash losses.

Thus, expensive resources are terribly wasted, and a greater number of servers means more personnel are needed for manning and managing data centers. In short, higher energy consumption, heat dissipation and greenhouse gas emission, increased costs for operators, and so on insist on exploring, experimenting, and espousing alternative solutions. Also the present-day data centers are not enabling business alacrity and affordability. A typical service infrastructure for supporting a service-oriented organization is vividly illustrated in Figure 3.1.

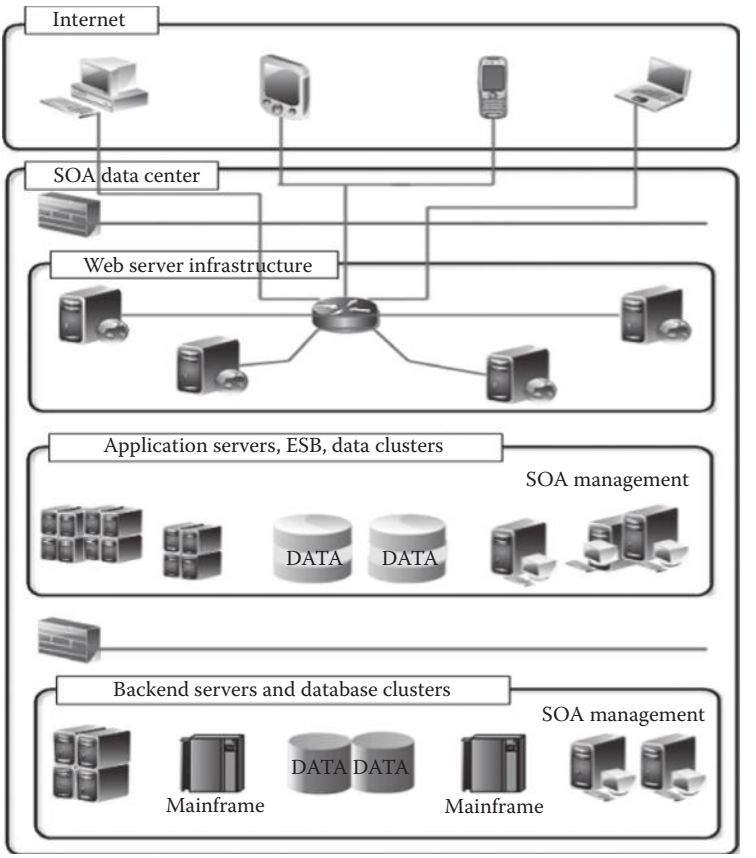

FIGURE 3.1
An enterprise-scale service infrastructure.

CLOUD INFRASTRUCTURES

Cloud computing is all about consolidation, centralization, optimization, higher utilization, smart delivery, and flexibility. In a way, sharing services, computation, and data from a highly modular server farm is the key differentiator. Services and data, made available in a cloud, can be more easily and ubiquitously found, bound, and accessed, often at a much lower cost. This shift solidly increases the monitored usage and leverage of IT resources as opportunities for enhanced collaboration, integration, and analysis on a shared common platform abound appreciably. A reference architecture for a cloud center is given in Figure 3.2.

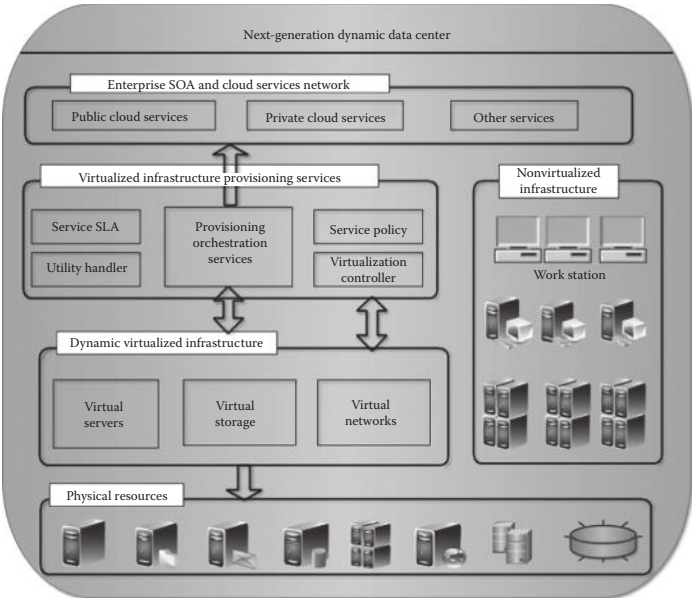

FIGURE 3.2
Next-generation dynamic data center.

Cloud Infrastructure Evaluation Parameters

Given the technological and organizational risks associated with the existing public cloud computing solutions, IT organizations evaluating these solutions need to determine the following:

- Whether the cloud infrastructure is standardized, consolidated, virtualized, and optimized
- Whether the infrastructure is modular, simplified, automated (automation of resource provisioning, VM creation, expansion, contraction, retirement, etc., job scheduling and load balancing, change and configuration management, service governance, fault diagnosis, patch management, etc.)
- Whether the cloud migration is made simpler and quicker
- Whether disaster recovery (DR), business continuity (BC), cloud center security, data integrity and confidentiality, and so on are facilitated by the cloud infrastructure providers
- Whether service integration, composition, and provisioning, flexible offerings, and so on are enabled

Cloud Infrastructure Capabilities

Given the technological [2] and organizational risks associated with public cloud offerings, organizations at the planning stage have to quiz CSPs to determine whether they are stringently providing the following facilities and features:

- The IaaS services advertised and articulated are fully compatible and competent to support their applications.
- The underlying cloud infrastructures are totally optimized and have reached a certain level of stability and maturity.
- The infrastructure should be strictly standards based. The infrastructural components such as servers, switches, gateways, appliances, storage networks, and so on have to be highly modular in order to support flexibility and modifiability. Also, the infrastructure has to be sensitive and simplified for configuration, customization, and consumption.
- CSPs have to have an extensive virtualization strategy as almost all the tangible IT resources such as server, storage, database, application, service, network, desktop, and so on are being virtualized. Lately, there are microvisors to enable virtualization of embedded devices.
- The CSPs must have automated as many data center processes as possible. This includes orchestration and provisioning; change and configuration management; resource reallocation; service monitoring; fault diagnosis; and software updates and maintenance.

There must be an appropriate level of redundancy throughout the infrastructure, coupled with a fast failover capability for secondary or backup resources. There must also be a multilayer security architecture that provides full isolation of virtual data centers and also provides the option of screening all host-to-host traffic within each tenant's virtual data center.

CLOUD INFRASTRUCTURE SOLUTIONS

As mentioned above, adept and assistive tools are very essential for the design and maintenance of a responsible cloud infrastructure. They enable quick identification of the environmental health status to facilitate effective capacity and environment planning, problem anticipation and instant resolution, and capacity expansion and contraction as needed to rapidly

adjust to changing support requirements. Data center asset and configuration information is collected into a centralized repository that provides a holistic view of the cloud implementation. Not only does this provide a single point of access for viewing details about individual IT components, but it also provides insight into how those components interact.

Modeling solutions can provide easily digestible and actionable infrastructure intelligence, which is critical for enabling rapid cloud expansion to meet changing customer requirements. Intelligent modeling solutions go further to allow organizations to generate hypothetical scenarios so that quick and informed decisions can be made on infrastructure growth and improvement [5]. For instance, before adding a new server to an existing cluster, a modeling solution can identify if there is sufficient rack space, power, networking, and structural support for the new server. Since responsible cloud environments must rapidly adapt to support requirement changes without diminishing infrastructure reliability, a modeling solution can be an indispensable tool.

Automated tools go a long way in moderating the management complexity of IT infrastructures. Dashboards are very important in indicating the correct status in real time so that administrators and others involved in manning mission-critical infrastructures can contemplate tactical as well as strategic decisions.

Identity and Access Management Suite

Today's extended enterprises face the challenge of providing everywhere, every time, and every device access to business-critical applications and resources, not just to employees but also to field force, sales team, executives on the move, business partners/suppliers, distributors, wholesalers, retailers, and end users [15]. The current setup is that these resources are available via web-based applications or network applications accessed through a virtual private network (VPN). The task of managing which users can access which resources, both for security purposes and for compliance requirements necessitating documentation of access privileges and actual usage, is often costly and time-consuming. This challenge has become even greater in recent years for organizations moving to cloud-based software solutions, which can be deployed more quickly than on-premise solutions.

Increasingly, scores of business software, software infrastructure solutions, and enterprise applications are being deployed, managed, delivered,

and billed in clouds. Salesforce.com is a highly successful customer relationship management (CRM) software in the cloud environment. Ramco Systems' enterprise resource planning (ERP) package is another popular one doing well. Corporations are delivering their software products as services from clouds. Every security solution is also being delivered from clouds these days. As clouds are being administered and managed by people with the right and relevant skills, many organizations have been moving their key business applications to public clouds. There are highly scalable directory services and identity management solutions in clouds. These cloud-based software modules offer compelling business efficiencies, less TCO, higher ROI, and so on. Centralized management is another main point in favor of overwhelmingly embracing clouds. Self-service is another favorable factor.

Now, with the opportunity to take advantage of hosted identity and access management (IAM), it is possible to deploy applications faster, control IAM operational and staffing costs, enjoy user-based and operational expense pricing benefits, and provide consistent, secure access to IT resources. Smaller organizations can now take advantage of security technology that may previously have been beyond their reach, and larger organizations can upgrade and extend access control to the applications that were not brought under their management due to resource constraints.

Cloud Infrastructure Management Solutions

In the past, the underpinning of any business service was limited to the IT resources that were wholly owned by the provider of that service. This had invited silo-based approaches to management of services in areas such as system, network, security, and IT governance. Now, with cloud computing, the business service architecture (BSA) crosses the organizational boundary and becomes a seamless composition of diverse and distributed resources which are separately manned and managed within different domains. Hence, the traditional IT management solutions do not work out well in this distributed and decentralized model. Cloud-centric IT management has to view the business service from a top-down perspective and provide capabilities in the following key areas.

Automated Management

Managing cloud infrastructure poses a number of unfathomable challenges due to consolidation, virtualization, and federation, which are the

centrality of any cloud environment. The best way forward is to automate the configuration, administration, monitoring, management, and maintenance of cloud infrastructures that support a variety of business applications, services, and data through a host of sophisticated software solutions. This results in a more flexible and controllable environment that can support up-to-the-minute business requirements, with an eye toward maintaining SLAs.

Resource Provisioning

Self-service is the unique selling factor of cloud systems. That is, business users can decide, create, and leverage their computational requirements. If not needed anymore, they can let go of them right away. That is, new resources can be realized easily and released instantaneously. In other words, provisioning and deprovisioning of a variety of IT resources (applications, platforms, and infrastructures) is being significantly simplified in order to attract people and to retain them. In short, IT is becoming simpler and sensitive enough to be dictated by business managers and nontechnical people. Another point is that computing is all set to become the fifth social utility. Such a seismic shift is being made possible by cloud computing.

Cloud Performance and Scalability

With the increased complexity, performance and scalability requirements definitely present a tough time for CSPs. Performance and scalability are interlinked. That is, all of a sudden, there are more users or higher workloads, but the response time still has to be within the originally decided limit. Cloud infrastructures have to be designed to meet these server-specific needs. Capacity planning is the preferred approach. There are performance optimization best practices. Cloud modularity and visibility is the prominent characteristic for ensuring high-end performance and scalability.

End-to-End Cloud Service Visibility

The deeper visibility into the components of a composite application that may reside in multiple organizational domains optimizes resource management and utilization, streamlines IT processes, and reduces costs considerably.

Security Management and Federation

IAM is a critical component in cloud security management [3]. Policy-based access, control, empowerment, and management have become popular mechanisms in the enlarging cloud environment. Messages in transit and data in persistence are being encrypted in order to guarantee the utmost security in any open environment.

Cloud SDP

Cloud services deployment and execution containers, cloud service management platforms, cloud service security solutions, and so on are the leading software infrastructure solutions for cloud-based service applications (CBSAs). SDPs are gaining much ground these days as services are centrally placed and provided to global users with much clarity and without any performance degradation. Presentation, rendering, aggregation, transformation, and mediation engines are the chief modules of any standard SDP. Cloud service bus (CSB) is the introspective middleware being utilized to route (content as well as context based) service messages to their rightful owner(s), to broker among services with varying capabilities and contracts, and to aggregate outputs of participating services that are situated in different VMs, physical nodes, and clouds. SDP is the front end for all the backend resources including the CSB. A service portal is the UI part of any SDP. A mashup editor is a well-known module in the cloud service platform.

Responsible Cloud Infrastructure

Responsible clouds are another twist in the cloud paradigm. There are best practices and key guidelines galore for carefully designing responsible clouds, which are well managed to provide secure, compliant, and high-quality business services. Responsible cloud environments [10] deliver more secure, reliable, and flexible IT services to meet organizational requirements and reduce both capital and operational expenses. Whether building a responsible cloud infrastructure from existing computing resources or an entirely new infrastructure from the ground up, there are three design considerations: effectively size the infrastructure, ensure high availability, and minimize operating expenses.

The number of powerful servers in a cloud center has a direct and distinct impact on the cost (capital as well as operational). Additionally,

the number of potential security and failure points is proportionally decreased, improving the overall reliability. Consolidated servers could be more easily pooled and could accommodate scores of shared resources. This allows new resources to be more rapidly added and provisioned to meet rising service demands. Capacity planning is essential for effective infrastructure sizing. Systems that consolidate a large number of resources, such as blade servers and mainframes, are physically larger and more powerful than standard servers. Automated tools should be employed as much as possible in order to make informed and instant decisions based on infrastructure usage, pilferage, performance, productivity, and so on. The information shared and knowledge gained help in quickly and cheaply accommodating newer services. The time taken to reach out to customers and consumers comes down sharply if the extracted and inferred insights are appropriately used.

Since cloud services are expected to be accessible all the time with high throughput, high availability is considered a mandatory infrastructure requirement. Clustered servers have the requisite ability to provide the much-desired capability of high availability. That is, if one server fails, the other servers in the cluster space take up users' requests so that the users do not feel any perceivable delay. That is, they can provide uninterrupted failover services in the event of an individual server experiencing a catastrophic failure or requiring downtime for maintenance. Load balancers are the primary module in understanding the workload of each participating server. Accordingly, service requests would be dispatched to those servers that are doing less work at any point in time. Thus, workloads are being equally segmented, failover and failback mechanisms are provided, job scheduling is being automated, resource provisioning and deprovisioning are being accomplished, and so on. All these portend a bright future for the cloud paradigm. Clustered environments are typically contained within a single physical location so that they can share storage systems and do not have any performance latency due to wide area network (WAN) traffic.

Large cloud implementations typically have multiple clustered environments at multiple facilities in different locations. This allows failover of a cloud service in the event of a site disaster due to a flood or fire. Individual cloud instances can be expanded to operate across multiple clustered environments, both local and remote, to create a "hub and spoke" architecture

that ensures highly available and reliable computing services. Scores of automated tools should be employed to monitor the health of these systems as well as the availability of support services, such as power and network connectivity.

Professors and professionals are keenly watching and working on overcoming the chief cloud issues. Primarily, all the major nonfunctional requirements such as security, scalability, availability, adaptability, quick recovery, throughput, fault tolerance, and dependability are being attended to so that the adoption and adaption of cloud computing are bound to rise and ride on.

Cloud infrastructures must be technically advanced and are, in a way, a dynamic pool of modular and shared servers. Service centricity is the foundational and fundamental criterion for all kinds of cloud resources. Virtualization-induced sharing, optimization, and enhanced utilization of IT systems, services, and solutions are gaining significant ground these days.

CLOUDS FOR BUSINESS CONTINUITY

Disaster recovery, fault tolerance, and BC are the indisputable characteristics of any enterprise IT environment. Load balancing, fault prognosis, identification, self-healing, and clustering mechanisms are very much prevalent and prominent in mission-critical enterprise IT environments for ensuring high availability, dependability, and scalability. Due to the innate power of realizing substantial improvements in the enterprise space, enterprise IT steadily tends toward cloud IT. The pioneering contributions of cloud infrastructures to business continuity are twofold. That is, cloud systems are inherently highly available and also are utilized as an off-premise backup. For example, an enterprise may operate the whole system in a public cloud to achieve high availability, affordability, and disaster tolerance. A different enterprise may use a private cloud or a traditional in-house data center for their day-to-day business operations and offerings, while using a distant public cloud for backup. Thus, clouds bring cheers for CIOs and chief operating officers (COOs) by drastically reducing the backup and business continuity (BC) costs. Suppose that there is a need for seven or eight servers for an enterprise package to run smoothly. Then,

there need to be another seven or eight servers at a DR site. Thus, there is a huge cost involved in guaranteeing BC. This is the reason that leveraging the cloud for BC is gaining considerable momentum these days.

THE RELEVANCE OF PRIVATE CLOUDS

The much-proclaimed cloud approach is definitely a trendsetter and clearly represents a bright spot for business transformations. The cloud paradigm is fast maturing and stabilizing toward a flexible and futuristic technology, not only for the service providers but also for service consumers, auditors, and brokers. The tactical and strategic implications are consistently on the rise. Data centers and server farms are being reimagined, rekindled, and recognized as cloud centers. Every single IT resource is being empowered and exposed as a virtual resource. A variety of automation and acceleration tools are being introduced for easier manipulation, monitoring, and management of all kinds of virtual resources.

A hybrid of bottom-up and top-down approaches is being recommended so both legacy as well as new applications can be in the cloud without a hitch. Business applications, services, and data are being accordingly modernized to be cloud ready and multitenant. It is not an exaggeration to say that the creation and sustenance of virtualized infrastructures and platforms are the tough and rough phases in the cloud journey. The cloud computing model brings together four dimensions of complexity:

1. Applications and services will further evolve from being monolithic and static toward being composite and dynamic. This in turn increases the reliance on network performance as well as the power of cloud center.
2. IT infrastructure will continue to shift from physical to virtual, complicating IT orchestration with more moving parts.
3. As infrastructure performance management becomes complicated, the operational domains of control will move from single to multiple entities.
4. Business models move from per-instance licensing to pay-as-you-go licensing, which will require better project financial management and exploration into chargeback methods.

The cloud style has brought forth a fresh set of ills and issues that cannot be taken lightly as their compact resolution leads to greater acceptance. As far as the third-party, external, commercial-grade, and public clouds are concerned, the major problem areas blocking the widespread adoption of the cloud style are listed as follows:

- Security and privacy
- Controllability and flexibility
- Visibility and availability
- Auditability and accountability
- Latency and performance/Throughput
- Compliance

Private clouds [4] are solving most of the problem areas of public clouds. However, the much-anticipated utility model gets missed out on in private clouds, which are catering to the needs of a limited set of users. For energy and cost efficiency, and for vertical applications, community clouds are being recommended. All kinds of underutilized and unutilized computing machines are being networked, clustered, and virtualized to act as community clouds that are capable of effortlessly tackling the specific needs of a particular community. Then, hybrid clouds are being suggested for enabling a seamless connectivity between private and public clouds through the cloud-bursting technique. This arrangement helps in times of greater needs of computing.

An overwhelming majority of users has voted and voiced that security is the main stumbling block; hence, CSPs and academic researchers are working overtime on minimizing the malevolent security threats and risks, thereby reversing the sagging and sluggish image of third-party clouds. Newer security holes via VMs have come to light. As the access for the public cloud is mainly through the Internet, all kinds of cloud sources and resources are very much liable for intensive and intimidating intrusion, hacking, and transgression. Therefore, myriad intercontinental initiatives are being expedited to unearth impenetrable and unbreakable security algorithms and solutions. There are security-specific best practices, key guidelines, and metrics. The currently used security mechanisms are also being strengthened for utilization with cloud systems. IaaS providers are lately open to providing more controllability, third-party auditability, flexibility, modifiability, and so on. Other drawbacks are also being attended to seriously. In summary, establishing private clouds is the logical step until there is a complete reliance on public clouds.

THE EMERGENCE OF ENTERPRISE CLOUDS

Every enterprise architect has to set his agenda and make his vision for instituting technology-sponsored private (internal) clouds clearly within his or her organization. Given the economic attractiveness of public clouds, it is logical to ask if there is a way to leverage the prime advantages of public clouds. The viable and value-added alternative for the looming cloud era would be to relate all the promising and proven cloud technologies into the organization's own data center. Clearly, if a commercial hosting entity is able to develop such an elastic and energy-efficient infrastructure, then it ought to be possible to create an "internal cloud" with equivalent performance and economics within the enterprise boundary.

Fortunately, there are competent and congenial solutions and technologies besides knowledge materials and know-how guides. These come in handy while revisiting and remodeling any existing data centers to function as an enterprise-wide private cloud. The high-level expectation is that the emerging and evolving cloud architecture should not adversely impact any existing assets and processes. On the other hand, the resulting private cloud has to smartly leverage the existing capabilities and capacities. The architectural stack of an enterprise cloud is given in Figure 3.3. The major requirements and constraints for typical internal cloud include

- Managing diverse compute, storage, and networking infrastructures
- Managing multiple and heterogeneous virtualized infrastructures
- Providing service-centric features for designing, measuring, and maintaining a growing catalogue of services and chargeback if necessary
- Not disrupting the existing security processes and procedures, application architectures, and application code bases or configurations
- Being compatible with tracking, logging, and compliance systems
- Providing per-user resource cost and usage metrics
- Ensuring utmost security for confidential as well as corporate information

With these operational requirements, an enterprise private cloud can generate the same value and verve as a public cloud. Essentially, the only difference is that the internal cloud is behind the firewall within our own facility and under our complete control. The private cloud is a completely

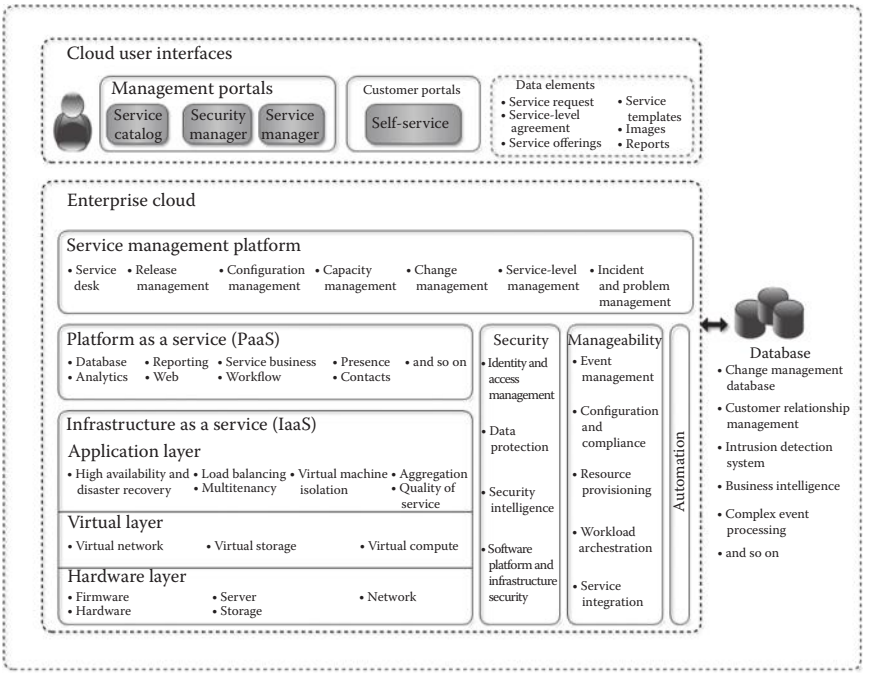

FIGURE 3.3
The architectural stack of an enterprise cloud.

shared and multitenant data center built on a highly efficient, automated, and virtualized infrastructure. Other key elements [1] of the cloud include standardized service, application, and database platforms provided as a service and a self-service portal that enables business analysts and managers to request and manage additional capacity for their applications. The short-term as well as long-term implications of cloud enablement and embarkation are manifold. All the deployment and delivery models are bound to instigate and inspire numerous improvisations and improvements in the current IT establishments and their operations. Above all, the traditional delivery mechanism will undergo a sharp turnaround toward synchronized and simplified service delivery. In this section, we will dig deeper in order to extract and enlighten all kinds of technical, business, and user-centric benefits. Enterprise clouds are for internal users only. Enterprise clouds [8] support

- Better visibility, traceability, flexibility, and controllability
- Resource elasticity and application scalability
- Auditability, accountability, and drillability
- Better capacity planning and management

- Unbreakable and impenetrable security
- Stricter privacy
- Fault tolerance and expandability
- High performance and workload predictability
- Improved infrastructure efficiency
- Real-time provisioning and higher resource utilization
- Agility, availability, adaptability, and autonomy
- Easy manageability, maneuverability, and malleability
- Consolidated, virtualized, dynamic, utility-like, and on-demand infrastructure
- Grid-enabled and optimized infrastructure
- Management console and automated job scheduling
- Compliant to SLAs, OLAs, government rules, and regulations

Affordability

There are expert ways and means to achieve huge cost reductions in setting up and sustaining enterprise clouds.

Resource Slicing, Pooling, and Sharing

Through the revolutionary virtualization technology, IT resources can be made, mapped, and managed as one or more configurable and composable pools of service-centric resources instead of islands/silos of independent elements. These pools can then be exposed in a granular manner for use by business applications and services. Fluctuations in the resource requirements of each application can be easily and quickly understood and met by using fewer technology resources. The economic benefits here are profound and paramount too. The risks of overprovisioning and underprovisioning are considerably reduced with this respectable advancement. The capital and operational expenses will come down as utilization rate goes up, and the number of data center devices and even data centers also slide down. In addition, the facility and overhead costs such as power, cooling, system administrators, and real estate expenses get remarkably decreased.

Clouds Are Lean and Green

Small and slim data centers ensure less energy consumption, heat dissipation, and CO_2 emissions. As the countries, counties, and cities across

continents are consciously and cautiously formulating successful schemes for arresting the dreadful climate change and for fulfilling environmental sustainability goals, green hardware and software solutions besides IT solutions for green enablement are being given their due recognition. In this regard, the cloud is being elevated and exhibited as a promising technology for green IT.

Decoupling of Software from Hardware

Today, applications and services run on their specific platforms. Operating systems (OSs) depend on specific process architectures. All these constricting dependencies are to be decimated hereafter. Any number of OSs can run on a physical server. Every service and application becomes virtualized so that they can all run on any platform and infrastructure without any hitch or hurdle. There is a clear separation between applications and their runtime containers. The end result is that IT portability and modifiability will become easier and elegant. This light and loose coupling goes a long way toward increased utilization of IT resources and hence entails less capital, management, and operational costs.

Virtualized Data Storage and Management

By virtualizing storage, enterprise cloud computing allows the physical location of data to be abstracted from the underlying platform, making data vastly easier to migrate. Data can be housed on the platform that best meets particular cost or the security criteria at a given point of time according to a given policy.

Data and Disaster Recovery and Business Continuity

Implementing a common set of standardized and integrated system packages within a data center and across geographically distributed data centers makes workload migration and DR affordable and achievable for more applications and data.

Automated Tools

Use of a single-pane management console gives IT administrators a consistent and common view for each step in a technology life cycle: configuration, provisioning, compliance, management, and monitoring across platforms. These management tools let administrators set up and run

automated utilization monitoring and workload-balancing policies. Load balancing, clustering, job scheduling, resource provisioning and deprovisioning, and workload management get completely automated.

The heightened resource utilization induced by virtualization and automation tools leads to a smaller team of IT administrators to manage a larger pool of resources. Capital expenditures to buy, install, and administer fresh infrastructures come down as existing resources can also be optimally used for new requirements. In other words, more with less is the goal in this uncertain economy, especially in advanced nations.

Multitenancy and Shared Environment

Shared resources, platforms, and infrastructures are the vision behind the cloud-emboldened and knowledge-driven service era. Multitenancy is the new buzzword with the uninhibited rise of the pioneering and path-breaking cloud idea.

In summary, a better understanding of the pros and cons of each contributive technology in the expanding cloud space is the first and foremost action point. Objective and unbiased analysis for precisely identifying all pain points and the probable areas of optimization in existing data centers is the second task. Capacity planning is a must to gain the decision-enabling details regarding the computing, communication, storage, and user-base requirements. The next activity is to incubate a new inclusive architecture with all the functional and nonfunctional information. Finally, refurbishing and reusing the existing investments to arrive at a vibrant cloud center is the reasonable and responsible mission.

CONCLUSION

Being an impactful technology, the cloud has brought forth a number of delectable innovations and renovations to both business and IT domains. Both business executives and IT professionals are equally ecstatic about the potential and promise of the cloud paradigm.

On the IT front, the major rejuvenation and restoration happens on IT infrastructures. Anytime, anywhere, and any device access of web-based content, components, services and data has been there. However, with the cloud eruption, application platforms and runtimes; service containers; integration backbones; orchestration and rule engines; management applications; software infrastructure solutions such as application servers,

service buses, and so on; database systems; and integrated development environments (IDEs) are also centrally hosted and efficiently managed in cloud infrastructures. That is, these advanced and complicated software infrastructure modules are being expressed and exposed as services to the outside world. Software products are being delivered and consumed as services over the web. Consumers could access them as services and pay for their usage. The capital costs are phased out and the operational expenses come down. That is, the service idea has permeated into every nook and corner now.

Finally, IT hardware components such as processors, memory, storage, and networks are also being accessed as services, and customers pay for their usage. Thus, there is a total revolution in realizing the vision of "IT as a service." Cloud technology is the strategic and singular phenomenon in opening up a series of IT simplifications to make IT discoverable, accessible, consumable, and composable.

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