A Virtual Enterprise Model for Enabling Cloud Computing for SMMEs

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DECLARATION

This dissertation represents the author's original work. The author submitted this work for the Master of Science in Computer Science in the Department of Science and Agriculture at the University of Zululand. The author has not submitted any part of this work in the past for a degree or examination at any other university. All material used in the dissertation has been acknowledged.

Signature:

Date:

DEDICATION

To my family

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DEFINITION OF TERMS

AJAX	Asynchronous Javascript and Xml
API	Application Programming Interface
B2B	Business to Business
BPMS	Business Process Management Software
BPU	Business Process Utility
CLI	Command Line Interface
CCOA	Cloud Computing Open Architecture
CRM	Customer Relationship Management
EA	Enterprise Architecture
ECSA	Enterprise Cloud Service Architecture
ERP	Enterprise Resource Planning
ESOA	Enterprise Service-Oriented Architectures
IAAS	Infrastructure as a Service
ICT	Information and Communication Technology
ISV	Independent Software Vendor
MSE	Medium-Sized Enterprise
MSP	Managed Service Provider
PaaS	Platform as a Service
REST	Representational State Transfer
SaaS	Software as a Service
SMME	Small, Medium and Micro Enterprise

SOA	Service-Oriented Architecture
SOAP	Simple Object Access Protocol
VE	Virtual Enterprise
VM	Virtual Machine
VMM	Virtual Machine Manager
VPC	Virtual Private Cloud
VPN	Virtual Private Network

ABSTRACT

Information Technology (IT) is a major aspect of most businesses. It has proven to increase productivity, reduce costs and improve a company's bottom line. This is also the case for Small, Medium and Micro Enterprises (SMMEs), which are usually family-owned businesses, and due to their nature they cannot afford to purchase ICT (Information and Communication) infrastructure. It is therefore not economically viable for SMMEs to acquire their own ICT infrastructure. However, they have the option of taking advantage of cloud computing capabilities instead.

In cloud computing, dynamically scalable resources are provided as a virtualised service. Cloud computing is patterned after a utility business model where you use only what you require. The cloud is an evolving concept derived from a service-centric point of view. All the resources and capabilities of a cloud are offered to users in the form of service that can be accessed through the Internet. Users are billed on a pay-per-use basis or through subscription. The cloud adopts virtualisation, a service-oriented architecture, infrastructure scalability, the web and utility computing as the underlying concepts to provide on-demand services.

This research work is an attempt to use the virtual enterprise (VE) concept to enable SMMEs to respond quickly to market opportunities and customer demands. Cost is a key constraint for African users of technology, thus our business model addresses such challenges. The largest percentage of users of the proposed VE model use mobile devices, because its design addressed challenges associated with generic cloud and mobile cloud. These are some of the ways in which the design of the proposed VE model is atypical.

Our VE-enabled cloud enterprise architecture for SMMEs is evaluated against the Amazon EC2 pricing model to prove that our pricing model is more suitable for SMMEs. This model is based on the realisation that it is not economically viable for SMMEs to acquire their own private cloud infrastructure or even subscribe to public cloud services as a single entity. The pricing model obtained from our proposed business model shows the benefits that are derived from using the VE cloud model over subscription to a public cloud as a single business enterprise. The pricing structure of our VE cloud model is up to 17.82 times more economical compared to the equivalent Amazon EC2 instance type pricing model. The results obtained show the benefits that are derived by integrating the VE alliance concept with the cloud computing concept. This is shown by evaluating our architecture through one of the open access cloud platforms.

CHAPTER 1
INTRODUCTION

1.1 OVERVIEW

Worldwide, small, medium and micro enterprises (SMMEs) contribute to monetary growth and upgrading equitable advancement (Christopher, 2008). Their service potential at lower capital cost has been the major advantage of the sector. The SMME sector's employment intensity is much higher than that of large enterprises. SMMEs represent over 90 per cent of overall enterprises in nearly all economies and are identified as the major factor in driving the highest rates of employment growth.

SMMEs account for the main share of industrial manufacturing and exports (Ayanda & Laraba, 2011, Kumar & Sardar, 2011; Sharma, Mehra, Jola, Kumar, Misra & Tiwari, 2011). What appears to be the major constraint to the development of SMMEs in many developing countries are limited access to finance, technology and markets, and lack of management skills. Access to and awareness of business information is also major constraints to the development and growth of SMMEs in developing economies. In the current e-business environment, individual enterprises, including SMMEs, cannot continue to exist as individual entities. It is crucial that SMMEs connect effectively with their customers and partners. These enterprises require a certain way of e-business interaction with their partners. The virtual enterprise (VE) business concept, also termed the networked organisation, includes distributed business utilities and functions, outsourced to associates who work with the organisation to offer services to end customers. The VE model is one such business environment that can facilitate cloud computing for SMMEs.

Emerging technologies, including cloud computing, have the potential to transform and automate the business processes of SMMEs and allow them to connect with trading customers and partners in international networks (Dai, 2009). In a rapidly shifting world where businesses are looking for greater agility in their operational and decision-making processes, cloud computing gives an extraordinary opportunity to deliver the Information Technology (IT) agility that organisations require. Cloud computing has changed and will keep on changing the role of IT in organisational structure. There are two major factors at play – the technology aspect and the organisational aspect (Mvelase, Dlodlo, Williams & Adigun, 2011b).

On the technology side, cloud computing represents a shift from highly specialised, advanced technologies to clustered, simpler on-demand technologies. This shift requires a corresponding change in the kinds of expertise that IT personnel possess, with less emphasis on technical know-how and more emphasis on real-time service management, end-user communication and a basic understanding of the economics of cloud usage. On the organisational side of things, one can expect a shift from internal IT towards managed service providers (MSPs), as well as an overall reduction in the need for personnel for the day-to-day running of IT.

A number of SMMEs have been using the cloud for some time already, and are the most important drivers of the fastest and largest growth curve surrounding cloud technology. Several SMMEs have contributed to the fast expansion of Software as a Service (SaaS) suppliers such as Salesforce.com. Nowadays SMMEs are looking to move their IT into the cloud, solely for the purpose of saving money. In addition to this, it mainly allows SMMEs more adaptability, a smaller existing framework and smaller resource budgets for buying in-house technologies. In the same way, SMMEs in developing markets are not burdened by traditional legacy framework, thereby reducing the difficulty of installing cloud-based solutions (Mvelase, Dlodlo, Williams & Adigun, 2011a). Regrettably, many cloud application providers and cloud computing providers are neglecting the rising SMME market and only concentrating on the main players (Lee, 2010).

In an attempt to find a solution to SMMEs' problems concerning the lack of growth, flexibility and agility, service orientation is a design paradigm which many enterprises have adopted in order to fight shrinking agility. Some implementations have been reported as successes and others as failures. Even for those success stories, however, finding a satisfactory solution to assist SMMEs in their businesses is a never-ending process, and there is no final answer to this problem.

This thesis attempts to find another solution to SMMEs' challenge of growth, flexibility and agility, but rather than reinventing the wheel, attempts have been made to find a solution by applying service orientation in a new and innovative manner. By doing so, the solution to the problem should in theory be confronted with fewer struggles based on a proven design paradigm. Consequently, this thesis proposes a cloud system based on Service-Oriented Architecture (SOA) and VE principles to overcome the problem that is faced by KwaNongoma arts and crafts SMMEs in KwaZulu-Natal, South Africa. The SMMEs are unable to grow their business due to limited funds, which hinders them from purchasing their own ICT infrastructure and employing dedicated people to look into their legal, accounting, human resources, etc. (Mvelase, Dlodlo, Mathaba, Krause & Kabanda, 2009). An initial research case study was conducted to determine the factors that impact on the growth and productivity of SMMEs. This research indicated the need for Information and Communication Technology (ICT) infrastructure in improving the productivity and global competitiveness of SMMEs (Mvelase et al., 2009).

ICTs are making a rising impact on business operations and provide distinctive opportunities for business success. However, organisations of different sizes and structures are adopting the opportunities provided by ICT at various speeds. Research shows that SMMEs do not take advantage of e-business and ICT solutions in the same manner as large organisations do. This exposes most SMMEs more to change economic conditions as they have comparatively lower competence levels.

The nature of SMMEs, because of their size, is that they do not commonly commit human and financial resources to investment in ICT in order to increase productivity and competitiveness. ICT is being used as a set of tools by several SMMEs to solve temporary operating issues rather than to meet permanent strategic objectives. ICT infrastructure provides many business opportunities, but still many SMMEs are not ready to adopt this infrastructure. A large number of SMMEs are not adopting e-business as the basis for business transactions and communications. However, ICT provides SMMEs with various benefits in increasing productivity and business growth. SMMEs can use ICT to manage complex business operations by considering ICT as the main driver of cost reduction (Dai, 2009).

1.2 CLOUD COMPUTING FOR SMMES: A USE CASE

Cloud applications are usually in the form of Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). Their primary target is end users – individuals, SMMEs or enterprises. Users do not have to own the infrastructure; they only pay for what they use (Mvelase et al., 2011b).

The SaaS model is particularly suitable for a planned services architecture that is positioned for SMMEs to provide cost-effective facilities to business, particularly to SMMEs who do not have resources for training budgets and high-end computing services. The service framework no longer runs on the premise of a customer's IT infrastructure, but is hosted in a SaaS provider's data centre and accessed via the Internet. Consumers can subscribe to or unsubscribe from the service framework as they wish (Dai, 2009).

The major benefit for consumers is that they make use of service architecture on the basis of demand, without the need to be able to afford the essential computing architecture that is required to run the software. In addition to this, cloud service providers also profit from the SaaS model by offering applications in the form of utility to consumers. This is comparable to common utilities such as power or water grids. SaaS providers can use economies of scale – they can provide the same cloud services to different service customers, therefore the required middleware and hardware only has to be acquired once and can be utilised for several customers indefinitely (Jaatmaa, 2010). The term SaaS is used for software services that are offered across systems such as the Internet.

The SaaS model can eliminate the need for purchasing a costly server framework. Complete cloud software applications are provided by the SaaS model, ranging from e-mail to organisational solutions for mobility. Customers are required to pay up front when using common software application models. The software can include many characteristics that consumers will not use, and in the majority of cases, this is not a cost-effective investment for SMME users. By establishing an environment where spending on IT is based mainly on facilities that are required, the cash flow of SMME operations will be improved (Dai, 2009).

1.3 PROBLEM STATEMENT

The adoption of ICTs by SMMEs is low due to the lack of relation between ICT firms and SMMEs outside the ICT sector. The ICT products available on the market are too complex and expensive. SMMEs usually have limited ability to make large investments in ICTs due to lack of financing (Alam & Mohammed, 2009). Cloud computing infrastructure is about the enabling of operational services based on an application programming interface (API).

SMMEs may not have sufficient resources to respond to a business opportunity or customer demand. To overcome this, SMMEs can engage in virtual enterprise (VE) collaboration to enable them to respond to varying market opportunities and react to customer demand to remain competitive. One of the defining characteristics of a VE is the collaboration of resources. To cope with temporary resource unavailability, a VE includes many members with identical capabilities, but this could lead to some resources remaining idle. In addition, the use of traditional outsourcing does not offer the VE the agility and control it requires. To obviate this, SMMEs should obtain resources from external sources. One of such source is cloud computing platforms. Access to these resources is not always guaranteed, or they may be too costly to access. We envisage a way of overcoming this problem by creating a VE-enabled cloud computing platform to enable SMMEs.

Due to the opportunistic nature of the VE business and the reluctance of the participating enterprises to make long-term investments, we argue that SMMEs participating in VE collaboration face the challenges of achieving the level of coordination of an extended enterprise without having prior long-term relationships within a supply chain and without the expectation of future economies of scale. ICT support for the coordination of services is missing in the VE that offers services (the service provider, or SP). Therefore this can be achieved by shifting the ICTs to the cloud, and hence adaptability, flexibility and agility can be realised.

In the SOA approach, applications are made by managing the behaviour of self-sufficient components that are distributed over an overlay network. The fact that cloud computing lowers participation and entrance barriers will help SMMEs to gain access to technologies and facilitate direct participation in SMME VE alliances. Cloud computing technology enables ICT solutions and e-business models to be crafted to allow SMMEs to gain access to ICT resources without purchasing the infrastructure.

Cloud computing architecture and VE architecture both utilise SOA and virtualisation as enabling technologies. It is against this background that we propose a VE-enabled cloud enterprise architecture aimed at SMMEs based on cloud technologies. This might provide them an opportunity to respond quickly to market opportunities and customer demand and give them the flexibility, adaptability and agility they need to remain competitive. Various VE architectures and cloud computing architectures have been independently proposed, but there have been no attempts to integrate them.

The following main research questions were addressed:

- How can cloud computing be applied to make a positive impact on the productivity of SMMEs?

To answer the main research question, the following sub-questions were addressed:

- Which VE model will be more cost effective for SMMEs to adopt if they are to benefit from cloud computing?

- How will deploying VE-driven Clouds for SMMEs enhance operational cost saving?

1.4 MOTIVATION OF THE STUDY

Cost saving is the key driver of the acceptance of cloud-based services. Nonetheless, research evidence indicates that some other business advantages of cloud computing are gaining ground. One of the major advantages of cloud computing is its ability to prepare an organisation well to respond and react to unexpected changes, or to simply add some new services as required (F5 Networks, 2009).

The power of enterprise collaboration from the VE model enables SMMEs to share their expertise. SMMEs can benefit from cloud computing as they do not have to invest capital in ICT infrastructure, therefore this concept provides them with opportunities to gain competitive advantage through technology at a minimal cost. The provision of resources on demand is beneficial to the VE set-up, unlike the traditional VE set-up where each participant offers his resources to the alliance.

The improvement in storage, processing power or technology offered by cloud computing enables innovations that were not possible before, therefore giving SMMEs the competitive advantage and enhancing their productivity. Cloud computing provide the agility and control that traditional outsourcers cannot offer. If an enterprise is not satisfied with the services of the cloud service provider, it can switch to another far more easily than changing IT outsourcers. The proposed cloud enterprise architecture will be the vehicle that will enable SMMEs to get digitally connected with their suppliers and customers at minimal cost, and it will therefore impact on business opportunities as well as provide a competitive advantage.

The cloud provides an environment where users can develop software services that improve coordination and encourage information sharing, not only in the organisation, but also among private and government entities.

1.5 RESEARCH GOAL AND OBJECTIVES

The main goal and objectives for this research are:

1.5.1 RESEARCH GOAL

The goal of this study is to develop a VE-enabled cloud enterprise architecture that will enable SMMEs to participate in a virtual operating environment.

1.5.2 RESEARCH OBJECTIVES

In order to achieve the main goal of this research, we employ the following objectives:

- To identify issues affecting SMMEs
- To identify existing VE models, that can be adapted to meet the acute infrastructural deficiency of SMMEs.
- To model a VE-driven cloud computing architecture custom-made or custom-tested for SMMEs and deploying a cloud for evaluation purposes.

Research Objective 1

Existing VE technology models were reviewed, which helped us to identify useful VE models that can be adapted to meet SMMEs' needs at both business and IT levels at optimised cost.

Research Objective 2

This was achieved by identifying relevant literature on existing VE architectures and cloud computing enterprise architectures to enable us to design VE-driven cloud enterprise architecture. A linkage between VE and cloud computing enterprise architecture was discovered. The transformation of cloud enterprise from virtual enterprise is facilitated by means of the Internet, SOA, web services, B2B and BPMS technologies. A conceptual analysis of existing VE architectures and cloud enterprise architectures relating to our study was conducted.

Research Objective 3

An experimental set-up of a VE-driven cloud enterprise architecture customised for SMMEs was deployed and evaluated.

1.5.3 RESEARCH PROTOCOL

Objective 1

To identify issues affecting SMME productivity

- A case study conducted in KwaNongoma on issues hindering SMMEs' productivity and growth was useful in assessing the above issue. Additional related literature was reviewed.

Objective 2

To identify existing VE models that can be adapted to meet the infrastructural needs of SMMEs

- The literature on VE models was useful as we were able to determine how to scale down to an advantageous model that could be adopted for our proposed architecture.
- The existing literature on VE architectures was also reviewed to help us find VE architecture components that relate to cloud enterprise architecture to enable us to design and deploy our customised cloud architecture for SMMEs.
- A conceptual analysis was done of existing VE architectures and cloud enterprise architectures relating to our study.

Objective 3

To model a VE-driven cloud computing architecture custom made or custom tested for SMMEs and deploy a cloud for evaluation purposes

- We designed a VE-enabled cloud computing architecture for SMMEs by combining the capabilities of both existing VE architectures and cloud enterprise architecture.
- Keeping in mind the financial state and the needs of SMMEs, we evaluated the cloud computing deployment models to choose a suitable one for SMMEs.
- We performed system design to be able to define the architecture, components, modules, interfaces and data for our prototype that satisfied specified requirements.
- We implemented and evaluated an experimental set-up of a VE-driven cloud computing architecture for SMMEs.

1.6 RESEARCH METHODOLOGY

1.6.1 DATA COLLECTION

A background study on rural communities and e-government models was conducted. This study spoke into a questionnaire to gather the information from both the community and SMMEs on their needs. The questionnaire was administered to three communities in KwaNongoma rural. These were KwaKhangela, KwaMeme and KwaSomkhele. Respondents were asked to give their opinions on how far their needs were being met and comment on how the current situation could be improved. The survey covered several issues related to health, energy, water, education, IT usage in the running of small businesses and transport, to name but a few. The questionnaires were arranged in sections to find out:

- The government services that were available in the deep rural area of KwaNongoma.
- How the community viewed these services.
- The levels of literacy and ICT literacy in the community.

Conceptual analysis

1.6.2 DATA ANALYSIS

The data were analysed according to the research questions parallel with prototyping. The findings of the survey showed that a higher percentage of SMMEs do not use ICTs in running their businesses. This is due to the lack of knowledge and affordability of such resources.

The conceptual analysis was done to find existing virtual enterprise and cloud enterprise architectures that can be used to develop a prototype of VE-driven cloud computing architecture custom made or custom tested for SMMEs.

1.6.3 PRIMARY AND SECONDARY METHODS

The main research method is conceptual design, where a VE-enabled cloud enterprise architecture custom made for SMMEs is designed to enable SMMEs to share IT resources, distribute responsibilities and capabilities hence become responsive to market changes and customer demand. The proposed architecture should provide SMMEs with the flexibility, agility and adaptability required for them to be able to cope with the rapidly changing market environment. We carried out a literature review and conceptual analysis in designing our architecture.

The secondary methods were: a literature review, and prototype. The literature review provided a theoretical background to cloud computing, virtual enterprise and other underlying technologies that make cloud computing possible.

A software prototype was used in evaluating our proposed cloud pricing model against the equivalent amazon EC2 instance type.

1.7 ORGANISATION OF THE DISSERTATION

Chapter 1: This chapter includes an introduction, the problem statement, motivation of the study and the statement of methodology.

Chapter 2: The background that broadly covers the related subjects to this study is presented. We highlight on business agility – the benefits of agility for a business to grow were shown. Chapter 3: Literature discussion on SOA and service-oriented cloud computing architecture, cloud computing architectures, VE architectures, and business models and value chains. Definitions and explanations of cloud computing and its enabling technologies for the virtual enterprise model and enterprise cloud are discussed.

Chapter 4: This chapter discusses model design and development.

Chapter 5: This chapter presents prototyping and evaluation.

Chapter 6: This chapter concludes our research work based on the results of the experimental set-up and its evaluation. Future work and gaps are also presented.

1.8 PUBLICATIONS ON THIS WORK

The following references are the publications from this work:

Mvelase, P., Oladosu, J., Dlodlo, N., Sibiya, G., Adigun, M. (2013). A comparative analysis of pricing models for enterprise cloud platforms. Published in IEEE Africon Conference Proceedings and IEEE Xplore.

Mvelase, P., Dlodlo, N., Makitla, I., Sibiya, G. (2012). An architecture based on SOA and virtual enterprise principles: OpenNebula for cloud deployment. Proceedings of the 3rd International Conference on Information Management and Evaluation. Retrieved from CSIR/http://researchspace.csir.co.za/dspace/handle/10204/5980.

Mvelase, P., Dlodlo, N., Williams, Q., Adigun, M. (2011). Virtual enterprise model for enabling cloud computing for SMMEs. Proceedings of the 2011 International Conference on Intelligent Semantic Web-Services and Applications, ISWSA '11. Retrieved from ACM Digital library/http://dl.acm.org/citation.cfm?id=1980822.1980835.

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1.9 CHAPTER SUMMARY

In this chapter we laid a foundation for our research study, hence the motivation for proposing cloud computing as a potential solution for SMMEs to be able to use technology for their business on demand. A well-spoken problem statement was presented. The problem formulation is presented clearly and briefly.

CHAPTER 2
BACKGROUND

2.1 INTRODUCTION

Nowadays organisations have to operate in a dynamically changing business environment. Cloud computing provides an innovative model of business where IT services are offered by partners and not by in-house members. In the organisational sector, cloud computing technology provides IT resources in the form of service to their customers. The actual development of cloud computing is in the business model and not in virtualisation, distribution or control. The best feature that cloud computing technology provides is a large amount of computing in a short period of time.

Cloud computing technology has gained ground in the technology market; however, the concept of developing a flexible and scalable solution of shared computing by means of the Internet has been around for more than a decade. Nowadays, cloud computing is increasingly replacing the very rigid service and software licence models, thanks both to an improvement in technological capabilities and to changes in marketplace demands (Mvelase, Dlodlo, Makitla & Sibiya, 2012). Research carried out in KwaNongoma in Zululand, South Africa, showed that small, medium and micro enterprises (SMMEs) did not develop their businesses because of limited funds which prevented them from acquiring Information and Communication Technology (ICT) infrastructure. SMMEs in developing markets are mainly unburdened by legacy infrastructure, which therefore reduces the complications in the deployment of cloud-based solutions.

The revolution of cloud computing has been influenced by the SOA. The SOA is a method for designing, deploying and implementing information systems such that the system is constructed of components that implement discrete functions of business. These components are termed services. These services can be provided and distributed across the enterprise and can be reconfigured into required business processes. Cloud computing and SOA improve the cost effectiveness and agility of an enterprise. This rental or subscription-based model is appealing to most enterprises, and this paradigm shift provides several benefits to SMMEs, the greatest being that SMMEs can easily increase their computing capacity without any start-up capital.

A computing paradigm that utilises SOA is grid computing. A study of existing scholarly sources reveals that the current cloud computing business model inherited the concept of the business model for grid computing (Abrahamson et. al., 2002). This chapter examines the body of scholarly research in order to present a historical view of the problem area of our research, which is the design of an appropriate model for cloud computing for SMMEs.

2.2 STATE OF THE ART IN THE VIRTUAL ENTERPRISE CLOUD COMPUTING BUSINESS MODEL

2.2.1 VIRTUAL ENTERPRISE ARCHITECTURES

Virtual enterprise architecture is presented in several works. The following literature on VE architecture was related to our study. Ahonena, Alvarengaa, Provedela and Paradab (2010) focus their attention on implementing system architecture with the functionalities of a virtual enterprise that follows the broker architectural pattern defined by Buschmann, Meunier, Rohnert, Sommerlad and Stal (1996). This pattern defines how the elements representing servers and clients can communicate with one another, through assistance of a particular broker component. This mediator element helps the consumer to set the services required without burdening them with unnecessary communication details. The architecture presents services offered by separate enterprises, but appear, from the client's perspective, as if they are all offered by only one enterprise. The selected architectural pattern makes it possible to extend the broker component from a simple message gateway to an intelligent agent, which, for example, negotiates with several service components in order to find the most appropriate service for a requesting client.

Jagdev and Toben (2001) discuss the major forms of collaboration (e.g. virtual enterprise, extended enterprise and supply chain). In the supply chain, participating enterprises are termed nodes; they agree to promote the supply and completion of a common end-product. Each node in the supply chain acts as both a customer and a supplier. A supply chain needs to be a sequential set of nodes, taking the form of an enterprise network.

Extended enterprise types of collaboration are evolutionary in nature. For example, consider organisations that have known each other and conducted business as a supply chain for some time. During this time a sufficient level of trust has developed to automate the sharing of day-to-day operational data. Each organisation will be ready to make an investment in modern ICT tools for the effortless information sharing; this implies their willingness to commit to a long-term relationship. Permitting the move of operational information from one partnership to the next differentiates the extended enterprise from other long-term partnerships (Camarinha-Matos & Afsarmanesh, 1998).

In a virtual enterprise type of alliance, the organisation responds to the globalised and dynamic markets of today. The main concern of virtual enterprise is to satisfy customer needs (Wood, Shenoy, Gerber, Ramakrishnan & Van der Merwe, 2011). These needs might be unique and wide (e.g. a large project-based contract) or small but with numerous distinctions. The authors give an example of a number of corresponding companies specialising in the maintenance and repair of household items which can form a virtual enterprise to provide a wide-range of services to its potential customers.

According to Aerts, Szirbik and Goossenaerts (2002), the power of VEs applies strong necessities to their ICT support. They argue that the ICT infrastructure must be extremely adaptable for the VE to be agile. The authors propose a mobile agent-based ICT architecture to offer the required flexibility. Mobile agents play a major role in managing the fulfilment of rush orders from when a customer places an order to order fulfilment. Customers place orders through a web portal, and once accepted, an agent is made responsible for filling the order.

For filling the order, agents are sent out to gather the necessary components. The agents are sent to those enterprises in the VE that have the capability to deliver the required components at the right time. An enterprise may require elements from other enterprises to create its own component; in that case another group of agents is sent out to supervise the delivery of these components. The agents are programmed to carry out the monitoring task, and also handle exceptions, for instance, if an enterprise in the VE cannot commit production capacity, for whatever reason, that it had previously advertised as available. The agent that comes to claim this capacity finds that it is no longer available and has to find another enterprise in the VE to provide the required capacity. This will of course involve some negotiations, e.g. to free the required capacity at the right time and arrange compensation. The agents take care of routine tasks, including negotiations, and in more complicated or unforeseen situations, a human decision maker may be needed. At the VE level there is scheduling and trading of services which determine whether it is possible to fill the order and allocate the proper enterprises to fulfil the order.

As Goel, Schmidt and Gilbert (2009) clearly point out, enterprise architecture (EA) deals with the structure of an enterprise, relationships and interactions of its elements. Enterprise architecture presents a holistic approach to reconciling IT and business concerns in an enterprise. The virtual enterprises architecture is built upon EA principles. They also mention that service-oriented architecture (SOA) in implementing EA has proved to be an enabler of VE at business and technology levels. The authors argue that enterprise architecture alone is not sufficient to overcome the three major challenges of VE which are flexibility, adaptability and agility.

2.2.2 VIRTUAL ENTERPRISE MEETS CLOUD COMPUTING

Virtual enterprise and cloud computing share some related concepts, e.g. virtualisation and SOA. In this section we discuss these concepts and their advantages for the SMME.

Business layer virtualisation is an enterprise architecture layer that uses an interface to provide business functions (Wood et al., 2010). A VE "is an ad-hoc coalition of independent enterprises and organisations, collaborating to achieve an explicit and specific goal of responding to a specific situation, by leveraging resources, skills and competences of members of the coalition. A VE has no dominant partner, legal existence or physical ownership of resource inventories. Members can join or leave the coalition at any time, but within contractual limits. A Virtual Enterprise is dissolved as soon as its explicit goal is achieved" (Amit, Heinz& David, 2010).

One of the major outstanding aspects of the VE is its opportunistic natural surroundings. SMMEs can employ the VE approach to meet unpredicted change and unexpected events, and in this way become agile. One of the useful outcomes is that unused capabilities or planned overloading can be made useful. To manage the provisional unavailability of a specific type of potential, a VE will take in several members with comparable capabilities (redundancy). This will assist the VE to attain agility. These aspects differentiate the VE from permanent inter-organisational structure such as the extended enterprise or the supply chain (Aerts et al., 2002).

Extended enterprises and supply chains can shift towards virtual enterprises in reply to competitive forces to better provide differentiation for the satisfaction of customers. They are then called supply chain VE or extended enterprise VE; however, it can be the other way round. The VE partners can build long-term alliances and can develop into a global organisation or supply chain if the undertaking of the VE has the potential of securing the market (Aerts et al. 2002). However, in actual fact the business fraction that connects the value chain is being outsourced to partners. Therefore cloud computing, i.e. outsourcing IT to third parties, becomes part of the Virtual Enterprise (Camarinha-Matos & Afsarmanesh, 1998). The main purpose of VE is to utilise information technology, such as networks of computer, business process/workflow management systems and service-oriented architectures, to achieve a dynamic business partnership that can easily respond to business opportunities as they occur. The formation of cooperation agreements between enterprises is not something new, but the use of IT to support the information networking is one of the features of the VE model.

The main reason for the enterprises to be engaged in a VE alliance is to provide the benefits of business opportunities and to control the core competencies. One other reason is that it requires less staff to deal with management and administrative details. The actual task is performed by the geographically separated partners who are connected together by means of computer software or hardware (Barnett, Presley, Johnson & Liles, 1994).

The coalition may gain benefits which they would not get if they were acting independently due to resource limitations. Above all, the key point to the formation of a VE is the prompt integration of business functions of contributing actors to enable them to respond quickly to customer demand and provide a new solution for an unpredicted opportunity. Communication between distributed sites is necessary for capturing a new opportunity quickly. Participating organisations establish a relationship through a suitable service provider. A VE may consist of a number of business process utilities or functions outsourced to various service providers. The use of cloud services by a virtual organisation can vary greatly.

A virtual organisation can be a start-up organisation that utilises an infrastructure cloud to install its computing services as the financial model is accurate; a pay-per-use method can be used by a virtual organisation at the time of its establishment, or the organisation can continue using this method throughout its entire existence. This type of organisation may be interested in expandable cloud resources; however, it does not require more advanced capacities (Winans & Brown, 2009).

Consider a virtual organisation that consists of several supply chain networks. This combined cloud makes use of a business interaction server. This server is hosted within a cloud that controls interactions in order to guarantee that they conform to contractual and legal policies. It provides all the participants with an interaction record for their contribution at the time of completion of the interaction. This virtual organisation might need the complete range of autonomic computing abilities in order to control the complexity of interoperating with several associate systems and accepting policy changes.

A virtual organisation consists of a large number of corporate customers who use entertainment and travel services that comply with corporate standards. The virtual organisation hosts all of these services. An individual can assume consolidation of the transactions and other clearing house operations that are the elements of this smaller ecosystem. Communication can be critical and to some extent long-lived and assisted by business policies, although the roles and responsibilities are likely to be simple (Winans & Brown, 2009).

Virtual enterprise is enabled by the Service Oriented Architecture (SOA). SOA also underlies the architecture of services in the cloud. It is essentially a collection of services; hence true service orientation allows cloud services to be componentised, pluggable, compatible and loosely coupled. These services communicate with each other. The communication might include simple data sending, or it could take in two or more services coordinating any activity. Both the cloud computing architectures (SOA) and VE need the means of connecting various services.

The provision of business functions is made possible by means of orchestration. Orchestration allows you to change the way your business functions as required, and to define or redefine any business process immediately. This method offers the business the agility, adaptability and flexibility needed to compete continuously in today's varying environment. In order to meet the demands of domain, orchestration should provide an adaptable or flexible method.

2.2.3 VIRTUAL ORGANISATIONS

The idea of virtual enterprise (VE) / virtual organization (VO) was not "invented" by a single researcher, rather it is a concept that has matured through a long evolution process. Some of the early references first introducing the terms like virtual company, virtual enterprise, or virtual corporation/organisation go back to the early 1990s, including the work of Jan Hopland, Nagel and Dove, and Davidow and Malone, hence these terms are used by different researchers interchangeably. However, concepts and definitions related to the VE/VO paradigm are still evolving, and the terminology is not yet fixed. There is still not even a common definition for the VE/VO that is agreed by the community of researchers in this area. Nevertheless, many real examples of VE/VO are already available and functional in different regions of the world, which indicates the importance of this area and the need for stabilizing the terminology and definitions for this paradigm, as well as research in developing a model of their life cycle, behaviour, and evolution. The area of VE/VO is particularly active in Europe, not only in terms of research and development, but also in terms of the emergence of various forms of enterprise networking at regional level. This “movement” is consistent with the process of European integration, which represents a push towards a “culture of cooperation”, but also with the very nature of the European business landscape that is mostly based on small and medium size enterprises (SME) that need to join efforts in order to be competitive in open and turbulent market scenarios (Camarinha-Matos, 2005).

Virtual organization integrates and generalizes several specialized constructs useful in the design of computer systems and networks. Virtual memory, virtual machines, and virtual circuit routing are well-known examples; less evident perhaps is that virtual reality also belongs to this family of constructs. But virtual organization has an even wider scope, in that it is also useful in modelling social systems. The wide applicability of virtual organization derives from some basic principles it offers for designing and managing systems to improve their efficiency and effectiveness. Anyone with a role in the design, development, deployment, or management of systems in organizations can profit from these principles. Characteristic of each stream is a new way of thinking about the organisation of computer based systems, but the confluence reaches beyond computers to embrace a variety of human activities. The notion of virtual organization touching on computers, operating systems, simulation, networking, management, community, even human personality—has the requisite generality. For theorists and practitioners alike, the main challenge is to chart the operative principles and the “boundary conditions” constraining its application. This special section captures some of the diversity of thinking about virtual organization, offering a first attempt at synthesis. Every scientific domain has its own peculiar conceptual and methodological culture that inevitably leads specialists to cast ideas in each domain’s idiom. So it is not surprising to find scientists from different intellectual backgrounds approaching virtual organization in different ways, which explains much of the difference in their vocabulary and treatment. The essence of virtual organization is the systemic ability to switch satisfiers in a decision environment of bounded rationality.

More and more organizations are looking at virtual organizations to address critical resource, personnel and logistical issues. There are many definitions of virtual organizations, including:

- A flexible network of independent entities linked by information technology to share skills, knowledge and access to others' expertise in nontraditional ways
- A form of cooperation involving companies, institutions and/or individuals delivering a product or service on the basis of a common business understanding. The units participate in the collaboration and present themselves as a unified organization.
- Virtual organizations do not need to have all of the people, or sometimes any of the people, in one place to deliver their service. The organization exists but you cannot see it. It is a network, not an office. To summarize these definitions, attributes of VOs include:
- A dispersed network of skills and capabilities--The structure of a VO is distributed among multiple locations resulting in the capacity of bringing in a wider pool of skills and capabilities.
- The use of telecommunications and computing technologies--These technologies serve as the enabler that makes a VO exist. One could argue that VOs have always existed--traveling sales staff, outsourced staff and staff working at home. However, what is new is that technology has made it much easier to support distributed work teams. Barriers of distance and time have been overcome by technology.
- Flexible, dynamic, restless--Organizations no longer are constrained by traditional barriers of place and time. VOs support dynamic changes to the organization including employee work environments and processing structures. Restlessness refers to the attitude to willingly change products and services, geographic dispersion, communication patterns. This has the potential of leading toward higher levels of innovation and creativity.
- Integration--When different individuals, groups and organizations get together in a VO, they need to interact collectively to achieve success. This implies greater levels of collaboration, cooperation and trust. Integration leverages the synergy of individuals.

Situations that are driving many organizations to examine and implement VOs include:

- A need for process innovation--This is often motivated by competitive pressures, stakeholder demands and other factors to achieve increased productivity and quality.

There is typically a 30 to 50 percent increase in productivity as result of implementing VOs.

- Sharing of core competencies--VOs help address the voids in an organization resulting from starting up, turnover and retirements.
- Globalization--Many organizations are finally realizing there is a vast pool of untapped skills, knowledge and abilities throughout the world.
- Mobile workers--VO concepts can help the numerous companies employing mobile workers such as auditors, consultants, salespersons and service technicians.
- Cost reduction--Improving efficiency often means reducing overhead, such as physical assets used to support traditional work environments or redistributing costs over several physical locations.
- Changes in employee values and attitudes toward work--Quality of life is a major factor particularly in attracting and retaining quality employees. Employers have realized that a balance of work and personal life, family requirements, personal fulfilment and flexibility are important considerations among employees.
- Costs and problems of traveling--VOs address transportation issues, such as unproductive commute time, traffic hassles, the cost of fuel and environmental impact of commuting vehicles.

2.2.3. 1 The Use of Virtual Organizations

Many organizations and governmental agencies have established virtual organizations. Below are descriptions of a number of them in the private and public sectors.

2.2.3.1.1 Private Sector Case Studies

Aventis (France)--One of the world leaders in pharmaceuticals and agriculture, Aventis was launched in December 1999 through the merger of Hoechst AG of Germany and Rhône-Poulenc SA of France. Its engineering department in the United States was made up of many technical islands that reported to different organizations and different businesses. There was no consistency in work quality, practical standards and little cooperation between any of the groups. In response, a virtual organization organized into five technical service groups (TSGs) and one technology group (TG) was formed. The TSGs were developed around process technologies and customer needs, not geography. The engineers in a TSG can be and are located anywhere in North America. The TG is based in New Jersey primarily because of the economies of a central lab facility. This new organization is highly mobile, focused on customer needs and aligned with business goals. It shares technology, information and best practices.

Dell Computers (US)--Companies are rapidly moving away from self-contained, vertically integrated organizations to virtual entities that rely on business partners to fulfil major parts of their supply chains. This means a company will outsource any part of its operations to companies that can more efficiently, reliably and cost-effectively implement the work. For example, most of the components in a Dell computer are made by other companies while Dell focuses on its strengths--marketing, customer support and integration of these components into the final computer products.

When buying a computer from Dell, the virtual organization includes the Dell customer service rep, assembly line and assembly crew, supply people for various components, the UPS truck and driver who delivers the computer and people from MasterCard who pay for it. All of the inventory in the system, regardless of location and ownership of the company, can be viewed as a single system. Benefits may include overall lower inventory levels in the whole system and better customer service. For example, Dell tries to keep as little actual inventory on hand as possible.

British Telecom (Great Britain)--British Telecommunications PLC is one of the world's leading providers of telecommunications services and one of the largest private sector companies in Europe. In April 2000, the company announced a reorganization of its activities into new, self-contained businesses that enable greater management focus. Process streamlining was initiated, concentrating on the way in which orders progressed through the organization. The preparation work was conducted in virtual teams where professionals from British Telecom and its consultants worked closely. Using the Internet and the extranet, British Telecom was successful in connecting the ordering system seamlessly to all the existing legacy systems in the organization.

Processing time was drastically reduced within the expected time frame. The company can deal with much greater volumes--three to four more than before--with the same number of people. A BT spokesman indicated: "With better information more quickly available, it is easier for us to convert leads into orders. Optimizing our electronic interface has vastly improved our collaboration with telemarketing companies."

Crowley Communications (US)--This public relations firm provides products and services such as press releases, brochures, photos and graphics. The firm has only one full-time employee, Jolene Crowley, who is in charge of contracting teams of people to work on projects as needed. These teams are spread around California and the rest of the United States and are made up of specialists linked by computers and telecommunications equipment. This virtual company partners with a marketing firm for larger scale projects.

Reuters Holdings (Great Britain)--This financial information services company created virtual teams with representatives from 12 companies around the world to work on user interfaces for the company. Facilitated by the signing of nondisclosure agreements, there has been savings in recruitment costs, staff benefits and overhead as a result of this virtual organization approach.

2.2.3.1.2 Public Sector Case Studies

US Department of Defence--All military services have constructed virtual battlefields as an integrated part of their military strategy. Besides training and mission rehearsal, these battle labs test weapons that have yet to be created. Often these battlefields are distributed and interactive. For example, war game participants are located at remote sites and use high-bandwidth telecommunication technology and high performance computing to simulate an armed conflict. Participants can provide online interactivity with real-time responses.

US Army--The Army Knowledge Online serves as a portal for army personnel to personalize content, access web e-mail and newsgroups, locate other army personnel, read army news, run web-based army applications and search all army web sites.

US Department of Agriculture (USDA)--USDA's Animal and Plant Health Inspection Service merged all 250 IRM employees throughout the agency's 11 units into a single organization. Instead of moving employees to a centralized location, they were left physically and budgetary where they were before the initiative began. Employees are funded by one unit and receive direction from another.

At the USDA's National Plant Data Centre, 90 percent of interaction is done via teleconferencing, e-mail and video conferencing. "Some of the team members have never met each other in person," a USDA representative said.

At its Agricultural Marketing Service, USDA avoided the costs of setting up a reading room by creating a virtual reading room online. This also significantly reduced Freedom of Information Act requests.

US Department of Energy--The department and its contractors uses advanced computer and communication technologies to manage a highly complex radioactive waste management project at Yucca Mountain, Nevada. The Yucca Mountain project has begun to implement "virtual teamwork" to provide more efficient and effective collaboration among employees.

US Social Security Administration--The administration links 36 sites of various sizes across the country in a virtual call centre operated by 3,800 full- and part-time employees, along with 4,000 more trained and equipped to back them up. Incoming calls across the United States are routed to whatever site has employees available to answer them. For example, someone from Baltimore may call the Social Security office in that city. If the representatives at the Baltimore centre are busy, calls are rerouted to the Birmingham, Alabama; centre assuming representatives there are free. This assists in levelling the workload and improving customer service by reducing busy signals. Last year, the call centre’s busy rate was a mere 7 percent, and the average time a caller waited to talk with someone was two minutes. In 1995, a study found that the average wait time of eight minutes among private sector firms was considered top-notch in customer service.

2.2.3.2 Technical and Managerial Issues

Several key technical issues surround VOs:

- The capability of the communications network--For example, the potential limitations on bandwidth for transmission. This has the impact of slowing down the necessary information flow and interactivity between the entities in a VO. Related to this problem is the reliability of the network and its servers. If the network is down frequently, it can have profound effects on the productivity of a VO.
- Hardware and software compatibility issues--For example, in a telecommuting scenario, home computers range in the type of hardware characteristics, such as processing power and memory. These inconsistencies often result in common applications being slow, difficult to use or even inoperative across the different computers.
- Computer security--Due to the multiple clients in a web-based architecture, there are many points of possible intrusion into the centralized applications and data sources of an organization.
- The dynamic nature of technology--This makes managing hardware and software upgrades a difficult task for any information technology manager in a VO.

2.2.3.3 Communication Issues

The communication issues are not necessarily technical in nature, but related to human factors. Members in a virtual team may find it frustrating that messages are misunderstood or not received by other members thereby resulting in inefficiencies. Areas causing these difficulties include e-mail slang and informalities, technical jargon, confusion over teleconferencing protocols and outdated distribution lists.

There is the problem regarding ambiguity about whom to include in the communications. To be conservative, a virtual team member may send messages to everyone on the team, which contributes to mailbox overload. On the other end of the spectrum, team members may inadvertently leave out important constituents in the communication loop, thereby leading to situations where critical information was not received in a timely manner.

The lack of face-to-face interaction and the absence of body language or vocal inflections tend to reduce the quality of the message delivered. Moreover, a receiver can misinterpret the tone of the message because of the way the message was constructed (e.g., use of capital letters, e-mail slang and icons, setting the level of importance as urgent).

Finally, there is a problem with store-and-forward asynchronous communication systems in that it often takes time to communicate. There is the delay in waiting for a response after a message is delivered. This may be an issue when critical information must be passed on in a timely manner.

2.2.4 CLOUD COMPUTING ARCHITECTURE

Zhang et al. (2009) propose a Cloud Computing Open Architecture (CCOA). The CCOA is a cloud computing-centric service-oriented architecture framework which bridges the power of SOA and virtualisation in the context of the cloud computing ecosystem. Seven principles of cloud computing architecture are also presented in this work. A new hybrid architecture style specified by a cloud service-oriented formula is proposed in this work, which includes basic architectural elements, service orientation and cloud principles.

Tang et al. (2010) explore the existing link between cloud computing and enterprise service-oriented architectures (ESOA) to realise cloud enterprise architecture. Cloud computing, a new paradigm of distributed computing, introduces many new ideas, concepts, principals, technologies and architectural styles into enterprise service-oriented computing. The ESOA style is an abstraction of concrete enterprise service-orientated architectures, which includes

SOA architectural elements, service design patterns as well as principles, and SOA quality attributes. It can be extended to a new style for realising enterprise cloud computing. Meanwhile, the principles and style of enterprise service-oriented computing facilitate the enterprise-wide adoption of cloud computing. Their work extends the ESOA style to a new hybrid architectural style, Enterprise Cloud Service Architecture (ECSA). The style is described by extending the enterprise service-oriented formula for ESOA. The study is noteworthy in that it combines both service-oriented and cloud architectural styles by specifying each element in the formula. Grigoriu (2009) views a company that is developed according to business process utility (BPU), virtual enterprise, cloud computing, enterprise architecture and service-oriented architecture as looking like a cloud enterprise architecture (i.e. a virtual enterprise with SOA-like architecture with its business functions, processes and IT resources supplied over the web by a cloud of business and IT service providers). Cloud computing covers both the IT applications and technology layers of enterprise architecture. SOA is an enabler of virtual enterprise, cloud computing and business process utility.

Hata, Kamizuru, Honda, Shimizu and Yao (2010) propose a dynamic IP-VPN architecture that runs on a virtual private cloud deployment model. It is connected to the users via IP-VPN on the Internet. There are different kinds of IP-VPN such as IPSec, L2TP or SSL-VPN. They assume that multiple protocol programmability on a single platform is one of external requirements to provide private cloud to enterprise networks at low cost. Agility is also required, which can be achieved through cloud computing environments as another external requirement. Cloud computing environments provide services by using virtual machines on one platform. This network structure will eliminate the use of corporate networks for the integration process to the virtual private network, and so further reduce cost.

What is extremely attractive is that cloud resources can be effortlessly incorporated into an enterprise’s current organisation infrastructure without having to deal with considerable configuration, address management or security concerns. Existing profitable solutions offer cloud servers as separate entities with their IP addresses space outside the customer’s control. In order to accomplish seamless incorporation, cloud platform architecture has been proposed by Wood, (2010) with the name of CloudNet. This architecture uses VPN that seamlessly and securely connects cloud and enterprise sites. VPNs are used by CloudNet to provide secure communication channels and to allow customers more control over network configuration and provision. The concept of a virtual private cloud is used to create a secure and flexible pool of resources, transparently linked to enterprise by means of VPNs.

Huerta-Canepa and Lee (2010) propose a virtual cloud computing platform using mobile phones where a mobile device can be a virtual cloud computing provider. They argue that a mobile device is resource constrained, and to solve that issue, mobile devices should obtain resources from an external source, in this case cloud computing. The proposed system uses a resource-sharing mechanism. If a user wants to execute tasks which need more resources than available on the device, the system listens for nodes in the surrounding area. If resources are available the system interrupts the application loading and modifies the application in order to use the virtual cloud.

2.2.5 CLOUD COMPUTING TO THE RESCUE OF SMMES

SMMEs are small, yet agile players that have an advantage over their larger peers due to their energetic, dynamic nature and ability to quickly respond to changes in the marketplace. Most of these companies have a mind-set of innovation and entrepreneurial focus, which makes them a very valuable force within the economy. At the same time, the SMME sector is also overwhelmed with challenges.

SMMEs often have to look beyond their personal workforce for IT expertise. By their nature, they tend not to have distinct IT departments with technology professionals. SMME employees tend to be all-rounders rather than specialists in a particular field. In the main, SMMEs realise that a certain IT expertise is needed in order to maximise the value of technology, and perhaps more pertinently, to minimise risks. But in many ways, the rise of cloud computing has provided a solution to this problem. There are many good reasons why SMMEs need to embrace cloud computing. There is a perception that cloud computing can reduce cost. In companies with limited personnel budgets, this gives cloud computing another opportunity to prove its worth. Rather than constructing and maintaining in-house data centres, SMMEs can simply delegate data storage and security to a cloud vendor. Cloud customers not only have access to advanced hardware and software tools, but also to the IT skills they need through their hosted services provider. This way, they can be sure that IT professionals rather than business generalists are keeping a close watch on their confidential data stores (Stibbe, 2011).

Cloud computing services may not provide the levels of reliability, manageability and support essential to large enterprises. Currently, many services are aimed primarily at SMMEs and consumers rather than at large enterprises. Nevertheless, there are definitive interests already being shown by enterprises in the SMME segment. Cloud computing, with the revolutionary promise of computing as a utility, has the potential to transform how IT services are delivered and managed. For all practical purposes, it is not a far-fetched idea to claim that apart from a locally installed computer operating system and a web browser, a good deal of today's small business technology requirements can be satisfied with the cloud-based offerings provided by cloud computing business models.

2.2.6 OTHER RELATED WORK

Rimal et al. (2011) observed that the biggest challenge in cloud computing is the lack of a de facto standard or single architectural method that can meet the requirements of an enterprise cloud approach. The paper explores the architectural features of cloud computing and classifies them according to the requirements of end-users, enterprises that use the cloud as a platform, and cloud providers themselves. They show that several architectural features will play a major role in the adoption of the cloud computing paradigm as a mainstream commodity in the enterprise world. The paper also provides key guidelines to software architects and cloud computing application developers for creating future architectures. As rightly observed in this work, no single architectural model of cloud computing will be suitable for all businesses. This accounts for why different cloud computing models have emerged for different business structures. A good number of researchers have proposed and investigated cloud computing models for various businesses and industries (Murphy and Goasguen 2010, Durowoju et al., 2011; Kuo, 2011; Patel, 2012 and Yoo et al., 2012), but suitable cloud computing models for SMME business structures in the developing world that are critically cost constrained are largely unaddressed. This research is an attempt to fill this gap.

As stated in Section 2.1, cloud computing has inherited some concepts from the grid computing paradigm. The business model is not an exception. An examination of the problem addressed in this work reveals that a number of researchers have proposed models from which the current work derives its concept. Abrahamson et al. (2002) discuss a resource management system for scheduling computations on resources distributed across the world with varying quality of service (QoS). The service-oriented grid computing system developed by the researchers is called Nimrod-G. It manages all operations associated with remote execution including resource discovery, trading, scheduling based on economic principles and a user-defined QoS requirement. The Nimrod-G resource broker is implemented by leveraging existing technologies such as Globus, and provides new services that are essential for constructing industrial-strength grids.

The authors presented the results of experiments using the Nimrod-G resource broker for scheduling parametric computations on the World Wide Grid (WWG) resources, which span five continents. Buyya et al. (2005) identify challenges in managing resources in a grid computing environment and propose computational economy as a metaphor for effective management of resources and application scheduling. The work identifies distributed resource management challenges and requirements of economy-based grid systems, and discusses various representative economy-based systems, both historical and emerging, for cooperative and competitive trading of resources such as CPU cycles, storage, and network bandwidth. It presents an extensible, service-oriented grid architecture driven by grid economy and an approach for its realisation by leveraging various existing grid technologies. The research shows that the concepts of virtualisation, service orientation and service brokering are not peculiar to cloud computing but existed in the grid computing paradigm.

Buyya et al. (2005) also present commodity and auction models for resource allocation. The use of the commodity economy model for resource management and application scheduling in both computational and data grids is also presented. Broberg et al. (2008) considered the inadequacy of traditional resource management techniques (resource allocation, admission control and scheduling) to address many shared grid and distributed systems, which consist of autonomous and dynamic distributed resources contributed by multiple organisations. The idea of collaboration and cooperation also has its root in grid computing. Distributed resources contributed by multiple organisations were used in the present research as in the work of Broberg et al. (2008).

Buyya et al. (2009) envisage computing as the fifth utility (after water, electricity, gas and telephony). Cloud computing is presented as the latest computing paradigm aimed at achieving this goal of utility computing. The paper provides the architecture for creating clouds with market-oriented resource allocation by leveraging technologies such as Virtual Machines (VMs), among other contributions.

Zhang et al. (2010) observed the state of the art and research challenges surrounding cloud computing. Research shows that cloud computing is a new paradigm for hosting and delivering services over the Internet. It is therefore attractive to business owners as it eliminates the requirement for users to plan ahead for provisioning, and allows enterprises to start small and increase resources only when there is a rise in service demand. Despite the fact that cloud computing offers huge opportunities to the IT industry, the development of cloud computing technology is currently in its infancy, with many issues still to be addressed. The paper presents a survey of cloud computing, highlighting its key concepts, architectural principles, and state-of-the-art implementation as well as research challenges. The research effort provides a better understanding of the design challenges of cloud computing and identifies important research directions in this increasingly important area.

Marston et al. (2011) discuss the business perspective as a crucial aspect of cloud computing. They argue that for cloud computing to achieve its potential, there needs to be a clear understanding of the various issues involved, both from the perspectives of the providers and the consumers of the technology. While a lot of research is currently being done on the technology itself, there is an equally urgent need for understanding the business-related issues surrounding cloud computing. Strengths, weaknesses, opportunities and threats of the cloud computing industry are identified by the authors. Various issues that will affect the different stakeholders of cloud computing are identified. The authors have issued a set of recommendations for the practitioners who will provide and manage cloud technology. The current work attempts to address the business aspect of cloud computing. Key guidelines to software architects and cloud computing application developers for creating future architectures are also provided in the work. As a new computing paradigm, cloud computing has received a lot of attention from enterprises and has being integrated or applied to enterprise architectures (Wang et. al., 2012). Integrating VE and cloud computing models to come up with a customised architecture is an attempt to fulfil the requirements of the SMME community.

2.3 CHAPTER SUMMARY

In this chapter, we presented the background to our research work and justified the need for customised cloud enterprise architecture for SMMEs. We discussed various research on virtual enterprise architectures to demonstrate their linkage to cloud computing. Virtual enterprise architecture is intended to satisfy customer needs through enterprise collaboration. Its weakest link is that it exists for an indefinite period of time. We also presented a case for the advantages of cloud computing for SMMEs. Based on this scenario, we discussed state-of-the-art of cloud computing, which includes the challenges of cloud computing as a business model, the significance of SOA in the cloud, concepts that form cloud enterprise, and the integration of cloud computing in enterprise architectures. We also discussed some other related work in the literature. We were then able to conclude that, although a number of research works have addressed the challenges of cloud computing, many of the existing solutions are not suitable for small enterprises.

CHAPTER 3
LITERATURE REVIEW

3.1 INTRODUCTION

This chapter discusses the literature review of cloud computing architectures and virtual enterprise architectures that relate to our study. We also observe the relation of SOA to cloud computing and virtual enterprise. Virtualisation as one of the key enabling technologies is also reviewed to discover its importance in the realisation of cloud computing. Ultimately, the role of business model and enterprise architecture is articulated.

3.2 ENTERPRISE CLOUD

Cloud computing is emerging as a major computing platform. It can help in resource sharing, where resources can include software, business processes, infrastructures and applications. Virtualisation is the major technology that enables the sharing of cloud resources. On the other hand, major existing platforms of cloud computing have not properly adopted service-oriented architecture (SOA). SOA provides the facilities of reusability, extensibility and flexibility. In this study, we combine the power of virtualisation and SOA in the context of the cloud computing ecosystem. A VE-enabled cloud enterprise is designed to enable SMMEs to form reusable and customisable cloud enterprise architecture. A case study of business and cloud is used to uncover the practical and business value of business processes and infrastructure provisioning services delivered via the Internet (Zhang & Zhou, 2009). We also present some possible value-added services – these services are related to the proposed cloud enterprise architecture to monitor structured planning and some other conferring exercises of cloud computing technology.

As a vital service delivery platform in the field of service computing, cloud computing provides environments to enable resource sharing in terms of scalable infrastructures, middleware and application development platforms, and value-added business applications. The operation model can include free infrastructure services and a platform such as value-added service models based on the concept of pay-as-you-go. Other models are infrastructure services that are fee-based with value-added application services or free services for providers but with the distribution of revenues generated from customers [Tang et al., 2010].

There are mainly four kinds of resources that can be consumed and generated over the Internet. These resources can be shared among users by leveraging economies of scale. Provisioning is the method of resource sharing with requesters on the network. One of the main goals of cloud computing technology is to leverage intranets or the Internet to specify resources to users (Zhang & Zhou, 2009). The first resource type consists of infrastructure resources, which include machine provision, storage and computing capacity. For instance, Amazon EC2 offers a web service interface that can easily configure and request capacity over the Internet (AmazonEC2, 2009). Xdrive Box provides users with online storage (Zhang & Zhou, 2009). Microsoft SkyDrive offers a free storage service with an integrated online and offline model. This model stores the private files on hard drives and allows users remote access to these files. In the area of computing power sharing, grid computing's main focus is to utilise parallel computing technologies to share computing power with others, based on the scheduling of tasks when the computers are inactive.

The second resource type in cloud computing technology is software resources. These software resources include development and middleware resources. Middleware resources include operating systems that are cloud-centric, databases, application servers, etc. The development resource includes design platforms, development tools, testing tools and open source-based reference projects. The third resource type in cloud computing technology is the application resource. The leading organisations in the information industry are increasingly shifting application and relevant data to the Internet. Software applications are delivered by means of a SaaS software model or mash-ups of value-added applications. For instance, Google uses the cloud computing platform to provide web applications for collaboration and communication. Google Docs moves productivity applications to the web, increasingly replacing heavy desktop applications. Thus, customisable and reusable cloud architecture is being developed to provide an environment for enterprises based on application. It is the major factor in the success of shared applications over the Internet.

The fourth resource type in cloud computing technology is business operations. Few applications can be represented as services, in other words inaccurately coupled tasks or sub-processes within customers' business processes. Business process sharing is a business-driven outsourcing application that supports reuse, composition and provisioning. Cloud computing technology includes a set of major technologies that address the sharing of resources based on the requirements of business (Zhang & Zhou, 2009).

In the areas of solution design and service provisioning, the following two major technologies could play a major role in the advancement phase: service-oriented architecture (SOA) and virtualisation technology.

Virtualisation technology controls how middleware images, applications and operating systems are allocated and procreated from an accurate slice of server stack or physical machines. These images can be turned around and placed into a production setting based on demand. Virtualisation technology may also help in the licence reuse of software applications, middleware and operating systems once a subscriber discharges his or her service from the cloud computing platform.

SOA is software and system architecture developed for addressing reusability, flexibility, computerisation and extensibility. In order to establish scalable platforms of cloud computing, we need to leverage SOA to form interfaces based on standards, extensible architectures of solution and reusable components. Establishing such a platform based on cloud computing technology is easy, as long as it can facilitate sharing of at least one of the resources.

3.3 CLOUD INFRASTRUCTURE VIRTUALISATION

In the cloud computing environment, virtualisation is made possible by two main approaches: the first approach is related to hardware virtualisation, which is related to managing hardware tools in a plug-and-play manner. Hardware tools can be removed or added without having any effect on the standard operations of other tools in the system. Storage or performance spaces can be dynamically altered due to these add-and-remove actions (Fujitsu, 2011).

The second approach is related to the virtualisation of software that makes use of software code virtualisation or software image management technology to allow the sharing of software. Particularly, software images can be created depending upon the amount of reusability of a set of system software that consists of applications, middleware and operating system. The other software technology virtualisation is dynamic code execution and assembly.

In this particular case, there are no software images. Code elements are copied dynamically from repositories and inserted in accurate places depending on business logic. For example, in the Internet application, a few elements of JavaScript code can be dynamically inserted and retrieved into a proper package of Ajax to create new features or functions for the web client.

By the same token, the programs on the server side can be integrated dynamically and executed depending upon the composition of elements of reusable code and just-in-time technologies of the compiler. With the expansion of parallel programming and multi-core technology, this technology of dynamic code assembly and execution will have various advantages. In particular, it will eliminate the needs of giant storage spaces for software images, development and middleware tools. However, in the present environment, both software virtualisation technologies can co-exist and support each other, depending upon the scenarios of usage.

In short, the cloud IT infrastructure management module covers software image management, hardware virtualisation and legacy application packaging. The focused resources are controlled by the cloud IT infrastructure management module. It is an infrastructure based on core cloud, which includes all supporting software, hardware and legacy applications for operating in a cloud computing environment. For instance, hardware can include shared clusters or servers, mainframe and data storages. Software can include database packages and relevant middleware. Legacy applications can include ISV (Independent Software Vendor) applications or home-grown applications that are part of the infrastructure.

It should be noted that virtualisation principle in the VE-enabled cloud architecture is an extension of the operational system layer in the SOA solution stack (SOA reference architecture) (Armbrust et al., 2007) in the framework of cloud computing enablement. For instance, a rack manager can be leveraged to handle wired hardware systems.

The interface of dynamically assembled IT resources, which allow provisioning of infrastructure, can be utilised to deploy or host business applications that leverage distributed resources for cloud infrastructure.

3.4 REUSABLE SERVICES

As mentioned in section 3.2, in addition to the characteristic of virtualisation, service orientation is another driving force of enabling cloud computing to further realise the business value of asset reusability, composite applications and mashup services. There are two major types of common reusable services: horizontal and vertical cloud business services.

Service orientation is the formalisation of the idea that adopters can realise a loose coupling and still enjoy far more system reuse if all interactions are done via well-defined and compliant services rather than with the components interacting directly. The actual components are abstracted away and hidden behind the services that are exposed (Sobotta, 2008).

There are four components of any service-oriented system, three of which interact with each other and one which specifies the terms:

- Service registry/service broker: This is the component that is involved when service providers advertise which services they can offer, and when service consumers search for services capable of fulfilling their requirements.
- Service providers: These are the components that expose services and are capable of utilising information fed on it. Service providers publish, unpublish and update the service registry with the services with which they have been implemented.
- Service consumers: These are the components that have a need and request that need to be fulfilled by a service provider. Therefore it is service consumers who invoke services exposed by service providers.
- Contracts: The contracts between consumers and providers are standards-conforming documents which stipulate the rules that must be obeyed when interacting with a service.

The cloud services for horizontal business consist of several service platforms that hide the complications of tools, database and middleware. Moreover, in developing tools and providing middleware as services in the environment of cloud computing, there are a few common services such as provisioning, on-boarding, billing tools, monitoring or cross-industry services, such as enterprise resource planning (ERP) and customer relationship management (CRM).

The cloud services for vertical business include all industry-specific or domain-specific utility services. Some examples are payment and shipping services. Both are ordinary reusable services in the enterprise architecture based on cloud, and can be reused to allow the subscription and provisioning services for the cloud core, as well as to develop cloud offerings such as PaaS, SaaS, and IaaS business processes as services.

The identified characteristics of cloud computing are massive scale, homogeneity, resilient computing, low-cost software, virtualisation, geographic distribution, service orientation, advanced security technologies and resource pooling (Mell & Grance, 2009). In cloud computing, dynamically scalable and often virtualised resources are offered as a service (Behnia, 2009). Therefore, SMMEs do not need to have knowledge of, be experts in, or have control over the technology infrastructure in the cloud that supports them (Menken & Blokdijk, 2009). In addition, cloud computing applies a model to enable available, convenient and on-demand access to the network to a distributed pool of accessible computing resources. These resources can be released and provisioned in a rush with minimum management attempts or interaction of a service provider (F5 Networks, 2009). The development and success of cloud computing are due to the maturity reached by virtualisation, web 2.0, grid computing, service-oriented architecture technologies and some other technologies.

Cloud computing offers IT infrastructure as an Internet service. On-going advances in ICT infrastructure and far more sophisticated applications provide individuals and organisations with the ability to connect to data anywhere and anytime. Cloud computing is powerful as it is based on a modularity system. The utilisation of virtualisation in the cloud platform makes it easier for organisations to separate systems and services into small elements, which can work separately or around a largely circulated network. Cloud services can be accessed through any devices that have Internet access (Greengard, 2010). Virtualisation is an important technology for many cloud computing environments. The greater part of the virtualisation power comes from the platform independence that virtual machines afford (Huerta-Canepa & Lee, 2010). IT computing becomes a utility, similar to a power utility. The organisations are billed either based on usage of resources or through subscription, and all this is achieved through virtualisation (Menken & Blokdijk, 2009).

Cloud computing as a service delivered over the network adopts a service-driven operating model, therefore it places strong emphasis on service management. A business has a different language and vocabulary from IT. The separation between business and IT in terms of skills and goals may be linked by cloud computing, supported through service-oriented architecture (SOA), and by outsourcing IT services to various service providers under service level agreement (SLA) contracts. SLA assurance is therefore a critical objective for every provider.

Although there has been a lot of publicity on cloud computing, there is as yet no official definition of what it is (no agreed standards). The most useful and updated definition has been provided by the American National Institute of Standards and Technology (NIST). Cloud computing is a prototype for facilitating on-demand, convenient access of the network to a distributed pool of accessible computing resources (e.g. servers, applications, storage, and networks) that may be rapidly released and provisioned with minimum management effort or interaction with the service provider. Availability is supported by the cloud model, the four deployment models and three service models (Figure 3.1).

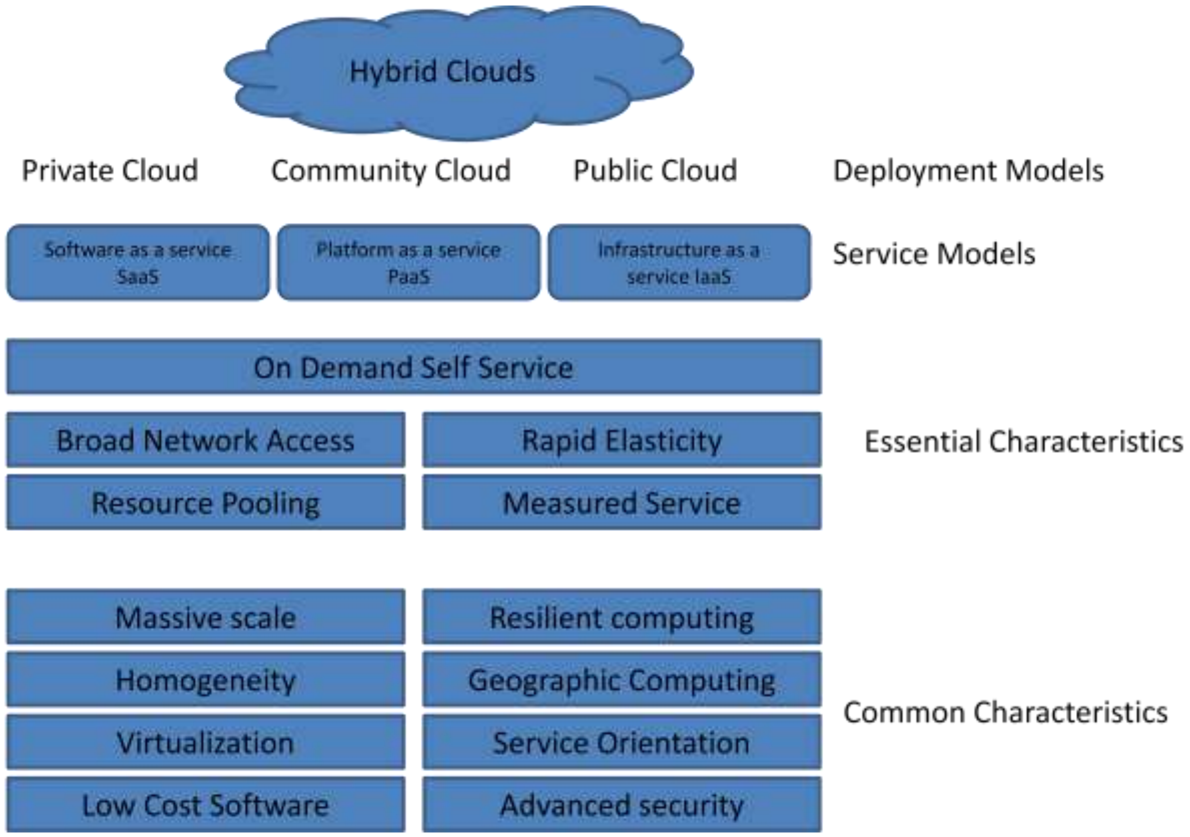

Figure 3-1: Cloud service delivery models (Mell & Grance, 2009)

3.5 CLOUD COMPUTING ARCHITECTURE

In order to understand the cloud computing system architecture, it will be helpful to divide it into two parts, the back end and the front end. The client sees the front end part; this client is the computer user. The front end part contains the client network or computer and the applications that are utilised by the cloud. The applications are used by means of a user interface such as the web browser. The back end of the cloud computing architecture is the cloud, which includes several data storage devices, servers and computers. The devices are linked by means of a network, mainly the Internet. The front end can include the client's computer, or it can include the network of computers, and the application needed to gain access to the cloud computing system. On the system's back end there are several servers, data storage devices and computers that create the cloud computing services. A middle server controls the system and monitors the clients' demands and traffic to guarantee that everything is running in a seamless manner. This follows a set of rules that are termed as protocols and makes use of a particular type of software called middleware. This facilitates the communication of grouped computers with each other (Strickland, 2011).

3.5.1 CLOUD DEPLOYMENT MODELS

In this section we discuss some of the cloud computing types and their offerings to businesses.

3.5.1.1 Public Cloud

A large group consisting of industry and ordinary people can access the public cloud infrastructure. This is accepted by an organisation that sells cloud services. The public cloud provides SMMEs and start-ups with a chance of benefitting from the agility, scalability and automatic cloud management by basically renting computing resources and avoiding expensive hardware outlay. However, compliance and security are serious concerns associated with public clouds; these are among the elements that drive the acceptance of private clouds. Concerns regarding reliability also restrain corporate acceptance of public clouds (Appistry, 2011).

3.5.1.2 Private Cloud

The private cloud infrastructure is leased or operated by a particular organisation and is operated exclusively for that organisation. There is improved utilisation of dedicated resources in this deployment model. It can be maintained by a third party or organisation and can be found off-premise or on premise.

Private clouds are often driven by concerns regarding the reliability and security of public clouds, and it is thought that private clouds might have advantages over public clouds with no drawbacks. The focus in private clouds is also determined by IT departments' attempts to create utility-like IT environments, where computing applications and resources can be provisioned with better efficiency. However, private clouds resolve the issue of reliability and security by storing data safely behind the firewall of an organisation. Their developments needs are primarily investments in hardware and in-house expertise (Appistry, 2011).

3.5.1.3 Community Cloud

The community cloud infrastructure is shared by various organisations and supports a particular community that has mutual concerns, such as security requirements, policy, considerations of compliance, and mission. This implies greater resource sharing and increased agility. This can be managed by a third party or by the organisation, and can exist off-premise or on premise.

3.5.1.4 Hybrid Cloud

The hybrid cloud infrastructure is a combination of two or more clouds (public, community or private) which may remain as unique entities but are linked together by proprietary or standardised technology that allows application portability and data storage, for example cloud bursting.

3.5.1.5 Virtual Private Cloud (VPC)

A VPC is a grouping of Virtual Private Network (VPN) infrastructure and cloud resources computing. A VPC provides users with a private cloud resource set that is securely and transparently linked with their personal infrastructure. To create a VPC, dynamically configurable pools of cloud resources are connected to enterprise sites with VPNs (Wood et al., 2012).

3.5.2 SERVICE OFFERINGS OF CLOUD COMPUTING

3.5.2.1 Software as a Service (SaaS)

In this section we discuss the service offerings of cloud computing and the advantages that can be offered to businesses.

This layer is what most people recognise. SaaS represents the customer’s interface. For the adoption of cloud computing, these services need to exist on a large scale.

SaaS customers tap into computing resources provided by a third party company on a pay-per-use basis or on the basis of subscription. Users do not have to worry about the underlying cloud data centre infrastructure (e.g. Salesforce.com, Google apps) (Schulz, 2009). The primary target is end users, individuals and SMMEs. Examples of cloud software as a service deliverable include hosted application software, such as spreadsheets, e-mail applications and word processors. It also includes video and photo sharing and social networking solutions. SaaS is influenced by SOA and allows the software applications to communicate with one another. Each software service can be used both as the requester of the service as well as the provider of the service.

3.5.2.2 Platform as a Service (PaaS)

PaaS targets developers, which provides them with the framework of programming language level, and a set of well-defined API (Application Programming Interface), which is maintained by the provider. Developmental platforms allow developers to write their own applications and upload their code into the cloud, where the application can be used and run in the same way as web-based applications (e.g. Facebook, Windows Azure). Developers have no need to worry about issues of scalability when application usage grows (Weinhardt, Anandasivam, Blau & Stober, 2009).

3.5.2.3 Infrastructure as a Service (IaaS)

IaaS consists of two categories: those providing storage capabilities and those providing computing power offered on demand. The consumer does not control or manage the underlying framework; however, the consumer does have control over the operating systems and the deployment of applications. The consumer can decide on the networking elements such as the load balancers and host firewalls. Computing resources offered as a service take the form of virtual machines (VM) (e.g. Amazon Web Services, Rackspace and GoGrid) (Kushida, Breznitz & Zysman, 2010).

3.6 SERVICE-ORIENTED ARCHITECTURE IN THE CLOUD

Service-oriented architectures use loosely coupled services to deliver functionality. Each service is implemented in a way that does not require or depend upon knowledge of the services used. Service-oriented architectures exchange data and invoke service standards such as Simple Object Access Protocol (SOAP) and frameworks such as Representational State Transfer (REST). By implementing service-oriented architecture in the cloud, customers consume only the services they need for as long as they need them and are billed only for that use. The same level of fine-grained control over resource usage that the cloud utilises at the server and storage level is available at the service level as well.

3.6.1 SERVICE-ORIENTED ARCHITECTURE

The vision of establishing and running a virtual enterprise that was once imaginary is now a reality because of the advancements of SOA. A virtual business is one in which the majority or all of the business operations are outsourced to online services. Cloud computing provides a closer look at SOA, in which IT resources are provided as services. These services are more attractive, affordable and flexible to organisations (Motahari-Nezhad, Stephenson & Singhal, 2009).

The idea of services within an application has been around for some time now. Services, much like components, are envisioned to be autonomous building blocks that equally represent the application environment. Unlike conventional components, these services have various exclusive characteristics that permit them to take part as SOA. Each individual service is characterised by total independence from other forms of services. This means that each service is accountable for its particular domain, which mainly translates into restricting its scope to a specific business function (or a collection of relevant functions) (Erl, 2004a).

This design methodology results in the establishment of isolated business entities' functionality being loosely linked together by general compliance to a standard framework of communication. Because of the independence that is enjoyed by the services in a framework, the programming logic they summarise does not need to meet the terms of any technology set or platform. In a real sense, a service is an execution of a well-defined functionality of business that operates separately from other services described in a system. These services have a properly defined interface set and they operate by means of a contract between the service client and the service (Linthicum, 2012).

Service orientation is more of a business concept and service-oriented architecture (SOA) is about the application of that business concept to the technology (Schekkerman, 2011). SOA is used to enable those with needs called consumers, and those with capabilities called providers to interact through services across different domains of technology and ownership. Therefore SOA can be thought of as a way the organisation does its business, i.e. the way organisation business units interact with and support each other with technology. SOA has existed for a while now, and depending on individual perceptions it may mean different things to different people. Some look at SOA from a web service perspective and as a means of integration using web services. Others look at SOA as a comprehensive architectural style which is firmly grounded on principles of enterprise architecture.

Another perspective of SOA is that it deals with application services which form a subset of software as a service (SaaS) (Mahmoud, 2005). In this case SOA enables the reutilisation of existing resources, where existing IT infrastructure is used to create new services. This means that it allows businesses to have an impact on existing investments by permitting them to reuse accessible applications, and guarantees interoperability between applications and mixed technologies. With the use of SOA, a level of agility and flexibility that was not possible before is provided (Mahmoud, 2005).

The definition of business services is a major aspect of SOA. A business service's requirement is to execute the entire working units, which are meaningful from the business perspective. The significance and completeness of business service makes it reusable and consequently a potential element of multiple future SOA applications. As a whole entity, the business service should integrate data access potential, business transaction logic and validation logic.

Cloud computing and SOA are related (Figure 3.2). Specifically, SOA is an architectural pattern that assists business solutions in order to organise, create and reuse its computing components, whereas cloud computing is a collection of enabling technologies that provide a more flexible and bigger platform for organisations' SOA solutions. We can then conclude to say cloud computing and SOA supports, complement and co-exist together (Tsai, Sun & Baalasooriya, 2010).

3.6.2 Service Orientation for Utility Pricing

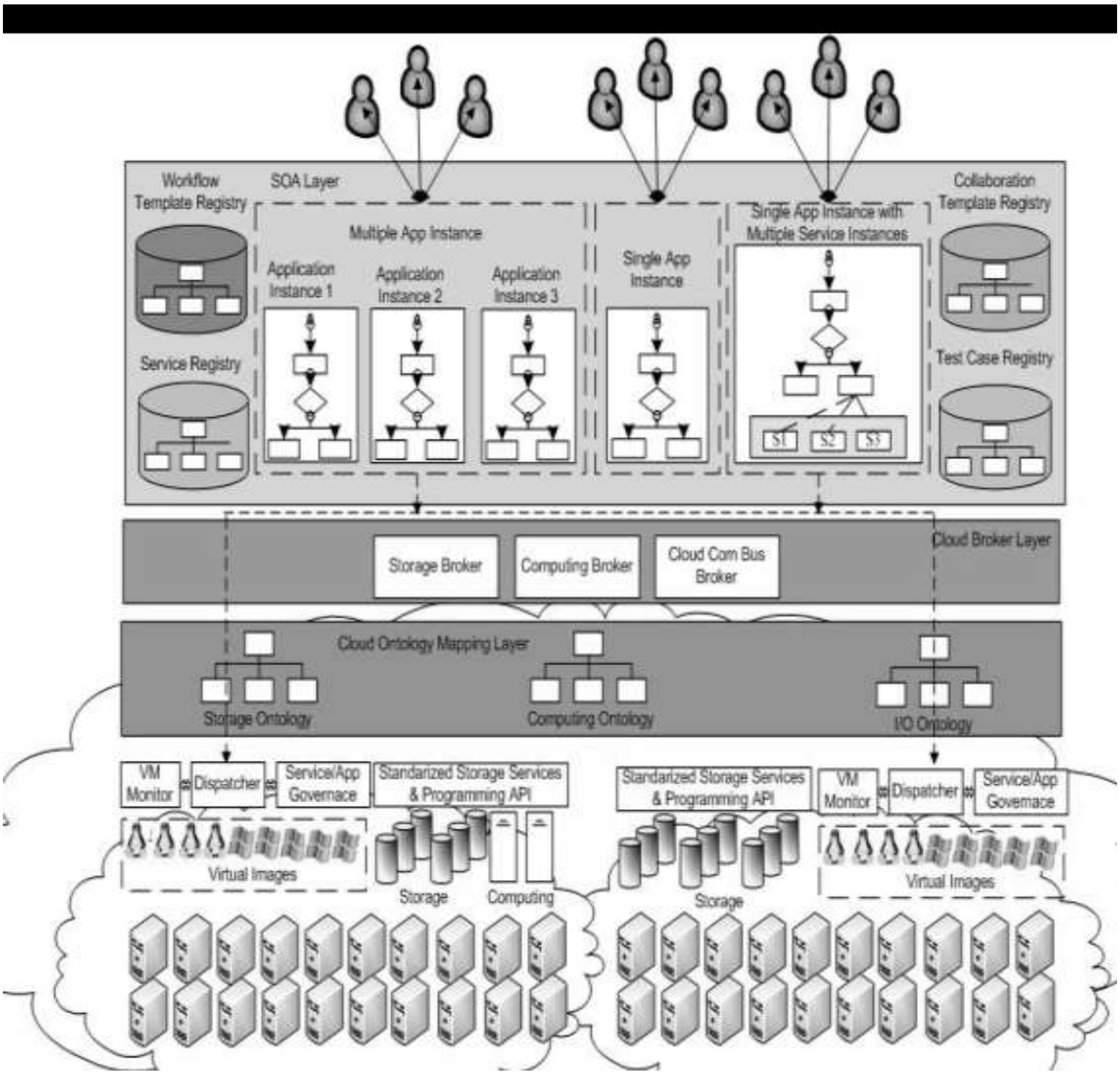

Figure 3-2: Service-oriented cloud computing architecture (Tsai et al., 2010)

In contrast, cloud computing is much more of a technical concept. It is about a technology that delivers services over the Internet; hence it adopts a service-driven operating model. In this way cloud computing and SOA can be seen as complementary, since cloud computing developed out of a need to provide IT resources as a service. Service orientation and cloud computing combined enable SMMEs of all sizes to buy services from different suppliers. These suppliers compete and are able to concentrate on the services that they are good at. In this way SMMEs do not need to waste their efforts on running an uneconomical IT department, which is not their primary business. An SMME can then outsource its IT needs to a third party specialist who can do it much better. The combination of cloud computing with SOA brings together speed and modularity; this allows enterprises to use evolutionary technologies and approaches and revolutionise the way IT interacts with their business (Mvelase et al., 2012).

The use of cloud computing resources, in the SOA environment, provides agility to the IT system. In addition to this, it also organises the enterprise to influence the enterprise cloud computing by developing the essential supporting standards and interfaces. Extending the capability of SOA to the cloud enables resource provision, when and where is needed, in order to cut down the cost and also take advantage of resources that are delivered over the Internet. Cloud resources give access to the built-in services and processes. In addition to this, it also provides access to platforms as a service and expandability value of cloud computing resources.

3.7 THE PERCEPTION OF VIRTUALISATION TECHNOLOGY

Scalability is one of the major ideas following cloud computing technology, and the major technology that makes scalability possible is virtualisation.

3.7.1 BUILDING BLOCKS OF CLOUD COMPUTING

The building blocks of cloud computing are embedded in software and hardware architectures that allow the new infrastructure virtualisation and scaling (Figure 3.3). Several data centres install these capabilities today. On the other hand, the advancements in infrastructure include the more dynamic management and provisioning in larger clusters both external and internal to the traditional enterprise data centres. For the next generation, there are also some implications for application design in order to make the best use of extremely parallel processing and fault tolerance (Menken & Blokdijk, 2009).

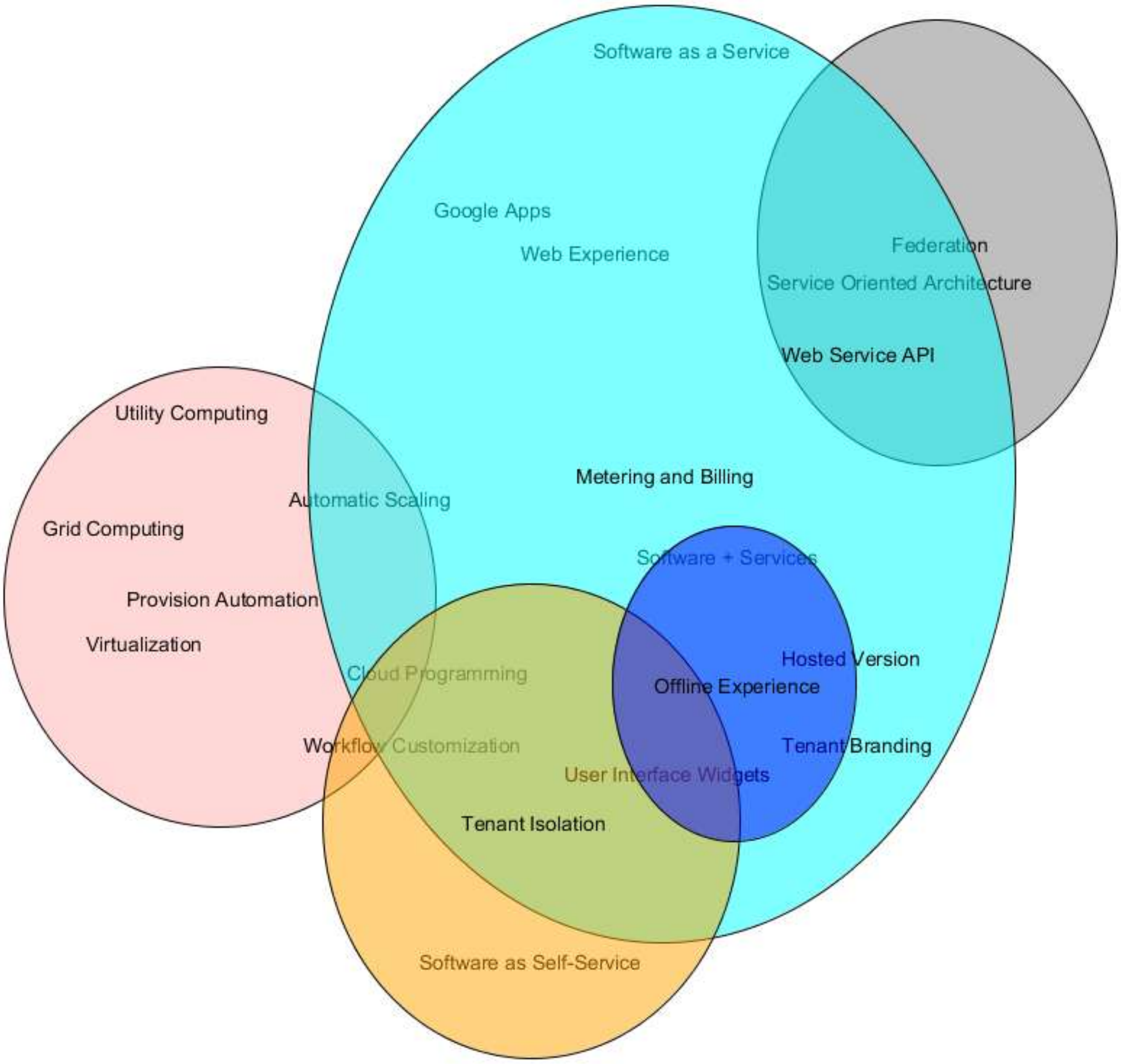

Figure 3-3: Related forms of cloud computing (Menken & Blokdijk, 2009)

3.7.2 VIRTUALISED APPLICATIONS

To enable flexibility in deployment, the virtualised applications are decoupled from the underlying operating system, hardware, network and storage. Virtualised application servers benefit from grid implementation coupled with SOAs and facilitates the largest degree of scalability in order to meet the business requirements.

3.7.3 ENTERPRISE MANAGEMENT

Enterprise management provides end-to-end and top-down management of applications used as business solutions, and also for virtualised infrastructure. The layer of enterprise management controls the complete lifecycle of virtualised assets and offers extra general infrastructure features for management at service level, metered usage, policy management, and licence and recovery disaster management. Developed cloud service management permits dynamic resource allocation and provisioning to allow applications to scale on demand and reduce the waste associated with static and underutilised computing resources.

3.7.4 IDENTITY AND SECURITY MANAGEMENT

Clouds should control an integrated security and identity infrastructure to allow flexible provisioning, yet apply security policies throughout the cloud. As clouds provision resources that are not within the legal boundaries of the enterprise, it becomes essential to execute the system for Information Asset Management to provide the essential controls to guarantee that private information meets the requirements of compliance and that this information is protected (Bennett, Bhuller & Covington, 2009).

3.7.5 DEVELOPMENT TOOLS

Next-generation development tools can control the cloud's distributed computing capabilities. These tools not only allow service orchestration that can control dynamic provisioning, but they also allow business processes to be developed that might control the capabilities of parallel processing available to the cloud. The development tools should promote dynamic provisioning and must not depend on hard-coded dependencies such as network and server resources.

3.7.6 ARCHITECTURE IMPLICATIONS AND PRINCIPLES

In order to take complete advantages of cloud computing, there are various architecture implications that must be observed. That includes business architecture, application architecture, information architecture and technology architecture.

3.7.7 BUSINESS ARCHITECTURE

The cloud provides outstanding monitoring of resource allocation to dynamically meet the varying requirements of a business. This is only effectual when the objectives of the business service level are expressed to assist the enterprise management layer of the cloud. SLAs and application performance metrics should be carefully documented and examined for an effective cloud deployment.

To take advantage of the distributed capabilities offered by clouds, business processes must identify fields where parallel or asynchronous processes can be utilised. Virtualisation is a technology that conceptualises the details of physical hardware and provides virtualised resources for high-level applications. A virtualised server is generally called a virtual machine (VM). Virtualisation technologies have facilitated the realisation of a new model called cloud computing.

Virtualisation provides the basis of cloud computing technology. This is done by offering the capability of gathering computing resources from server clusters and dynamically assigning or reassigning virtual resources to applications on demand. The basic idea is to have one resource pretend to be another; it allows one physical computer to become several different computers. This concept is essential to cloud computing and to storage as a service (Menken & Blokdijk, 2009).

Basically, virtualisation reduces complexity. In this way a virtualised network is easier to manage, hence there is less cost in administrating a complex solution. Enhanced scalability, flexibility and utilisation provide additional cost savings. Automation is an additional functionality available through virtualisation. Without it, resolving problems would require an understanding of the specific characteristics of each component in the solution. The main benefits of virtualisation for enterprises are:

- Standardised configuration of storage devices – A virtual environment requires a minimum level of standardisation of the storage components. With a consistent configuration throughout the drives, it is easier to drive availability uptime in the environment. The virtualisation software allows all operating systems to map to the same file system.
- Easier migration – Data migration can result in lengthy downtime; it can be reduced through virtualisation.

Cloud computing leverages virtualisation technology to attain the provision of computing resources as a utility. The primary driver of virtualisation is cost savings. Therefore virtualised technology offers many benefits for SMMEs that locate their ICT part of the business in the cloud. The advantages include elimination of issues related to compatibility, ease of management, fault isolation, increased security, efficient use of resources, portability, problem-free testing, rapid deployment, reduced costs, the ability to separate applications, easier manageability and improved uptime, all of which are critical to SMME growth.

3.8 ADVANTAGES OF CLOUD COMPUTING

The major benefits of cloud computing must be understood by architects in order to provide a future-state architecture – an architecture that considers cloud computing potential. Many major benefits emerge when cloud computing technology starts to take hold:

- Separation and decoupling of business functions from the framework required to run it.
- Adaptability to select various vendors that offer scalable and reliable business services, development environments and a framework that can be leveraged out of the box. This is charged on the basis of metering with no permanent contracts.
- Adaptable nature of the framework in order to speedily allocate and de-allocate extremely scalable assets to business services on the basis of demand.

The cloud ensures that the costs of attaining, delivering and managing computing power are cut down by allowing agencies to buy only the required computing services, rather than investing in expensive and complex IT infrastructures. The development costs can be borne by the agencies. In addition to this, agencies can cut down the costs of maintaining and testing existing and new systems. Organisations can also drive down the costs of administration and licensing of software as they can use online service with the help of the cloud.

Within a network access device, the cloud guarantees to provide users access to high-powered computing and storage resources. By providing these services, cloud computing technology helps to facilitate telework initiatives. In addition to this, it also helps to strengthen the continuity of organisational operations. The cloud is an on-going computing resource that helps users to get used to the consumption of resources to satisfy their needs. Significantly scalable, cloud computing technology facilitates its infrastructure to expand in an expedient and efficient manner, without the need for major capital investments. Since the resources are required and ended within a very short time interval, capacity should be added.

Therefore enterprises can avoid the expense, latency and risk of buying software and hardware that absorbs the data space centre, and cuts down the conventional time needed for scaling up the application to maintain a job.

Cloud computing facilitates enterprises to easily shift direction, remove capacity and therefore expenses as required (Mantri, Nandi, Kumar & Kumar, 2011). Cloud computing can provide the advantage of resource maximisation. This technology significantly eases the load on already thin IT resources which are important for an enterprise lacking IT professionals.

The advantage of collaboration is also provided by cloud computing. The cloud provides an atmosphere in which users are allowed to develop the software-based services that improve collaboration and promote greater sharing of information, not just inside the organisation but also among other private and government departments (GTSI solutions, 2009).

Cloud computing also gives the benefit of customisation. Cloud computing technology is a platform with extraordinary potential for customising and creating applications in order to address a variety of challenges and tasks. Its agility means that particular processes can be altered easily in order to meet the varying agency needs, as the processes are mainly changeable by making an organisational change, and not by forcing redevelopment of the back-end systems.

3.9 MAJOR BENEFITS OF CLOUD COMPUTING FOR SMMES

The capability of cloud computing of placing the responsibility of maintaining and upgrading the service on the service provider makes it simpler for SMMEs to manage their businesses. Since they do not require all the services on a daily basis, the issue of underutilised IT resources is eliminated (Mvelase et al., 2012).

There are two major benefits of cloud computing for SMMEs. The first is the elimination of main IT infrastructure investment. Secondly, the users of the system can access their data from anywhere in the world. Any computer with Internet access will suffice. These advantages may lead to the main modification in the way that businesses of every size use computers. First and foremost, SMMEs will be the ones to take advantage of this. For the SMME, cloud technology computing offers the best platform to host the requirements of a business platform. The system is managed in a protected environment, where data are backed up daily. The cloud meets organisational needs, and as a result, small businesses and start-ups in particular are able to acquire agility and speed, reduce time to market and update operations. In addition, it also improves customer satisfaction and engagement. There is thus an increased focus on business other than technology.

3.10 ENABLING BUSINESS AGILITY

Almost all enterprises desire business agility. Bloomberg and Schmelzer (2006) call agility the “mother of all business problems”. This holds true at least to some degree regardless of the type of enterprise or the environment within which it operates. When an enterprise is in its infancy stage, it is obvious that the desired level of agility is fairly easy to attain. However, as the enterprise grows and evolves, the level of agility enjoyed can easily be eroded. This is due to the simple fact that the larger the enterprise, the more complex and resistant to change it becomes. However, what makes businesses complex is not just the number of employees, systems and processes they are composed of, but also the absolute number of decisions that their people make on a daily basis (Bloomberg & Schmelzer, 2006; Sobotta, 2008).

Due to factors such as globalisation, ubiquitous availability and distribution of information, and the accelerating pace of technological change among others, enterprise success and survival are becoming increasingly difficult to ensure. This fact is ingrained in the emergence of a new business age that has “change” as one of its major defining characteristics (Davis, 1995; Sharifi & Zhang, 1999; Zhang & Zhou, 2009). Enterprises cannot combat change, but can ensure they are capable of adjusting or strategising around these changes. Most importantly, enterprises need to be able to do so more efficiently and effectively than their competitors so as not just to survive in such a dynamic environment, but also to thrive at the expense of the competition.

3.10.1 FLEXIBILITY

The simplest definition of flexibility is that it is the ability to “adapt to change”. Nevertheless, Conboy and Fitzgerald (2004) believe that the main problem with that definition is that the word “embrace” is a better way of thinking of flexibility than “adapt to”. Furthermore, they put forward the idea that robustness or resilience is also a component of flexibility, which is not expressed in the simplistic explanation. This concept suggests that in order to be truly flexible, a unit should not only be able to get used to change by taking necessary measures, but should also be able to embrace change by taking none.

In addition to this, there is a difference between offensive and defensive strategies. It raises the concern that, when change takes place, the unit does not just make an effort to return to its actual state, but can benefit from this change by placing itself in a proper situation. This supports the use of the word “embrace” instead of “adapt to” because to “embrace” a change suggests that not only will the entity identify and respond to change, it may also capitalise on it. Conboy and Fitzgerald’s (2004) argument is that it is significant to note that a unit itself is not adaptable, and that rather a unit attains flexibility through the several resources, activities and sub-systems that comprise a single unit.

Some scholars claim that “an organisation is only as flexible as its people”, but that due to the changing times, to some extent “an organisation is only as flexible as its information technology”. Therefore within a business context, the definition of agility is: “Business agility is the ability to respond quickly and efficiently to both internally and externally induced changes and to leverage/seize those changes for competitive advantage within the business environment (Arteta & Giachetti, 2004).”

3.10.2 BENEFITS OF BUSINESS AGILITY

Agility is not easy to achieve, and is a continuous effort that needs constant consideration. Therefore, it is important to briefly look at all the major benefits of agility in an enterprise. Agility is the main problem that enterprises face today. If an enterprise is agile enough, it can solve all its current and future problems, since no solution is beyond the reach of an adequately agile enterprise (Bloomberg & Schmelzer, 2006). If enterprises are flexible and lean enough, they have the ability to build new products and services and adjust quickly and efficiently so that they profit from any change in their environment.

The increased use of technology by private individuals, enterprises, governments, etc. is one of the reasons why today’s business environment is characterised by frequent unpredictable change. Technology is also a commonly used tool used to deal with such change. Specific technologies are also used to improve agility.

In general terms then, the benefits of business agility are that an enterprise gains the necessary requirements for being able to continue to effectively compete (and hopefully thrive) in an ever-increasing competitive and unforgiving environment. However, the perceived benefits of business agility according to Sobotta (2008) can be summarised in more specific terms of the following:

Better equipped for today's environment

Global competition demands greater agility, and improved agility provides the enterprise with an important feature to deal with this environment.

Flexibility benefits of business processes

Business processes are changing more rapidly and are coming to possess an adequate level of agility. Agility facilitates the ability to change business processes more rapidly.

Improved growth opportunities

For enterprises to move into new markets, agility is required to respond to new and previously unseen changes.

Cost savings

Being able to respond quickly to change for strategic gain is far more cost effective than ignoring an **opportunity** or being unable to respond in a timely fashion.

After reviewing the literature, we concluded that a definition of flexibility of an enterprise is "The ability of an entity to proactively, reactively or inherently embrace change in a timely manner, through its internal components and its relationships with its environment."

To study business agility, it is important to consider high levels of abstraction and to drill down to specifics. By taking this approach, it is possible to gain a balanced understanding of the forces working against enterprises from fulfilling their strategic and business goals due to inadequate levels of agility, and what measures can be taken to avoid or counteract these forces.

Information technology, defined as technology used to acquire and process information in support of human purposes, has for many decades affected the work we do and how that work is done. In recent years IT has even played a central role in both promoting and inhibiting business agility (Weil & Broadbent, 1998; Overby, Bharadwaj & Sambamurthy, 2006; Bharadwaj, 2000; Leonard-Barton, 1992).

3.11 SCALABILITY

Scalability deals with the capacity of the software system to accomplish rising complexity when given additional resources. In cloud computing, scalability with large data set operations is a requirement. The cloud provides horizontal scalability by means of application delivery and load balancing solutions. Examples of horizontal scalability are horizontal partitioning, column orientation and the Distributed Hash Table (DHT). Vertical scalability is related to resources used, much like the old mainframe model. If an application is not properly scaled in vertical manner, it increases the cost of running in the cloud (Rimal et al., 2010).

Failed applications that do not properly scale up vertically can result in increased cost during deployment in the cloud as demand for computing resources required increases. For the purpose of running simple business applications, Force.com was created; it is based on database-centric architecture. It appears to be restricted in the requirements of the architecture for the system's scalability of cloud computing as it divides its database per application. This means that if an application needs to scale more than a single database can provide, there is a problem.

Although document-centric, column-oriented store or DHT approaches were created to address the scaling issues, as was writing heavy applications, they cannot support complex joins, reporting and foreign keys. They can be considered as part of general architecture and they can play an important role in reducing heavy writing bottlenecks. On the other hand, they should not be considered as a substitute for a relational database. Concerns of cloud-based scaling are ultimately dependent on the nature of the applications and the expected volume of usage (Rimal, Choi & Lumb, 2010).

3.12 LOAD BALANCING

Load balancing is a fundamental part of elastic scalability and cloud computing, which can be offered by virtual ware, software or hardware. It is the method of self-regulating the workloads properly within the cloud's entities (one or more hard drives, servers, IT resources and network). Cloud data centres and infrastructures require large computing hardware, IT and network resources that are always subject to failure at the time when demand is exceeded.

Load balancing is often used for failover implementation. Failover occurs due to the limited resources allocation, hardware failure, power and network interruption, etc. The service components are monitored constantly, and when one becomes non-responsive, the load balancer is informed and no longer sends traffic to it. This is a feature inherited from grid-based computing that has been transferred to cloud-based platforms.

A load balancer is a key requirement for building dynamic cloud architecture. It provides the ways in which application instances can be provisioned and de-provisioned. There are some architectural considerations when designing the load balancers:

Design to provide scalability that could be at the CPU level, at the machine level, at the network level, or even at the application level and data centre level.

- Capability to manipulate client requests and forward them to the selected target resources by using load balancing policies.
- Automatic scalability of the request-handling capacity.
- Fault tolerance for applications handling of more complex and higher traffic needs such as Apache Traffic Server. Apache Traffic Server 12 provides high-performance web proxy cache to advance network efficiency and performance and improves content delivery for enterprises' backbone providers and large intranets by exploiting existing and available bandwidth (Rimal et al., 2010).

3.13 DEFINITION OF CLOUD FROM ECONOMIC PERSPECTIVE

There are several definitions of cloud computing. Possibly the definition that is most widely accepted is the one that the National Institute of Standards and Technology developed, at present steady at version 15 (Mell & Grance, 2011). From the perspective of economy, we can utilise a semantically equal mnemonic cloud (Cai, Zhang, Wang, Li, Sun & Mao, 2009) that can help bring the economic advantages to the surface. A cloud service has the following features:

Utility pricing

Pricing based on usage and the pay-per-use method, with advantages applying in situations with changing levels of demand.

Common infrastructure

Standardised and pooled resources with advantages generated by numerical multiplexing.

Location independence

Ubiquitous availability in meeting performance requirements, with benefits deriving from latency reduction and user experience development.

Online connectivity

An enabler of other attributes ensuring service access. Costs and performance impacts of network architectures can be quantified using traditional methods.

On-demand resources

Elastic, scalable resources de-provisioned and provisioned without costs or delay related to change.

We will highlight the outcomes regarding these advantages and additional relevant topics. These outcomes are often counterintuitive. Various layers of Platform as a Service, Software as a Service and Infrastructure as a Service all have dissimilar advantage drivers. At this point, we emphasise on Infrastructure as a Service, which is the basis of several other advantages. Finally, an exceptional difference between SOA and platform services and integrated development environments in the end comes down to infrastructure resources, and an exceptional difference between SaaS and licensed software will eventually exist in infrastructure flexibility and cost, including elasticity and pricing. We shall therefore focus on infrastructure.

3.14 BUSINESS MODEL AND VALUE CHAIN

The concept of business model is highly relevant in the context of cloud computing. According to Iyer and Henderson, (2010), cloud computing is an evolution of the dominant business model for delivering IT-based solutions. Similarly, Zhu, et al. (2009) argued that cloud computing distinguishes itself from previous computing paradigms by its emerging business model, which creates remarkable commercial value in inventive developments. The concept of the business model is still relatively poorly understood and there is much confusion in the terminology (Osterwalder & Pigneur, 2009; Rajala & Westerlund, 2007; Jaatmaa, 2010). Some authors use the business model to simply refer to the way a company does business, whereas other authors emphasise the conceptual model aspect. Nevertheless, previous research agrees on the business models' position as a conceptual and theoretical layer between business strategy and business processes (Rajala & Westerlund, 2007). According to Osterwalder and Pigneurs's (2002) business logic triangle model, the business model represents the architectural level between planning and implementation (Figure 3-4).

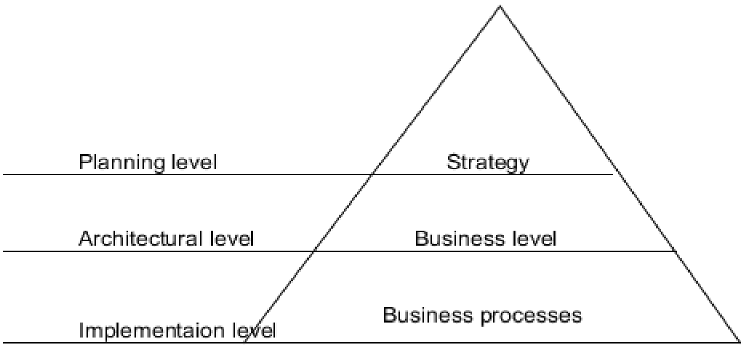

Figure 3-4: Business logic triangle (Osterwalder & Pigneur, 2002)

Rajala and Westerlund (2007) define business model as ways to create value for customers: "The concept of the business model in the literature on information systems and business refers to ways of creating value for customers, and to the way in which a business turns market opportunities into profit through sets of actors, activities and collaboration." Osterwalder (2004) defines a business model as a tool for expressing business logic and describing customer value:

"A business model is a conceptual tool containing a set of objects, concepts and their relationships with the objective to express the business logic of a specific firm. Therefore we must consider which concepts and relationships allow a simplified description and representation of what value is provided to customers, how this is done and with which financial consequences."

Osterwalder (2004) proposes a single reference model based on the similarities of a wide range of business model conceptualisations. The model comprises nine "building blocks" categorised to four elements (Figure 3-5). The element of financial aspects is composed of cost structure and revenue model building blocks, and together they determine the business model's profit/loss-making logic.

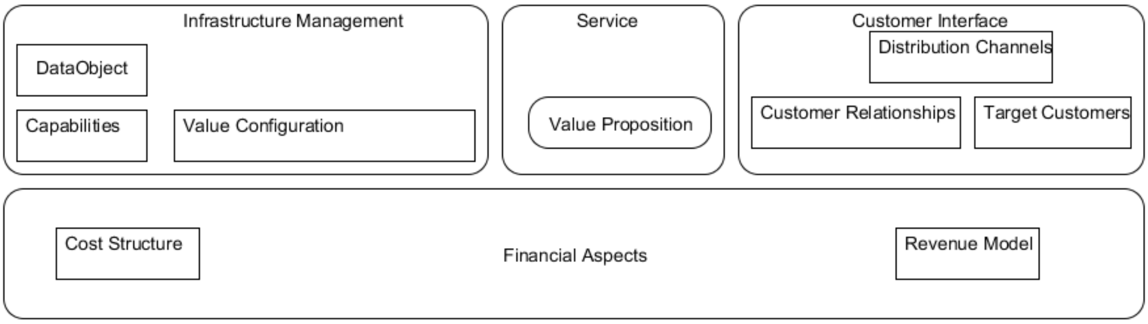

Figure 3-5: The business model ontology (Osterwalder, 2004)

Chesbrough and Rosenbloom (2002) discuss the role of the business model in capturing value from an innovation. Since cloud computing is generally regarded as some type of innovation, the business model could serve as tool for capturing economic value from this new technology. Chesbrough and Rosenbloom define a business model as a mediating construct between technology and economic value (Figure 3-6). The business model mediates technical inputs such as feasibility and performance to economic outputs such as value, price or profit.

Other authors argue that the function of the business model is to justify the financial capital needed to realise the model and to define a path to scale up the business.

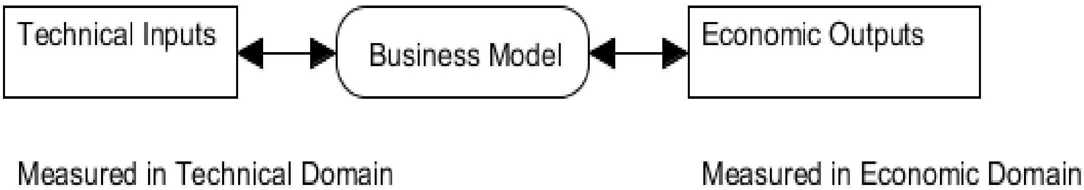

Figure 3-6: The business model as a mediating structure (Chesbrough & Rosenbloom, 2002)

Weinhardt et al. (2009) connect the business model concept to cloud computing by proposing a cloud business model framework (Figure 3-7). The framework suggests that different business models could be derived from the different cloud service models as shown in Figure 3-7:

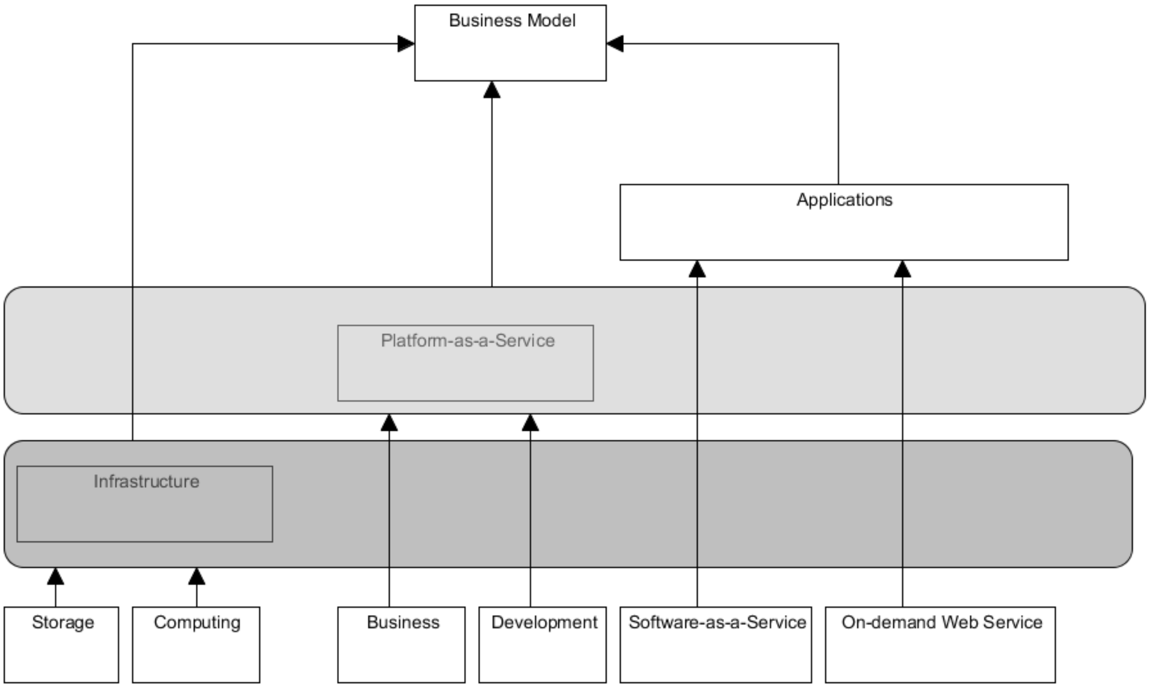

Figure 3-7: Cloud business model framework (Weinhardt et al., 2009)

Leimeister, Riedl, Böhm, & Krcmar, (2010) also argue that each of cloud service should be based on a certain business model. However, Leimeister et al. argue that because of the dynamic and highly evolving nature of the cloud services market, also the business models must be dynamic. They argue that conventional static models do not reflect the real world and lack substantial elements of changing market environments. Leimeister et al. therefore suggest that business models are continuously adjusted to the current hype cycle phase, technology changes, regulations and market developments, which helps service providers to create stable businesses. Some authors (e.g. Altmann, Ion & Mohammed, 2007; Zhang, Lu & Boutaba, 2010) compare the business model in the cloud computing context with the role of service providers. Leimeister et al. (2010) discuss cloud computing value network and identify five primary actor roles among customers:

- Consultant: Works as a support for the selection and implementation of relevant services to create value for a customer's business model.
- Service providers: Develop and operate services that are offered and deployed on the cloud computing platform and access hardware and infrastructure through service providers. In return, this offer value to the customer and service providers respectively.

- Aggregate service providers (aggregators): Might be regarded as a specialised form of the service provider, offering new services or solutions by combining pre-existing services or parts of services to form new services which they offer to customers.
- Data integrators: Focus more on the technical aspects necessary for data and system integration.
- Service aggregators: Also include the business aspects of merging services to offer new service bundles.
- Platform provider: Offers an environment within which cloud applications can be deployed. Acts as a kind of catalogue in which different service providers offer services.
- Infrastructure providers: Supply the value network with all computing and storage services required to run applications within the cloud and provide the technical support.

Figure 3-8 illustrates a cloud computing value chain based on the work of Jaekel and Luhn, (2009), Leimeister et al. (2010) and Zhang et al. (2010).

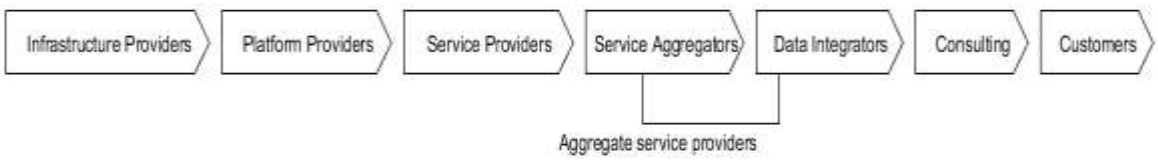

Figure 3-8: Cloud computing value chain

The real-life cloud computing value network may be far more complex. Iyer and Henderson (2010) analysed the cloud services industry ecosystem and identified strategic relationships, technical alliances, reseller relationships, original equipment manufacturer (OEM) or independent software vendor (ISV) arrangements, and consortium memberships between different companies.

The cloud computing literature discusses some of the pricing mechanisms found in a cloud pricing model. Cai et al. (2009), Weinhardt et al. (2009), Yeo, Venugopal, Chu and Buyya (2009) and Youseff, Butrico and Da Silva (2008) discuss the pay-per-use mechanism, which is widely hyped to be one of the key changes that cloud computing brings to the IT services business. With the pay-per-use mechanism, capacity units such as number of transactions, gigabytes of storage or memory or units per time such as gigabytes of memory per hour are associated with resources and assigned fixed price values, and the customer pays according to his metered usage of resources. The capacity unit may be also artificial as in the case of Amazon Web Services (2010) that sells “instances” of their capacity pool. Pay-per-use pricing is typically used with IaaS and PaaS services and its benefit is that it allows customisation to specific application needs. Ouyang, Sahai and Pruyne (2007) note that quantification of resources and measurement of dynamic usage may be a challenging task with cloud services. Denne (2007) discusses various advanced ways to implement the pay-per-use pricing mechanism.

Table 3–1: Pay-per-use mechanism implementation (Denne, 2007)

Implementation	**Description**
Pricing based on time	Pricing relies on the consumed units of time. The variation of the real pricing of subscription mechanisms discussed below is that a fixed contract is not signed by the customer.
Pricing at peak level	Pricing is based on peak consumption within a defined window.
User-based pricing	Pricing depends upon number of different users presenting themselves to the system.
Ticket-based pricing	Pricing is based on fixed price electronic tickets that the services provider issues for the use of the service (for a specific period of time).
Integral pricing	Pricing is based on peak utilisation of a defined capacity unit divided by average utilisation.
Overage charges	Pricing changes if the customer exceeds the average consumption of the service.
Consumption commitments	Pricing is based on estimated average consumption, and exceeding or undercutting the consumption commitment affects the price.

3.15 USEFUL CONCEPTS

The table below consist of key concepts used in this study, showing strengths and weaknesses for each concept.

Table 3–2: A comparison table for approaches and techniques

Concept/Theory	Strengths	Weaknesses
Cloud Computing	- Reduce IT labour costs - Improve capital by significantly reducing license costs - Provides much needed scalability. - Cloud architecture is built on service-oriented architecture(SOA)principles, therefore services are reusable - Cloud computing offers unlimited supply of central processing unit (CPU) capacity, storage and bandwidth - Application designers are free to focus on features and usability and not hardware aspects. - While e-governance applications face data outburst, cloud computing can scale better. - Cloud-computing-supported e-governance can provide efficient management and disaster recovery. - The cloud helps to increase the number of resources dynamically to maintain quality of service intact even at the times of high load, which generally happens in e-governance. - With cloud, e-governance applications can manage the policies well by providing security and adoptability. - Various e-governance applications can be integrated easily.	**Possible downtime:** Cloud computing makes your small business dependent on the reliability of your Internet connection. When it's offline, you're offline. And even the most reliable cloud computing service providers suffer server outages now and again. **Security and privacy issues:** Security is the biggest concern when it comes to cloud computing. By leveraging a remote cloud based infrastructure, a company essentially gives away private data and information, things that might be sensitive and confidential. It is then up to the cloud service provider to manage, protect and retain them, thus the provider's reliability is very critical. A company's existence might be put in jeopardy, so all possible alternatives should be explored before a decision. On the same note, even end users might feel uncomfortable surrendering their data to a third party. Similarly, privacy in the cloud is another huge issue. Companies and users have to trust their cloud service vendors that they will protect their data from

		unauthorized users. The various stories of data loss and password leakage in the media do not help to reassure some of the most concerned users. **Dependency and vendor lock-in:** One of the major disadvantages of cloud computing is the implicit dependency on the provider. This is what the industry calls “vendor lock-in” since it is difficult, and sometimes impossible, to migrate from a provider once you have rolled with him. If a user wishes to switch to some other provider, then it can be really painful and cumbersome to transfer huge data from the old provider to the new one. This is another reason why you should carefully and thoroughly contemplate all options when picking a vendor. **Technical Difficulties and Downtime:** Certainly the smaller business will enjoy not having to deal with the daily technical issues and will prefer handing those to an established IT company, however you should keep in mind that all systems might face dysfunctions from time to time. Outage and downtime is possible even to the best cloud service providers, as the past has shown. Additionally, you should remember that the whole setup is dependent on internet access, thus any network or connectivity problems will render the setup useless. As a minor detail, also keep in mind that it might take several minutes for the cloud to detect a server fault and launch a new instance from an image snapshot. **Increased Vulnerability:** Related to the security and privacy mentioned before, note that cloud based solutions are exposed on the public internet and are thus a more vulnerable target for malicious users and hackers. Nothing on the Internet is completely secured and

		even the biggest players suffer from serious attacks and security breaches. Due to the interdependency of the system, If there is a compromise one one of the machines that data is stored, there might be a leakage of personal information to the world.
Virtual enterprise	**PORTABILITY** One of the advantages of a virtual enterprise is that it can be operated from anywhere. When you run a business that is entirely virtual in nature, absolutely nothing ties you to a given location. A business of this type functions equally well when run from your office, home or laptop while you are sitting on a beach in the Caribbean. The freedom from being tied to a desk is part of the appeal of this model for many who try it. **COST** The cost of operating a business on the Internet is typically much less than the cost of operating a traditional business. First, the infrastructure requirements are very minimal. A personal computer for access, web server space and possibly a Web designer are the only really essential costs. This eliminates the cost of production equipment, transportation and office space that most businesses must contend with. Even hiring help can be cheaper online, as telecommuting support staff is available through freelance sites at a fraction of the cost of traditional in-office help.	**WORK ENVIRONMENT** This is a disadvantage for certain types of people. Some employees require the structure and supervision that come with an office environment. Without oversight some people do not have the discipline and focus to be productive throughout the day. For others, the distractions of working at home or on the road prove too much. This type of person should engage in more traditional business, because without that structure the virtual business will quickly drop off in productivity. **SOCIAL** One downside to not having a traditional office is that it removes the social aspect commonly associated with work. Most people make friends at work and spend breaks or lunches socializing. If you work from home alone, this is not part of your work experience. In addition, in a position where you occasionally need to meet clients face to face, you won't have a place to do that like you do in an office. Instead, you'll have to rely on restaurants, golf courses or cafes as places to meet clients.

3.15 CHAPTER SUMMARY

SOA appears to be an important technology for any provision of IT services. The status quo of the cloud computing paradigm has been presented. In a nutshell, we can say that cost and security are the important factors for any enterprise to adapt cloud computing. Enterprises tend to choose their preferred payment methods for paying cloud computing providers. The most common payment method for enterprises and cloud providers is “pay as you go”. This is one of the novel feature of cloud computing, which is cheaper in the long term than having an own data centre. However, cloud computing is cheaper for SMMEs than for large enterprises. The importance of virtualisation and SOA in building the cloud has been confirmed. VEs form part of our customised cloud enterprise architecture – they are the window for SMMEs to be able to access required services remotely, i.e. without purchasing the infrastructure. As a result, this chapter touches on the importance of agility in general terms, and then focuses on agility related to the business domain.

CHAPTER 4
MODEL DESIGN AND DEVELOPMENT

4.1 INTRODUCTION

This chapter describes the design and experimental set up of the proposed cloud enterprise architecture. It begins by discussing the design requirements of the proposed model to show how design requirements are a fundamental part of any cloud services definition and development effort. We concentrate on the requirements of the service catalogue of the cloud computing architecture. The importance of addressing the problem of SMMEs' lack of business growth is also highlighted. Thereafter, key requirements for cloud enterprise are identified. This is followed by an in-depth discussion of the proposed cloud enterprise architecture. An explanation of some of the design concepts is also presented. The chapter concludes with a discussion of how the architecture can be useful in overcoming SMMEs' growth problems.

4.2 DESIGN REQUIREMENTS

In the context of cloud computing, the service catalogue is an integral and critical component of the cloud computing architecture. Information Technology Infrastructure Library (ITIL® v3) service design defines a service catalogue as a list of technology-enabled services that an organisation provides, often to its employees or customers. More specifically, the service catalogue is an expression of the operational capability of a service provider or enterprise within the context of an end customer, a market space, or an internal business unit stakeholder (Cisco, 2011).

4.2.1 CHARACTERISTICS OF A CLOUD SERVICE CATALOGUE

A cloud service catalogue:

- Contains a set of cloud services that an end user can request (usually through a web self-service portal).
- Acts as the ordering portal for cloud end users, including pricing and service-level commitments and the terms and conditions for service provisioning.
- Can also be used as a demand management mechanism, directing customers toward particular services or service configurations or away from legacy or

declining services, as well as making sure of alignment with governance and standards through default configurations and service options.

- Has a self-service look and feel; that is, it provides the ability to select service offerings from the cloud service catalogue and generate service requests to have instances of those offerings fulfilled.
- Is useful in developing suitable cloud-based solutions, thus enabling other IT and business services, which in turn creates the value propositions for the investments in cloud architectures.
- Contains features and characteristics that can be configured and preferably priced based upon a "cloud chargeback" mechanism to fulfil a particular need.
- Serves as the provisioning interface to automated service fulfilment using a cloud orchestration subsystem.

4.2.2 DEVELOPING AN OPTIMUM SERVICE CATALOGUE

An optimum catalogue is one that maximises the alignment of infrastructure capabilities with business requirements while delivering the best value for the end consumer. The service catalogue can be used as an effective tool by IT organisations to implement enterprise standards, introduce new technologies, and enforce default regulatory requirements. The enterprise architect is responsible for the service catalogue's alignment with the business architecture, thereby helping to maximise the return on investment in cloud and service catalogue development. It is important to note that an optimised cloud service catalogue can only be built when both the business perspective (for example, which services does the business need to deploy?) and the IT perspective (for example, what services can be provided?) are taken into consideration at the same time (see Figure 4-1).

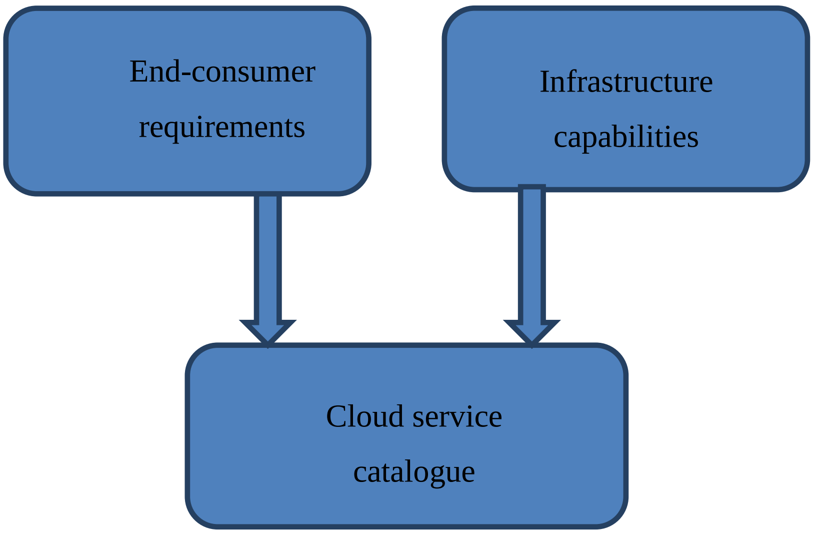

Figure 4-1: Cloud service catalogue inputs

The cloud service catalogue development methodology should be:

- **Repeatable:** When a service catalogue is built for a customer, the process could be taken and repeated for multiple customers.
- **Measurable:** A service catalogue's items should also be measurable in order to be priced for chargeback, as well as managed for availability and performance.
- **Comprehensive:** A service catalogue should encompass all the possible combinations of infrastructure capabilities as well as different deployment requirements.

As a result, the cloud service catalogue development framework should be:

- **Scalable:** To enable services provided to scale up or down according to market and end-user requirements. It should enable horizontal and vertical scaling requirements of the services provided through transparent integrated automation.
- **Flexible:** To accommodate new and changing service requirements for end consumers and implications on the IT service catalogue.

In order to elicit the design criteria for this work, we considered the following scenario instance of the cloud enterprise architecture for SMMEs.

Let us consider KwaNongoma arts and crafts which comprise dissimilar groups of SMMEs. These SMMEs want to purchase services from the cloud service provider since it is a cheaper business model for enterprises who cannot afford to purchase the ICT infrastructure necessary for running the business. SMMEs select the services they need from the cloud service catalogue. After selecting the services, the user places an order for them and sends the request to the cloud service provider. When the cloud service order is received, it is filled by creating a virtual machine with the requested service applications. The user can now enjoy the benefits of legacy applications sitting on the cloud on a pay-per-use basis without purchasing huge servers. On completion of the session, the SMME signs out, which means that the virtual machine provided to the SMME is destroyed immediately. Virtual machines run the task as long as required and then shut down when the task is complete (the implementation details such as whether a virtual machine is actually shut down or allocated to another job, are cloud specific; logically, it appears to the cloud users that the virtual machines are no longer allocated to them). In the cloud, physical servers become shared resources without the drawbacks, such as:

- Incompatibilities with the operating system or applications server.
- Conflicts in the workloads scheduling.
- Difficulties allocating costs to service consumers for jobs running on the server.
- Irresolvable violations of security policies regarding access control and data protection policies.

These problems can occur when trying to share a single server across application or organisational boundaries, let alone hundreds or thousands of servers that may be required for a computing-intensive job. The problems are avoided with cloud computing because of three technological characteristics:

- Rapid allocation of servers.
- Standardised hardware.
- Persistent cloud storage.

Together, these characteristics provide the benefits of sole-use servers with the efficiencies of shared resources.

4.3 A MODEL FOR CLOUD-ENABLED SERVICE-ORIENTED ARCHITECTURE FOR SMMES

The proposed model of the cloud-enabled SOA for SMMEs is shown in Figure 4-2. There are three layers in this model: business level, middleware layer and technological level. We have a situation in which small SMMEs located in rural KwaNongoma cannot afford the services of a legal services, market analyst, accountant, etc. Since these are services that are required once-off as and when necessary, the architecture proposes that these SMMEs obtain these services from a private cloud, which is a network of medium-sized enterprises (MSE) participating in a VE-enabled cloud enterprise structure. The private network is made up of the virtual enterprise setting which in itself is the business aspect and the technology.

A VE-enabled cloud enterprise structure and operation consists of the medium-sized enterprises in a VE alliance with all its business process utility and IT cloud computing services and their providers. The cloud enterprise architecture for medium-sized enterprises participating in a VE setting is made up of the business context, business services, business processes and IT services. The business context layer is responsible for the definition of business goals, strategies, structure, policies and performance metrics and indicators. The main users of services at this level are business owners and executives who are hardly ever IT experts. The main functions of a business such as human resources, payroll, accounting, etc. are defined as coarse-grained services, called "business services" in the business services layers. Users such as businesses or IT architects may define or select the required business services from out-of-box business services blueprints. The IT services layer represents the services that are obtainable in the cloud. Finally, the business processes layer is the illustration of the selection, design, integration and composition of IT services in the form of workflows that fulfil the needs of the outlined business services. In this architecture, the medium-sized enterprises in the virtual setting share business context, business services and business processes to improve competitive advantage, and quickly respond to market opportunities. Hence the VE-enabled cloud enterprise architecture comes down to a value system, which involves a number of companies' value chain that is collaborating to deliver the end product to the customer. The aspect of value chain is not covered in this research work.

Rather than relying on established organisations (e.g., Google Cloud, Amazon EC), MSEs in the VE setting form their own private cloud, where they collaborate on their existing IT infrastructure, skills, processes, organisational models and core competencies. There should be in place strategies on sharing competencies. We should remember that the MSEs also compete with one another; hence they cannot reveal all their competencies. The reason that they do not host their IT services on a third party cloud service provider is because of the advantages gained by the collaboration of resources within the VE. Hosting their entire IT infrastructure on established clouds could cost them even more, and the resources may be underutilised. Assuming that the MSEs in the alliance understand each other, no one MSE can dominate. In case of insufficient resources, the MSEs can then tap into the external public cloud. This comes down to a hybrid deployment model. Therefore cloud computing capabilities provide the VE alliance with the agility, flexibility and adaptability required due to its highly flexible ICT infrastructure.

Nimbula is the middleware used for the cloud model. The middleware uses SQLite for database management, the information manager for resource planning, and the virtual machine manager to provide the cloud owners with virtual machine power (PaaS, IaaS). The virtual manager manages one or more virtual machines. Each virtual machine runs particular software. SaaS subscribers use these applications. In this case the subscribers are SMMEs from KwaNongoma. These virtual machines run off physical machines. The network manager manages the communications within the cloud architecture. Nimbula hides the complexity of the whole cloud system but gives the impression that it is a single physical resource.

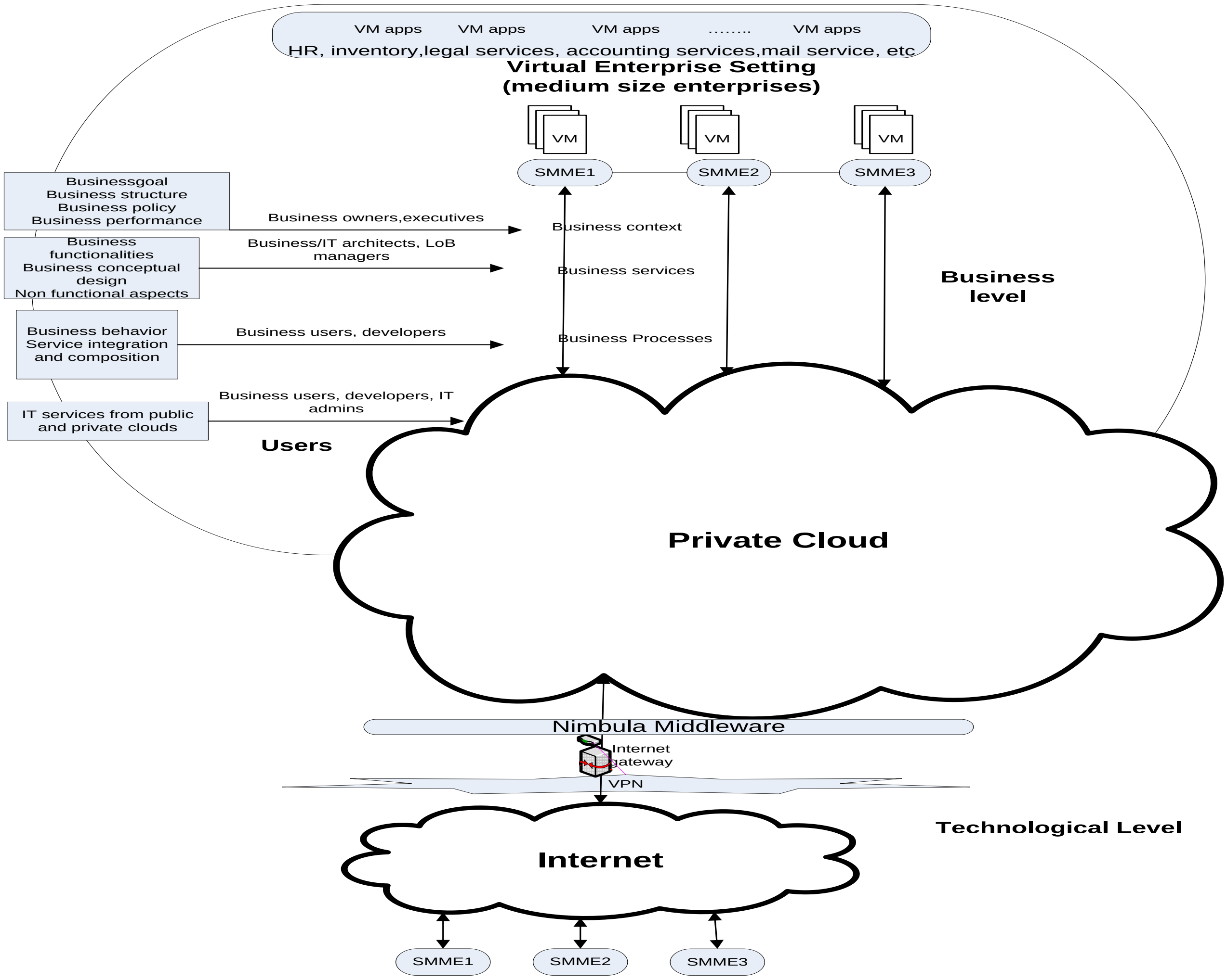

Figure 4-2: VE-enabled cloud enterprise architecture for SMMEs

4.4 VE-ENABLED CLOUD ENTERPRISE ARCHITECTURE PROTOTYPE DESIGN

VE-enabled cloud enterprise architecture for the SMMEs' experimental set-up illustrates the basic functions of our customised architecture. We now present the experimental set-up of our model. The architecture use case scenario is described in section 4.5. The experimental set-up supporting the SMMEs needs is explained using UML design diagrams. The SMMEs need an enabler that will help them to grow their businesses, gain competitive advantage, and hence participate in the global market irrespective of their financial challenges.

4.4.1 USE CASE SCENARIO

The use case diagram is represented in Figure 4–3. The cloud service provider customises the images from the desktop before uploading it to the cloud. For example, we assume that a cloud service provider would have carried out his task of finding out the needs of the users to whom he will be providing services. Therefore the images are customised according to individual user groups. A Windows image, for example, may be loaded with HR, inventory, ERP, CRM, legal services and accounting applications. To cater for users who might not need all these services, other images may have only one or two of these services. In this case we are avoiding a situation where a user might be accessing a virtual machine with services that he does not need, which will make the bill unnecessarily high.

The customer requests IT services from the cloud and the system machine image provides a hard disc snapshot used to launch a virtual machine (VM) instance. The VM instance has RAM, a number of CPUs and the network interface attached. Depending on individual customer’s requirements, the VM instance may contain SaaS (HR system, inventory management, legal services, etc.) and a specified RAM and number of CPUs. The cloud service provider creates a customer’s account and instantiates a VM instance dedicated to that customer. The requester logs in to access the VM instance, as and when needed. The VM instance appears as if it is running on the user’s machine when in actual fact it is located in the cloud server because of the abstraction that the cloud provides. An instance can be accessed by a number of users simultaneously by using their login credentials. The customer only uses the cloud services when needed and is billed according to usage (i.e. the utility business model). Customers are recognised by the IP addresses assigned to their VM instances. A customer is billed when the VM instance is in the running mode. A customer completely ends the session by shutting down the VM instance, and the IP address can be allocated to another user. If the customer merely logs off the VM instance keeps running and the customer is billed even though he is not using the cloud services. The cloud automatically scales up and down depending on the users’ needs. Now, the customer can enjoy the benefits of the cloud by having access to services that he could not have afforded had it not been for the cloud business model. Once the session is closed by the customer, the administrator sends the bill to the customer.

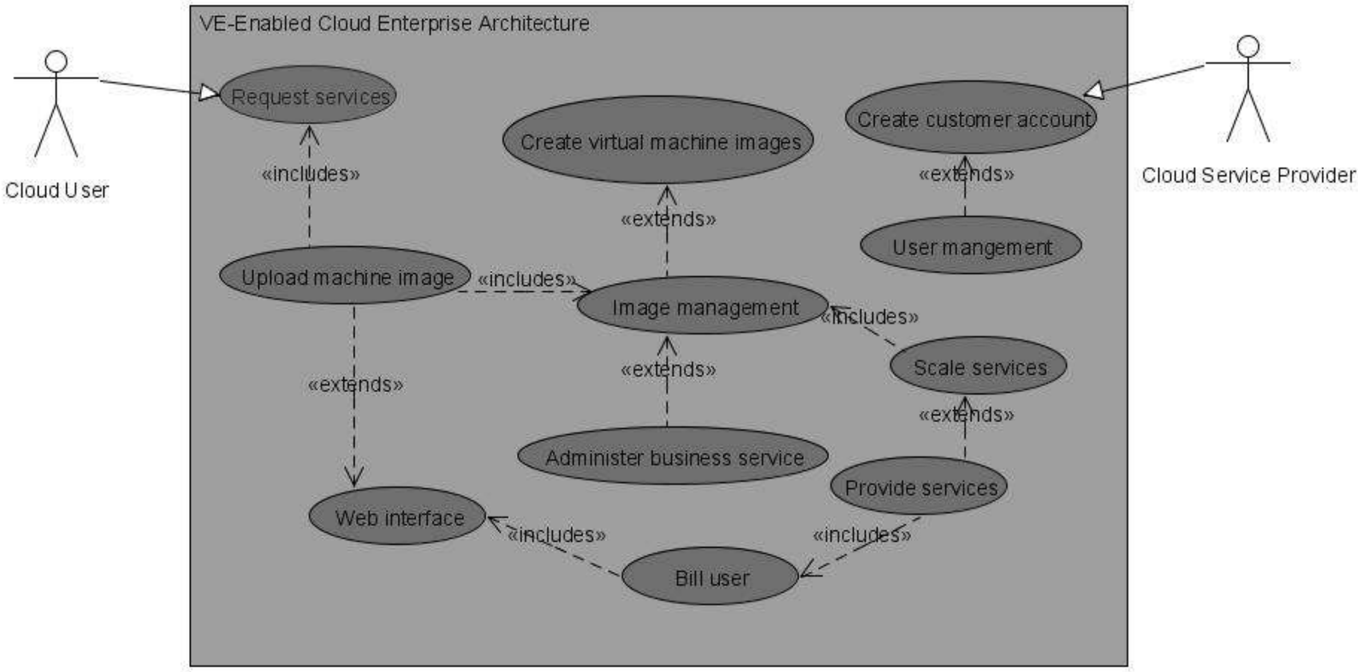

Figure 4-3: Use case diagram of VE-enabled cloud enterprise architecture

4.4.1.1 The Customer

In this case the customer is a small SMME user who cannot afford to purchase ICT infrastructure due to financial constraints. The customer utilises the cloud services on a pay-per-use basis which is cheaper than buying the ICT infrastructure. The cloud service provider does not grant the customer permission to create an instance – instances are created by the cloud SP. Utilising the cloud services enables small SMMEs to become agile, expand their businesses, and compete with advanced SMMEs.

4.4.1.2 The Administrator

The administrator is an organisation or department which is responsible for the cost incurred by using the system. In actual fact, this is the cloud SP site. From the definition found in Nimbula Director this is the customer, which has been explained section 4.5.1.

4.4.2 SEQUENCE MODELLING

In Figure 4-4, which shows the sequence diagram, we demonstrate the flow of messages among the objects of the VE-enabled cloud enterprise architecture. The flow of messages is initiated by the customer who requests a VM instance from the cloud administrator. The administrator handles the customer’s request message by looking at the customer requirements to determine the VM instance to allocate to individual customers. The user management object creates the user account and groups if need be. In object user management, users may be granted permissions for some of the activities. The image management object is responsible for creating and managing the image list and machine images. The image list is the persistence list of machine images that can be used to keep track of different versions of a machine image. The machine image is a VM template that can be launched into a running machine instance. The administrator allocates quotas, etc. that fulfill the requestor’s requirements. To fulfil the users requirements the cloud automatically scales up and down. The customer is given the VM instance to use, and is billable after the utilisation of resources.

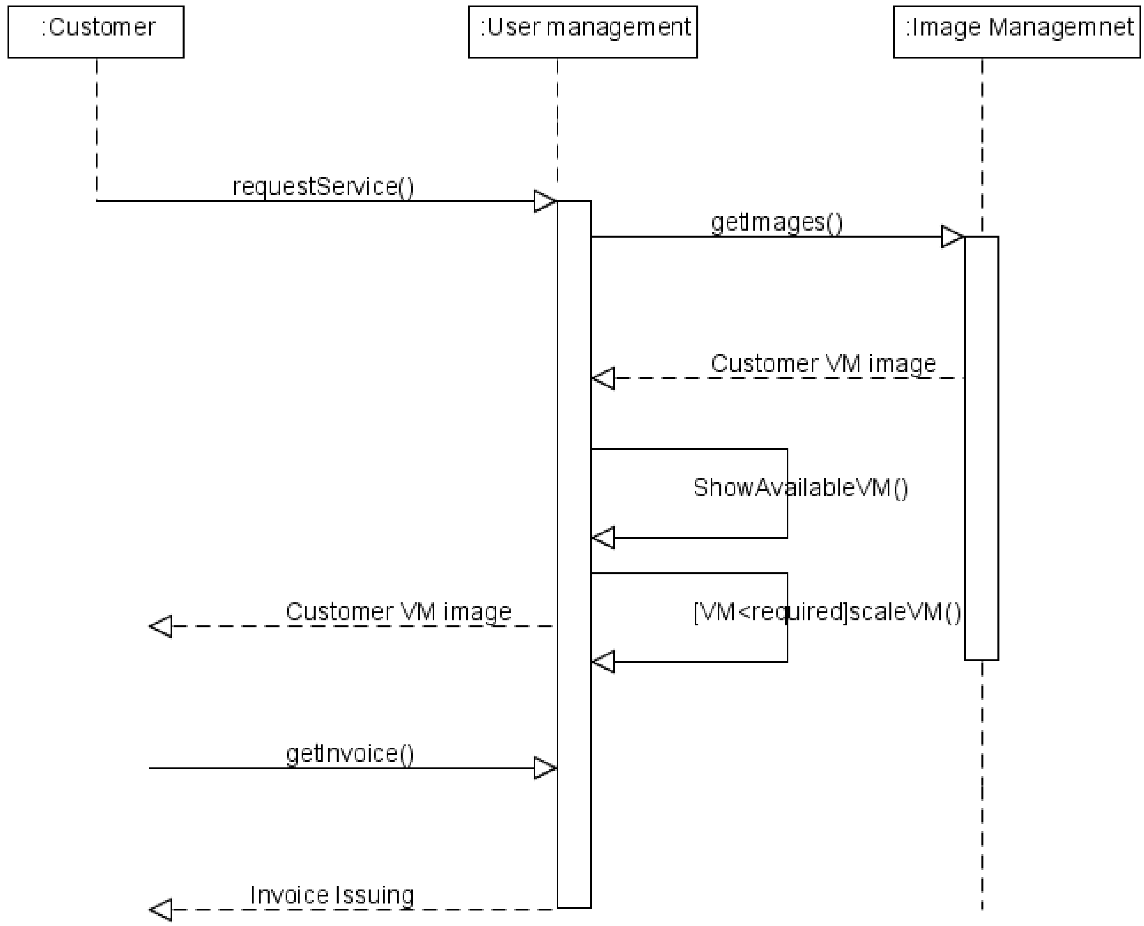

Figure 4-4: Sequence diagram of VE-enabled cloud enterprise architecture

4.4.3 ACTIVITY MODELLING

Figure 4-5 shows the activity diagram of our VE-enabled cloud enterprise architecture. The flow of events starts by a service request action being initiated by the customer when the customer logs onto the system. The user management object authenticates the user, and this is where a decision has to be made. If the user is a registered customer, the request is attended to. At this stage, the request is fulfilled by creating the VM instance. The image management object uploads the VM instance, or the cloud server is scaled to cater for the request. The VM instance containing the application requested by the user can now be provided to the requestor of the services . It then uploads to the desktop of the requestor through a web interface. It must be noted that for services to be accessed from the cloud, the customer must have Internet access – any device that allows Internet connectivity will do. When the requestor finishes using the cloud services, the administrator bills the requestor per utilised services. The requester closes the session by paying for the utilised services on a pay-as-you go basis.

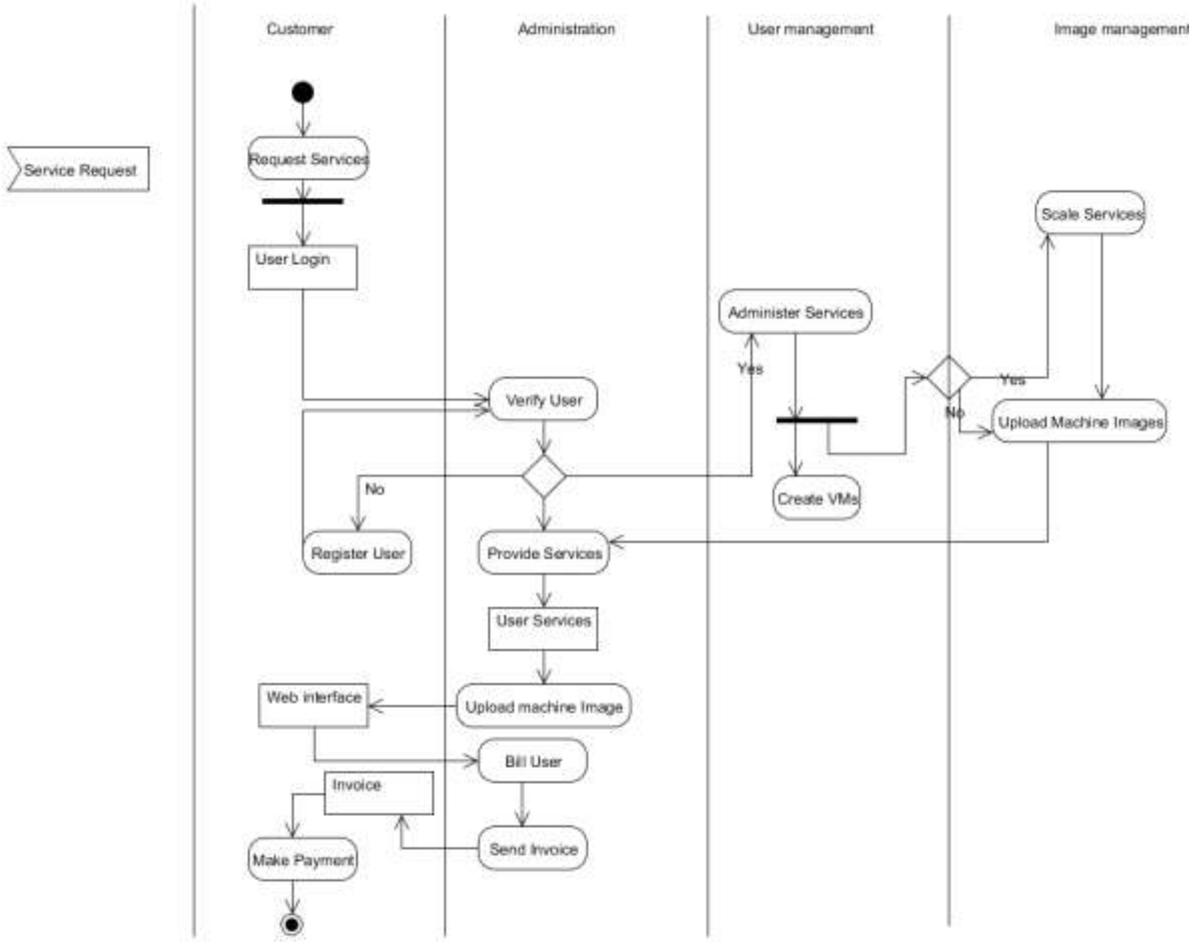

Figure 4-5: Activity diagram of VE-enabled cloud enterprise architecture

4.5 CHAPTER SUMMARY

In this chapter we presented the prototype design architecture of our work which will be used in the demonstration of our cloud. Design requirements were presented using cloud service catalogue to show the significant synergy between actors and elements that embrace cloud computing model, therefore considerable for our architecture. The use of UML was to graphically represent objects of the systems by the use of sequence modelling. A use case model portrayed the proposed functionality of a new system between a user (human or machine) and the system. The sequence model was used mainly to show the interactions between objects in the sequential order that those interactions occur. The activity modelling was used to map the activities that make up a process and showing their interconnections and interactions, inputs and outputs, types of resources assigned, and the nature and extent of constraints and controls.

CHAPTER 5
MODEL PROTOTYPING AND EVALUATION

5.1 INTRODUCTION

In Chapter 4, we presented the scenario of our customised cloud enterprise architecture model, which provides our approach to using the cloud for enabling SMMEs. The intention of the scenario was to show the interaction of the system with its external components. We presented our model design using the UML diagram approach to show the system's architectural blueprints, which include activities, actors, business processes and reusable software components.

In this section we evaluate the cloud deployment in terms of scale, automation, identity, permissions and delegation, openness and choice. The SMMEs were running their businesses manually, which hindered their businesses growth. They were doing so because they lacked information and were not aware of how ICT can help them in the running of their businesses. We proposed cloud computing as a solution in this regard because of its utility model incorporation. Cloud services are a perfect fit for SMMEs. Capital cost savings and rapid application deployment are strong positive reasons for adopting cloud solutions. Taken together, these add up to significantly lower barriers to entry than solutions developed in-house. Some SMMEs are taking advantage of lower financial and technical barriers to entry to accomplish what otherwise would be unaffordable.

5.2 BASIC ASSUMPTIONS OF THE EXPERIMENTAL SET-UP

For our experimental set-up, the following assumptions were made, bearing in mind the duration of the project:

- The cloud infrastructure is running; services are deployed and service consumers request services.
- Services are consumed by users on a pay-per-use basis, hence maintenance, scalability and infrastructure is third party’s concern.
- VMs are created and customised as per users’ request and requirements.

5.2.1 DESCRIPTION OF THE EXPERIMENTAL SET-UP

The scenario described in Chapter 4 is considered in the experimental set-up of our model. The end-consumer requirements, infrastructure capabilities and cloud service catalogue that operate in fulfilling a particular request were considered. In order to fulfil a request, end-user requirements are the deciding factor. The cloud is scaled according to the number of users (Sibiya, Venter, & Fogwill, 2012).

5.2.2 EXPERIMENTAL SETUP ENVIRONMENT

For simulation and evaluation of our model/concept we used Nimbula Director (Nimbula.com). "Nimbula Director is an automated cloud management system which allows customers to easily repurpose their existing infrastructure and build a private computing cloud in the safety of their own data centre." This cloud deployment model is appropriate for our architecture since medium-sized enterprises will form a cloud using their existing infrastructure to become cloud SPs for very small enterprises. To install a Nimbula Director site, we needed to set up a minimum of three machines and a seed node machine with a DVD drive. The machines comprising the Nimbula Director cluster(s) need to comply with the hardware and software requirements given in Table 5–1. The machines we used met the standard.

Table 5–1: Machine specification for installing Nimbula Director

CPU	64 bit Intel® VT-x or AMD-V™ required, 2 or more cores recommended
RAM	2 GB minimum, 4 GB or more recommended
Local hard drive	100 GB required, 500 GB–1.5 TB recommended
NIC	1 Gb/s, 10 Gb/s minimum. PXE boot support. Nimbula Director supports any network cards supported by CentOS 5.6 or CentOS/RHEL 6.0
BIOS	CPU virtualisation enabled, PXE ROM enabled, boot order disk first, then network
DVD	At least one machine needs to have a DVD drive to facilitate the installation of the seed node that then propagates via the network
Boot settings	Machines should be configured to boot in the following order so that they normally boot the Nimbula OS but can easily be re-installed by removing the boot loader from the primary disk: *Disk* Network. In order to make initial installation easier by not having to manually tell each machine to boot from the network, we recommend removing any boot record from the primary disk in each node. This will allow the system to fall through to network boot and start the Nimbula Director installer.

Nimbula Director user interface is divided into a top pane and a bottom pane, which allows one to create, modify and destroy objects.

The five main tasks at the top pane perform the following functions:

- User management creates and manages groups and their permissions.
- Image list contains a persistence list of machine images that can be used to keep track of different versions of a machine image. A machine image is a VM template that can be launched into a running machine instance.
- Virtual network allows one to create and manage VEthernets and VDHCP servers. VEs are virtual layer 2 networks that provide isolation and the implementation of VLANs. VDTP servers can be created for each VEthernet to dynamically assign IP addresses to VM instances running in that VEthernet.
- Network security list lets one configure a built-in distributed firewall for isolating instances and regulating traffic in and out of the cloud that is dynamically configured and independent of the underlying network.
- Instance management allow one to view and launch machine images into running machine instances.

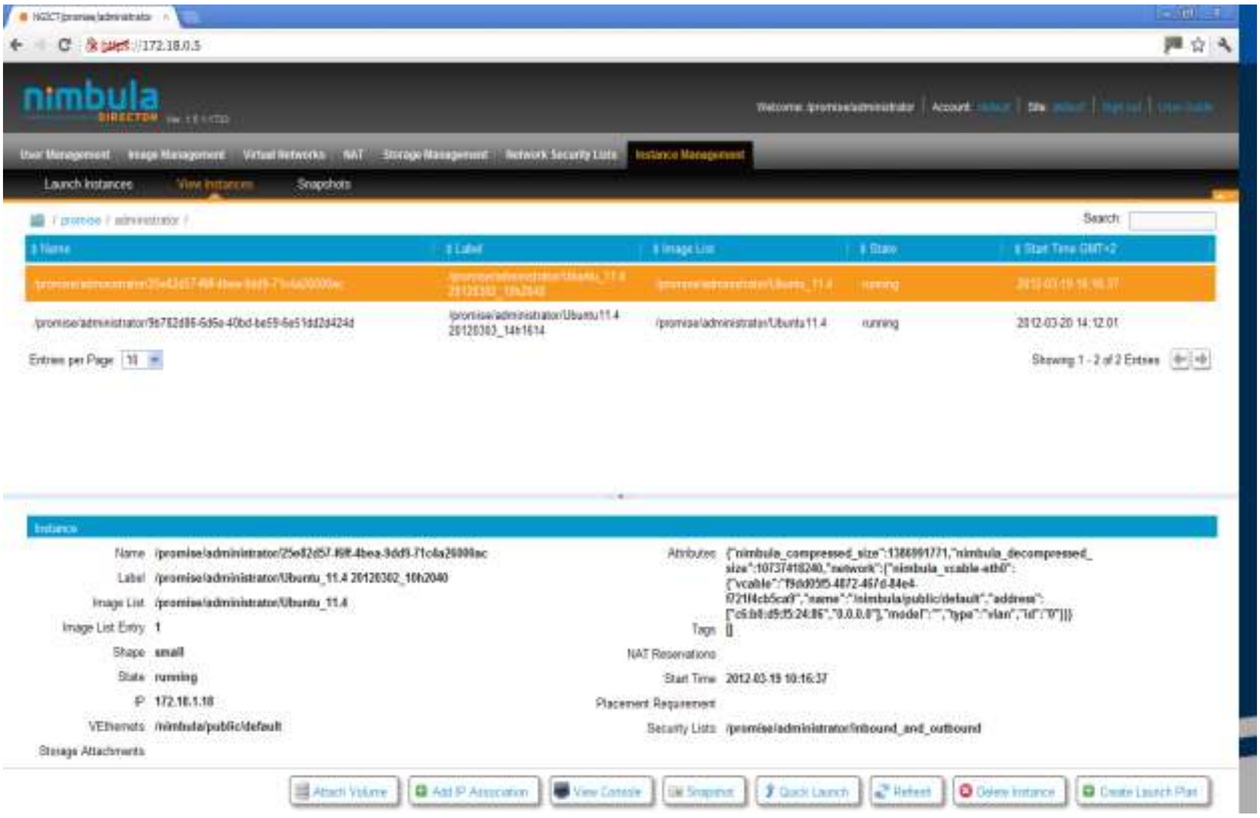

Figure 5-1: Cloud remote access

Figure 5–1 shows a running VM instance created by the SMME cloud administrator. The VM instance is created using Quick Launch. The VM instance is created via instance management task: here an instance can be launched and viewed. Instances are customisable according to user requirements. The administrator verifies that the new VM instance has been launched and is running. The web interface displays details such as the image list, state, placement requirements, etc. for the new VM instance. An IP address used to connect to the VM instance is also provided (e.g. VM: 172.18.1.18). Before creating a VM instance the SMME administrator creates the user SMME under the SMME customer.

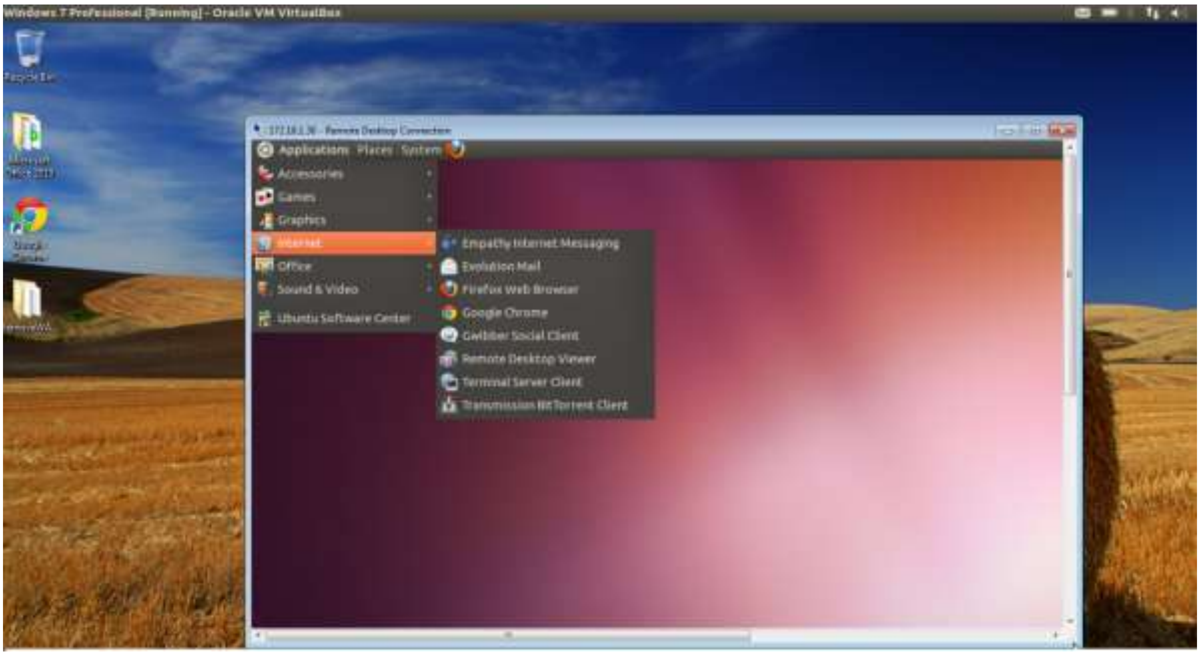

Figure 5-2: Cloud remote desktop

Figure 5–2 shows a remote desktop where a user can access the cloud remotely. A user is registered to the cloud to be able to access its content. An instance running in the cloud can be accessed via a web browser or a remote desktop software client from a local machine or client device.

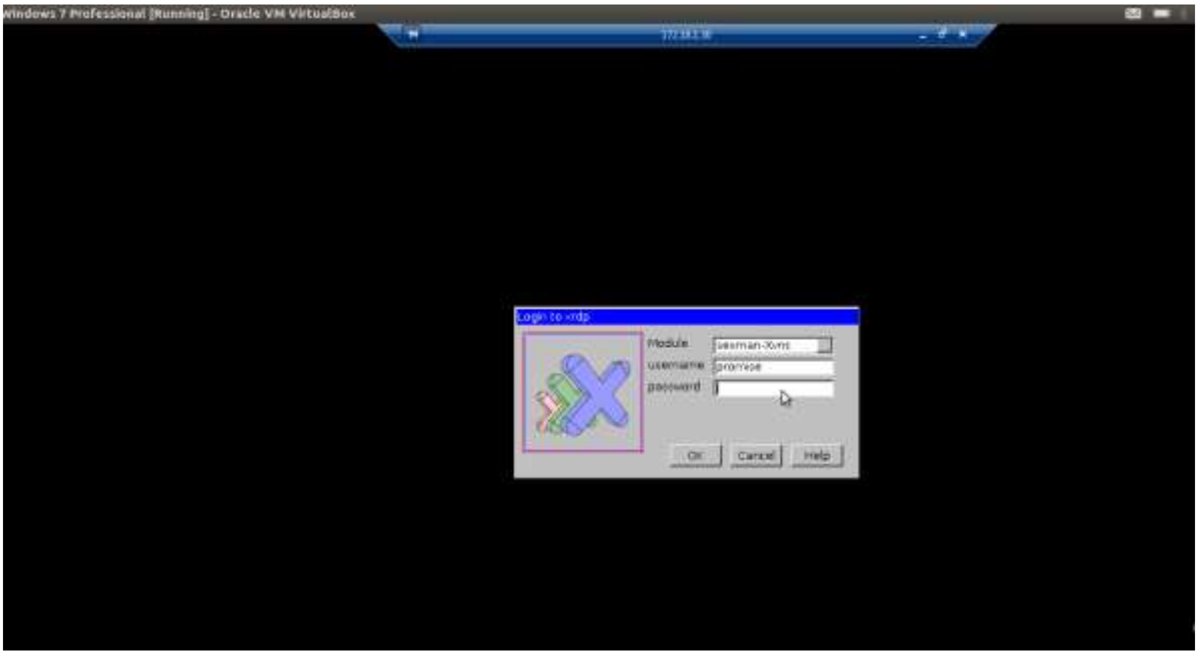

Figure 5-3: VM launch

Figure 5–3 represents the launching of a running virtual machine to the user's desktop. A remote VM is launched as a result of a request issued by the user which contains the applications requested by the user. As mentioned in section 5.2.2, the VM is destroyed as soon as the user completes the task. Each time a user requests a VM, a new instance is created.

The administrator is in charge of ensuring that the cloud is up and running at all times. Back-up, security, maintenance, etc. are the administrator's concern. The VM assigned to the user is accessed remotely from the user's desktop.

5.3 PERFORMANCE EVALUATION

We evaluated the performance of our model according to the utility evaluation of SMMEs to see if the utility requirements were met. The capability of the cloud computing business model is the obvious reason why we recommended it for small businesses.

To evaluate our cloud, we compared our model with the pricing of Amazon EC2. We used the Amazon EC2 Standard on Demand EC2 cost model to evaluate our model. EC2 has a number of pricing models (Amazon Web Services). The Amazon EC2 Standard on Demand model is the pricing model equivalent to the cloud infrastructure in this work. In the Standard on Demand model, the user pays for computing capacity by the hour with no long-term commitments or up-front payments. Our pricing starts at US$300 per year per processor core – including support and maintenance. This is equivalent to our model. Our model is based on Nimbula Director, where the software price is only based on a number of physical processor cores on which it runs (i.e. the bigger the physical infrastructure, the more you pay because you have more cores). This is the same criterion for similar Amazon EC2 pricing models. However, for the configuration and proposed model in this research, the Amazon EC2 Standard on Demand pricing model is the ideal comparable model. The pricing model of the proposed VE-enabled Cloud Enterprise Architecture for SMMEs is therefore based on the EC2 Standard on Demand pricing model. This does not suggest rigidity of the pricing model of the proposed architecture, but the analysis was done to show the cost-saving capability of the model.

5.3.1 COMPARATIVE ANALYSIS OF THE PRICING MODELS OF EC2 AND VE-ENABLED CLOUD ENTERPRISE ARCHITECTURE

To illustrate the cost estimation, we examined the case of VE-Enabled cloud enterprise architecture using the Nimbula Director Instance type. Table 5–3 and Table 5–4 show the estimated costs based on instance type obtained in our private cloud and Amazon EC2 respectively. Table 5–4 shows a Linux-based double extra-large instance in Amazon EC2. We used a double extra-large Amazon machine instance type for the cloud configuration in this research. The price of the EC2 instance type configuration is 17.82 times greater than the equivalent VE-cloud configuration in the proposed architecture. This is a huge saving for SMMEs who are the target users of the proposed architecture.

Table 5–2: Nimbula Director instance type used for our cloud

Instance	Virtual cores	Memory	Instance store volumes	Platform	Platform	Price
Standard on-demand instances	4 (4 x 4 virtual cores) = 16 cores	8 GB (3 x 8 RAM) and 4 GB (1 x 4 RAM) = 32 GB	250 GiB (3 x 250 HD) and 500 GiB (1 x 500 GiB) = 1 250 GiB	64-bit	High	$0.034 per hour

Table 5–3: Amazon EC2 instance-type with high-memory double extra-large

Instance	Type	Name	EC2 Compute units (ECU)	Virtual cores	Memory	Instance store volumes	Plat-form	I/O	Price
Standard on-demand instances	High-memory double	M2.2x large	13	4 (with 3.25 ECUs each)	34.2 GiB	840 GiB (1 x 840 GiB)	64-bit	High	$0.640 per hour

5.4 CHAPTER SUMMARY

In summary, it can be said that the proposed cloud architecture for SMMEs shows incredible cost savings for their business. This implies that the VE alliance formed by medium-sized enterprises will work better in practice in terms of providing services to small enterprises through the cloud rather than consuming services through established cloud SPs.

CHAPTER 6
SUMMARY, CONCLUSION AND FUTURE WORK

6.1 INTRODUCTION

The goal of this research was to design a cloud enterprise architecture customised for SMMEs. In this study, cloud enterprise architecture was designed for SMMEs that is meant to give disadvantaged SMMEs access to ICT infrastructure on a pay-per-use model without having to own ICT infrastructure. This chapter summarises and draws conclusions on the results of this research work. It also gives a critique of the work and its limitations, and makes some suggestions as to how the model can be extended in future. The rest of this chapter is arranged as follows: Section 6.2 summarises this research work and presents the conclusions drawn from the work. Section 6.3 encapsulates the contributions of this research, and Section 6.4 presents limitations and future work.

6.2 SUMMARY AND CONCLUSIONS

This research achieved the following objectives:

Issues affecting the productivity of SMMEs were identified. A case study conducted in KwaNongoma in KwaZulu-Natal on issues hindering SMMEs productivity and growth was useful in assessing these issues in addition to the review of the relevant literature.

Existing VE models that can be adapted to meet the infrastructural needs of SMMEs were identified from a review of the relevant literature on VE models. This review was useful as it helped to select an advantageous model and modify it for our proposed architecture. The literature on VE architectures was also reviewed to help us find VE architecture components that relate to cloud enterprise architecture so that we could design and deploy our customised cloud architecture for SMMEs. A conceptual analysis of existing VE architectures and cloud enterprise architectures relating to this study was conducted.

A VE-driven cloud computing architecture was developed. This model was custom made for SMMEs and deployed on a cloud for evaluation purposes. This was achieved by designing a VE-enabled cloud computing architecture for SMMEs by combining the capabilities of both existing VE architectures and cloud enterprise architecture. Keeping in mind the financial constraints and the needs of SMMEs, this work evaluated cloud computing deployment models so that a suitable one could be selected for SMMEs. System design was performed so as to define the architecture, components, modules, interfaces and data for our prototype that satisfied specified requirements. An experimental set-up of a VE-driven cloud computing architecture for SMMEs was implemented and evaluated against existing cloud models to validate the relevance of the proposed model.

6.3 RESEARCH CONTRIBUTION

This research covered various virtualisation solutions. The cloud computing architecture proposed in the research will help in the deployment of virtualisation solutions in the areas of server consolidation, infrastructure, virtual desktops, application virtualisation and management of virtualised infrastructure for the SMMEs. The Nimbula Director pricing model which was used in our work was compared with the Amazon EC2 pricing model. It was discovered that the price of the EC2 instant type configuration is 17.82 times higher than the equivalent VE-cloud configuration in the proposed architecture. This means that our pricing model has huge cost savings for the targeted SMME users.

This thesis also attempted to address the problem of enterprises needing an ever-increasing level of agility to compete effectively. The environment in which today’s enterprises must operate is becoming very dynamic for enterprises from both internal and external sources. If an enterprise is adequately agile at a given time, then no change would be too big for it to respond to and even benefit from – hence the importance of agility. This research work is not the first to suggest a solution to SMMEs that lack agility and the flexibility to grow and be competitive within the context of IT. However, its distinct contribution is in providing an appropriate pricing model for economically disadvantaged business enterprises.

Although there is convincing empirical evidence that virtual enterprise does indeed work, models derived from it have received some criticism. The criticism is based on the opinion that implementing virtual enterprise can in some situations actually result in increased complexity and still lack the desired level of flexibility. This is due to the fact that VEs are formed to provide a solution for an unpredicted opportunity. Therefore this research aimed to find a solution to the lack of agility, not by reinventing the wheel, but by pooling resources from VE architecture and cloud architecture in such a way that the shortcomings are addressed. The core concept is that rather than each enterprise owning, maintaining and operating its own IT resources, they can share common infrastructure provided by external third parties over the Internet.

The question is what mechanism cloud computing providers use to allocate their vast resources to a huge number of customers. The utility model is the mechanism/model discussed in this thesis. It makes the use of cloud-based computing resources in theory as easy as using electricity from a socket. To validate these claims, a theoretical case study was conducted. It is clear that consuming IT services as a utility will benefit the SMME. From a theoretical point of view, the design paradigm does enhance the level of agility of SMMEs, but in practice the design paradigm can be confronted by many real-world issues that would significantly hinder its adoption. The recommendation is that, as an interim step, smaller private cloud providers could help the move towards the ultimate vision of cloud computing. Usage of the resources offered by the smaller cloud providers should be subject to approval by other members. This approach would not only help the technology to mature, but also help break down psychological barriers in the same way a small electricity generation plants do.

In addition to prior point, this work has made the following contributions:

- A well-articulated problem formulation was presented in Section 1.2. The problem formulation was presented clearly and concisely.
- A sound solution was proposed which was determined via the use of SMME custom-based cloud enterprise architecture that resulted in the deployment of cloud using Nimbula Director.
- A strong solution validation was conducted through a detailed literature review in addition to the analysis of a case study. The suggested solution to the research problem is well justified and validated. However, it is not without some limitations. These limitations are discussed in the next section.

6.4 LIMITATIONS AND FUTURE WORK

Deploying the cloud confirmed the suitability of the proposed architecture for SMMEs. However, the simulation is only an approximation of reality; therefore another primary goal of future work is to observe the behaviour of the proposed approach in a real-life environment. It would be useful to add an element of mobile cloud to allow disadvantaged SMMEs the opportunity to access cloud services since; for the most part disadvantaged SMMEs do not possess computers but use mobile devices.

This research focused on cloud service offerings for SMMEs who cannot afford to buy ICT infrastructure due to financial constraints. However, our investigation also pointed out some relevant issues that need to be addressed in the process of cloud service consumption and provision. Regarding the issue of the creation of VMs by the SP administrator, in future work, human intervention must be eliminated from this process.

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APPENDIX A

I. AMAZON EC2 STANDARD INSTANCE TYPES

Instances of this family are well suited for most applications. This family has small instance, medium instance, large instance, and extra-large instance. Amazon EC2's extra-large specification appears appropriate for arguing our cost saving case. The following section contains a list of available standard instance types for Amazon EC2.

Small instance – default++ (Amazon web service)

1.7 GB memory

1 EC2 compute unit (1 virtual core with 1 EC2 compute unit)

160 GB instance storage

32-bit or 64-bit platform

I/O Performance: moderate

EBS-optimised available: No

API name: m1.small

Medium instance

3.75 GB memory

2 EC2 compute units (1 virtual core with 2 EC2 compute units)

410 GB instance storage

32-bit or 64-bit platform

I/O Performance: moderate

EBS-optimised available: No

API name: m1.medium

Large instance

7.5 GB memory

4 EC2 compute units (2 virtual cores with 2 EC2 compute units each)

850 GB instance storage

64-bit platform

I/O Performance: high

EBS-optimised available: 500 Mbps
API name: m1.large

Extra-large instance

15 GB memory
8 EC2 compute units (4 virtual cores with 2 EC2 compute units each)
1 690 GB instance storage
64-bit platform
I/O performance: high
EBS-optimised available: 1 000 Mbps
API name: m1.x large

Amazon Elastic Compute Cloud (Amazon EC2) provides the flexibility to choose from a number of different instance types to meet the user's computing needs. Each instance provides a predictable amount of dedicated compute capacity and is charged per instance-hour consumed. The standard instance type has memory-to-CPU ratios suitable for most general-purpose applications.

Table A–1: Amazon EC2 standard instance type

Standard on-demand instances	**Linux/Unix usage**	**Windows usage**
Small (default)	$0.080 per hour	$0.115 per hour
Medium	$0.160 per hour	$0.230 per hour
Large	$0.320 per hour	$0.460 per hour
Extra large	$0.640 per hour	$0.920 per hour

APPENDIX B

II. NIMBULA DIRECTOR CLOUD SET-UP FOR VE-ENABLED CLOUD ENTERPRISE ARCHITECTURE

The ICT infrastructure used to set up our cloud met the minimum requirements of Nimbula Director:

3 x Dell T1650 machines with 4 x core Intel processors, 8 GB RAM and 250 GB HD each

1 x Dell Precision T1500 with 4 x core Intel processors, 4 GB RAM and 500 GB HD1 x Ubuntu Linux box used as a router