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An Enterprise Architecture Driven Approach to Virtualisation

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Abstract

Organisations have shown a significant interest in the adoption of virtualisation technology for improving the efficiency of their Data Centres (DC) from both the resource performance and cost efficiency viewpoints. By improving the efficiency of data centres we can sustainably manage their impact on the environment by controlling their energy consumption. The intentions are clear but how best to approach to Data Centre virtualisation is not. This paper proposes an integrated Enterprise Architecture and Information Infrastructure (EAII) driven approach to guide the Data Centre virtualisation. The EAII approach has been developed based on the review and analysis of well-known The Open Group Architecture Framework (TOGAF) and Information Infrastructure (II) model. The proposed integrated EAII approach seems appropriate to guide and align business strategy and virtualisation implementation for data centres of any size in any industry vertical.

Keywords: Information Infrastructure, Enterprise Architecture, TOGAF

1 INTRODUCTION

The typical data centre is considered to be a separate facility or part of an existing building which is dedicated to house server systems. These server systems then provide data or application services to an organisation or customer. The U.S. Environmental Protection Agency (E.P.A.) defines data centres as “facilities that primarily contain electronic equipment used for data processing (servers), data storage (storage equipment) and communication (network equipment)” (U.S. E.P.A. 2007 p.17).

Over the last two decades, the data centre has become a core component of our digital economy. In the coming decades, their utilisation and demand is expected to grow at unprecedented rates as more and more of our information is expected to be centrally stored and managed (Johnson and Marker 2009). Data centres provide critical services to governments, the private sector, financial institutions, media, universities and also internet services (Johnson and Marker 2009). Many governments around the world have moved to electronic tax reporting where all the tax information is stored, retrieved and processed in data centres (DC). Media companies are using data centres for storing and processing huge archives of video and photos. Universities are storing their student databases and performing research calculations in data centre. Internet services are increasingly being offered online such as e-commerce, internet banking, and social sites such as Facebook and Twitter that all operate from data centres.

The demand for electronic and web-based services is driving demand for data centres at unprecedented rates, and they are an increasingly important part of a nation’s economy. However at the same time – there is a crisis facing the data centre in what Brill (2007) calls the “economic meltdown of Moore’s Law”. Organisations have shown a significant interest in the adoption of virtualisation technology for improving the efficiency of their DC from the resource performance, cost efficiency and environmental viewpoints (Environmental Protection Agency 2007). DC virtualisation is aimed at establishing a shared and flexible computing environment, which allows creating and using a number of virtual machines from a single physical machine. Each virtual machine has its own CPU cycle, memory, storage and operating system. It enables the optimal use and sharing of underlying scarce hardware and software resources. DC virtualisation typically involves the virtualisation of DC servers. It can also be aimed at enabling Software as a Service, Platform as a Service or Infrastructure as Service for a cloud computing platform. However, the challenge is how best to adopt virtualisation in improving the efficiency of data centres (Star & Ruhleder, 1996; Ciborra & Hanseth, 2000; Hanseth & Lyytinen, 2010). There is a need to develop a systematic framework or approach to guide the virtualisation adoption for DC. The aim of our research is develop such a framework or approach. This paper describes a conceptual analysis of data centre efficiency and proposes an integrated Enterprise Architecture and Information Infrastructure (EAII) approach to guide the DC virtualisation.

2 BACKGROUND

As a society we often consume the services and data provided by data centres without concern to the underlying crisis which surrounds their energy efficiency. With demand for data centre services outstripping the supply of capacity in data centres, data centre operators are expanding their current facilities and building entirely new ones (Datacentre Dynamics 2011). With this growth comes higher energy demand, and with energy demand comes increased Greenhouse Gas emissions from the electricity generation. Electricity is still primarily generated from non-renewable resources such as Coal and Oil, with only approximately 16% of worldwide electricity coming from renewable resources such as hydroelectric, wind and solar (REN21 2011). Clearly, there is significant scope to reduce Greenhouse Gas emissions through a reduction in electricity consumption by data centres.

To understand the significance of data centres and their impact on the environment through energy consumption consider the following facts. Datacentre Dynamics (2011) conducted a survey of 100,000 of the world’s largest data centres. Their combined energy consumption was 31GigaWatts of electricity, and this is expected to increase by 19% in 2012. This amount of electricity is enough to power 23 million homes. The number of data centres worldwide is expected to increase by 7% in

2012. Some countries such as Turkey are seeing growth in existing data centres at 60% per year, whilst South-East Asia is seeing data centre capital investment at 118% year on year (Datacentre Dynamics 2011).

Worldwide, the amount of energy consumed by data centres is estimated to be as much as 3% of total energy consumption – which is a similar amount of energy used as the entire airline industry (Brill 2007b). Each 1% increase in electricity usage worldwide is enough to require seventeen 1000MegaWatt base load power plants (Koomey 2008). During the period of 2006 to 2011, the number of users on the internet doubled to 2.11billion (Internet World Stats 2012). With the increased number of internet users comes increased demand for data centre services.

It has been argued that virtualisation has the ability to realise energy efficiency saving in the data centre and in turn reduces their environmental impact through greenhouse gas emissions. Virtualisation also allows a more sustainable growth strategy for data centres through server consolidation, allowing better use of existing facilities rather than extending or building new facilities. In the following, we explain ….

2.1 How Virtualisation Affects Energy Efficiency

General data centre efficiency refers to the facility infrastructure such as ancillary services and additional efficiency measures implemented on the IT equipment side. Greensburg et al. (2006) conducted a study of 22 data centres and provided some best practice recommendations for energy efficiency from an infrastructure perspective. Some of their key recommendations included better use of ‘blanking panels’ sealing cable opening to optimise the hot isle and cold isle arrangement typical in data centres. They also suggest the use of right-size cooling systems. When designing data centres most designers tend to oversize the equipment capacity for longevity – however this results in inefficient operation of the cooling system and a waste of energy. Instead Greenburg et al. (2006) recommend the use of upsized ducting and fans, and right-sized chiller plant (the external air conditioning unit) – allowing for future expansions. They also recommend capitalising on free-cooling wherever possible – such as using external air to cool (where low outside temperatures exist) the data centre rather than using the energy intensive chiller plant.

Brill (2007b, 2007c) highlights a number energy saving mechanisms in his papers on high density computing and energy efficiency/productivity. He suggests a number of easy targets for improving the energy efficiency of data centre including enabling power saving features on servers. These features are often disabled in the factory for a number of reasons. Some examples include: If not enabling these features all the time, then enable power saving features in off-peak hours and on weekends, consider raising the ambient temperature in the data centre by a few degrees, as this often has little impact on server reliability, identify poorly coded software running in the datacentre, examine the lack of interoperability (data sharing) and patch the software to later versions to reduce energy wastage on excess processor cycles.

The U.S. E.P.A.(Environmental Protection Agency) (2007)’s report to congress on data centre efficiency also detailed some of the current best practice for energy efficiency in the data centre with a focus on emerging opportunities for energy efficiency. Based on a scenario analysis, U.S. E.P.A. calculated the approximate energy savings from applying the concepts outlined for three specific scenarios:

1. Improved Operation – improve the efficiency beyond the current trend, such as adopting more energy efficient servers, eliminating unused servers, and enable power saving features
2. Best Practice – efficiency gains from the most energy-efficient technologies of today such as consolidation, energy efficient servers, improved power equipment efficiency, free cooling
3. State-of-the-Art – maximum efficiency gains such as aggressive consolidation efforts and on-site power generation methods

U.S. E.P.A.’s report showed that the traditional focus of data centres providers was to minimise energy consumption via hardware mitigation tactics, and these tactics still apply today as well.

However after exhausting all the practical energy gains they could achieve, their attention shifted to virtualising their servers. Virtualisation has roots in a number of articles such as the work of Graupner, Kotov and Trinks (2002) on resource sharing in virtual data centres. Graupner, Kotov and Trinks describe virtualisation as a way to abstract resources at a higher level. Business needs, workflow and applications are all hidden from the actual platform architecture and encapsulated within the virtual environment. Graupner, Kotov and Trinks highlighted the issues and challenges facing virtualization deployment on large scale such as management and control issues. These scholars explored the idea of massive instance service deployment where they discuss the infrastructure required for such a system.

The literature has shown virtualisation to be effective in improving data centre efficiency. Talaber et al. (2009) showed the approximate energy and cost savings that can be realised through a standard consolidation effort. They conducted and analysed research on the average server utilisation and found that volume servers (the most common server in the data centre) are more efficient when moderately to fully-loaded compared to when idle. The amount of energy they use increases at a much slower rate than the processor utilisation does. They also outline a basic consolidation strategy which we will extend later in the paper.

A typical advantage of a consolidation strategy using virtualisation is reducing the number of physical servers. By reducing the number of physical servers the energy consumption is reduced whilst still doing the same amount of compute work. Another advantage of consolidation is the freed-up floor space in the data centre. There is also the opportunity to facilitate shifting loads between servers and data centres to balance the overall data centre load and make the most efficient use of the compute resources available (Talaber et. al. 2009 and Bouley 2010).Uddin and Rahman (2010) also highlights some of the advantages such as an environment for testing applications, encapsulating legacy applications, and the ability to run multiple operating systems on a single piece of hardware.

In addition to the efficiency advantages of virtualisation using consolidation, load shifting and balancing. There is also performance advantages gained using virtualisation technology, such as the ability to establish up new servers within minutes in a large-scale deployment scenario (Graupner et al. 2002). Data centres no longer need to control resources. Instead customers can directly start and stop virtual machines and directly control virtual resources abstracted through the virtual layer which they have leased in the data centre. This increases application performance and functionality utilising virtualisation technologies.

Customers and no longer need to wait days to launch new applications either because business services are accelerated by spinning-up virtual services using existing hardware. This avoids the need to traditionally acquire new hardware, configure the server, and install the operating system which used to take days (Talaber et. al. 2009). Customers also receive better Return on their Investment by utilising their existing capital hardware more efficiently.

Virtualisation technology has the ability improve the efficiency of the data centre. Once implemented organisations may believe they have realised the complete efficiency and performance benefits available from virtualisation – however, this is not the case. Virtualisation is an ongoing exercise to continually improve performance and efficiency throughout the data centre. The Virtualisation Maturity Model (Lester, Alessio, Ansbergs, et al. 2011) provides a gauge to measure current virtualisation maturity and provides the basis for organisations to plan their next phase of maturity.

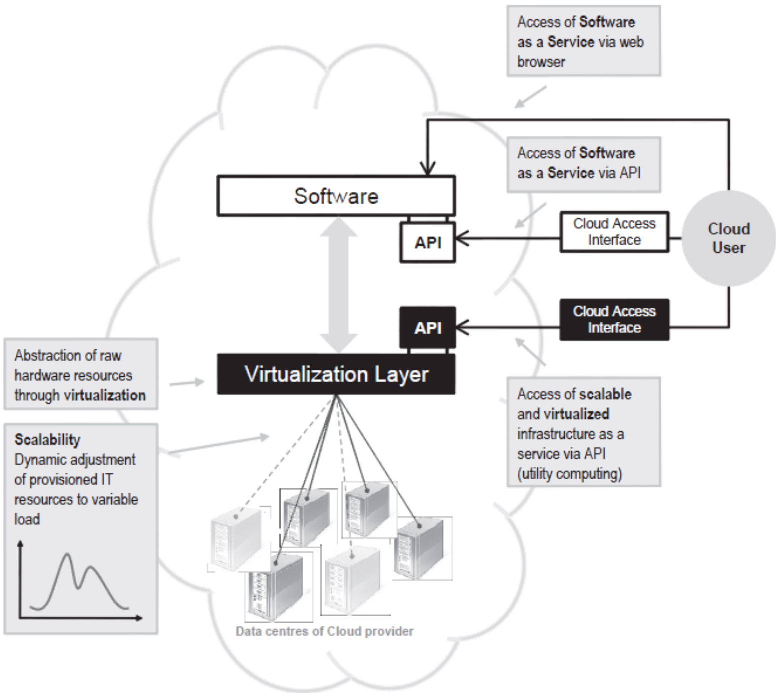

Figure 1 – Cloud Providers use of Virtualisation technologies
(from Stanoevska-Slabeva and Wozniak 2010 p.50)

Virtualisation is also linked to cloud computing in two ways (see figure 1). Firstly, virtualisation is a pre-requisite for cloud computing. The abstraction of hardware resources in virtualisation is required for moving to cloud environments, such as is the removal of hardware dependencies from the operating system (Uddin and Rahman 2010). Secondly, cloud computing providers operate on a virtualised platform. The virtualised platform provides the required load balancing, scalability and hardware recovery features which are essential to providing a reliable cloud service (Stanoevska-Slabeva and Wozniak 2010 & Feuerlicht and Govardhan 2009).

The dependency of virtualisation in the cloud shows just how important efficiency improvements using virtualisation technology are for large-scale application providers such as Amazon Web Services. They operate a virtual layer which abstracts the hardware resources for customers who then rent virtualised systems on top of the virtual layer. The boom in cloud computing demand will thus lead to more virtualisation utilisation in data centres.

The current research in the data centre area is closely linked to the work in general data centre efficiency. Current literature doesn't link the virtualisation benefits to environmental benefits and itdoes not clarify the huge energy saving that is possible using virtualisation technologies. In addition, the literature discusses a number of advantages and basic process as if virtualisation is a shallow concept that once implemented the virtualisation process is complete. Commonly, virtualisation is a section within a larger report or document on energy efficiency. Only a few articles outline some possible future directions for virtualisation, but there is disconnect between the ideas. This paper will instead focus just on the virtualisation technology and its practical implementation in the data centre. We question these limitations in the current literature and focus on highlighting that virtualisation is far from a mature technology – and there is scope to continue to improve data centre efficiency using virtualisation, even if data centres have started on a virtualisation strategy.

2.2 Virtualisation Cases

In this paper, we draw upon three real world cases of data centre virtualisation.

These cases are at opposite ends of a maturity spectrum, one organisation is taking an initial look at virtualisation and the other is a highly mature cloud service provider. The purpose of looking at them is to look at strategies and management practices, energy savings and environmental saving through the implementation of virtualisation. These cases of virtualisations are discussed below:

U.S. Kentucky Department of Education (KDE)

In the first case, U.S. Kentucky Department of Education (KDE) provides IT and data centre services to 174 school districts, and 700,000 users. The users are typically teachers and students. They had 200 servers located in a central data centre and other servers spread out over the school districts running specialised systems (Microsoft 2008). Like many public institutions, KDE was facing budget cuts in IT expenditure (for new servers), facing high maintenance costs for their IT infrastructure, and needed to provide improved educational IT services to the school districts – as IT becomes a central teaching tool in the classroom.

Among their 200 data centre servers, most were running well below 10% utilisation with some systems just setup to provide a single small load such as a cafeteria management system. The high maintenance and energy costs were preventing new IT initiatives, and reliability was emerging as a problem. KDE was clearly at a pre-virtualisation phase and needed a way to (Microsoft 2008):

- Reduce IT expenditure
- Improve reliability and reduce maintenance of systems
- Provide improved education, and
- Reduce energy expenditure and greener provide operation

Amazon's Elastic Compute Cloud (EC2)

The second case is Amazon's Elastic Compute Cloud (EC2) which is a large scale deployment of virtualisation in the cloud. EC2 is virtualised cloud layer which manages thousands of customer virtual machines. EC2 provides customers the ability to rent compute time and capacity in the cloud through instances which are virtual machines running Linux, Sun's Open Solaris and Windows Server operating systems (Amazon Web Services 2012).

Amazon has a number of both business and consumer customers. Some business customers include Reddit (online social site) and Netflix (online video streaming service) (Musil 2011). These customers use Amazon's Web Service system to host their web sites and in Netflix's case their video streaming platform. Customers can lease compute time and storage space in the Amazon EC2 cloud from a few cents per hour (depending on compute capacity required) (Amazon Web Services 2012). In any case, Amazon is considered one of the flagship cloud computing providers of today. Some of the key goals for creating a virtualised platform in Amazon's case were (Amazon Web Services 2012):

- Allowing customers to completely control virtual resources,
- Scalability of the customer's instances,
- Increased reliability of customer instances, and
- Security and disaster recovery in case of failures

University of Canberra (UoC, 2011)

The final background case is the University of Canberra (UoC, 2011) in Australia i which is a major university and contributes Australia's export industry of which higher education represent 20%. UC has over 10,000 students and 400+ staff and began in 2007 to development Business Strategies "The University of Canberra Strategic Plan 2008-2012ii attempted to cut costs and combat the threats from other international universities. Also they envisaged changes in technology where standardised business functions could be outsourced and provide to same service levels at a reduced overhead. As the report (3) stated "the project team did not set out to implement an outsourcing strategy". However, the project team was faced with more complex information processing and reducing server capacity the team chose to implement virtualisation of their data centre. The benefits of virtualisation for UC are:

- Affordable and reliable technology,
- Easy implementation and management,
- The ability to implement new technologies quicker,

- Provide improved education, and
- A 20% drop in energy consumption

It is clear from these three cases that the potential benefits of DC virtualisation are lucrative. However, the adoption of virtualisation is not straight forward and organisations need a less risky and systematic approach to virtualisation. Because of the risky and strategic nature of virtualisation we have used Ciborra's Information Infrastructure framework as a lens to make sense of the transformation to virtualisation.

3 INFORMATION INFRASTRUCTURE

The virtualisation of existing traditional data centres or information infrastructure is a strategic and transformational change. The state of the existing information infrastructure, in many organisations, looks like a chaotic collage (Ciborra and Hanseth, 2000). The transformational activities itself are complex and difficult to manage. It requires top-down and controlled approach to transformation in order to avoid any drift, i.e., deviation from its planned purpose. The challenge is how best to proceed with the DC virtualisation and ensure DC virtualisation activities are strategically controlled and aligned. DC virtualization requires a collective paradigm shift and the understanding of how each of the organisation's existent data centres or information infrastructure's components operates and how the related chained processes cut across the organisational boundaries. Accordingly, data centre's virtualisation is by no means an easy task to do and needs support from standards and reference models to move towards a virtual system. A successful virtualisation needs to be guided by a business strategy, driven by market forces, limited by technology innovations and needs to agree on industry standards and reference models. A Top-down strategic approach would be appropriate to control and handle transformational changes such as DC virtualisation. The Ciborra's (2000) Information Infrastructure (II) model (Figure 2), suggests the "Top-down Strategic Alignment" driven approach, and so its in alignment with our reasoning in this regard.

The concept of 'Information Infrastructure' was introduced in the early 1990s adding a focus on networks and infrastructures to the prevailing organizational systems concentration of IS research and allowing for emergent perspectives on information systems development (Star and Ruhleder 1996). The notion of 'information infrastructure' received limited attention through the 1990s and 2000s but has re-appeared in more recently literature.

The concern for online services in the 1990s and a business consolidation focus in the 2000s are only now giving way to Data Centres to innovate the globalisation of business. Information infrastructure is now re-defined as "a shared, open (and unbounded), heterogeneous and evolving socio-technical system consisting of a set of IT capabilities and their user, operations and design communities" (Hanseth & Lyytinen 2010 p5). In Ciborra's (2000) framework (Figure 2), we see an alignment of our analysis with different parts of this framework leading to a sharp focus on the element of "Top-down, strategic alignment" to explain this can be achieved in a virtualisation context. Also how this develops "more complex IT, processes and standards"

The Ciborra II (Figure 2) model suggests the need for the top-down strategic alignment for the successful DC virtualisation. However, it does not provide any concrete guidelines on how to actually achieve top-down strategic alignment. EA is a strategic discipline that can be used in realising the top-down strategies. Therefore, we consulted enterprise architecture body of knowledge for help and reviewed a number of enterprise architecture frameworks (see Section 4). Based on our analysis, we identified that with Ciborra II and one of the enterprise architecture frameworks, can be integrated to answer our research question. Hence, the integrated EAII (Enterprise Architecture and Information Infrastructure) approach naturally emerged and is presented in this paper. The integrated EAII approach seems useful for guiding the DC virtualisation. The benefit of using the integrated approach is that it brings the best of the Ciborra II and Enterprise Architecture elements, and provides a holistic approach for the necessary top-down strategic alignment in the context of DC virtualization. One of the perceived disadvantages of using the Enterprise Architecture driven approach is that it requires enterprise-wide engagement and governance, which may be perceived as an overhead by the organisations. The next section discusses the EA approach.

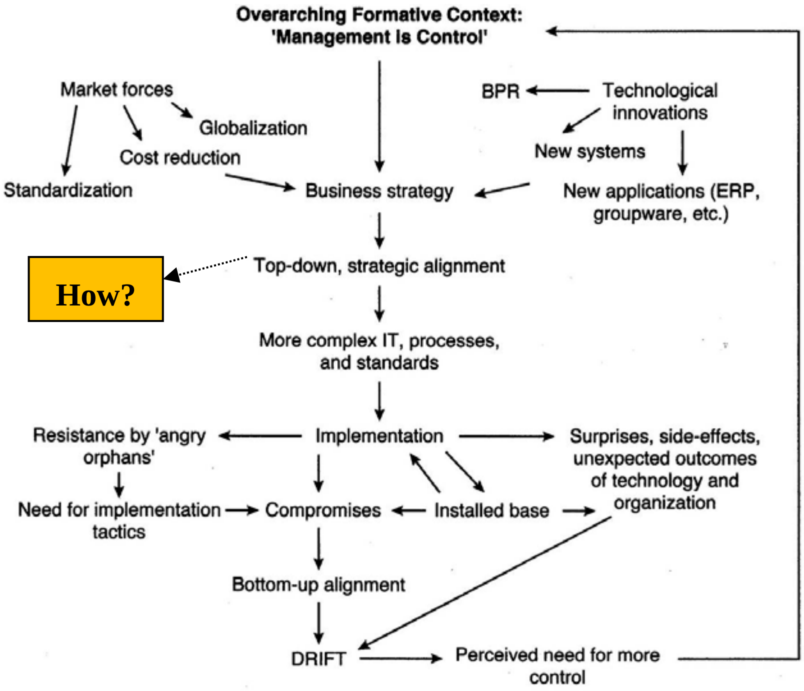

Figure 2 – The Dynamics of Information Infrastructure (Ciborra, 2000)

4 ENTERPRISE ARCHITECTURE

DC virtualisation is a strategic change. DC virtualisation requires a holistic, top-down and strategic approach rather than looking at the individual local component level virtualisation approach. EA is a strategic discipline that can be used in defining and realising the virtualisation strategies and roadmaps as indicated in the II model. Specifically, Enterprise Architecture is the "organising logic for business processes and IT infrastructure reflecting the integration and standardisation requirements of the firm's operating model" (Ross et al. 2006).

There are a number of Enterprise Architecture frameworks such as Zachman (1987), Federal Enterprise Architecture (CIO Council 2001), and The Open Group Architecture Framework (Harrison 2011) etc. The challenge is which EA framework is appropriate for guiding the DC virtualisation. After analysing the well-known frameworks, we believe The Open Group Architecture Framework (TOGAF) provides the most comprehensive method and guidelines to enterprise architecture capability (see Figure 3). For instance, The Zachman EA framework only provides the architecture taxonomy and does not provide any concrete EA guidelines and method as provided in the TOGAF. Federal Enterprise Architecture (FEA) is mainly focused on the implementation aspect of the EA as opposed to the actual development of the EA. Therefore, in this research, we identified and propose TOGAF as a framework to develop the DC virtualisation architecture according to the top-down virtualisation strategy.

The development of the DC virtualisation architecture is critical for a controlled, less risky and strategic implementation. TOGAF provides an EA continuum approach. The EA continuum can be used to define the DC virtualisation architecture from two perspectives: generic foundation architecture to organisation specific virtualised architecture in accordance with the top-down strategy.

The Foundation Architecture refers to the TOGAF Technical Reference (TRM). TRM (see figure 3) outlines the five generic architecture components and their relationships: (1) applications, (2) application platform interface, (3) application platform, (4) communication infrastructure interface and (5) communication infrastructure. Application component of the TRM refers to Information Infrastructure application. Application Platform refers to the platform that hosts the Information Infrastructure applications. Applications interact with the application platform via an Application Platform Interface. Communication Infrastructure component of the TRM refers to underlying infrastructure that allows communication between different Information Infrastructure applications through Application Platform. Application platform interacts with the communication infrastructure via communication infrastructure interface.

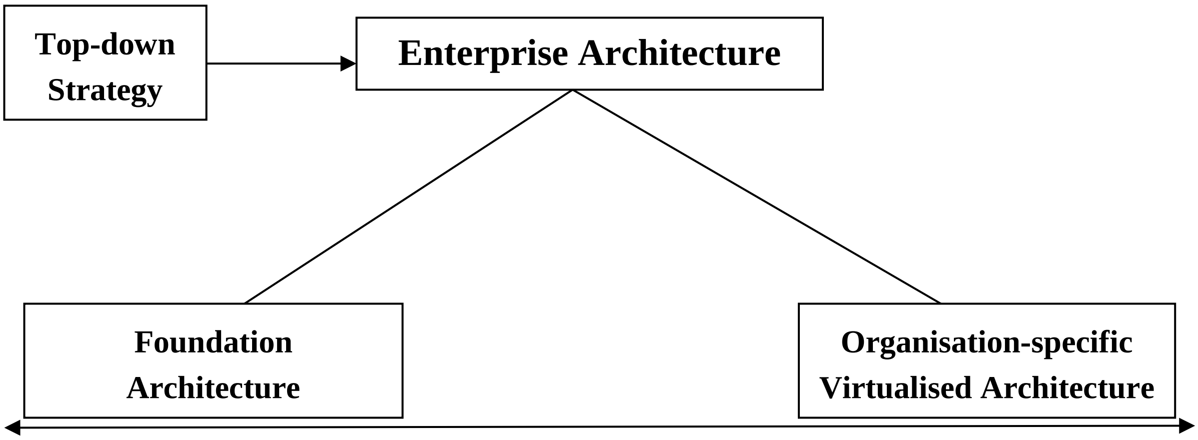

Figure 3 – Enterprise Architecture Continuum

TRM components can be used to develop DC foundation architecture. TRM can be used as a guide to architect the current (non-virtualised) and future DC virtualisation foundation architecture (see figure 4). For instance, which II applications, platform and communication infrastructure of the DC are currently virtualised and which will be virtualised in the future foundation architecture. For instance, in the case II applications, it can be used to identify which information consumer, development, brokering, management utilities and information provider applications are currently virtualised and which will be virtualised in the future organisation-specific virtualised architecture in accordance with the virtualisation strategy – ensuring top-down strategic alignment.

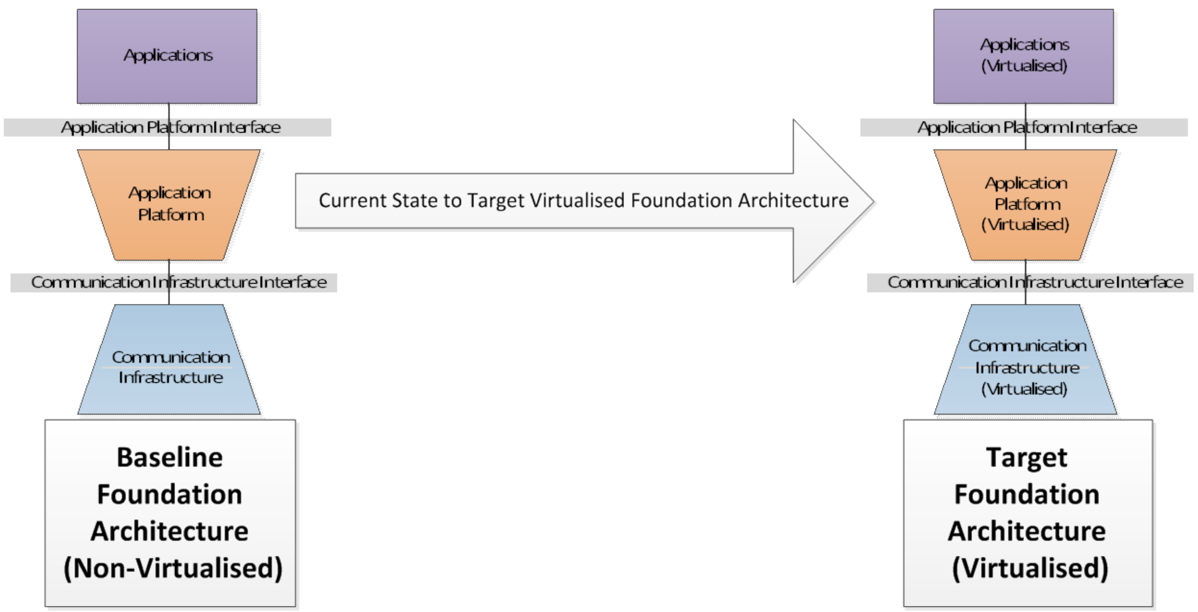

Figure 4 – Enterprise Architecture – (based on TOGAF 9.1 TRM 2011)

5 THE INTEGRATED EAII MODEL

The II model (Ciborra, 2000) suggests the need for developing business strategy, its top-to bottom alignment, the use of industry vertical specific standards (e.g. Health, Education, Financial). However, it does not provide any guidelines about how to realise business strategy and strategic alignment in the context of DC virtualisation (see figure 2). It also does not provide any foundation model or architecture that can be sued as a guideline for developing DC virtualisation II architecture.

We propose to use of the EA (TOGAF and the embedded TRM) for realising the business strategy and guiding the top-down strategically aligned DC virtualisation II architecture development and implementation. Hence, we integrated EA and II model to create the Integrated Enterprise Architecture and Information Infrastructure model (EAII - see Figure 5). The integrated EAII has been decomposed into three layers: Strategic, Integration, and Implementation:

- The top part "Strategic View" refers to the development of business strategy related to virtualisation.
- The bottom part "Implementation View" refers to actually implementation of the business strategy related to virtualisation.
- The middle part "Integrated EA with II" connects the Strategy to Implementation through the top-town strategic alignment via EA.
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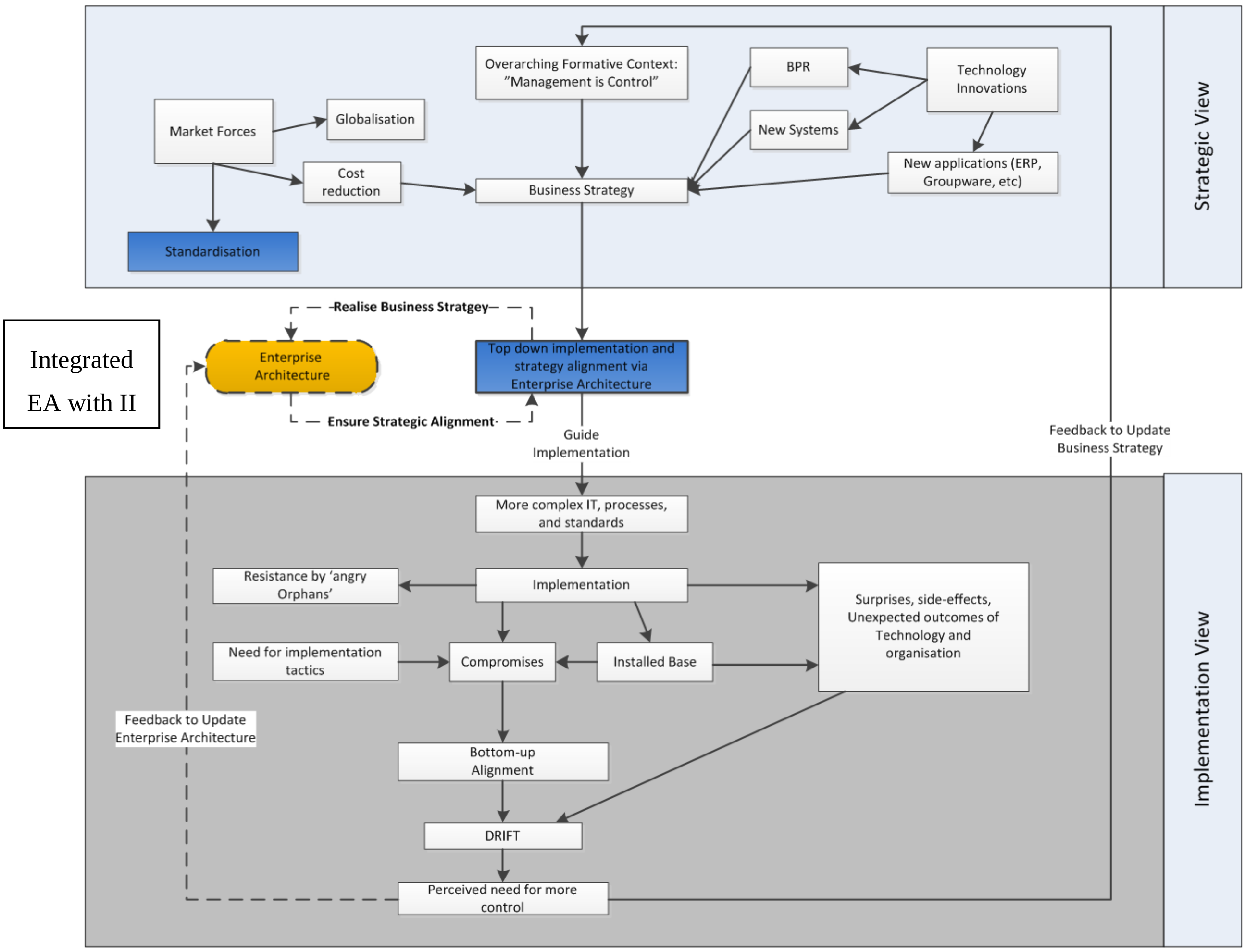

Figure 5 – The Integrated Enterprise Architecture and Information Infrastructure (EAII)

The integrated EAII (Figure 5) provides bottom-up feedback that may result in the adjustment of the business strategy (e.g. Feedback to Update Business Strategy) and/or EA (e.g. Feedback to Update

EA) due to needed drift or changes identified during the virtualisation implementation. Here the novel addition in the original II model (Ciborra, 2000) is the integration of EA with extra EA feedback loop, which is the main contribution of this paper. EA, in the middle layer, is critical for guiding the bottom implementation layer for ensuring the strategic alignment and architecture driven implementation of DC virtualisation. The TRM of the EA can be used as foundation architecture (as discussed in Section 4) with the specific industry standards to create an organisation specific DC virtualisation II architecture.

The virtualisation-enabled II architecture of a DC can then be then implemented (see Figure 5: Implementation View) through the execution of a number of II virtualisation projects. This integrated EAII approach would provide a controlled and top-down strategic approach to DC virtualisation as opposed to a local ad-hoc approach. The TRM, as foundation architecture, is appropriate for architecting virtualised DC of any size in any industry vertical. Industry Architecture refers to the industry vertical specific standards and architecture for DC virtualisation (e.g. Health, Education, and Financial). Organisations may choose common industry standards relevant to their domain. Finally, Organisation-Specific architecture refers to the actual organisation context specific DC virtualisation architecture, which is based on the industry, common and foundation architecture components.

6 DISCUSSION

It is critical that DC virtualisation activities require a strategic approach as opposed to an individual project and operational approach. It is more complex information systems than those described in literature (Talaber, Brey and Lamers 2009). Organisation needs to first develop virtualisation strategy and roadmap at the enterprise level and then should use an enterprise architecture driven approach to realise the virtualisation strategy and roadmap. The architecture of the virtualised DC needs to be first developed before actually implementing the virtualisation through the execution of a number of virtualisation project. In this study, we argue that the strategies like virtualisation can be realised by using an integrated EA and II approach. The EA was first introduced and discussed by Zachman (1987) in the IBM Systems Journal. The EA concept was further developed and The Open Group introduced a formal EA framework in 1995, which is called The Open Group Architecture Framework (TOGAF). TOGAF provides a generic architecture method, tools and references model for developing different domain and organisation specific architectures including information infrastructure architecture. The TOGAF provides an III-RM than can be used as a guide for developing an information infrastructure (II) architecture for the virtualised data centre. The II concept was introduced in the early 1990s adding a focus on networks and infrastructures to the prevailing organisational systems concentration of IS research (cf. Ciborra & Hanseth, 2000). It encompasses a growing acceptance of globally distributed IS enabled by the Internet and allows for emergent perspectives on information systems development (cf. Star & Ruhleder, 1996).Traditionally Information systems are assumed to be individual components however infrastructures evolve from the traditional deployment of technology and strategies (Hanseth, 1996) into dynamic and more advanced types of IS artefacts generically labelled Information Infrastructures (II).

Information Infrastructures received little accepted in the literature when first proposed however it has appear more frequently in recent literature as researcher and organisation's seek a rationale for innovation. Today businesses face challenges from unexpected areas like the global financial crisis, climate change, globalisation, data security and social media. Yet in the development and management of Data Centres they focuses on business imperative => solutions => benefits with little thought to interpretation and explanation. Ciborra and Hanseth (2000) defined II as "integrated sets of equipments, systems, applications, processes and people dedicated to the processing and communication of information". A more recent view of II is of "a shared, open (and unbounded), heterogeneous and evolving socio-technical system consisting of a set of IT capabilities and their user, operations and design communities" (Hanseth & Lyytinen, 2010, p.5).

7 CONCLUSION

Applying an EA umbrella to virtualisation through an II framework is a valuable tool to improving the efficiency of DC's from several viewpoints, namely strategic financial, operational and resulting in an environmental efficiency. This paper has used Ciborra's II framework as a lens the managing the concept of virtualisation and highlighted the opportunity of an EA to further gain efficiencies through standardisation

In order to account for the consequences of virtualisation and its effect on an organisation a framework such an II needs to be identified and applied. However the benefits of this function (virtualisation) are not fully realised unless the infrastructure is standardised (ie EA), otherwise the maximum potential gains of virtualisation or not achieved. The access of information and the efficiency of processing and presenting data is compromised without a standard architecture. This is turn increases costs, processing and larger infrastructure is required to process the same information.

Our investigation has highlighted that DC virtualisation requires a holistic and strategic approach rather than looking at the individual local component level. We highlight an extension to Ciborra model by incorporating the strategic discipline of Enterprise Architecture (EA) fitting under the organisation's business strategy and aligns with a top down strategy as depicted in Ciborra's model.

The ideas and concepts proposed in this paper offer a theoretical framework for the large scale adoption of virtualisation and cloud computing. These architectures are an aid the increasing the speed and volume of information processing, while reducing the complexity of the information structures, thus gaining efficiency. In future, we intend to further extend our research and apply the proposed conceptual framework in practice for empirical evaluation.

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