

## A Glimpse into Software Defined Data Center

UM GLIMPSE EM SOFTWARE DEFINED DATA CENTER

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**Abstract** – Existing data centers today are not ready to support IT organizations to meet the ever changing business demands. Therefore, next generation of data center like Software Defined Data Center (SDDC) is explored and expected to come to rescue. However, SDDC is relatively new since its inception in 2012 whereby there are different early interpretations on its definition, criteria, reference architecture and values that SDDC brings. There is also limited literature and sharing on how a SDDC works. The objective of this study is to shed some lights on SDDC operational definition, criteria, reference architecture, and depiction on how SDDC works in three scenarios as well as standardized the values it brings. Moreover, some factors to guide IT organizations on how to adopt SDDC are also discussed. This study has taken a qualitative approach in which SDDC literature is reviewed and some SDDC IT professionals are interviewed. Lastly, limitations of the study, future research and conclusion are also provided.

**Keywords** – Software Defined Data Center, SDDC operational definition, SDDC criteria, SDDC reference architecture, SDDC values.

**Resumo** – Centros de dados existentes hoje não estão prontos para apoiar as organizações de TI para atender às demandas de negócios em constante mudança. Assim, a próxima geração de centro de dados como *Software Defined Data Center (SDDC)* é explorada e deverá vir para ajudar. No entanto, o SDDC é relativamente novo desde a sua criação, em 2012, em que existem diferentes interpretações iniciais sobre a sua definição, os critérios, a arquitetura e os valores que SDDC traz referência. Há também limitada literatura e compartilhamento sobre como o SDDC funciona. O objetivo deste estudo é esclarecer a respeito da definição operacional do SDDC, critérios, arquitetura de referência, representação em obras como SDDC em três cenários, bem como padronizou os valores que ela traz. Além disso, alguns fatores para guiar as organizações de TI como adotar SDDC também são discutidos. Este estudo teve uma abordagem qualitativa em que a literatura SDDC é revista e alguns profissionais de TI SDDC são entrevistados. Por fim, as limitações do estudo, futuras pesquisas e conclusões também são fornecidos.

**Palavras-chave** - Software Defined Data Center, definição operacional SDDC, critérios SDDC, arquitetura de referência SDDC, valores sddc.

## Introduction

Today, business is demanding Information Technology (IT) organizations to deliver more with less, hence existing data centers have been stretched to produce the best that they can deliver (Hewlett-Packard [HP], 2013). This situation is unsustainable because existing data centers are complicated and rigid i.e. too many products, tools, complex processes as well as too specialized IT skills that have been built throughout the history of the data centers (Raghuraman, 2013; HP, 2013). These data centers cannot cope with the agile demand from business in which 70% of the IT expenses are incurred to maintain the ongoing IT operations whereas only 30% is invested for innovative or new IT project initiatives (HP, 2013).

In order to achieve the next generation of data center that meets the business needs, Software Defined Data Center (SDDC) is coined and explored. The adoption of a SDDC is not like completing a project in which all its end results are delivered at the end of the project. Instead, the adoption of a SDDC today is like embarking on a journey whereby SDDC is evolving for better value creation (Raghuraman, 2013, VMware, 2013). However, the earlier an organization successfully adopted SDDC, the sooner it will reap the benefits and has better competitive advantage over its competitors.

VMware started to coin the term SDDC in 2012 whereby SDDC refers to a unified platform that provides automation, flexibility and efficiency for an IT organization to transform the way it delivers its data center services (VMware, 2013). Data center services like compute, storage, networking, security and availability are pooled, aggregated and delivered as software. These services are also managed by intelligent and policy driven software. SDDC encompasses features which include user's self-services, policy based automated infrastructure and application provisioning as well as business oriented management. The end result is that the data center is optimized for cloud era, providing the expected business agility with Service Level Agreements (SLAs) for all applications, simplified operations as well as lower total cost of ownership. According to IDC (Raghuraman, 2013), SDDC is a set of software components to virtualize and federate all the data center hardware resources for examples, compute, storage, network and facility resources. The objective is to tie these disparate data center resources together in order to deliver an integrated service to users. Moreover, Forrester (Raghuraman, 2013) defined

SDDC as an abstraction layer of software that presents the data center resources as a pool of virtual and physical resources so that users can compose those resources according to their needs as user-defined services.

SDDC is also synonymously addressed as Converged Data Center (CDC) in HP and Software Defined Environment (SDE) in International Business Machines (IBM). Albeit SDDC has different synonyms, but their definitions are similar to those coined by VMware, IDC and Forrester as mentioned earlier. For examples, HP's CDC refers to the vision of future data center whereby data center facilities i.e. power and cooling, IT infrastructure i.e. server, storage, network and security, operations and management are converged. Convergence refers to bringing multiple components together in order to achieve synergy. Once they are converged and fully integrated, they can support multiple IT delivery models which include traditional IT, outsourcing and cloud computing (HP, 2013). Moreover, CDC is software defined whereby resources are shared, processes are standardized and automated as part of a service oriented approach. This service oriented approach will enable IT to align with business so that business can respond in real time to changes in its environment. IBM's SDE refers to an approach to create and implement an optimized IT infrastructure that can help enterprises to attain competitive advantage, higher value and profitability through speed and efficiency in delivering IT services (International Business Machines [IBM], 2013). This SDE approach can help an enterprise to meet its business requirement and respond to environmental conditions faster and more effectively.

Based on the literature reviewed and interaction with IT organizations, SDDC in this study is defined as the *next generation of data center that can virtualize most of the data center resources as optimized IT services to be controlled by automated software in order to deliver business values which include effectiveness, adaptiveness and responsiveness*. Data center resources encompass all the compute, storage, network, security, data center facility i.e. power and cooling resources. As of today most of the data center resources can be virtualized. However, there are some which cannot be virtualized, these include physical equipment and servers supporting legacy applications as well as power and cooling resources. Automated software refers to the SDDC controller that is intelligent, SLA, policy and business driven. Effectiveness includes IT operations efficiency and cost effectiveness. Adaptiveness comprises flexibility and elasticity of the IT services. Responsiveness encompasses agility and manageability of the IT services.

Problem statements triggered this study include: (a) there is no common operational

definition for SDDC, (b) there is no commonly agreed criteria and reference architecture for SDDC, (c) lack of end to end depiction on how SDDC works, (d) lack of agreement on what are the key values after implementing a SDDC. Hence, objective of this study is to provide some insights by clarifying the problems as mentioned above through qualitative research.

Qualitative content analysis is adopted in this study whereby literature was searched and 32 IT professionals were interviewed in Klang Valley, Malaysia. The location Klang Valley was selected because it is one of the most developed locations in terms of advanced and large IT projects deployment in Malaysia. The interviews were guided by pre-prepared semi-structured questions and were conducted after some IT organizations had implemented SDDCs or after the author had made SDDC presentations to some IT organizations. Due to limited length allowed for this article, verbatim transcription of interviewed data had been abstracted and summarized into descriptive findings as provided in the subsequent sections. This article intends to address some questions raised pertaining to: (a) what is the operational definition of SDDC? (b) what is the criteria and reference architecture for SDDC? (c) how SDDC works? and (d) what are the values of SDDC?

### **Proposed Criteria and Reference Architecture for Software Defined Data Center**

This section of the study illustrated both the criteria and reference architecture for SDDC. Rationale to develop SDDC criteria is to enable one to evaluate whether an IT system is SDDC or not so that true values of SDDC are derived. The purpose to develop SDDC reference architecture in this study is to facilitate organizations how to build a standardized and structured future SDDC.

#### ***Criteria of SDDC***

Three SDDC criteria are delineated in the following three sub-sections. In order to differentiate SDDC from other styles of IT like virtualization, cloud computing, big data analytics and Virtual Desktop Infrastructure (VDI), a comparison between SDDC and other styles of IT are performed based on these three criteria.

#### **Data Center Resources Virtualization**

Server virtualization has started more than 10 years ago in which it has become a core technology in the data center. Many new styles of IT are embracing server virtualization, these include cloud computing, big data analytics and VDI. Server virtualization is based on the concept to decouple the compute functionality from the physical platform so that IT organizations can consolidate the infrastructure effectively (Kerravala, 2013). However, storage, network and security virtualization are not progressing at the similar speed of server

virtualization in which only until recently they are getting more prevalent. Many research pour into these areas and numerous technologies have been surfaced which include software defined storage, software defined networking, network function virtualization and software defined security or protection just to name a few. The objective of these technologies is to virtualize all the resources under their control. Generally, resource virtualization can be performed in two ways. One way is to take a physical hardware for example a server, from there create multiple virtual resources like virtual machines. The other way is to combine multiple physical hardware like storage and security equipment into one large virtual pool for logical sharing. In the new dawn of SDDC, all these server, storage, network and security virtualization will be amalgamated together to form an integrated and dynamic resource. Hence, data center resources virtualization is the first criteria of the SDDC.

Besides IT infrastructure virtualization, power and cooling of data center facility also need to be coordinated and controlled accordingly to support SDDC. In order to achieve this, power and cooling will be managed by another upper layer called Data Center Facilities Hardware Abstraction Layer or more commonly addressed as Data Center Infrastructure Abstraction (DCIA). DCIA offers a set of services to inform SDDC about the status of the data center physical infrastructure as well as provide mechanisms how to alter the infrastructure (Ungar, 2014; HP, 2013).

### **Automated Software Control**

Automated software control is using software to replace IT staff in decision making, controlling and automating IT processes. Capability to perform automated software control is the second criteria of a SDDC. SDDC can perform this via its SDDC controller which is the brain of the SDDC. The SDDC controller works collaboratively with other resource controllers as well as business logics which have been programmed or defined into the SDDC in order to make decisions and initiate all the SDDC actions via API calls. Other resource controllers include server virtualization manager, software defined storage controller, software defined networking controller, software defined security or protection controller as well as DCIA. Each of these resource controllers is to have a better control over its virtual or physical resources. Generally there are two main approaches to control resources using automated software. One is driven by software vendor like VMware whereby software defined controller is using server computing power to emulate certain functions like switching, routing, network function virtualization and security protection. The other approach is driven by hardware vendor for example, Cisco in which the device architecture is

separated into two parts i.e. centralized control plane and distributed forwarding plane. The centralized control plane is where the software defined controller is residing that enable the control plane to become directly programmable and its underlying hardware (i.e. distributed forwarding plane) to be abstracted for application services. Albeit current cloud computing technology includes some automation capabilities like provisioning and de-provisioning of VMs, charge back, show back and others, they are not completely software defined. In some instances, human decision makings are required to configure the rest of the processes which are not being automated. For example, in order to cater different workload requirements, “T-shirt” size of small, medium and large VM options are created. User or IT staff needs to select accordingly when he or she needs specific resource to process his or her application workloads. On the other hand, SDDC can handle the entire process automatically after an application workload requirements have been entered into the SDDC portal. At the moment unlike SDDC, other new styles of IT like big data analytics and VDI are only partially automated.

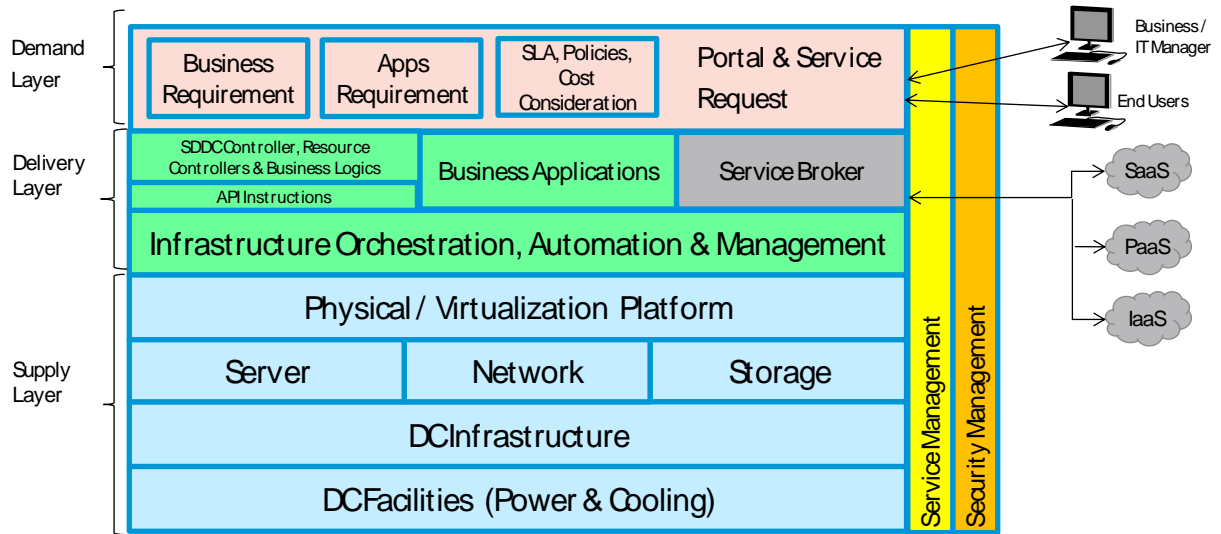
### **Business Values Delivery**

The third criteria of a SDDC is to deliver business values which include effectiveness i.e. IT operations efficiency and cost effectiveness, adaptiveness i.e. flexibility and elasticity as well as responsiveness i.e. agility and manageability. All these business values will be addressed in details under Section 4 – Values of SDDC for IT Delivery and Business. Although SDDC can deliver all the business values as mentioned above, other new styles of IT like big data analytics and VDI can only yield effectiveness values i.e. IT operations efficiency and cost effectiveness which is mainly due to virtualization. Since cloud computing includes some sorts of automation, it has also yields some values related to elasticity, agility and manageability.

### ***Reference Architecture for SDDC***

As of now, there is still no agreed understanding on what should be the SDDC reference architecture. Some organizations and IT vendors had started to develop their own SDDC architecture based on their understanding on SDDC and what their organizations are capable to contribute or deliver (VMware, 2013, HP, 2013, IBM, 2013). In view of these disparities and after literature reviewed, the author had proposed the following reference architecture for SDDC:

## Proposed Reference Architecture for Software Defined Data Center



**Figure1:** Proposed Reference Architecture for SDDC

The author (2014)

Proposed SDDC reference architecture consists of three layers i.e. demand, delivery and supply layers as well as two supporting pillars i.e. service and security management pillars. Following sub-sections described each of the layers and pillars.

### Demand Layer

This layer includes all the service requests and portal that a user interacts with in the SDDC. At this layer, the SDDC user can specify all the business and application requirements as well as the conditions in which the particular application should operate for examples, SLA, policies and cost considerations. This layer serves as the touch point for user to interact with other subsequent layers and other pillars.

### Delivery Layer

The delivery layer or sometimes also addressed as control plane is the heart of the SDDC. This layer includes SDDC controller, other resource controllers, business logics, Application Programming Interface (API) instructions, library or repository that contain all the pre-installed applications. Moreover, this layer also includes other non-SDDC cloud computing related modules like service broker that can interface with other external services like Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS). The delivery layer also includes SDDC infrastructure orchestration, automation and management functions. SDDC controller is the brain of the SDDC in which it works collaboratively with the business logics which have been programmed or defined into

the SDDC to make decisions and initiate all the SDDC actions via API calls. The API calls can trigger actions like asking orchestrator to load or orchestrate certain templates or workflows to be run, automating certain provisioning or de-provisioning of resources, loading specific applications from library into the resources provided, as well as interfacing with cloud service broker to import or connect certain external services.

### **Supply Layer**

Supply layer or sometimes also addressed as forwarding plane consists of all the virtualized and physical resources which include physical and virtualization platforms, server, storage, network and security infrastructure as well as data center facilities like power and cooling. All the virtualizable resources will be virtualized leaving behind only physical resources to support applications that cannot be virtualized. A resource unit that comprises fractions of server, storage, network and security will be extracted from the virtual resource pool to support and operate certain application workload.

### **Service Management Pillar**

This pillar refers to all the required IT Infrastructure Library (ITIL) or IT Service Management processes that are required to run a SDDC. Some of the management processes include incident, problem, change, configuration, release, capacity, availability and service level management. All these management processes are automated by software tools whereby they are managing all the components at each demand, delivery and supply layers.

### **Security Management Pillar**

The security management pillar refers to all the automated security controls and processes that are required to put in place to protect the SDDC. These controls and processes include performing security threats detection, events and logs correlation, security health check, patches updates and distribution as well as risk management.

### **How Software Defined Data Center Works?**

In order to illustrate how SDDC works, three scenarios are provided. These include (a) how a new application is deployed? (b) how an increase of application workload will increase the required resources? (c) how the existing application is decommissioned?

#### ***Scenario of New Application Deployment***

Before an application is rolled out, all the business and application requirements will be defined in a programmable interface of a portal. The portal interface will solicit information pertaining to the application which includes: number of tiers for the application architecture, database and middleware requirements, number of concurrent and named users,



location and mode of access, and others. Besides, SLA and policies requirements will be collected also through the portal interface. An example of SLA is like 99.99% availability or certain performance perimeter to be expected by the application. An example of policy is: when most of the provisioned resources for the application are exhausted or reached certain thresholds, other unused assigned resources will be relinquished and transferred to support the application workloads.

Once business, application, SLA and policies requirements are entered into the portal, SDDC controller with its supported business logics will calculate and convert all these requirements into a workload index which is similar to how Systems, Applications, Products in Data Processing's (SAP) SAP Application Performance Standard (SAPS) index is derived. The computed index for SAP's SAPS is used to determine what kind of server configuration is required in order to run SAP applications optimally. Similarly, the calculated SDDC workload index will determine how much resource is required to operate the workload effectively. For example, size of server or compute power, storage capacity, network bandwidth, security protection, power and cooling, and others will be determined. Then the SDDC controller will make API calls automatically to assemble all the resources required forming an integrated resource in order to meet the workload index or requirements. In SDDC context, all the various resources like server, storage, network, security, power and cooling are treated as fluid or dynamic resources and they are application-aware i.e. capable to be provisioned or de-provisioned automatically based on the dynamic requirements of the application (Volk & Frey, 2014).

Once the integrated resource is prepared, deployed and ready, the SDDC controller will perform an API call to load the specific application from the IT organization's library or repository into the integrated resource for operations. All the SLA and policies set initially will be applied accordingly. All these steps will be handled automatically with minimum human intervention which will reduce error caused by human. Human intervention is only required when decision needs to be made for example, approval to grant permission to deploy a specific application into SDDC or exceptional report generation for audit compliance is required.

### ***Scenario of Existing Application Workload Increases***

While the integrated resource is supporting the application workload, usage of the integrated resource components i.e. server, storage, network, security, power and cooling is monitored and managed based on the policy, SLA and performance requirements (Volk &

Frey, 2014).

When there is an unexpected surge of business demand that increases the application workload, SDDC controller will automatically evaluate the new requirement as well as the impact on the existing integrated resource. The SDDC controller will also validate all the SLA and policy set initially. Then the SDDC controller will refer to the business logics to determine what are the steps that need to be executed when certain condition are met or not met. For example, when an increased application workload causes the integrated resource exceeding its threshold, the SDDC controller will evaluate the policy. When conditions within the policy are met, additional un-used resources are supplied. Alternatively, un-used resources assigned to other underutilized Virtual Machines (VMs) will be re-claimed in order to support the surge of the application workload. All these steps can be completed without IT staff manual intervention.

In the event that the SDDC controller tried to re-claim some VMs which are hosted by the physical servers in the middle of the data center hot zone, this might further increase the already hot temperature. When this happens, the DCIA system can provide real-time summary information about the environmental conditions on all the areas of the data center. Equipped with this information, the SDCC controller can automatically select other cooler servers to be provisioned.

### ***Scenario of Existing Application Decommissioning***

When an existing application needs to be retired or decommissioned i.e. to be removed from a production environment, SDDC user can just initiate a command or by clicking and selecting from the portal interface. Once the instruction is received, the SDDC controller will issue API calls to unload, backup, archive, delete the application from the integrated resource or perform whatever steps required as defined initially. Then all the resource components contributed to the integrated resource for examples, server, storage, network and security will be de-provisioned and return back into the common pool accordingly. At the same time, data center facility's power and cooling will be adjusted or reduced accordingly. This is possible because the DCIA system can provide information to the SDDC controller about the power loading on the circuits as well as the mechanism to alter it (Ungar, 2014; HP, 2013). Again, all these steps can be performed automatically with minimum IT staff manual intervention.

### **Values of Software Defined Data Center for IT Delivery and Business**

SDDC's values include effectiveness, adaptiveness and responsiveness.

Effectiveness comprises of IT operations efficiency and cost effectiveness. Adaptiveness encompasses flexibility and elasticity of IT services. Lastly, responsiveness covers IT services' agility and manageability. Following sub-sections explained how these values are achieved through SDDC.

### *Effectiveness*

#### **IT Operations Efficiency**

With SDDC deployment, times for new IT services provisioning or existing IT services modification are reduced from months to minutes before end users can start using the IT services. This is because in SDDC, resources are deployed automatically from pools, speeding the time to applications or services rollout and providing unprecedented degree of IT operations efficiency (VMware, 2013; Kerravala, 2013). Besides, decommissioning of an existing IT application or service also takes minutes to de-provision instead of hours. Moreover, the deployment of ITIL or IT service and security management tools also contribute to IT operations efficiency as IT staff does not need to perform those management tasks manually which are error prone. When IT operations efficiency improved, IT staff and business users' productivity increased.

#### **Cost Effectiveness**

When SDDC resources are pooled and assigned intelligently, this can improve the resource utilization to more than 70% by extending the value of business investment (VMware, 2013; Kerravala, 2013). Before the era of virtualization or SDDC, infrastructure utilization was poor i.e. less than 30% in many cases. This is because the infrastructure was deployed in silos and there was no capability to share the infrastructure. Besides, most of the SDDCs make use of x86 server hardware which is cost effective. This will reduce the capital spend as well as the on-going maintenance expenses compared to some proprietary solutions. Moreover, with the deployment of SDDC, IT staff productivity improves as they do not need to spend much time on routine tasks for examples, manually deploy, provision or de-provision infrastructure resources like server, storage and network. This is possible because SDDC can automatically conduct its infrastructure tuning and configuration tasks that would otherwise require specialized IT skills (IBM, 2013). The net benefit is that the capital expenses (Capex) and operating expenses (Opex) are greatly reduced.

### *Adaptiveness*

#### **Flexibility**

The SDDC can provide a flexible platform for various types of applications inclusive services like high-performance computing, big data analytics, latency-sensitive applications, legacy applications and others. Besides, provisioning is automated by programmable policy-based software which is flexible. When business changed, workload demands and resource supplies will balance accordingly by adjusting the software layer rather than the hardware. Moreover, SDDC is flexible whereby its controller can redirect workloads automatically to other servers anywhere within the data center in order to minimize service outages or recovery time (VMware, 2013).

### **Elasticity**

In order to support evolving business needs in real time whereby business requirements keep changes or business service loads fluctuate in unpredictable cycles of demand, SDDC can reconfigure its resources elastically so that more important workloads are given higher resource priority according to the business rules (IBM, 2013). This value of elasticity is similar to rapid elasticity, which is one of the cloud computing characteristics (National Institute of Standards and Technology [NIST], 2011). According to NIST (2011), rapid elasticity refers to the ability that can scale resources up or down as well as outward or inward depending on the workload demands. Hence, adopting SDDC is one of the strategies in complementing the deployment of cloud computing.

### **Responsiveness**

#### **Agility**

Since SDDC can rapidly and automatically deploys optimal resources to the workloads based on fluctuated business needs, it provides agility to business as new market opportunities arise (IBM, 2013). Moreover, since SDDC can configure the infrastructure resources automatically, this capability enables IT architects and developers to focus on writing code and quickly test and deploy the solutions in order to accelerate software delivery. In fact, SDDC offers agility to business by reducing time to market from weeks to days (IBM, 2013).

#### **Manageability**

SDDC inclusive of ITIL or IT service management tools offer centralized management by enabling a single point of visibility, control and manageability. Prior to SDDC, infrastructure management has been performed in silos whereby each functional area of IT i.e. server, storage, network and security has no visibility or awareness on the other functional areas (Kerravala, 2013). This has caused troubleshooting and resolving IT issues

more difficult. Moreover, manageability is achieved when SDDC users can be self-serviced compared to going through multiple touch points or hands offs within the IT team in order to resolve issues or fulfill specific requests pertaining to provisioning or capacity enhancements (Raghuraman. 2013).

## **Factors to Consider When Adopting a Software Defined Data Center**

### ***Assess Your Needs for SDDC***

Before embarking on the SDDC journey, an IT organization should assess its needs for SDDC. SDDC offers various functions and values as depicted in the previous sections. Mapping the SDDC functions, values and needs enable the IT organization to make a more rationale decision in adopting SDDC. After the assessment, the IT organization might realize that it only needs server virtualization or even full fledged clouds or others. Assessing its own needs also enable the IT organization to chart out a vision and roadmap how to rollout SDDC in stages for example, may be start and stop on server virtualization or all the way to include SDDC or clouds.

### ***Do Your Own Research***

After identifying there is a need for SDDC, then doing your own research on SDDC is crucial especially for IT organizations that have limited experience in implementing virtualization, automation or cloud computing. Besides extracting required information pertaining to the organization like vision, mission, strategies, challenges, requirements, Key Performance Indicators (KPIs), budget and others, it should perform its own research on SDDC. These include the underlying technologies of SDDC from various vendors and maturity of the SDDC technologies in the market. Moreover, the IT organization should evaluate its own readiness to adopt the SDDC as well as suitability of SDDC for production environment, R&D environment or both. Furthermore, the IT organization should also consider the migration approach to SDDC, proof of concept, impact of SDDC on IT processes, capacity, security, compliance and business continuity or disaster recovery plans. On the other hand, the IT organization also needs to pay attention to some of the soft-factors. These include overcoming the resistance to change among IT staff when adopting SDDC as well as redefining future IT staff's job requirements and organization charts. Last but not least, provision of adequate SDDC training to IT staff on both technical and operational perspectives also deemed important.

### ***Choose a Standard-based Open Solution***

The IT organization should explore standard-based open solutions or invest in infrastructure that leverage on open standards such as OpenStack and Open Virtualization. This is because solution provider that offers standard-based open solutions or controller can facilitate better interoperability, choice and innovation for SDDC customers by integrating different software products and infrastructure together. Prior than this, a typical data center was an ecosystem of proprietary technologies from different solution providers. This situation significantly limits the customer's interoperability, choice and innovation. According to Kerravala (2013), a standard-based open solution is one of the most critical success factors for SDDC deployment.

### ***Choose a Trusted Partner to Work With***

Although SDDC market share's leader may seem the obvious choice but IT organizations should evaluate and choose a vendor that is committed and support SDDC or its principals (Raghuraman, 2013). This is because SDDC keeps evolving and only committed and supportive vendors can see it through. Moreover, committed vendor can also source resources to support the integration of legacy software and physical infrastructure with SDDC through programmatically controlled environment.

## **Conclusion**

### ***Answering Study Questions***

This study is guided by several questions posed at the beginning of the study. In answering what is the operational definition of SDDC, this study has addressed the question after completed some literature reviews and interviews. SDDC is defined as the *next generation of data center that can virtualize most of the data center resources as optimized IT services to be controlled by automated software in order to deliver business values which include effectiveness, adaptiveness and responsiveness*. As for what is the criteria and reference architecture for SDDC, this study has provided three criteria which include data center resources virtualization, automated software control, business values delivery as well as a reference architecture. This study also addressed another question that is on how a SDDC works. Finally, this study also delineated what are some of the values when an IT organization has adopted SDDC.

### ***Limitations of the Study***

There are some limitations within this study. Firstly, this study aimed to provide a

“glimpse” or high level information about SDDC which is not meant for detailed technical drill down. This study also tried to be SDDC product neutral and minimized the citation of SDDC vendor brands and their specific technologies. Secondly, SDDC encompasses some technologies or approaches which are relatively new but they are keep evolving and changing. Hence, some depiction within this study might be obsolete after a period of time. Thirdly, this is a qualitative study in which some interviewed transcripts had been collected. However, due to the article length’s constraint, the narration to capture how those comments emerging as main themes were not demonstrated. Some examples on such themes include: operational definition, criteria as well as values of SDDC.

### ***Future Research***

One of the future research that can be embarked on is the in depth study on SDDC especially how its controller are inter-linked with other resource controllers like server virtualization manager, software define storage, software defined networking and software defined security or protection. Moreover, how the controllers make use of the business logics as well as how a SDDC is first setup will be an interest to many. Secondly, SDDC enables IT staff to be more productive and their time or effort can best channel into innovative IT initiatives. However, this change might result some IT staff might lost their jobs due to redundancy. Hence, further qualitative or quantitative research can be conducted to evaluate their perception before IT organizations adopt SDDC. On the other hand, research also can be conducted on the job behaviors of the IT staff after their organizations have adopted SDDC.

### ***Conclusion***

SDDC is relatively new to many IT organizations since its inception in 2012 (VMware, 2013). However, it has started to evolve and more and more IT organizations are embracing SDDC as part of their IT strategies to achieve IT-as-a-

Service (ITaaS) and to meet business expectations. The values that SDDC bring looks promising, however IT organizations need to equip with the right knowledge to make the right decisions at every step of the implementation in a SDDC journey.

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