Cloud Adoption Hurdles, Competence Model, and Opportunities in the African Context: Proof from Ethiopia

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ABSTRACT

Cloud computing refers to both the resources provided over the internet as services and the systems software and hardware in the data centres that provide these resources. These resources can then be used by users for various purposes and provide the benefits of low ongoing cost, more computational power, and optimization of processes of computing among others. To take advantage of these benefits, adopting the cloud and the cloud computing paradigm is a necessary step and has the potential to transform Information Technology (IT) capabilities in developing and under-developed countries. However, in these countries, currently there are some adoption hurdles around this technology. Government agencies need to balance and regulate both hurdles and hype around the technology. Before cloud can be widely adopted, a systematic model of cloud adoption needs to be designed which can help the agencies in charge to navigate the hurdles and the hype. In this work, we have studied this problem in the context of adoption in Africa. The aim of this research is to investigate local cloud adoption threats, hurdles, synergies, opportunities, human capabilities, and other disciplines' theories to design a model which will serve as a guide to the local cloud adoption hurdles in the African context, especially in Ethiopia. More specifically, the key intention and goal of this research is twofold: first, to assimilate the existing game theory and reverse engineering theory, that is, the part of economic theory into the cloud adoption techniques, and second, to look at the effects of open source cloud computing resources on the reduction of aforementioned hurdles via experimentation with OpenStack. The OpenStack is used as a test-bed for the designed mechanism for building a private cloud for the targeted organization to examine the competence of IT experts and pave the way for future research.

The model is designed through various context-based competence possibilities for academia and government. It can be used to mitigate the bottlenecks that arise from the lack of up-to-date cloud knowledge, the lack of a context-based model, the lack of government control, and the lack of well-poised competent IT experts. These bottlenecks lead to the lack of hands-on technical skills, confusion in cloud adoption lack of standard models, under-utilizations of the opportunities of open source cloud platforms, and loose interpretations around the security, trust, legal, regulatory model, control mechanism, and privacy issues.

This research is foundational in nature which assimilates and translates well-established theories of other disciplines into a theory of systematic cloud adoption. The assimilated model minimizes the cloud adoption hurdles by maximizing government power to facilitate, regulate, understand the cloud adoption complexity, and control the cloud adoption rate. It is also a useful lens for cloud experts to see how each hurdle is paired up with some opportunities as it maximizes their competence.

Keywords: Cloud adoption, cloud hurdles, cloud models, cloud computing opportunities

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Notations and acronyms

F	Cloud goal function i.e., regulated cloud computing fully as a public utility without insecurity.
SA	Doing cloud Adoption versus doing Security pressure action function, in short sa-function
Agent one	Cloud enablers, cloud service providers, attackers, cloud supporters, brokers, and other stakeholders-those who benefit from moving to the cloud- prefer more services move to the cloud
Agent two	Defenders, concerned security professionals, cloud opponents, inhibitors, and others-those who consider the cloud as a spying machine, and they have negative attributes of the cloud- prefer less services move to the cloud
SA_i	Cloud security-adoption pressure function by agent i where, $i \in \{1,2\}$
SA_i: $[0, 1] \rightarrow R^+$	$[0,1]$ denote the collection of players i's information set, R^+ is the set of possible actions in the game.
IT	Information Technology
λ	Lambda cloud adoption rates or percentage of legacy IT workload
CCA	A cloud commissioning agency or a mediator of a cloud game
ICT	Information Communication Technology
t	The CCA announces or posts a provisional moving rate at any time t
Θ space or C space	Capital theta or capital C used for cloud computing Environment or cloud Space.
θ	Small theta it is a sub set of capital theta and prevailing cloud environment used for cloud computing platforms and services adoption most that are frequently available today.
M space	Message space
μ	message correspondence or message exchanger from the cloud environment to M space
$\theta = (a, b)$ or $\theta = (a_1, a_2, b_1, b_2) = (a, b)$	A prevailing cloud environment, a and b are cloud environment parameters, a is cloud adoption environment known by agent 1 and b is cloud security environment known by agent 2, but not known by CCA.
$\theta = (\theta_1, \theta_2)$	$\theta_1 = (a_0, a_1, a_2, a_3)$ and $\theta_2 = (b_0, b_1, b_2, b_3)$, where a_0, a_3, b_0, and b_3 are constants and known by agent one, agent two, and by CCA.
Π	Mechanism designed in a third cloud message space M to realize goal function F
h	Outcome function or competence function
$[0,1]$	Cloud adoption rate between 0 and 1 i.e., 0 no adoption and 1 all legacy IT workloads moved to the cloud
Z space	Ideal outcome of cloud computing, i.e., fully as a public utility.
φ	Phi
k_i	Agent 1 or Agent 2 pressure interval, it can be max or min pressure
$CSNs$	Cloud Service Partners
CSP	Cloud Service Provider
$CSUs$	Cloud Service Users
CI	Cyber Infrastructure

EAs	Enumerator Areas
PPS	Probability Proportional to Size
R	Real number
R_{+}^{2}	The nonnegative quadrant of the two-dimensional Euclidian space, or cloud bundles, or cloud space i.e., adoption versus security.
R^{+}	Positive real number
X-as-a-Service	Everything as a Service is made available to the public over the cloud, often virtualized resources are provided.
Mechanism	Competence Model
"yes" or "no"	According to rules of a verification, the *CCA* "posts" a message (sends it to each agent); both agents 1 and 2 see the message, and each respond either *"yes" or "no"* based on their craiteria and cloud environment.
$K*$	The amount of moving into the cloud and the *CCA* will permit if the agents behave strategically.
$\lambda*$	Computed rate if agents behave strategically.
$\lambda = F(\theta)$	Desired level of cloud adoption that is agreed by all agents
φ	Small phi, the function φ: $[0, 1] \rightarrow R^{2}_{+}$, where $\varphi(\lambda) = (\varphi_1(\lambda), \varphi_2(\lambda))$ where, $\varphi_1(\lambda)$ is the amount of cloud service operated and $\varphi_2(\lambda)$ is the amount of data insecurity produced. In short, cloud adoption function.
"no experience no model"	Independent variable indicates experimentation with out OpenSatck and model
"experience with OpenStack no model"	Independent variable indicates experimentation with OpenSatck and without model
"experience with OpenStack and model"	Independent variable indicates experimentation with OpenSatck and with model
API	Application Programme Interface
CC	Cloud computing
3*Cs*	Cloud computing concepts

Chapter 1: Introduction

A new technology can act as a catalyst of change in the social and economic behaviour of developing and developed countries. The assimilation of new technologies as an instrument of change, to accelerate the socioeconomic development in the desired direction is called technology adoption. One of these new technologies is cloud computing, and it can be a catalyst of change in developing and developed economies. Cloud computing technology is rapidly penetrating within the academia, industry, and government sectors around the globe [1]. The developed countries are rapidly adopting the cloud to not only reduce their computing costs but also to accelerate and optimize computing processes and time to market. Currently, many factors, including enabler technologies, security, Information Communication Technology (ICT) friendliness, financial resource, competence of ICT experts, lack of controlling and regulating models, geographical location, and political stability impact cloud adoption worldwide, thus, leaving various countries with noticeably different cloud adoption rates [2]. Recent surveys suggest that many organizations are unprepared for their clouds' security. According to April 2010 International Data Corporation (IDC) cloud computing poll conducted in China, Singapore, Australia, India, Hong Kong, and South Korea fewer than 10 percent of the respondents were confident about their security measures to entirely move their ICT into the cloud. In Africa, in particular Ethiopia, ICT experts consider themselves as only Cloud Service Users (CSUs) rather than Cloud Service PartNers (CSNs) [3]. This trend leads to cloud adoption hurdles, such as, lack of readiness, lack of ownership of cloud infrastructure, inability to see hurdles as opportunities, underutilizing of free open source cloud platforms, lack of regulations, lack of consulting opportunities, lack of understanding the implication of using the cloud, and persuading organizations about cloud rationale for its offer of economies of scale, standardization, integration, affordability, scalability and other benefits that would otherwise be unavailable within the current ICT settings. In addition, The ICT experts of Ethiopia can be considered as end-users based on the assumptions that they have limited contextual framework (or mechanisms, or models) to adopt cloud computing. Also, their lack of skills, low awareness of underlying management and code behaviour of the cloud, categorises them as mere end-users. Ethiopians are way behind in controlling closed or open source cloud management platforms such as OpenStack, AWS, CloudStack, Microsoft Azure, Eucalyptus, IBM Cloud, OpenNebula, which further preclude them from adopting cloud computing.

This research looks at cloud computing adoption, and its hurdles, opportunities, and competence models or mechanisms. It considers assimilating the existing game theory and mechanism design theory, that is, the ‘reverse engineering’ part of economic theory, into cloud adoption techniques. The research assimilates these theories into cloud adoption techniques to minimize the cloud adoption hurdles (such as technical incompetence, failure to see opportunities, threats, lack of balancing adoption rate, and cloud hypes) by maximizing ICT experts’ competence and the government power to facilitate, regulate, and understand the cloud adoption complexity, which leads to control of the cloud adoption rates with the global and local community participations. It is also a useful lens for cloud experts to see how each hurdle is paired up with some opportunities as it maximizes their competence.

While cloud computing offers many benefits such as initial investment cost reduction, speed up computing process, time to market, and so on. Recently, looming cyberattacks and cloud adoption confusions, technical incompetence, cloud overhypes, and others such as failure to see opportunities, are chronic hurdles in Africa. As it stands, attackers, cloud providers, and brokers prefer everything, including mission critical applications, move into the cloud−this is dangerous, and it should be balanced by the government regulatory bodies. In contrast there are professionals, non-professional opponents, and others, who would prefer that less applications move to the cloud. These two groups’ preferences lead to the cyber gaming against each other (game from game theory perspectives). This can be regulated or moderated by the game and mechanism design theories. For the purpose of this study, it is called an assimilated model, and it will serve to minimize these hurdles.

The outcome of this work is assimilated models from the existing game and economic mechanism theories. This has resulted into three models that can be levelled as low-level, intermediate-level, and high-level. They are used for digital balance and skill: cloud enabled systems or applications can be adopted, and cloud experts’ competence can be maximized via this designed model. In addition, the government Cloud Commissioning Agency (*CCA*) can control or regulate the cloud adoption amounts or rates and preserve mission critical data from cyber-attack until the cloud become threats free.

The organization of the rest of the report is as follows: under chapter one–central research questions and problem statement specified, chapter two builds upon the background and previous work on the hurdles, and their solutions, comparing their approaches and justifying the reasons behind this paper’s approach to tackling the hurdles. The third chapter reports on this researches approach as to systematically assimilating the theories into the cloud adoption and security balancing via a model modified. The fourth chapter presents the experimental evaluation, analysis, result, and proof from Ethiopia to test the model modified by interpreted theories. Finally, the fifth chapter provides a conclusion recommendation, and future work on the argument at a more general level by showing how this studies approach has supported the cloud adoption at government and expert level.

1.1 Problem statement

Africa, in particular Ethiopia, is not adopting cloud computing technologies, and the country is not utilizing open source cloud management platforms (such as OpenStack and CloudStack) being developed by the global community. This is due to a combination of hurdles including: awareness, readiness, a lack of competent ICT experts, a lack of community participation, and an absence of universities taking a leading role in cloud computing concepts. Other hurdles involved are a lack of mechanisms; the lack of a government tool to regulate cloud adoption; the lack of hands-on competence; poor psychology of service provision; a failure to see hurdles and free open source cloud platforms as opportunities; the lack of mechanisms to control the cloud adoption rate, with the global community participations; and misunderstandings relating to security, trust, legal, and privacy issues. The problem statement for this study is comprised of the following central research questions:

- How can other disciplines' theories and models be assimilated into cloud adoption techniques to alleviate the country's cloud adoption hurdles?
- How do assimilated competence models, supported by open source cloud computing resources, contribute to ICT experts' competence? How are these models used as a useful lens for cloud experts to see how each hurdle is paired up with some opportunities?
- How can the way be paved to overcome the cloud adoption hurdles in Africa, in particular Ethiopia, using open source cloud management platforms via newly-formed competence models?
- How can cloud adoption rates be regulated and controlled, using the local and global community participations as agents, via game and economic mechanism theories?

1.2 Rationale

The rationale behind looking for a solution for cloud adoption hurdles via experimentation with OpenStack is that the cloud computing can offer economies of scale, standardization, integration, scalability, and other benefits that would otherwise be unavailable with the current ICT settings. The cloud is rapidly being adopted in various domains worldwide, including education, commerce, healthcare, scientific computing, agriculture, and tourism [2]. The survey currently shows, however, that Africa (specifically Ethiopia) is not adopting the cloud, including the open source cloud management platforms such as OpenStack. In addition, technically there is lack of insight into the cloud adoption benefits such as:

- Reduction of initial and continuous upgrade costs
- On demand capacity utilization of services (enhanced elasticity)
- Greater flexibility and mobility of access to data and services
- Immediate upgrading of software
- Saving operational costs (30% [$60M] savings in the case of Korea [to appear])
- Better Disaster Recovery and Business Continuity

1.3 Research coverage

This work primarily involves the identification of adoption hurdles in the cloud, then assimilating theories and designing a mechanism, followed by the analysis of the experiments (such as OpenStack setup with and without models) which take place at different institutions (universities, Ministry of ICT, private service providers, and other government offices) in Ethiopia. To identify the hurdles and get evidence for the assumptions made in this study a purposive sampling technique and survey design was implemented. Data was collected using face-to-face interviews, discussions, demonstrations and questionnaires which were distributed to these institutions.

1.4 Assumptions of cloud adoption hurdles

A cloud adoption process involves a wide range of different players ranging from government to business. The interactions between these players in pursuing their own interests, drives the development of the cloud computing industry into being. Some of these drive the business forward while others hold it back (such as cloud attackers, providers, enablers, brokers defenders, opponents and supporters). This study also found that various parties have participated in the process stimulated by different interests, and their interactions drive the development forward even with its security threats. African organizations need to rely on one government regulation model to get out of the cloud adoption confusion and to have enough confidence to adopt the cloud. The lack of human resources in the Information and Communication Technology (ICT) sector is seen as a major hurdle in Ethiopia. Progress has been made in raising overall knowledge levels in the ICT sector, yet Ethiopia still lacks highly experienced and skilled experts capable of dealing with the complex cloud computing, regulations, ICT networks, markets, policymaking, and the implementation of large sociotechnical projects [3].

The work by K. Jackson [12], and K. Chandrasekaran [13] shows that OpenStack is now a global success, developed and supported by many people around the globe, including some of the leading players in the cloud space today. The confidence and understanding of OpenStack is important to roll out into one's own data centres and into the cloud ecosystem. Currently, Ethiopia's technology experts are not active participants on free open source cloud resources like OpenStack software due to challenging hurdles.

The current cloud situation can be divided into two spaces: cloud space and outcome space, but there are a lot of adoption hurdles in business as usual. Therefore, in this paper, an additional third space, called message space, was created for a mechanism to alleviate the current cloud adoption hurdles; that is, additional means of achieving the goal. This study supposed that competency mechanisms were designed for a clientele, who may be a political authority, African government, African government agencies, African society or a firm. The goal function, *F*, reflects the clientele's criterion for evaluating the cloud outcomes. The works of L. Hurwicz [6] and [7] have been syntactically borrowed for this purpose. The research translates well-established methods from other disciplines into new solutions for cloud studies by assimilating the existing game theory and mechanism design theory; that is, the 'reverse engineering' part of economic theory into cloud adoption mechanisms. The game theory was used for players, and the mechanism design theory was used for the government to regulate or mediate the cloud adoption.

Chapter 2: Background and related work

During the modelling approaches, different processes and strategies for assimilating the existing legacy theories were followed. This included game and economic mechanisms−designing theories into the new paradigm; that is, assimilated cloud adoption models. The game computing was used for the cloud players and the low-level economic mechanism designing theory was used for the government regulator (a mediator), in our case, the Cloud Commissioning Agency (CCA). The mechanism designed in this paper is called informational efficient mechanism. It is also called informationally efficient decentralized truth-telling mechanism. This means that the CCA, including the players, can get more communication with less computing. The high-level abstracted mechanism was used for the experimentation with OpenStack to test competence of IT experts of organizations.

2.1 Cloud computing background

The cloud is developing not just as a vertical sector, but also as a horizontal sector enabling other domains ranging from large enterprise, entertainment, education, health, military to constantly changing business needs, social and individual development worldwide from underdeveloped to developed countries. Similarly, the research in cloud computing is focusing across the vertical and horizontal sectors including all domains. There are six major research themes of cloud computing investigated by researchers in the field information system: foundations, literature review, SaaS model, security and risk, adoption and impacts, and modelling [8]. This research is focused upon only two themes: adoption hurdles and modelling including opportunities. Thus, before going to the main studied themes, the following section introduces the fundamental concepts of cloud computing including other disciplines' concepts assimilated into the cloud adoption techniques.

2.1.1 Cloud computing

Cloud computing is fundamentally a set of capabilities, applicable to all aspects of Information Communication Technology (ICT), from acquisitions, architecture, infrastructure, development, deployment, operations, automation, manageability, optimization, cost, and so on. Based on an individual's background and experience, cloud means different things to different people [9]. The work [10] shows that cloud computing is defined and refined depending on the content. Most the definition, concepts are focused on: potentials, requirements, success factors, and challenges, issues, risks, business models, decision guidance, and provider topics. This work concentrates on the concept defined as potentials and challenges by [11] (see Section 1.1.1.2). Academic definition of cloud computing seems technically complex. In practice, we might not worry whether we are practicing something that is technically "the cloud" or not. The services are just part of our business [5]. For this study, we need to define a formal definition, that is, the National Institute of Science and Technology (NIST) in the USA defines cloud computing, which is primarily taken by most academia and cloud vendors, it also most researches content focus is NIST oriented (see Section 2.1.1.1). Alternatively, section 2.1.1.1.1 shows the NIST definition depicted to be more clear and understandable by nontechnical peoples.

2.1.1.1 The NIST definition of cloud computing

NIST defines cloud computing as a model for enabling suitable, on-demand network access to a shared pool of configurable computing resources (such as computer memory, servers, networks, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics (On-demand self-service, Broad network access, Resource pooling, Rapid elasticity, Measured Service); three service models (Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS), Infrastructure-as-a-Service (IaaS)); and, four deployment models (Private cloud, Community cloud, Public cloud, Hybrid cloud). Key enabling technologies include: (1) fast wide-area networks, (2) powerful, inexpensive server computers, and (3) high performance virtualization of commodity hardware [12].

2.1.1.2 Armbrust et al.'s definition of cloud computing

Cloud computing refers to both X-as-a-Service over the internet and the systems software and hardware in the data centres that provide X-as-a-Service. The data centre software and hardware is what we will call the swarm. When the swarm is made available on a pay per use manner to the public, we call it a public cloud; the service being sold is utility computing. We apply the term private cloud to refer to internal data centres of an organisation, not made available to the public [11].

2.1.1.3 Architecture of cloud computing

The architecture of the cloud environment is demonstrated with three resource pools: storage, networks, and compute (see Figure 2.1). Each is an abstraction offered by a virtualization layer.

Server virtualization presents a pool of computing with virtual machines which supplies the computing, that is, processor (CPU), power to execute code and run instances.

2.1.1.1.1 Simplified interpretation of the NIST definition

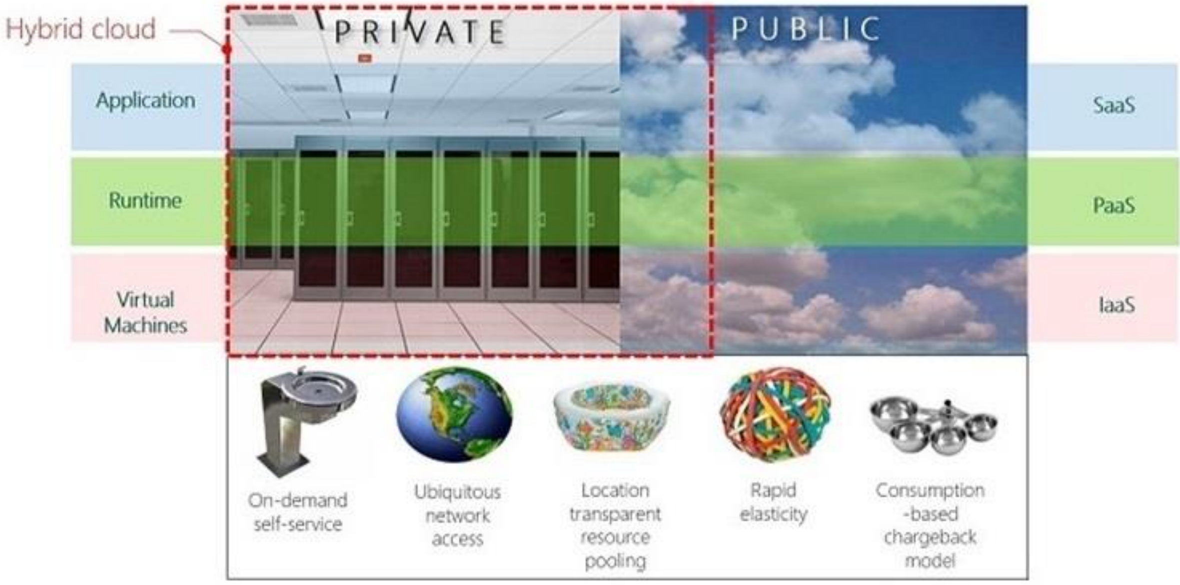


Figure 2.1: Depicts the NIST definition for nontechnical people

(Reproduced from: https://blogs.technet.microsoft.com/yungchou/2011/03/03/chous-theories-of-cloud-computing-the-5-3-2-principle)

Network virtualization offers a consortium of network and is the mechanism to allow multiple tenants with identical network configurations on the same virtualization nodes or hosts while segmenting, connecting, isolating network traffic with virtual network interface cards, address space, internet protocol (IP) pools, logical switches, network sites. Storage virtualization offers a logical storage device with the capacity that appears continuous and aggregated with a storage pool devices behind the scene [9].

The vertical architecture in Figure 2.2 served as four layered models: standard hardware layer, infrastructure layer, platform and application or software layer. Hardware layer or bare metal layer: CPU, router, hard disk, switches, and so on. Infrastructure layer responsible for managing the virtual server, storage media and balance the different nodes. The platform layer is like infrastructure layer but also includes operating systems and required services for applications. And applications layer, which is shown on top of the stack allows users to run applications remotely from the cloud.

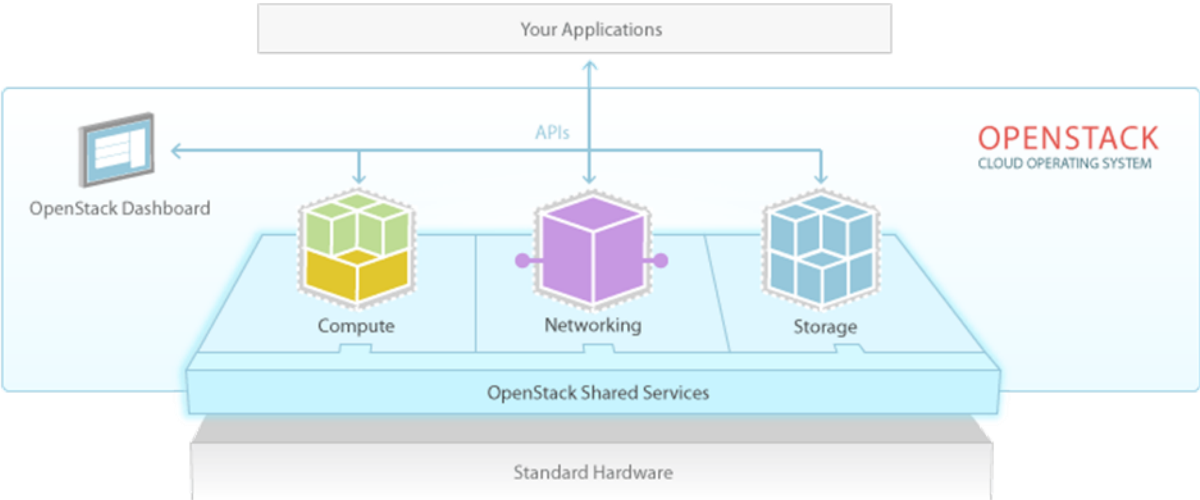


Figure 2.2: High level architecture of OpenStack cloud OS

(source credited: openstack.org)

These days, the providers hype is users can run everything as a service i.e., X-as-a-Service. For instance, According to Linthicum [13], categorization X-as-a-Service can be categorized as Application-as-a-Service, Storage-as-a-Service, Database-as-a-Service, Information-as-a-Service, Governance-as-a-Service, Management-as-a-Service, Process-as-a-Service, Infrastructure-as-a-Service, Platform-as-a-Service, Integration-as-a-Service, and Testing-as-a-Service. In a more comprehensive manner, X-as-a-service categorized by ISO/IEC 17788, can be Communications-as-a-Service (CaaS), Compute-as-a-Service (CompaaS), Data-Storage-as-a-Service (DSaaS), Infrastructure-as-a-Service (IaaS), Network-as-a-Service (NaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service (SaaS) [14].

2.2 Game theory

What is a game? A game is a formal representation of a situation in which number of self-interested individuals interact in a setting of strategic interdependence [15].

Game theory provides many conceptual solutions to compute the outcome of a game with self-interested agents, given the assumptions about the agent preferences, rationality, and information available to other agents about each other. Although the term "game" may seem to undersell the theory's importance [15]. It might be important in the current state of computing and for the future world.

To describe a situation of strategic interaction, we need to know the following:

i. The players: who is involved?
ii. The rules: who moves when? What do they know when they move? What can they do?

iii. The outcomes: for each possible set of actions by the players, what is the outcome of the game?
iv. The payoff: what are the players' preferences (utility functions) over the possible outcomes?

2.3 Mechanism

A mechanism is a mathematical pattern that models organizations through which economic activity is channelized and coordinated [7]. In the context of this study, a mechanism is a formal competence model intended to represent a system for organizing and coordinating cloud activities. The need for such a mechanism can arise at different levels of cloud entities, ranging from private firms to government agencies. The cloud activities can be classified as enabling, providing, adopting, consuming, and sharing of X-as-a-Service. These activities are constrained by restrictions on resource availabilities, securities, and on the knowledge of technological possibilities, all of which form the cloud environment space. In addition, mechanism design is the 'reverse engineering' part of economic theory. Usually, economists study existing economic institutions and try to explain or predict what outcomes institutions will generate. In mechanism design, however, the direction is reversed: it starts with identifying the desired outcomes, and then asking what institutions could be designed to achieve those outcomes. The theory has found wide application in public good provision, auction design, environment-pollution control, and elsewhere [16].

According to L. Hurwicz [17] formulation, a mechanism is a communication system in which participants exchange messages with each other that jointly determine the outcome. These messages may contain private information, such as an individual's true or pretend willingness to pay for a public good. The mechanism is like a machine that compiles and processes the received messages, thereby aggregating (false or true) private information provided by many agents. Each agent strives to maximize its expected payoff (profit or utility), and may decide to withhold disadvantageous information or send false information. This leads to the notion of implementing outcomes as equilibria of message games, where the mechanism defines the rules of the message game [18].

The rationale of choosing a mechanism design approach is to decide, strategize, and design the cloud hurdles and opportunities; thinking more clearly about the cloud. It creates intelligent citizens of the world for using and understanding data, and it is used as a lens to see some complicated aspects of the cloud [19]. Specifically, in a cloud computing adoption, it is useful to develop backward and forward linkages between the most important cloud entities (end user, authors, integrators, cloud service partners, cloud service providers and cyber infrastructure developers) and other stakeholders.

The mechanism works as a game, which forms message exchange processes between these entities and stakeholders. The analogy of the mechanism design theory to the cloud, is the goal of the cloud or the social choice, like economic mechanism design theory, but to achieve this goal different adoption mechanisms are needed. Within an African context, the focus is on hands-on experimentation using an open source platform and some pairing opportunities via a model to mitigate the hurdles.

We suppose that competency mechanisms are designed for a client, who may be in our case, African government, a firm or a political authority. The goal function, F, reflects the clienteles' criterion for evaluating outcomes. We syntactically borrowed the works of [7]. The model can be visualized as a machine that accesses as input the cloud environment, and some possible criteria of the goal function at that environment and produces as its outcome. The current cloud situation can be considered in two spaces: cloud space and outcome space, but there are a lot of adoption problems as business as usual. Therefore, in this paper we created additional third space called message space to design a mechanism to alleviate the current cloud adoption hurdles, that is, additional means of achieving the goal. During the modelling approaches, followed different processes and strategies for assimilating the existing legacy theories, such as, economic mechanisms and game designing theories into the new paradigm, that is, cloud adoption mechanisms. The game form computing was used for the cloud players and the economic mechanism designing theory was used for the government regulator (a mediator) in our case, the Cloud Commissioning Agency (CCA).

The mechanism we designed is called informational efficient model, it is also called informationally efficient decentralized: truth telling model, which is incentive compatible truth-telling mechanism, i.e., the CCA, including the players who can get more amount of communication with less computing.

The organization of the rest of the paper is as follows. The second chapter builds upon the previous work on this problem and their solutions comparing their approaches and justifies the reasons for our approach to tackle the problem. The third chapter reports on our approach as how we systematically assimilated the theories into the cloud adoption and security balancing via a mechanism modified. The fourth chapter presents the experimental evaluation, analysis, result, and proof from Ethiopia to test the mechanism modified by interpreted theories. Finally, the fifth chapter provides a conclusion on the argument at more general level by showing how our approach is supporting the cloud adoption at government and expert level.

2.4 Identified worldwide and local hurdles

Key hurdles in the world of cloud computing are: technical incompetence, data security, data privacy, trust, ownership, policy, social, business, worldwide framework, worldwide standards and continuous availability of services (internet failure). There is also no central body governing use of the cloud for services and storage. The following sections show the main identified hurdles to the adoption of cloud computing.

2.4.1 Worldwide hurdles

- Technical hurdles to the adoption of cloud computing
    - Availability of data or service: due to performance and data transfer rate, bandwidth limitation, latency constraint, and Denial of Service (DOS) attack-result outage. What happens if a cloud service is offline for a period?
    - Data Security: is my data secure? Attacks on infrastructure, cyber-attacks, malicious insiders
    - Data confidentiality, and auditability: How do I know if my data is truly unusable when I delete it (even on-premises cloud)?
    - Vendor data lock-in or APIs, interoperability platforms, protocol translation, and standard APIs
- Policy and business challenges to the adoption of the cloud.
    - Legal issues: cross-border storing and processing, or data sovereignty, or transfer of legal liability. Cloud providers would want legal liability to remain with the customer and not be transferred to them.
    - Privacy: is my data protected? Privacy violations, information disclosure from government agencies is another challenge that decelerate cloud adoption. In 2014, Google positively responded to a majority of about 27,477 information disclosure requests by the US government.
    - Trust: due to off-premise clouds
    - Standards
    - Compliance: am I in compliance? What happens if a provider loses a disk drive?

    - Separation of ownership of data on the cloud is opaque: cloud is a shared environment with other users, cloud providers and data owners
- Technical challenges to the growth of cloud computing
    - Scalable storage
    - Bugs in large-scale distributed systems
    - Performance unpredictability–virtualization level
    - Off-shoring industry problems: malicious insider hazards

2.4.2 Local hurdles

The following are Africa's local hurdles to adopt cloud computing:

- Ministry of ICT has cloud initiatives, but it has no cloud strategies
- International communication barriers
- The complexity of the bank system for paying to a cloud provider is one hurdle to cloud adoption
- No Reliance on cloud provider
- Limited fund to invest in cloud computing
- Policy makers, law makers, and all ICT stakeholders have used old ICT policy (lack of review) to adopt cloud computing
- Information access and distribution policy
- Ecosystem problems or synergy problems (finance, skill, university, companies) are not working together
- Infrastructure hurdles: Africa still live far from the nearest fibre node
- Security and resilience: no cybersecurity preparedness include legal, technical, organisational, and cooperation
- No capacity building in security, including IT security, digital forensics, university courses, and industry-academic cooperation
- No mentorship for graduates to offer detailed insight into the software, infrastructure and technology delivering those services
- Almost all African policy development processes are not supported by experienced international consultants
- Shallow and narrow Internet penetration (3 percent)
- Lack of understanding about what is happing in cloud computing in the world

- Ethiopian telecommunication behaves as a monopoly by, for example, setting its own prices
- Strategic gap in the development of a sustainable information society and knowledge economy
- Lack of effective ICT governance, lack of models, lack of mechanisms, and lack of frameworks
- Monopoly of ISP and infrastructure quality (lack of alignment during road construction and power installation)
- Power interruption (infrastructure quality)
- No competitive and innovative environment
- No awareness: public, industries, enterprises (both medium and small), law makers to revise acts, government, and universities
- Readiness: infrastructure, cloud concept including enablers (like virtualization, stack software, and more
- No academic curricula
- Lack of skilled cloud experts
- Shortage of financial resources
- Political issues (monopoly of data centres and ISP)
- Lack of leading universities or research institutes to paired up hurdles to opportunities
- Lack of adopting cloud environment in context
- Limited open source software utilization
- Poor psychology of service provision

Current worldwide attempts to pass cloud computing hurdles both internal (technical) and external (social and business): -

- To minimize the attack surface data in use or memory with encryption. That is, if encrypted data can be processes in servers without the need to be decrypted, the privacy of data in foreign environments will be addressed effectively
- Standards for interoperability and cross-bordering
- Hardware, Operating System (OS) and Virtual Machine (VM) hardening by focusing hardening the underlying VM
- End to end encryption
- Attesting software for the integrity of the compute host or node

- Behaviour-based sensation of malware to eradicate the effect of new generation malicious application (cryptocurrency mining, rootkit and multisector attacks)
- Data provenance
- Block-chain technology
- Revising policies, regulations, laws of security and privacy
- Creating different adoption toolkits, mechanisms, and models
- User-centric, data centric, and responsibility sharing point of views.

2.5 Previous related works

In theory, developing economies could catch up with developed countries as the cloud gives them access to the same X-as-a-Service and virtualized data centre infrastructure. However, developing countries could avoid some hurdles in realizing the cloud's full potential through better flameworking and efforts to address human resources competence and lack of government powering tools [20]. Developing countries must take measures to develop cloud related competencies, and universities must provide hands-on experience. The evolution of the cloud computing led telecommuting in South Africa, for example, can be attributed to the country's ICT growth , minimum cost internet bandwidth [21]. According to innovation Africa digital summit of 2016 report, for Africa to adopt the evolving digital landscape, emerging cloud computing trends should be systematically categorised into opportunities, threats, hurdles, synergies and capabilities.

The cloud computing hurdles can be grouped as: policy and business hurdles, technical incompetence to the adoption, and technical hurdles to the growth of the cloud. Recent studies of the cloud adoption hurdles have been carried out mostly on the business even though the hurdles come from other groups as well [22]. According to K.-H. Ali et al. [23] the researchers have started to focus and renewed their interest on the business view of the cloud. That is, over 61 present publications are focusing on the business aspect of the cloud. This renewed interest in publications affect and contributes in the declining of technical view and technological aspects of the cloud hurdles publications, especially, in the African context still need more technical view publications. Many researchers have proved that finding competent cloud experts is a chronic problem in developing countries. Until now, the cloud hurdles in Africa are due to lack of skilled experts, lack of systematic mechanisms, or models, or frameworks, and technological factors. This indicates that in the last few years the technical competency view, such as, skills, awareness, technical modelling, and readiness issues are declining in several studies. The United Nation report [24] noted to adopt the advantage of the cloud potential in developing economy. Several steps should be considered by African governments, first, they need to assess the cloud readiness of the country, second, they need to address the need for competent IT experts, and third, they need to address their own framework. In addition, other studies on the topic by L. Adam [3], asserts that the lack of competent ICT experts is a challenging hurdle in Ethiopia. An early work by N. Kshetri [21] states that developing countries governments must take measures to develop cloud computing related competence, and universities must provide fundamental concepts and hands-on experience and some mechanisms.

With an exception to South Africa, the adoption rate and other challenging hurdles for rest of the Africa are not known very well. L. Adam carried out a research on understanding the ICT context in Ethiopia for evidence of policy action in telecom projects, but cloud computing was outside the scope of his research. The Software Alliance analysed cloud readiness rates across the globe to gain insights into the adoption rates, challenges, and possible solutions to expedite cloud adoption in 24 countries. According to the BSA the aim is to identify the potential and challenges of cloud adoption and suggest solutions to the problem with the help of major cloud vendors, government cloud stakeholders, decision makers, and cloud consumers. In addition, in 2018 using the Scorecard, BSA tracked the evolution of the legal and regulatory environment for cloud computing in 24 countries around the world [25]. To this day, regulatory environment for the cloud is a ranking criterion of countries' preparedness for the adoption and growth of the cloud services. Thus, the governments need to control or regulate cloud computing adoption at the country or worldwide level. By putting it into the free play without the involvement of stakeholders such as. academia, industry, cloud professionals, customers, government, even attackers, and defenders, may yield unexpected results [1]. For these regulations of the cloud, we need a systematic mechanism like a mathematical structure that models institutions through which economic activity is guided and coordinated [7]. In our assimilation context, a mechanism is a formal competence model intended to represent a system for organizing, coordinating, and regulating cloud activities. The need for such a mechanism can rise at different levels of cloud entities, ranging from private firms, to government agencies. The cloud activities can be classified as enabling, providing, consuming, and sharing. These activities are constrained by restrictions on resource availabilities, securities, and on knowledge of technological possibilities, all form part of the cloud environment space.

Research and development is also undertaken in different countries. For instance, the Malaysia public universities and research institutes leveraging cloud adoption to undertake efficient research and development efforts. Among Malaysian public universities, the university of Malaya has already built cloud computing data centre based on Microsoft Azure, OpenStack, and similar cloud platforms that will be available to researchers and students in the near future [2]. However, effective adoption of cloud services requires thorough revision of networking policies in such institutes and requires competent staff to run and maintain such a virtually unified cluster of resources. Currently, Ethiopian universities showed some interest but they need competence and the tools used for cloud computing [26].

The Malaysia researches have indicated the lack of competent cloud experts, knowledgeable cloud law makers, and service consumers as the most notable hurdles in the adoption of cloud computing in Malaysia. Reportedly, 20 percent of Malaysian users have not even heard of cloud computing. Thus, developing varied technical programs and hands-on workshops for technical staff, decision makers, and law makers in addition to cloud-awareness programs for public need quick momentum in Malaysia. Some Malaysians might be familiar with the concept of utility computing, but possess limited knowledge. Therefore, the universities and other academic institutes must take the lead on educating and training of the cloud computing concepts and applications. Gaining insight into the advantages, disadvantages, and implications of adopting the cloud for stakeholders, including law makers and service consumers, is a significant need [2]. It is the worst in case of Africa and need more researches to provide innovative solutions.

The existing empirical evidence shows how effectively these theories, ideas, and mechanisms can be translated into practice. A close look at the early stage of the cloud enterprise development indicates that these observations might underscore how economic and competence problems remain central to the development and diffusion of information technologies and entrepreneurial functioning in the developing world. For one thing, the cloud is inherently linked to the multiple aspects of data security [27].

Researcher by K. AlAjmi [28] describes the General Services Administration office (GSA) presented a recommendation to former US President on how strategically the informal use of the cloud computing should be formally framed via a clear and serious-minded policy. Moreover, the GSA's recommendation put forward to the former President predicted a 50 percent decrease in the cost in maintaining web portal has the cloud computing been adopted.

The President and his chief information officer found opportunities in the cloud computing to reduce cost and increase efficiency keeping in mind the emerging issues this could bring to the government. We think it was very important for the GSA officer who presented a recommendation to the former President. At that time may be the experts “traditionally” examine the cost and range of socio technical factors into account to present and to move the portal into the cloud. In the government context or country level context, once the examined organizations fit into the cloud presented, using the cloud adoption mechanisms the government needs to focus on balancing, crafting and enforcing policies, laws, standards, and regulations that govern and control the threat, accessibility, interoperability, traceability, auditability, availability, capacity, integrity, negotiability confidentiality, and usage over the cloud [29].

Mechanism design theory has a huge effect on our thinking about development hurdles in poor countries, where these are used to decide, strategize, think more clearly, understanding processes and data, and used as a lens to see some complicated things [30]. Today’s focus is on fostering institutions and individual initiative. Traditional solutions to community problems such as access to credit, land sharing arrangements and natural resources management have been revisited and improved considering mechanism design theory, and new solutions have been proposed. The theory represents a breakthrough in the modern economic analysis of institutions and markets and will have a lasting influence for the design of economic policies[31]. In our case, all the terms can be assimilated as a security adoption design, a security control, a cloud commissioning agency establishment, a message exchanging process, the cloud resource management, and competence model.

Mechanism is used to decide, strategize, and design the cloud hurdles, competence and opportunities; thinking more clearly about cloud; it creates intelligent citizens of the world; for using and understanding data; and it is used as a lens to see some complicated things of the cloud [6]. Specifically, in a cloud computing adoption, it is useful for backward and forward linkages between the most important cloud entities (end user, author, integrator, cloud service partners, and developers) and other stakeholders. The mechanism works as a message exchange processes and game forms between these entities and stakeholders. The analogy of the mechanism design theory to the cloud is the goal of the cloud or the social choice, like economic mechanism design theory. However, to achieve this goal we need a different adoption mechanism (in the African context, we focus on hands-on experimenting using open source platform and some pairing opportunities via model) to mitigate the hurdles.

In the first Figure 2.1 by R.Kenneth [32] shows that given the performance function P there are generally several decentralized mechanisms that realize *P*. This concept leads to the second Figure 2.2 and Figure 2.3 by N. M. Prize [7] and [18] shows that in games of mechanism design, agents send messages *M* in a game environment *Θ*. The equilibrium in the game *Π= (M, μ, h)* can be designed to implement some goal function *F(Θ*). The competence function *h(μ(Θ))* or *g(μ(Θ))* translates or overcomes the messages or hurdles into outcome using different mechanisms *Π= (M, μ, h)* to realize function F (i.e. desirable/ acceptable outcome *A*, *Z* or *X*). *μ(Θ*): acceptable messages or *m(Θ*).

Mechanism design theories translated in the following sequence from Figure 2.3 in 1900 to Figure 2.4 to 2006, then Figure 2.5 in 2017.

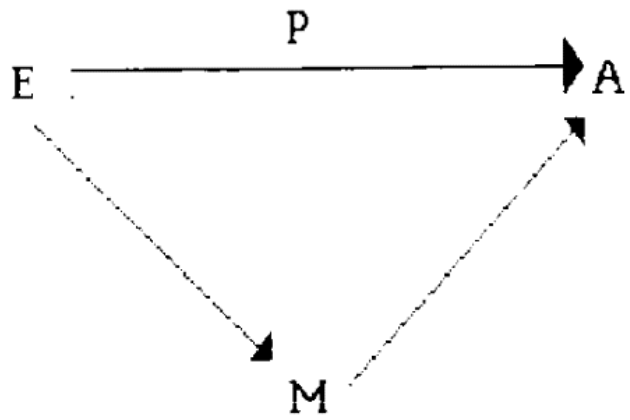


Figure 2.3: Depicts commuting as lower-level concepts in 1900 [32]

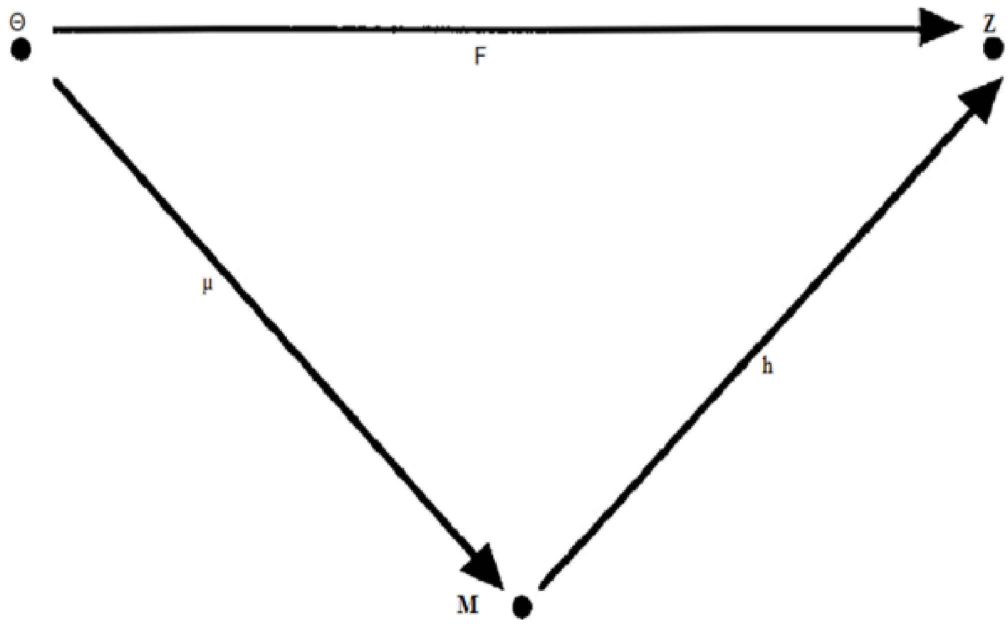


Figure 2.4: Depicts commuting as lower-level concepts in 2007 [7]

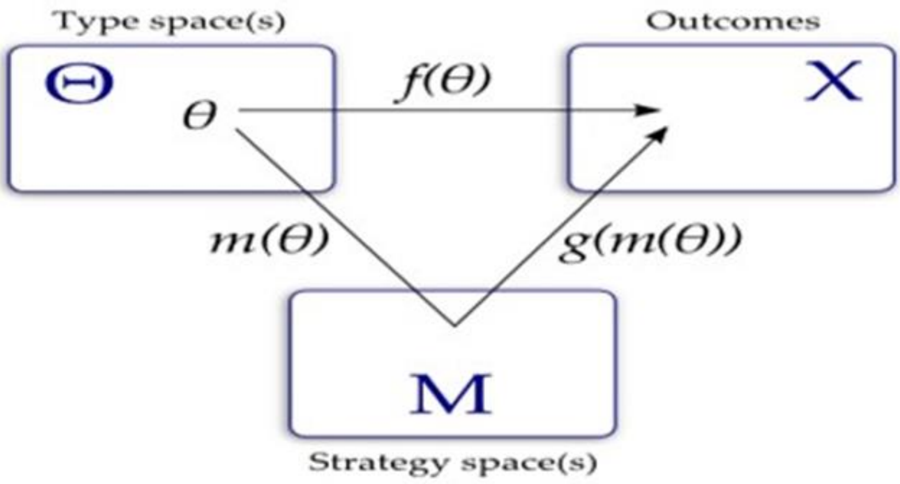


Figure 2.5: Depicts commuting as lower-level concepts in 2017 [18]

The Software Alliance (BSA) analysed cloud readiness rates across the world to gain insights into adoption rates, challenges, and possible solutions to expedite cloud adoption in 24 countries. According to the BSA, the aim is to identify the potential and challenges of cloud adoption and suggest solutions to the problem with the help of major cloud vendors, government cloud stakeholders, decision makers, and cloud consumer [25]. Currently, the Africa's adoption rate and other challenging problems are not known very well except South Africa.

The main limitation of previous studies have only focused on cost, feasibility, and challenges at an enterprise level including the following works: The work [33] identifies that due to the fast growth, the cloud has become a non-transparent market with providers and customers willing to embrace it. Moreover, many offers only partially meet clients' requirements and it is not clear how exactly the cloud influences the IT. That makes it hard for clients to plan migration projects and implement sustainable cloud solutions. There are important factors and considerations for the conclusion to adopt the cloud. The current surveys and inquiry in this area can be summarized to focus closely on the questions as why adoption of the cloud would occur, how much adoption would take space or how it would be taken. Only the adoption requirements covering all three service models have hardly been talked about in literature so far. Yet, how much adoption would take place is posted by enterprise level and by providers only. In our argument, there should be a mechanism that shows how much adoption would take place from both the cloud opponents and from the cloud supporters at a government level.

Similar work by K.-H. Ali [23] describes and models the challenges that decision makers face when assessing the feasibility of the adoption of the cloud in their organisations, and describes their cloud adoption toolkit, which has been produced to support this operation. Cost modelling shows its strength by demonstrating how practitioners can practice it to study the costs of deploying their ICT systems on the cloud. However, the research does not take into account on how at the country level it works. A comparative study by M. Mujinga and B. Chipangura [34] shows that at country level, hurdles in developing economies are the hurdles faced by cloud service providers and their consumers. However, the study did not provide a framework to solution to tackle these hurdles.

2.6 Specification of the hurdles

This section specifies the hurdles of the cloud adoption via identification of local and worldwide cloud adoption hurdles, competence, and opportunities. It gives an indication of how cloud computing fits into the African context, particularly in Ethiopia. In Ethiopian universities, cloud computing is not truly part of a national curriculum yet. Currently, the construction of a data centre and private cloud are near-future government projects in Ethiopia, in order to stimulate growth and enhance ICT [3]. To successfully achieve this objective, the ICT experts should have the required competence, and this is gained from an academic curriculum, mechanisms, or models to systematically and continuously address the existing competence gaps. The absence of a context-based competence model or mechanism in the country are assumed to be among the major cloud adoption hurdles. This implies that there is limited competence among the cloud experts, which reflects on the utilization of the open source cloud resources in the cloud ecosystem, and runs all the way to the grassroots of cloud computing. In order to adopt the cloud, the government will need some models (such as regulating and controlling mechanisms).

2.6.1 Survey approach

This study first conducted a current state assessment and investigation to find the causes of local cloud computing hurdles and opportunities using a combination of primary survey studies (face-to-face interviews, group discussions, questionnaires) (see Figure 1.2). Next, secondary data was gathered from desk research (existing standards, frameworks, guidelines, ICT policies, and literature), and international experience (Egypt, South Africa, India and New Zealand). This was used to lay the foundation and build evidence for further experimentation.World-wide open source community platforms such as OpenStack and the proposed competence mechanisms then used to bridge the gap (see Figure 1.1). During further experimentation, Likert scale data was collected via observation of participatory demonstrations of OpenStack and models from potential cloud experts. More specifically, the study took the following approches:

- Quantitative information was collected using hard copy questionnaires before the practical participation of the experts. There was also a combination of face-to-face interviews and group discussions conducted (see Figure 1.2).

- Experimental demonstrations were conducted, for the participants to observe and track their competence.
- Desk research, analysis and interpretation were used
- A mechanism for future state cloud competence was designed as a solution to bridge the cloud adoption gaps (see Figure 1.1).

The participants selected based on characteristics of their current ICT usage and their expected potential to adopt the cloud, for providing the cloud and potential cloud experts. Their involvement was systematically classified using a stratified two-stage cluster sampling method, and was performed in five steps for the target population (see Appendices).

The data will be analysed using the Kruskal Wallis H test (see Chapter 4). The top hurdles of cloud computing will be observed such as skills of IT experts, and framework deficiency.

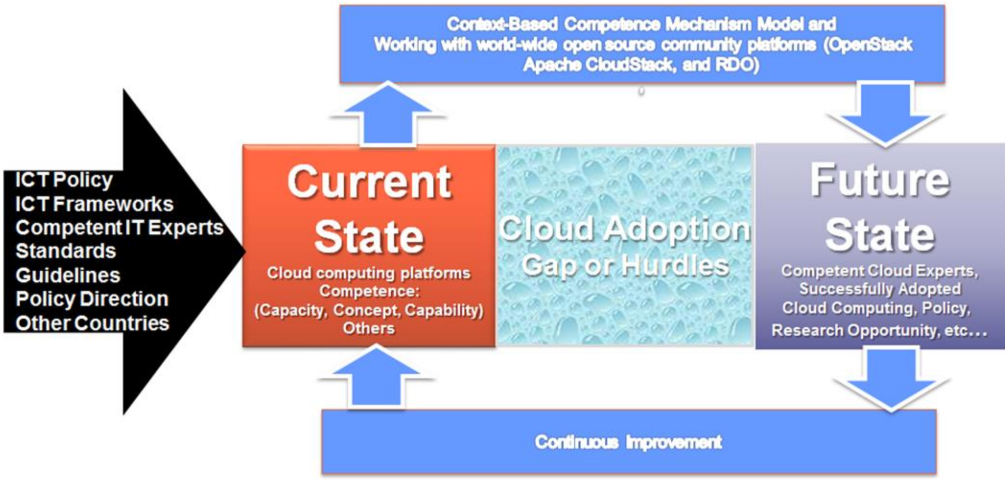


Figure 2.6: The final hurdle specification

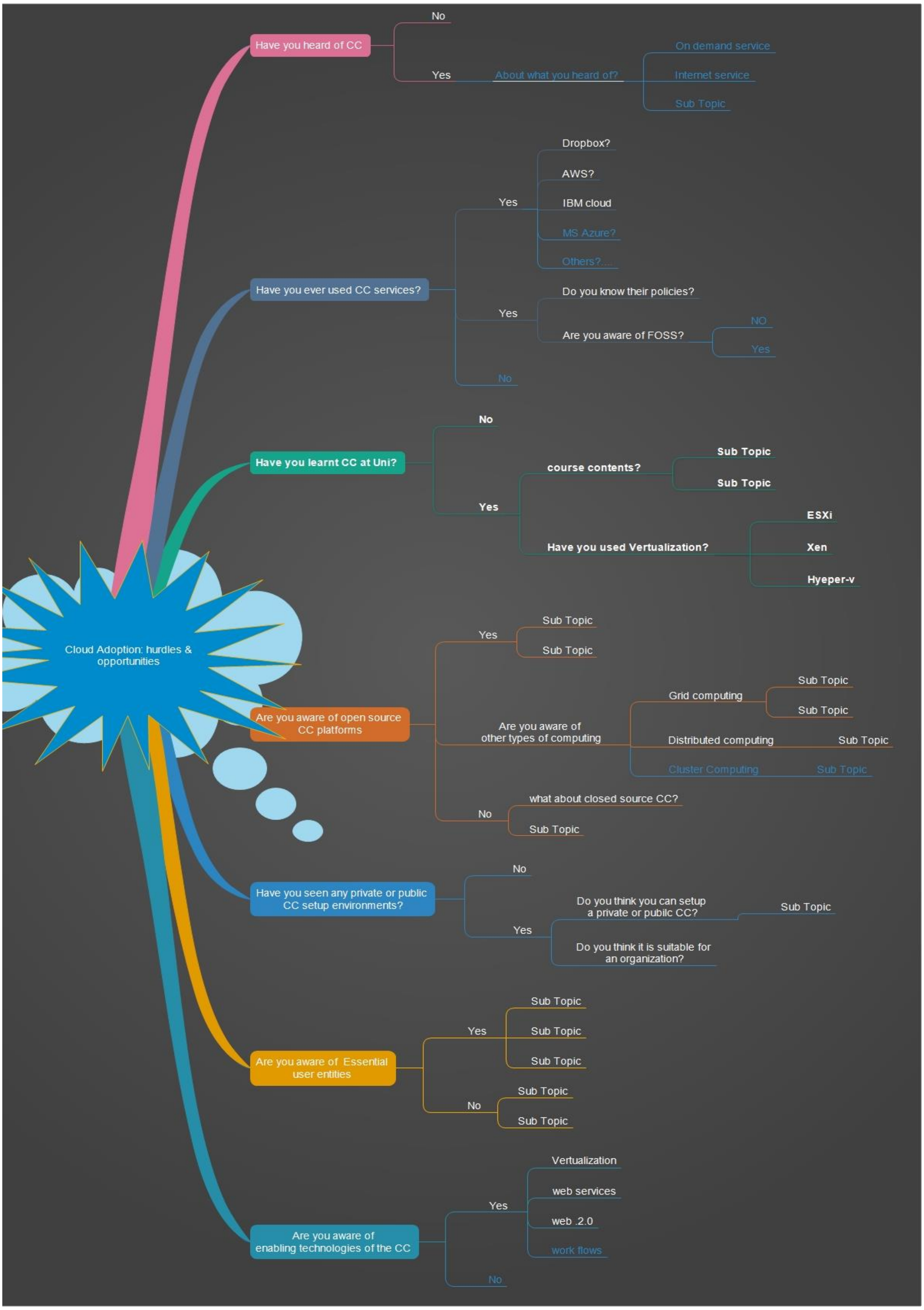


Figure 2.7: Face-to-face interviews and group discussions

Chapter 3: Proposed models

Our research assimilates three abstracted level models: low-level, intermediate-level, and high-level. The low-level abstracted model uses for game strategy to balance the cloud security and adoption at country level; the intermediate-level abstracted model used for a mathematical structure to transit from low-level abstraction to high-level model, we call it the competence model.

The assimilated game strategic interactions in cloud computing situation can be translated as low-level abstracted models. The situation we created as a low-level model is a game for balancing or regulating adoption and security pressure at the government level. Cloud adoption is regulated and controlled by a government agency, called Cloud Commissioning Agency (*CCA*) which is responsible for deciding (mediating) how much legacy IT workloads or services should be move to the cloud. Therefore, we need a representation of the technology of moving to the cloud in terms of the variable controlled by the *CCA*. Let that variable be $\lambda \in [0, 1]$. This is the amount of adoption, normalized for this study to the adoption of the cloud so that $\lambda = 0$ represents no adoption, $\lambda = 1$ represents moving the entire legacy IT workload or services into the cloud, and $0 < \lambda < 1$ represents partial migration into the cloud (see Formula 3.1). The following Formula 3.1 and Figure 3.4 represent the technology.

$$If \begin{cases} \lambda = 0, then\ rate = 0\%\ \ or\ no\ adoption\ or\ no\ moving\ into\ a\ cloud \\ 0 < \lambda\ \ < 1, then\ 0\% < \ rate < 100\%\ or\ partial\ migration\ into\ a\ cloud \\ \lambda = 1, then\ \ rate = 100\%\ or\ moving\ an\ entire\ IT\ services\ into\ a\ cloud \end{cases}$$

Formula 3.1

For simplicity we assume that there are two groups, adoption agents and –security agents (agent one and agent two). Agent one represents the group of cloud adopters; agent two represents the security preservationists. Agent one knows that the adopters are willing to support cloud adoption action that advocates more moving into the cloud. Agent one also knows that the amount of support forthcoming from the adopting stakeholders depends on the amount of moving to the cloud that would be allowed by *CCA*; that is, on the value of λ (see Formula 3.1). If $\lambda = 0$ is the proposed (proposed by *CCA*) or λ is prevailing amount of moving to the cloud, then adopters are willing to support more intense or extensive adoption action than they would if $\lambda = 1$, in which case they might be unwilling to pay much efforts. Thus, agent one knows the function SA_1: $[0, 1] \rightarrow R$ whose value, $sa_1 = SA_1(\lambda)$, is the intensity of adoption pressure that agent one expects to be generated from the support of the stakeholders of adopters; where the amount of moving into the cloud allowed is λ.

Similarly, agent two knows the function SA_2: [0, 1] → R, whose value is the amount of security pressure agent two generates at the moving amount λ. The functions called SA_i security-adoption action functions, or *sa*-functions, for short. For simplicity, the *sa*-functions are treated as primitives (derived from utility functions). We make two assumptions directly about them. First, we assume that the function SA_i takes values in the interval $[k^i_{min}, k^i_{max}]$, $i \in \{1,2\}$. The end points of the interval are the minimum (k^i_{min}) and maximum (k^i_{max}) levels of security-adoption pressure (k) Agent i can does. We assume that the function SA_1 takes its maximum at 0, and is strictly decreasing on the interval [0, 1], and that SA_2 takes its minimum at 0, and is strictly increasing on [0, 1]. Furthermore, we assume that each *sa*-function is piecewise linear: it consists of three-line segments corresponding to the three-line segments in the graph of φ. It follows that a possible *sa*-function SA_1 for agent one is completely specified by its value at each of four points:

$\lambda = 0, \lambda = \lambda_1, \lambda = \lambda_2, \lambda = 1.$

Let $k^1_{max} = SA_1(0)$, $a_1 = SA_1(\lambda_1)$, $a_2 = SA_1(\lambda_2)$, *and* $k^1_{min} = SA_1(1)$.

Similarly, for SA_2, we write $k^2_{min} = SA_2(0)$, $b_1 = SA_2(\lambda_1)$, $b_2 = SA_2(\lambda_2)$, and $k^2_{max} = SA2(1)$.

In this notation, the graph of SA_1 consists of three-line segments, one with the endpoints $((0, k^1_{max}), (\lambda_1, a_1))$, the second with the endpoints $(\lambda_1, a_1), (\lambda_2, a_2)$, and the third with endpoints $(\lambda_2, a_2), (1, k^1_{min})$. The assumption that SA_1 takes its maximum at 0 and its minimum at 1, and is strictly monotone, is expressed by the requirement that

$k^1_{max} > a_1 > a_2 > k^1_{min}.$

The two endpoints of the middle segment correspond to the points at which the graph of φ has kinks. Similarly, SA_2 consists of three-line segments with endpoints $(0, k^2_{min}), (\lambda_1, b_1), (\lambda_1, b_1), (\lambda_2, b_2)$, *and* $(\lambda_2, b_2), (1, k^2_{max})$, respectively, where

$k^2_{min} < b_1 < b_2 < k^2_{max}.$

Where $\theta = (a_1, a_2, b_1, b_2) = (a, b)$ *are the prevailing cloud environments* $\theta = (\theta_1, \theta_2)$ *specified by the parameters* $\theta_1 = (a_0, a_1, a_2, a_3)$ *and* $\theta_2 = (b_0, b_1, b_2, b_3)$ used for cloud computing platforms and services adoption, most that are frequently available today (see Figure 3.4). In other words, θ is the prevailing cloud environment, *a* and *b* are cloud environment parameters. The cloud adoption environment known by agent one is *a*, and *b* is the cloud security environment known by agent two, but not known by *CCA.* Constants known by agents one and two, and by *CCA*, are a_0, a_3, b_0, and b_3. To delineate a situation of a strategic interaction in the cloud, the game playing is between the following entities and environments:

i. The Players or Agents:

Who is involved? Two agents and one mediator or Cloud Commissioning Agency (*CCA*)

Agent One: Cloud enablers, cloud service providers, attackers, cloud supporters, brokers, and other stakeholders.

Agent Two: Defenders, concerned security professionals, cloud opponents, inhibitors, and others.

Mediator: Government, government agency, Chief Executive Officer (CEO). In our case, hereafter we call it Cloud Commissioning Agency (*CCA*).

ii. The Rules:

Who moves when? A natural way of thinking about a mechanism is to think of the private agents (agents one and two) sending information – messages – to the *CCA*, perhaps in an ongoing dialogue. This suggests some sort of dynamic process, for instance: a discrete time message exchange or adjustment process as follows.

1) $SA_i(t) = SA_i\left(\left(\lambda(t)\right), \theta_i\right), i \in \{1, 2\}$. *Where θ is the current cloud environment known by agent one and agent two, based on this calculation they respond "yes" or "no" in answer of their agreement rate to move to the cloud.*
2) $\Delta\left(\lambda(t)\right) = SA_1\left(\left(\lambda(t)\right), a\right) - SA_2\left(\left(\lambda(t)\right), b\right)$ *, the CCA calculate at a time t+1, where a and b are the current unagreed cloud environment.*

Formula 3.2: The rule formula for regulating the cloud adoption

At time *t* the CCA announces or posts a provisional moving rate $\lambda(t) \in [0, 1]$. A moving rate λ (lambda) is a percentage of legacy IT resources allowed to move to the cloud by *CCA* (see Formula 3.1). Agents respond with "yes" or" no". Agent *i* responds with the message $SA_i\ (t) = SA_i\ (\lambda(t), \theta_i)$, $i \in \{1, 2\}$.

At time $t + 1$ the *CCA* calculates $\Delta\lambda(t)) = SA_1(\lambda(t), a) - SA_2(\lambda(t), b)$ and adjusts the value of $\lambda (t)$ according to the rule $\lambda (t + 1) = \lambda(t) + \eta(\Delta (\lambda(t)))$, where η is a sign preserving function of Δ such that $\eta(0) = 0$. Thus, according to this process, the *CCA* proposes a moving rate; each agent responds with a message that informs the *CCA* of the amount of security-adoption pressure that the agent can provide. If the pressure from the movers exceeds the pressure from the concerned security stakeholders, the *CCA* proposes a higher moving rate. If the pressure from the movers is smaller than that from the concerned security stakeholders, the *CCA* proposes a lower moving rate. If the pressures are equal, the *CCA* announces that rate as its decision. The players can use the current technologies– such as, distributed ledger or public blockchain in order to send information, perhaps in an ongoing dialogue.

What do they know when they move? The rule formula is known by all players, and agents know their environment θ, but the *CCA* do not know the current cloud environment or prevailing environment θ_i.

What can they do? Agents send a message to the *CCA*, and the *CCA* posts and calculates using pre-specified rule calculations, to assign an outcome (such as adoption rate calculations) for every collection of received messages.

iii. The Outcomes:

For each possible set of actions by the players, what is the outcome of the game? Security-adoption pressure rate is the outcome of each possible set of actions by the players. SA_1: $[0, 1] \rightarrow R$ whose value, $SA_1=SA_1(\lambda)$, is the extent of security-adoption pressure that agent one expects to be generated from the support of stakeholders of adopters when the amount of moving to the cloud allowed is λ. Similarly, agent two knows the function SA_2: $[0, 1] \rightarrow R$, whose value is the amount of security-adoption pressure agent two generates when the moving to the cloud amount is λ.

We call the function *SA* security-adoption action pressure function. Thus, SA_i: $[0, 1] \rightarrow R^+$, $i \in \{1,2\}$. [0, 1] denotes the collection of players i's information set; *R* is the set of possible actions in the game. We assume that the functions SA_i are continuous, and piecewise linear (see Figure 3.4), with linear segments on the intervals $[0, \lambda_1)$, $[\lambda_1, \lambda_2]$, $(\lambda_2, 1]$ It reflects the simplifying assumption for all admissible environments $\theta = (\theta_1, \theta_2)$ specified by the parameters $\theta_1 = (a_0, a_1, a_2, a_3)$, $\theta_2 = (b_0, b_1, b_2, b_3)$.

iv. The Payoffs:

What are the players' preferences (such as utility functions) over possible outcomes? Less move to the cloud or more move to the cloud decision.

To do this the *CCA* needs a mechanism (see Formula 3.1 and 3.2) Our algorithm constructs an informationally efficient (less resources required to operate the mechanism; less computing, more communication) decentralized (privacy preserving) mechanism that implements that goal function in a revelation mechanism, in which truth-telling is an incentive compatible. Decentralized means information is preserving privately by each player, because it is self-interested interaction.

3.1 Intermediate-level model

Our research translates the mathematical structures of economic mechanism design from low-level abstraction to an intermediate-level model, to assimilate into the cloud adoption techniques. It is a mathematical structure used for the transition from low-level to high-level models as shown in Figure 3.1.

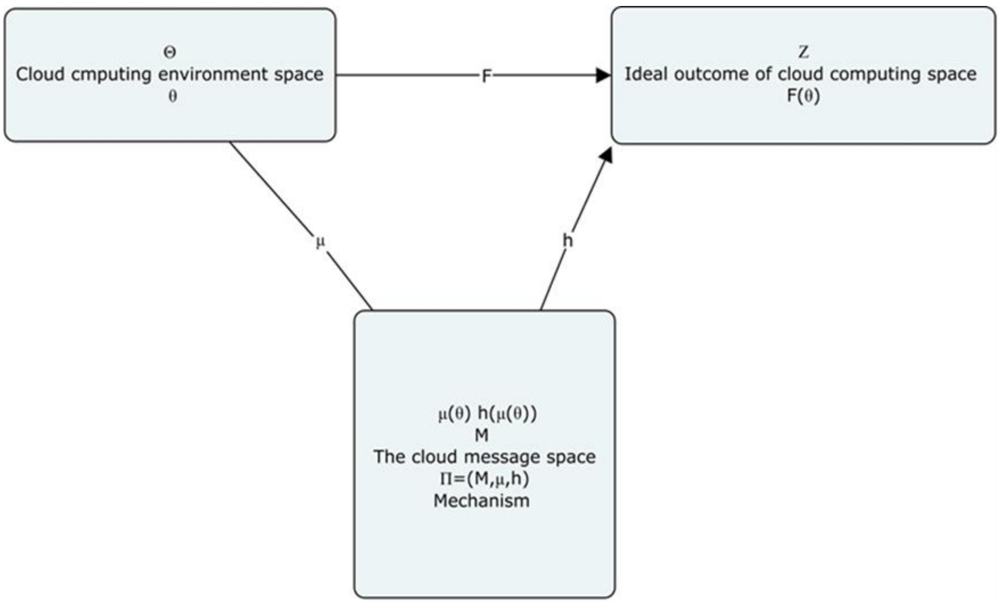


Figure 3.1: Depicts the commuting of Intermediate-level abstracted model

In the figure *F*: is a goal function of the cloud computing that is, fully public utility without insecurity.

h: the outcome function that translates message into outcomes, or implementation function, or competence function. That is, the paired hurdles with some opportunities translated into useful cloud outcomes.

μ: is a message exchanger (survey information, cloud reports, end-users, providers, regulators, attackers, supporters, enablers opponents, brokers, researchers, Cyber Infrastructure (CI) developers, authors, academia, etc)

Θ: the current most frequently or very commonly adopting clouds. That is, Θ subset of Θ.

$F(\Theta)$: the current adopted cloud outcomes that are at least acceptable according to some criterions embodied in F.

$\mu(\Theta)$: acceptable messages. There are issues in cloud computing such as VM underling hardening; VMs isolation and co-location, scalability, weak application processing, visibility control, attesting of integration of servers and computing node; trust, privacy, legal, and policy hurdles.

Π: Extra Mechanisms to realize F that is, $\Pi=h(\mu(\Theta))$ - Pairing hurdles with some opportunities and competence function h translates into the desired outcome; these mathematical structures work for the next high-level model.

3.2 High-level model.

IT experts of the organizations easily understand the cloud hurdles, can see some opportunities and processes, and know their needed competence. They can play inside these three spaces and translated mechanisms to achieve a desired goal or ideal outcome of cloud computing, or to achieve game at equilibrium by collecting every possible piece of information and actions of all of the cloud players.

In Figure 3.2 the processes and the concepts from Cyber Infrastructure (CI) to cloud services reproduced from [35] are listed below. From each process, the Information Communication Technology (ICT) experts found opportunities and hurdles. They were designing a mechanism to get information, and pairing hurdles with opportunities.

Cyber Infrastructure (CI) Development: integrate system networks, hardware, storage, interfaces, workflow generation, administration, virtualization and management software, access algorithms, scheduling, and authoring tools.

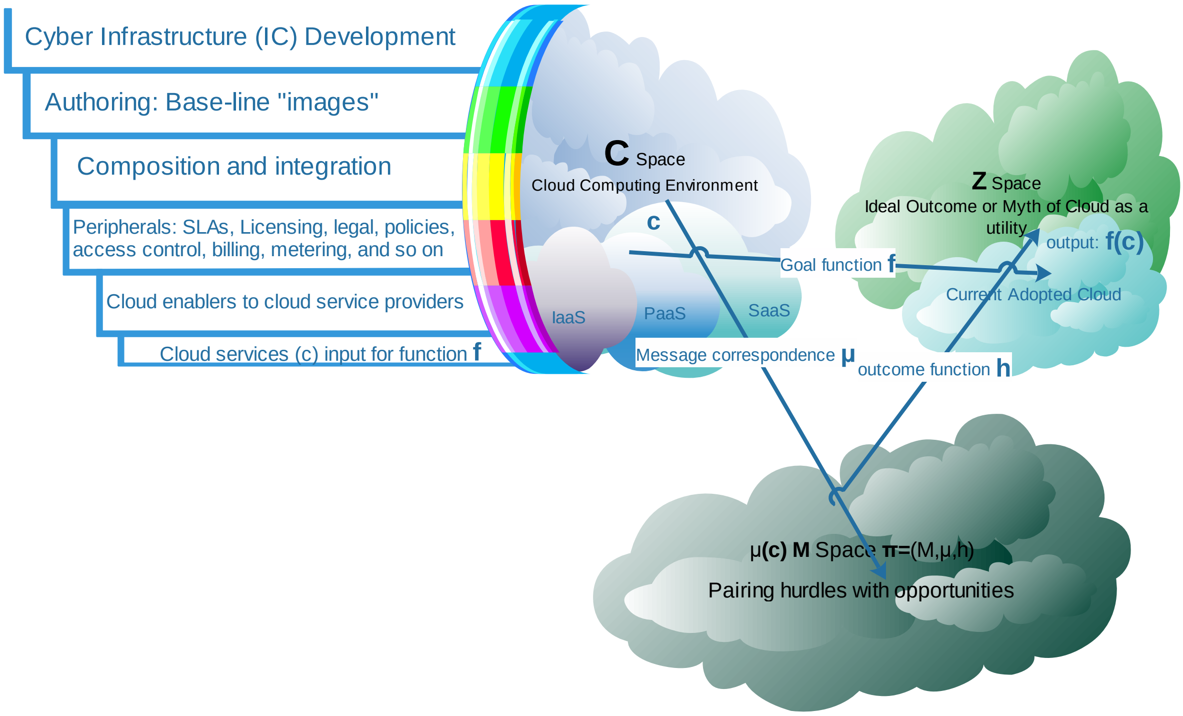


Figure 3.2: Depicts the commuting of High-level abstracted concepts

Note: The arrows show the mapping or translation.

Authoring: individual base-line 'images' and services that may be used directly, or may be integrated into more complex service aggregates and workflows by service provisioning and integration experts.

Composition and integration: tool set integration: provisioning and integration experts should be able to focus on the creation of composite and orchestrated solutions needed for an end-user.

Goal function *F*: criterion embodied in *F* such as failure free, dynamically scalable in and out, malicious insider free, DDOS free or availability of service, trustworthy, secure data throughout its lifecycle (data confidentiality), attest mechanism of integrity of computing nodes or server, and Auditability; bugs free in large distributed systems or debugger that relies on distributed VMs, VMs isolated, End-to-end QOS, data to data ownership principle, can track data provenance as it moves as well as visibility and control over data; and server, advanced persistent threat control system, can avoid having a compromised sever or VM before infected other, and verification data deletion.

The equilibrium message correspondence μ represents the behavior of the agents. μ: Technical & non-technical (legal, political, business, & social hurdles) hurdles as well as unlimited information via message exchanger agents (survey information, cloud reports, researches, cloud enablers, CI developers, Authors, experts, hackers, opponents, supporters, end-users, providers, regulators, attackers, etc).

Outcome or Competence function *h*: Mitigate and translate the hurdles message into outcome using free cloud platforms via cognitive competence (methodological)-based on cloud academic concepts, functional competence (technical), personal competence (social competence), and value competence (individual competence).

3.3 Low-level model

Mathematical interpretations and applications of low and intermediate level abstracted theories by setting up the cloud computing specific goal function, we can design informationally efficient mechanisms such as *F*: adopting to the cloud and terminating from the cloud using decentralized informationally efficient mechanism. Its objective is for balancing security-adoption pressures at the government level.

The mechanism must realize the goal function (objective). A cloud adoption can produce two things: cloud service environment, briefly “X-as-a-Service”, and an insecure environment, briefly “information insecurity”. Thus, current cloud service and information insecurity are a joint product of moving into the cloud. The amount of movement into the cloud determines the amount of operation inside the cloud, and the degree of degradation of the legacy ICT. Information security is measured as the amount of secured information that remains. The cloud adoption is run by a government agency, cloud commissioning agency (*CCA*), CEO, or IT manager, who is responsible for deciding how much moving to the cloud can be done there. Therefore, we want a representation of the process of moving to the cloud in terms of variables controlled by λ. Moving to, or adopting, the cloud is subject to pressures, such as: security, privacy, trust, policy, an effective network, technological readiness, business competitiveness, cost saving, simplicity, potential for scalability, reliability, high performance service, prediction of growth (such as from $46.3 billion in 2008 to around $222.5 billion in 2019[36]), complexity, loss of control over data, and the possibility that the user might become dependent on proprietary systems whose costs will escalate, and the terms of services might change. The stakeholders of those who benefit from moving to the cloud includes CSPs, cloud enablers, brokers, attackers, end users who have insensitive data, and supporters. These stakeholders prefer moving more ICT services into the cloud. On the other hand, those who consider the cloud as a spying machine, and they have utterly negative views of the cloud (such as weaker at application processing, ownership complexity, privacy and trust immature, complex, and insecure), and those who have sensitive data also prefer moving less of their ICT services into the cloud. We suppose that the preferences of stakeholders in the two different groups are diametrically opposed: Agent one and Agent two.

For simplicity we assume that these are two diametrically opposed groups -security-adoption agents - agent one and agent two. Agent one represents the group of adopters to the cloud; agent two represents the security preservationists, or stakeholders (prefers less or no moving to the cloud). The government or organization's CEO or IT manager who controls the cloud adoption assigns responsibility for that cloud adoption to a bureaucrat, who is represented here by an agent, called "CCA". The role of the *CCA* is to decide how much service moving to the cloud to permit, that is, to choose the value of λ.

The *CCA* knows the function φ , but does not know the function SA_i (threat-adoption-business pressure), $i \in \{1, 2\}$; that is, the *CCA* does not know the prevailing environment, namely, $\Theta=(a_1, a_2, b_1, b_2)=(a, b)$ or the function SA_i: $[0,1] \rightarrow R$, function φ: $[0,1] \rightarrow R_+^2$, $\varphi(lambda)=(\varphi_1(lambda), \varphi_2(lambda))$, here $\varphi_1(\lambda)$ is the amount of cloud service adopted on the cloud when the intensity (amount) of moving into the cloud is λ; $\varphi_2(\lambda)$ is the amount of data or information insecurity produced (see Figures 3.4 and 3.5).

We assume that the function SA_1 takes its maximum at 0, and is strictly decreasing on the interval [0, 1], and the SA_2 takes its minimum at 0, and it strictly increasing on the interval [0, 1]. The *CCA* is supervised by one or more committees and ultimately by the national data centre CEO. Therefore, the *CCA* must be able to justify its decision based on some coherent principle, or set of principles, which can be represented formally by a goal function (*F*) that associates the desired level of moving to the cloud, $\lambda=F(\theta)$, with each possible environment θ. The *CCA* must, in one way or another, get information about the cloud environment, and be able to explain or rationalize its decision.

3.3.1 Balancing adoption-security pressures

To apply the low-level model, we need consider the following economic theory:

Currently, X-as-a-Service operation and data insecurity are joint issues, with joint appearance of moving into the cloud or adopting to the cloud in the cloud space or in the cloud environment. In our case, we call it a cloud bundle R_+^2, that is, in the non-negative quadrant of the two-dimensional Euclidean space (see Figure 3.3).

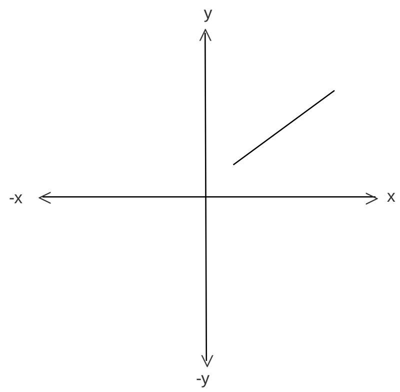


Figure 3.3: Two-dimensional Euclidean space

As shown in Formula 3.1 if $\lambda = 1$ all cybercrime attack that will cost the world \$6 trillion by 2022 and then will apply to entire ICT services in the cloud [37]. According to the Cisco Security Capabilities Benchmark Study, about a quarter of the organizations that have suffered an attack lost business opportunities. Four in ten said those losses are substantial. One in five businesses lost customers due to an attack, and about 30 percent lost revenue. Nation conflicts are increasingly being played out in cyber space, targeting critical infrastructure, companies, and public sector organisations. Hacking is now an organized crime or nation-sponsored event [38].

If $\lambda = 0$ we will not be taking advantage of all the available processing power and untethering of the hardware from a single server model. Cost efficiencies are being realized in both private and public cloud.The function φ: $[0, 1] \rightarrow R^2_+$, where $\varphi(\lambda) = (\varphi_1(\lambda), \varphi_2(\lambda))$ where, $\varphi_1(\lambda)$ is the amount of cloud service operated and $\varphi_2(\lambda)$ is the amount of data insecurity produced.

Agent one knows a strategy (contingent plan), that is, the function $SA_1: [0, 1] \rightarrow R$ whose value, $sa_1 = sa_1(\lambda)$, is the intensity of adoption pressure that agent one expects to be generated from the support of the stakeholders of adopters.

Similarly, agent two knows the function $SA_2: [0, 1] \rightarrow R$, whose value is the amount of security pressure agent two generates from the security stakeholders. $sa_2=sa_2(\lambda)$. We call the functions SA_i security-adoption action functions, or sa-functions. The environment consists of a possible pair of functions (SA_1, SA_2)

The cloud commissioning agency knows the function φ, but does not know the functions SA_i, $i \in \{1, 2\}$; that is, the cloud commissioning agency does not know the prevailing environment, namely, $\theta = (a_1, a_2, b_1, b_2) = (a, b)$.

The function SA_i takes values in the interval $[k^i_{\min}, k^i_{max}]$, i = 1, 2. SA_1 takes its maximum at 0, and is strictly decreasing on the interval [0, 1], and that SA_2 takes its minimum at 0, and is strictly increasing on [0, 1] (see Figure 3.4).

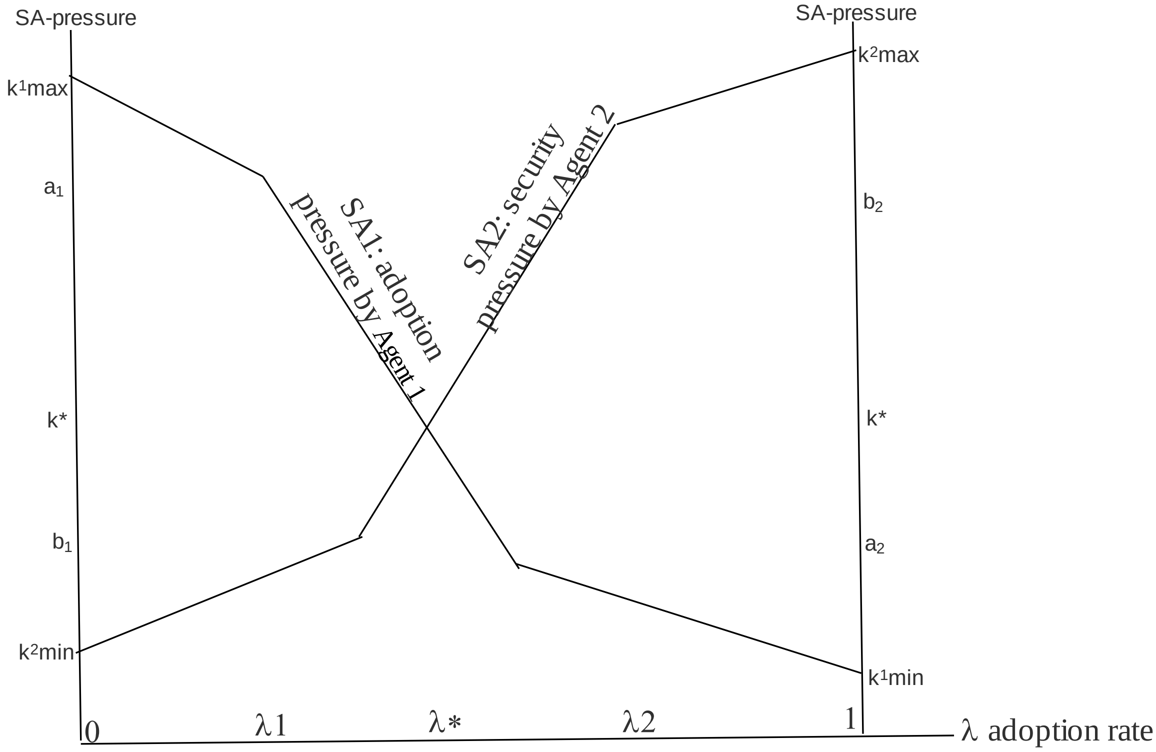


Figure 3.4: Security-adoption (*SA*) pressures by Agent one and Agent two

(Adapted from Leonid Hurwicz)

The piecewise linear curve shown in Figure 3.5 is the cloud adoption set. It is not necessarily the efficient frontier of a larger set, as it would appear to be in a conventional representation of cloud adoption, although the example could be reformulated to fit that interpretation. Note that the point in the cloud space that represents the result of no moving into the cloud is the point (0, N), where N denotes the amount of safety provided by the unmoved IT services. The curve shown in Figure 3.5 is the image of the unit interval by the function φ: [0, 1] → R^2_+, where $\varphi(\lambda) = (\varphi_1(\lambda), \varphi_2(\lambda))$. Here $\varphi_1(\lambda)$ is the amount of X-as-a-Service operation produced when the amount (intensity) or rates of moving services into the cloud is λ, and $\varphi_2(\lambda)$ is the amount of data insecurity so produced. The function $\varphi = (\varphi_1, \varphi_2)$ maps the interval of the possible adopting amount λ ∈ [0, 1] onto piecewise linear curve $\varphi(\lambda) = (\varphi_1(\lambda), \varphi_2(\lambda)) = (n, w)$, where n denotes the amount of X-as-a-Service operation produced, and w is the amount of data not exposed to the cloud insecurity as it is remaining securely from the cloud, when the amount of adopting is λ (see Figure 3.5).

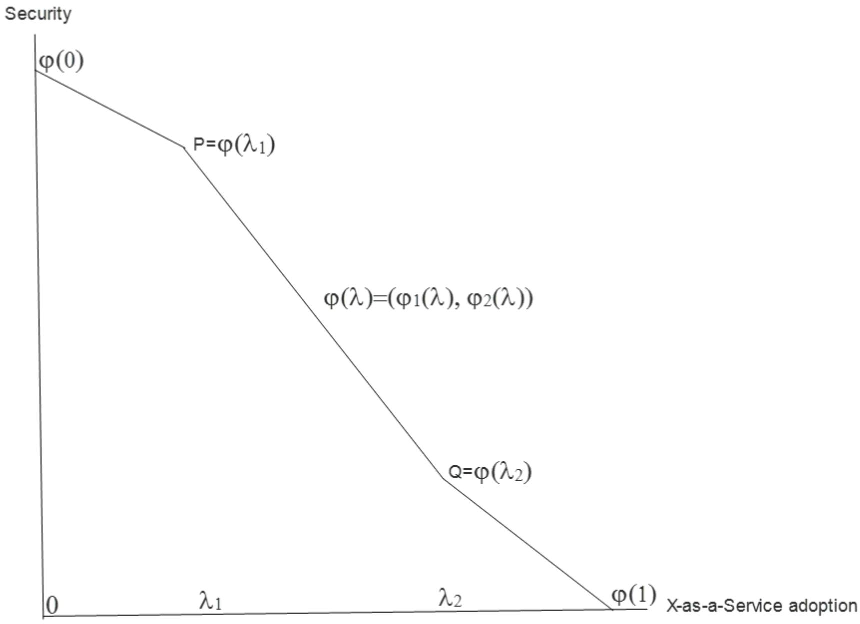


Figure 3.5: Cloud adoption vs security of piecewise linear curve.

Thus, SA_i: [0, 1] $\rightarrow R^+$, $i \in \{1, 2\}$. [0, 1] denotes the collection of players *i*'s information set (such as cloud computing security environment information and adoption information), R^+ is the set of possible pressures actions (such as adoption pressure and security pressure) in the game. We assume that the functions SA_i are continuous, and piecewise linear, with linear segments on the intervals $[0, \lambda_1)$, $[\lambda_1, \lambda_2]$, $(\lambda_2, 1]$, admissible environments $\theta = (\theta_1, \theta_2)$ are specified by the parameters $\theta_1 = (a_0, a_1, a_2, a_3)$, *and* $\theta_2 = (b0, b_1, b_2, b_3)$, where

1) $a_0 = k^1_{max}$, $a_3 = k^1_{min}$, $b_0 = k^2_{min}$, $b_3 = k^2_{max}$ here *k is the level of security or adoption pressure agent i can does.*

2) $a_0 > a_1 > a_2 > a3$, $b_0 < b_1 < b_2 < b_3$

3) $a_0 > b_0$, $a_3 < b_3$ (see Figure 3.4).

At time *t* the *CCA* announces a provisional adopting rate λ(t) ∈ [0, 1]. Agent *i* responds with the message $SA_i(t) = SA_i(\lambda(t), \theta_i)$, $i \in \{1, 2\}$. At time *t* + 1 the *CCA* calculates: $\Delta(\lambda(t)) = SA_1(\lambda(t), a) - SA_2(\lambda(t), b)$ and adjusts the value of $\lambda(t)$ according to the rule $\lambda(t + 1) = \lambda(t) + \eta(\Delta(\lambda(t)))$, where η is a sign preserving function of Δ such that $\eta(0) = 0$. A fixed rule called the outcome function, which is a function known by all three agents. Thus, according to this regulating process, the *CCA* proposes a moving rate; each agent responds with a message that informs the *CCA* of the amount of security-adoption pressure that the agent can exert. If the pressure from the adopters exceeds the pressure from the security preservationists, the *CCA* proposes a higher adopting rate. If the pressure from the movers is smaller than that from the security preservationists, the *CCA* proposes a lower adopting rate. If the pressures are equal, the *CCA* announces that rate as its decision.

An example scenario:

In April the cloud commissioning agency posts or announces a provisional adopting rate:

λ (April) = 0.3 that is, 30% rate of non-mission critical ICT workloads can move to the cloud Agent one responds SA_1(0.3, 0.5) and agent two responds SA_2(0.3, 0.25).

Then in May, the cloud commissioning agency calculates as $\Delta(\lambda(\text{April})) = 0.5\text{-}0.25\text{=}0.25$

λ(May)= 0.3+0.25=0.55 (see Formula 3.2).

The *CCA* propose a high moving rate of 55% because adopters' pressure is greater than the security professionals' concern pressure. Again, it will post this rate (0.55) for verification. According to the rules of a verification, the *CCA* announces a message (sends it to each agent); both agents one and two see the message, and each respond either "yes" or "no." Here we are assuming that both agents answer truthfully. (We can drop this assumption subsequently, but it is beyond our research scope.)

Chapter 4: Experimental analysis and evaluation

In this experimental evaluation, the theories assimilated into the theoretical idea of the cloud can be divided in to three abstraction levels: low-level model, middle-level model, and high-level model. These models consist of three Euclidian spaces. The current cloud computing situation can be considered as in two spaces cloud space and outcome space, but there are a lot of adoption problems. In this paper we therefore created an additional third space called message space to alleviate the current cloud adoption hurdles, that is, an additional means of achieving the goal of the cloud as a regulated public utility. Firstly, we have evaluated our suggested low and middle levels mechanism. By using these levels of the mechanism, we could control, balance, and regulate the security adoption hurdles and different self-interested issue, and we could yield a benefit in terms of cost. Secondly, we have evaluated our suggested high-level model with real cloud deployment using an open source cloud computing platform, that is, OpenStack. We chose OpenStack because it has benefits for developing countries, such as it is free, open source, has a more user-friendly GUI, is widely used by world communities, and has compatible APIs. It also has support for different virtualization technology like Xen, ESXi, hyper-v, UML, KVM, and LXC, so it helps experts and researcher as a test bed [39]. Finally, we have measured the overall IT experts' competence by tracking and observing their performance during their participatory demonstrations.

4.1 Evaluating cost-benefit

Lower abstraction level works for digital balancing or are used for regulating cloud adoption rates in terms of security-adoption hypes. These level is evaluated in terms of cost benefit analysis.

In 2016, extremely challenging cyber-attack was 3 % − up to 6 % difference compared with legacy IT workloads or on premises IT services [40]. By balancing security-adoption via a gradual, step-by-step, or regulated manner, that is, $0 < \lambda < 1$, at least we will save − up to 3% of \$6 trillion by 2022.

Moving to the cloud is under the control of a government *CCA*, or an organization CEO or IT manager, and it is subject to pressures, such as: security, privacy, and so on as discussed before. The stakeholders of those who benefit from moving to the cloud includes CSPs, cloud enablers, brokers, attackers, end users who has insensitive data, and supporters. These stakeholders prefer more moving to the cloud. On the other hand, those who concerned about the security implication of the cloud, and they have negative views of the cloud (such as weak application processing, ownership complexity, privacy and trust issues, complexity, and insecurity), and those who have sensitive data also prefer moving less applications into the cloud. We suppose that the preferences of stakeholders in the two different groups are diametrically opposed: Agent one and Agent two.

4.2 Experimentation with and without higher-level model

Before beginning the experiment, and to get the best out of OpenStack and the model, the three randomly selected ICT experts groups discussed the Cloud Computing Concepts (3Cs): what is the cloud, what is cloud computing, what are cloud services? What is cloud security, what are the cloud enablers? What are open source and closed cloud platforms? OpenStack packages, SQL databases, Python, Message queue, Basic Linux commands and shell scripting, Linux flavours (Centos, Ubuntu, Red Hat), APIs, VM image or virtual appliance) image creation or modifying, and its format), obtaining, scheduler, plugins, agents, virtualization (type1, type 2, hypervisor, virtual machine, QEMU, KVM), (see Appendices). During the experiment, data were collected from potential cloud experts via participatory demonstration, observation, and tracked competence. This experiment showed that working with OpenStack leads to increased awareness, readiness, and competence, and it reduces hurdles.

4.2.1 Working with OpenStack and without high-level model

To expose the experts to various methods of interacting with the OpenStack Configurations, we installed, configured, and built private cloud computing using both Multi Node (OpenStack services on different nodes, such as, compute node, network node, and controller node) and Single Node, or Stand Alone (OpenStack services in one node including Control, Network, Compute, Storage services) architectures as well as local and flat networks. We used both DevStack (for Ubuntu distribution) and TripleO (Red Hat Distribution of OpenStack- packaged by the open source community for users running Fedora and CentOS OSs). OpenStack components were run on standard hardware that ranged from PC to Enterprise Servers.

Installing OpenStack: This research model shows how the cloud hurdles paired with opportunities by improving the competence of the cloud experts via general cloud computing concepts (principles, enabling technologies, RESTful API, web services, service flows and work flows, virtualization, networking, web 2.0 and mashup, elasticity apps, libraries) including practical instances. For instance, we can set up a private cloud environment using open source cloud platforms like OpenStack (architecture, controller and compute nodes installation and configuration, and leveraging the service of open stack (database as a service (MySQL), web service as a service (WAMP server), and platform as a service(CentOS))). In addition, we have seen closed sources like: Amazon.com provides IaaS (AWS cloud platform), Microsoft Azure cloud platform application platform as a service, and Google App engine cloud platform (a web application platform as a service; python run time environment). Finally, we selected the test bed, that is, OpenStack cloud environment (in this case, open source opportunity) which is implemented based on kilo OpenStack version (see Appendices).

We have experimented based on availability of the resource scenarios, design choices and technical skill. The network layout of OpenStack can be in three forms:

1. All network, compute and controller which can be in one node or single server (see Figure 4.1) need more network configurations. We used this when we had limited resources, and based on the infrastructure capacity we needed. For more experimental configurations see Appendices.

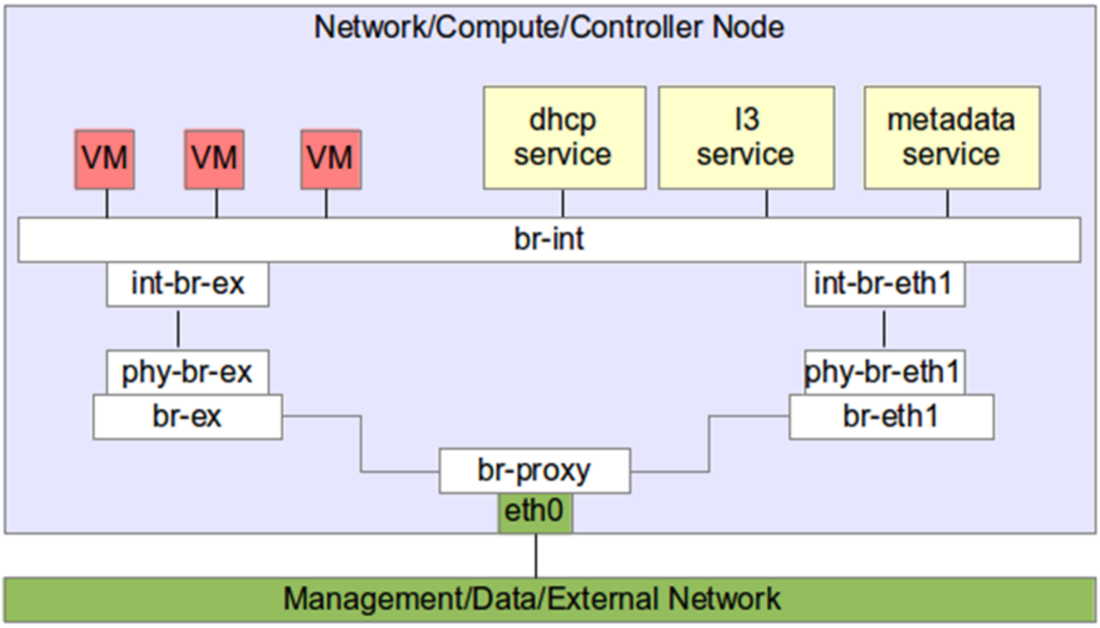


Figure 4.1: One node or single machine and single NIC OpenStack

(Reproduce from Ubuntu OpenSatck configuration)

2. We have used two dedicated servers (network and controller in one node or cloud controller and one or more compute node) (see Figure 4.2). For more configurations see Appendices.

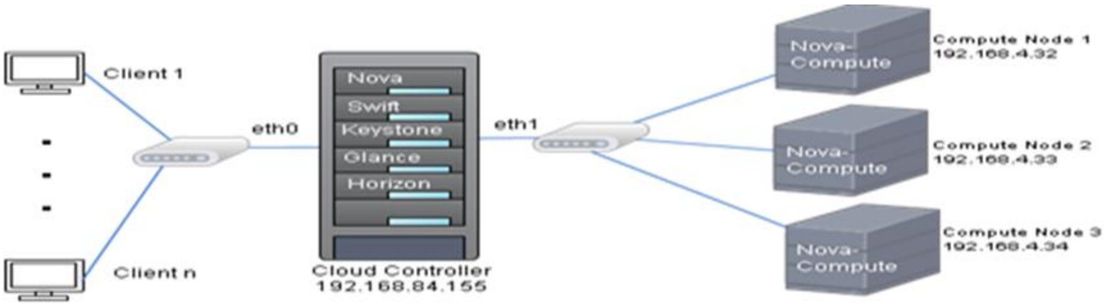


Figure 4.2: Two nodes architecture (adapted from [39])

3. We have experimented in three nodes (see Figure 4.3).

NICs: eth0 (Ethernet interface1 or10.10.10.11/24): management network: 10.10.10.0/24, eth1 (interface2/10.10.10.21/24): VM data network or tunnel network.: 10.10.11.0/24 - called tenant networks. eth2 (interface3): external network: unnumbered: provider network or front-end (WAN) network for neutron router: 203.10.113.0/24. Optional eth3 (interface3 on compute node or 10.10.12.31/24) storage network: 10.10.12.0/24.

eth0: All inter-process communication happens. MySQL server, messaging queue server, and so on, are listening. This network used services which exchanged information among themselves. If NICs resources are available this network should be isolated and secured and should not be added to the bridge. Eth0 connected to the LAN.

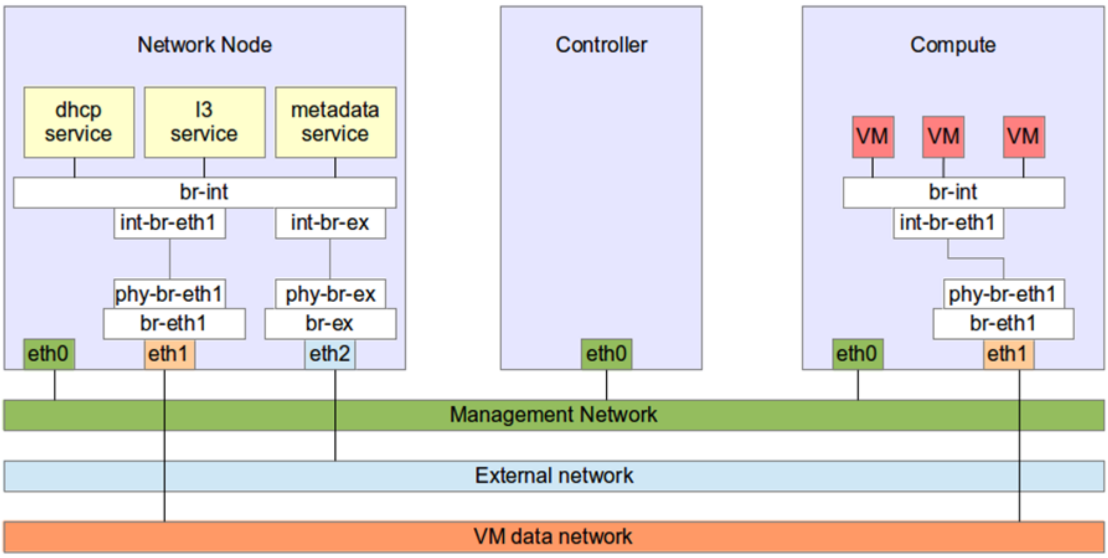


Figure 4.3: Three nodes architecture OpenStack networking layout using three machines (Reproduced from Ubuntu OpenStack configuration)

eth1: Instances talk to each other and to their network's l3 and DHCP services.

eth2: We used this for two purposes: to expose the services (such as nova API and glance API) to consumers outside of OpenStack or API network server access and to allow our instance to be accessible from outside of OpenStack via external network or floating IP. Eth2 attached to the Internet or upstream internet service provider router. For more configurations see Appendices.

4.2.2 Working with OpenStack and with high-level model

In addition to the above experimentation, we used the high-level mechanism during the experience of the third group. The ICT experts were taken a responsibility as (end user, author, integrator, cloud service partners, developers, provider, and so on). The ICT experts visualized the model as a machine that process and access as input the cloud environment, and some possible criteria of the goal function. It was also used as a communication system in which participants sent messages to each other, and perhaps to a message centre, and a pre-specified rule assigns an outcome (such as pairing of hurdles with opportunities and decision to be made) for every collection of received messages see Figure 4.4

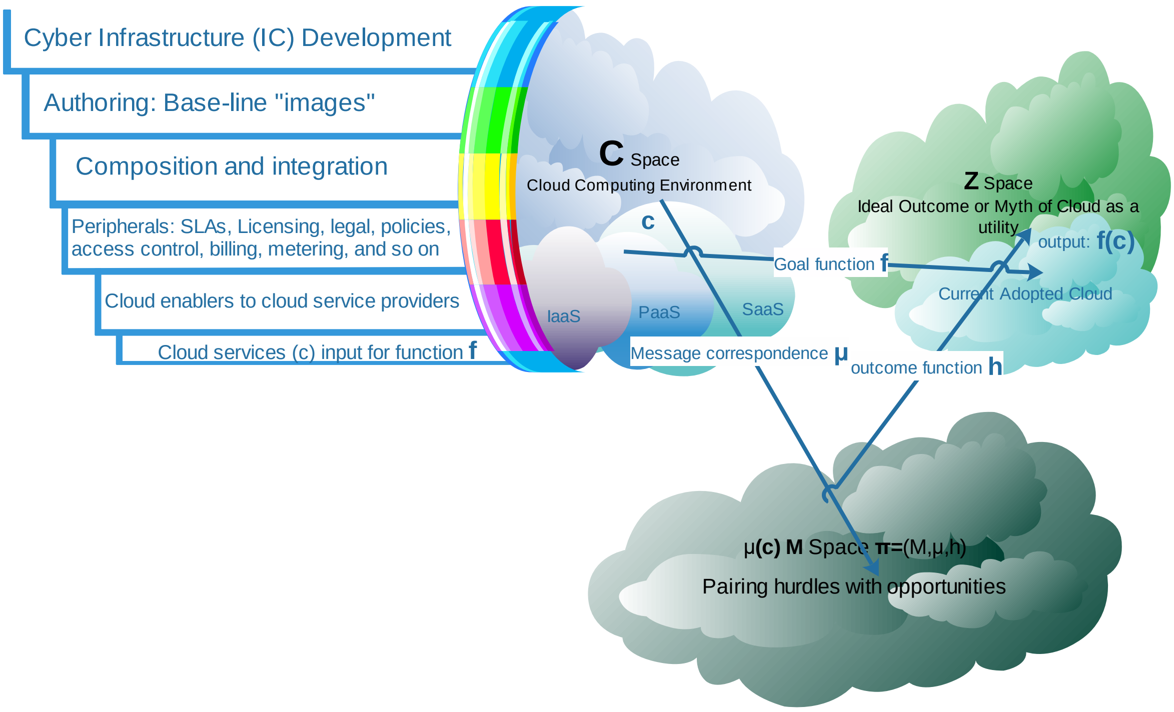


Figure 4.4: High-level abstraction competency model

4.3 Analysis

The information analysis techniques used in this research were driven by the nature of our research enquiries. The intent was to manipulate some independent variables and then test the consequence that this change had on a dependent variable [2].

In this work, the independent variable was experience with model and without a high- level model (indicates a role of a model and cloud computing platform such as OpenStack and context-based model), and the dependent variable was competence (outcome variable indicates competence of the ICT experts).The competence variable or outcome variable of the groups was measured in terms of high level agreement with proposed opportunities or benefits and hurdles as well as observation working with OpenStack to the adoption of the cloud. The sample framework was developed using a random sample of 39 ICT experts (see Appendices). 39 participants were randomly split into three independent groups with 13 participants in each group. This is equal to 39 observations. Likert scales are frequently used in end of rotation trainee feedback, faculty evaluations of trainees, and appraisal of performance after an experience intervention [41]. Each point on the scale is assigned a numeric value from 1 upwards to 5. We used Likert scale (Ordinal data) which was a competence response scale (primarily used in questionnaires and observations) to assess the cloud's perception, readiness, awareness, opportunities, and hurdles (see Formula 4.1). The agreement level of each IT expert was determined by the following formula: (highest point in Likert scale − lowest point in Likert scale) divided by the number of the levels we used. For our 5-point Likert scale it will be $(5 - 1)/5 = 0.80$, where the agreement level of each IT expert was determined by the following formula: (highest peak on a Likert scale − lowest point on a Likert scale) divided by the number of the scale we used.

For our 5-point Likert scale it will be (5 − 1) /5 = 0.80, where
1 - 1.80 reflected by 'strongly disagree or 1'
1.81 - 2.62 reflected by 'disagree or 2'
2.63 - 3.43 reflected by 'moderate or 3'
3.44 - 4.24 reflected by 'agree or 4'
And 4.25 – 5.05 reflected by 'strongly agree or 5'

Formula: 4.1

An Example scenario: For the first IT expert to the total Likert questions were 34 and 15 questions were strongly agreed, we will then have 15*5=75, 10 questions were neutral 10*3=30, 9 questions were agreed 9*4=36, total score 141/34= 4.15 we can conclude that the first IT expert agree to all Likert question, because it fall within the range of 3.44- 4.24. Then the competence value is 4.

4.3.1 StataCorp analyses

We used StataCorp to perform our Likert data analysis. In StataCrop, we separated the three groups for analysis by creating the independent variable, called Experment_with_Model, and gave: (1) a value of “1- -No Experience - No Model - Awareness” to the control group; (2) a value ” Experience - No Model - Awareness” to the treatment group who had taken practical experience, but had no model of what they taken practical experience; and (3) a value of “Experience with OpenStack and Model - Awareness” to the second treatment group who taken practical experience using OpenStack with context-based mechanism model.

The practical experimentation lasted for one year to find the result of the dependent variable, called Competence (see Figure 4.5).

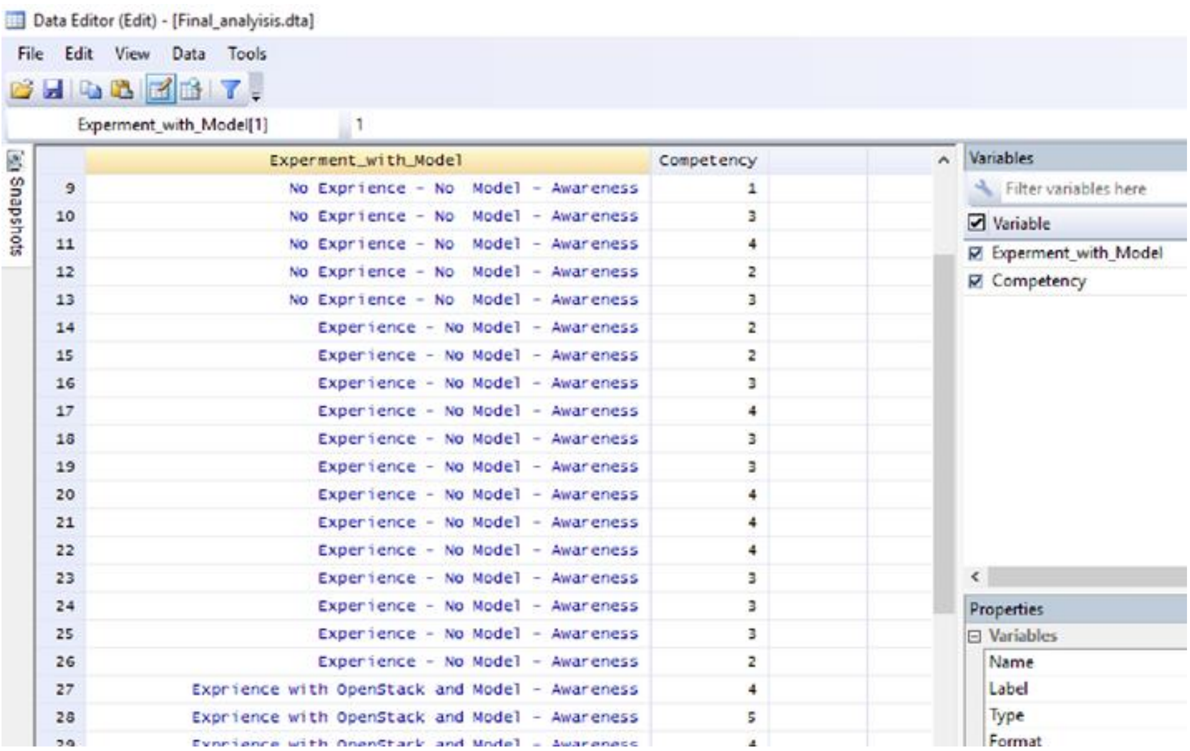


Figure 4.5: Experimental variables setups in StataCrop data Editor

4.3.2 Nonparametric and Kruskal Wallis H tests

To be meaningful and illustrative the data analysis techniques utilized in this research were nonparametric tests. Nonparametric tests are also called distribution free tests [1] because we do not assume that our data follow a specific distribution. Likert answers are not truly normally distributed because of their ordinal nature. Likert scales fall within the ordinal level of measurement. That is, the response categories have a rank order, but the intervals between values cannot be presumed equal [42]. This is a straightforward way to choose, but there are additional considerations we have taken

Consideration 1: Our area of work is better exemplified by the median - nonparametric analysis to test group medians. Here we need a parametric analysis to test group means for post-hoc trial.

Consideration 2: We have a modest sample size (because of limited resources and ICT experts in our selected organizations), but even so it fulfils sample size guidelines for non-normal data.

Consideration 3: We have ordinal-data, ranked-data, or outliers that we can't get rid of.

When we matched all the premises in the nonparametric test, we had Likert data and wanted to compare three groups, thus the best room to analyze our Likert item data was a Kruskal Wallis H test using StataCrop.

A Kruskal Wallis H test is a rank based nonparametric test that can be applied to find out if there are statistically significant deviations between two or more groups of an independent variable on a continuous or ordinal dependent variable. It is considered the nonparametric alternative to the one way ANOVA, an annex of the Mann-Whitney U test to allow the comparison of more than two independent groups [43].

Whole of the assumptions that our data met apply a Kruskal Wallis H test. The test was conducted to determine cloud adoption hurdles, competence model and opportunities in experience with and without model and OpenStack were different for three groups that either experienced to (1) No Experience – No Model (n=13); (2) Experience using OpenStack, but given that were experience without model (n=13); and (3) experience using OpenStack with newly created context-based mechanism model (n=13) (see Results 4.1 and Figure 4.6).

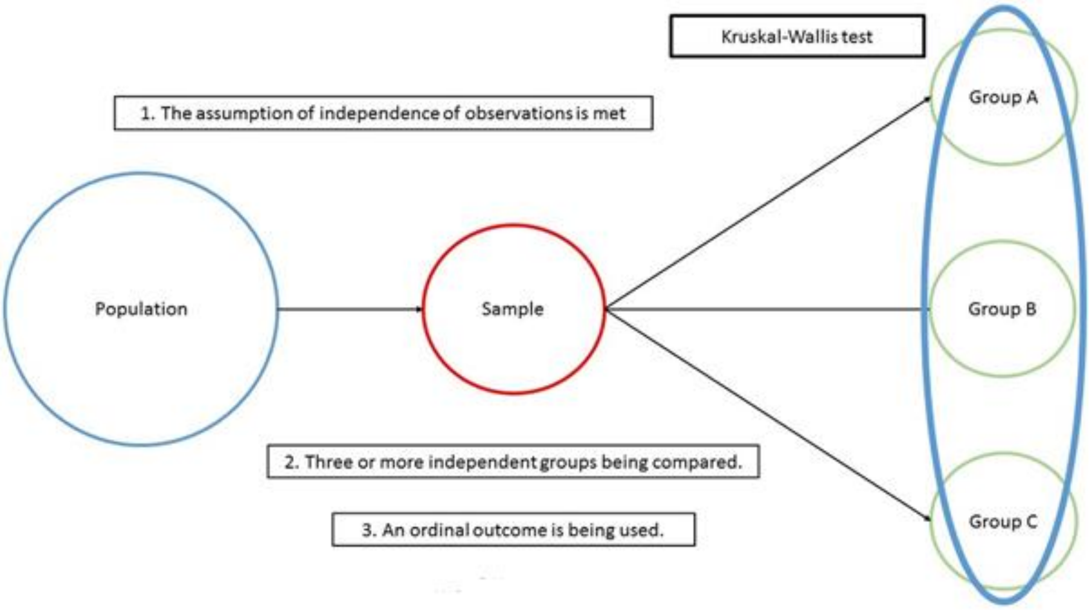


Figure 4.6: Kruskal- wallis test between the three groups (Reproduced from scalt)

```
. kwallis Competency, by(Experment_with_Model)

Kruskal-Wallis equality-of-populations rank test
```

Experment_with_Model	Obs	Rank Sum
No Exprience - No Model - Awareness	13	141.50
Experience with OpenStack - No Model - Awareness	13	234.50
Exprience with OpenStack and Model - Awareness	13	404.00

```
chi-squared =     20.964 with 2 d.f.
probability =      0.0001

chi-squared with ties =     22.884 with 2 d.f.
probability =      0.0001
```

Result 4.1: Rank sum test result of Kruskal-Wallis

A Kruskal-Wallis H test was conducted to determine if competence in an open source cloud computing platform and model understanding facility was different for three groups that either experienced (1) No OpenStack No Model (n=13); (2) OpenStack No Model (n=13); and OpenStack and Model (n=13). The test indicted that there was a statistically significant difference in competence between the three groups, the observed x^2-value and degrees of freedom (x^2 (2) = 22.884), and significance level (p = 0.0001). We can ensure that the significance level is 0.0001 (that is, p =.0001), which is below 0.05, and, therefore, on that point is a statistically significant difference in the median competency between the three different groups of the independent variable: experiencewith_model (“no experience, no model”, “experience with Open Stack no model”, “experience with Open Stack and model”).

4.3.3 The Tukey post-hoc test

Kruskal Wallis H test tells us whether we have an overall difference between our groups, but it does not tell us which specific groups differed. Post-hoc test does. Because post-hoc test is run to confirm where the differences occurred between groups, it should only be run when we have demonstrated an overall statistically significant difference in group means [43]. (see Figure 4.7).

The Tukey test shows in result 4.2 that firstly, statistically there is significant difference between group one and group three−that is, the model and OpenStack both contribute to group three. Secondly, there is also a statistically significant difference between group two and group three−that is, the model contributes to group three. Finally, the statistical difference between group one and group two shows that OpenStack contributes to group two.

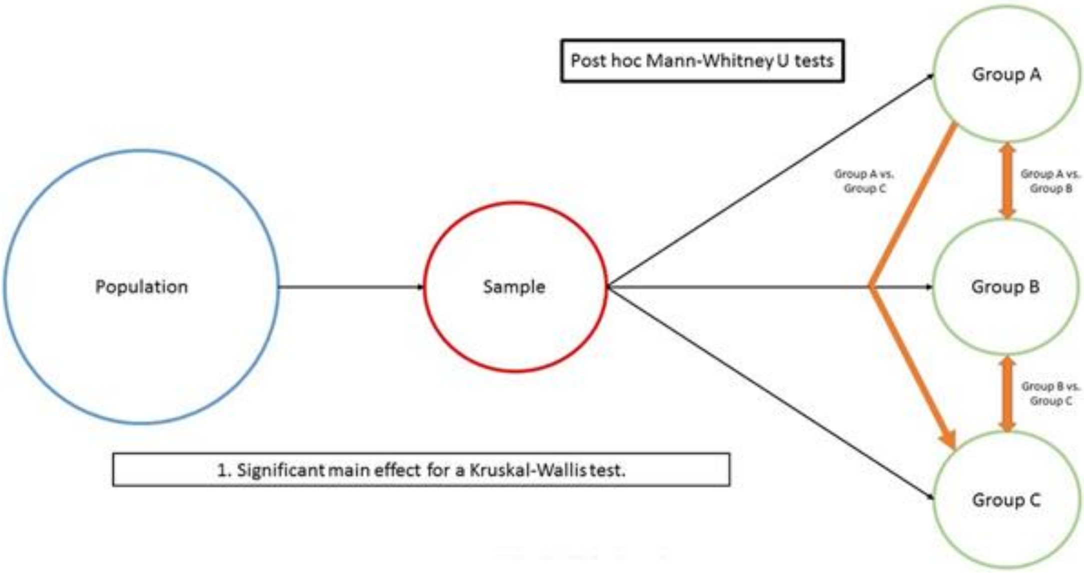


Figure 4.7: Pairwise comparisons *(Reproduce from scalt)*

4.3.4 Competence patterns

We can see that the patterns move on improvement, that is, working with OpenSack and model for long time improve competence of IT experts (see Figure 4.8 and 4.9).

```
. pwmean Competency, over(Experment_with_Model) mcompare(tukey) effects

Pairwise comparisons of means with equal variances

over          : Experment_with_Model
```

	Number of Comparisons
Experment_with_Model	3

Competency	Contrast	Std. Err.	Tukey t	Tukey P>|t|	Tukey [95% Conf.	Interval]
Experment_with_Model						
Experience with OpenStack - No Model - Awareness vs No Exprience - No Model - Awareness	.8461538	.3033887	2.79	0.022	.1045817	1.587726
Exprience with OpenStack and Model - Awareness vs No Exprience - No Model - Awareness	2	.3033887	6.59	0.000	1.258428	2.741572
Exprience with OpenStack and Model - Awareness vs Experience with OpenStack - No Model - Awareness	1.153846	.3033887	3.80	0.002	.412274	1.895418

Result 4.2: Tukey test

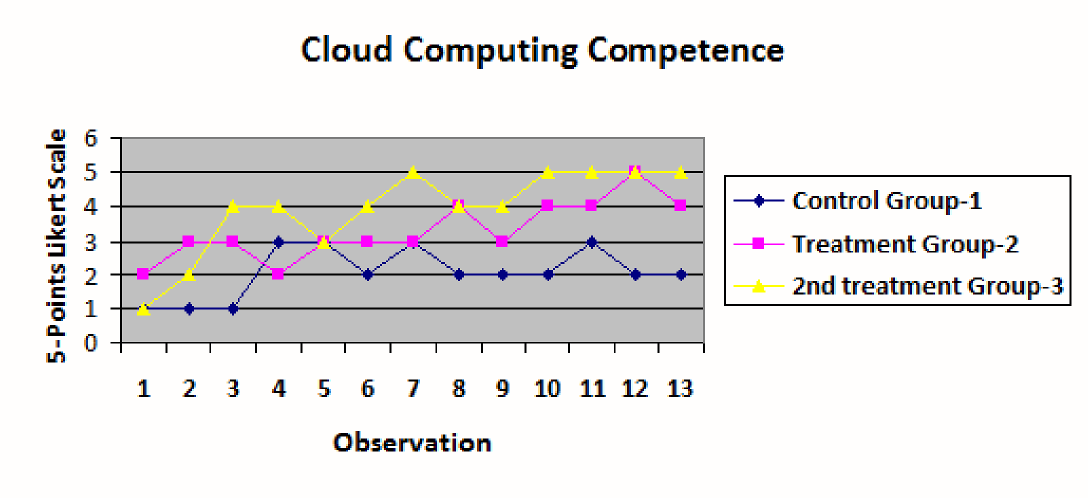


Figure 4.8: Competence pattern of the three groups

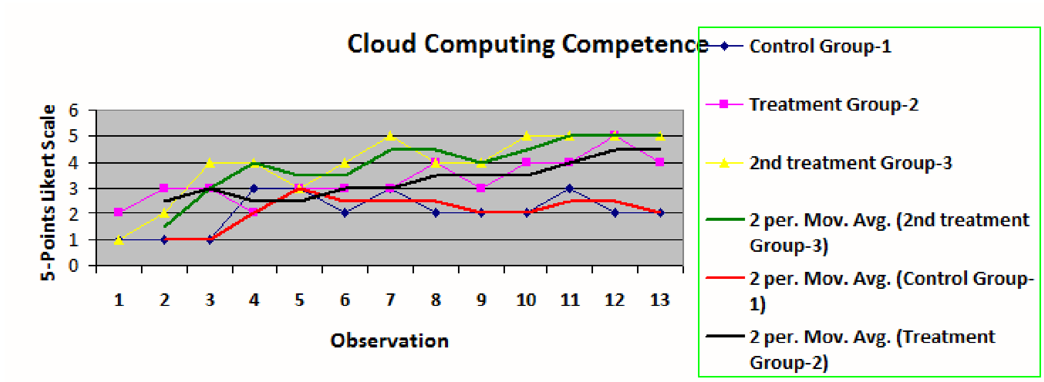


Figure 4.9: Competence per average or smooth pattern

Chapter 5: Conclusion and recommendation

The underlying cloud's code behaviour seems a hidden art, and this leads to the cloud adoption hurdles in the African context. However, by using open source cloud platforms as opportunity, the African ICT experts can be competent cloud experts. Even the initial stages of the emerging free open source cloud platforms, for information sharing and communication, are deemed useful for developing competence. The next stage of information moving and processing on the cloud needs careful planning, competent cloud experts, framing, modelling, balancing securing, regulating rates, and policy creation. Cloud computing is not truly in the national curriculum yet; it should be integrated into academic curricula. Many African countries are still in an emerging stage of the cloud adoption, but developed countries are at scaling stage of the cloud even though some universal issues still exist. Specifically, data security, privacy, balancing for moving into the cloud, and trust. Developing countries find out about something after it happened. The countries are not trying to catch up with the latest strives and developments in the cloud computing technologies.

A Kruskal Wallis H test indicated that there was a statistically significant difference in the competence between the three groups of the independent variable. The suggested OpenStack platform, and the designed mechanism using game and economic mechanism design theories in a real private cloud environment, is a workable mechanism for Africa, particularly for Ethiopia, as a lens to: see opportunities, alleviate skill gaps, synergies, threats, regulating security, balancing adoption rates, and to pass adoption hurdles. By playing with the game theory model cloud cyber-attacks can be reduced by $1.5 trillion by 2022 because, local and global community participations can regulate and control the cloud adoption rates. The participants are agents playing via assimilated game and economic mechanism techniques.

This study recommends that academic institutions need to lead the cloud technology via academic curricula, research, short trainings, and local (contextual) or international summits: inter-university panels to incubate skilled graduates. The government needs to improve IT policy and infrastructure. The private ICT service providers should work with academic institutions and governments so that the countries can reap cloud benefits. Mentorship for graduates is needed, in order to offer detailed insights into the software, infrastructure and technology delivering those services. There is also a need to cascade the concepts of the cloud into high school level to incubate competent cloud experts in Africa.

Further, the findings add to our understanding of skilled labour, energy and cost. Many of the researchers have proved that reduced energy use is cost effective. Data centres, along with the availability of natural lighting, play a decisive role in this view. Geographically, data centres should be located where electricity is cheap, and there are skilled resources. Africa, especially Ethiopia, has a bright future in terms of natural energy: hydropower, wind, geothermal, and solar energy, as Ethiopia is with 12 months of sun-shine. Moreover, Ethiopia's population is very young with 52% of 108 million Ethiopians less than 15 years old, and 1.2 million youths join the labour force every year[44]. Thus, Ethiopia is full of opportunity to get cheap, skilled resources, and it is geographically suitable for data centres to promote cloud adoption, and green cloud or green ICT. Finally, this research mechanism and theories will work for the rest of African countries, as well as developed countries.

5.1 Future work

For future work, we will need to consider how to avoid disparity, bias, and malicious insider, because we rely on the *CCA* to maintain moving rates by post and agents' messages. Merely what if the *CCA* biased, what if agents not followed truth-telling principle, and what if the government pushes the *CCA*. Fortunately, block-chain technology allows us to maintain these rates assures, since it ensures that the rate is the same for everyone. We can store online excitable JavaScript code into the block chain. Let us say we have a piece of code only written to the blockchain in JavaScript, so we will have the piece of JavaScript code no one can change. This JavaScript code is also targeted with CCA's address. The *CCA* of that address gets to decide what operations are open to the local and global public and what only the agents can run. The agents get to make decisions at the time the JavaScript code is written (the rate result can be set by the committee and it cannot be changed). Agents still can see the JavaScript code and what is doing, but can only interact with it in the ways specified by the committee and *CCA*. The committee control the *CCA*, the *CCA* control the local and global public or community agents via the ledger technologies.

References

[1] J. Zhu, “Cloud Determinism,” in *China Cloud Rising*, Berlin, Heidelberg: Springer Berlin Heidelberg, 2014, pp. 7–10.

[2] S. Abolfazli, Z. Sanaei, A. Tabassi, S. Rosen, A. Gani, and S. U. Khan, “Cloud adoption in Malaysia: Trends, opportunities, and challenges,” *IEEE Cloud Comput.*, vol. 2, no. 1, pp. 60–68, 2015.

[3] L. Adam, “Understanding what is happening in ICT in Ethiopia,” *Evid. ICT Policy Action Policy Pap.*, vol. 3, 2012.

[4] K. Jackson, *OpenStack Cloud Computing Cookbook*, 2nd ed. Livery Place 35 Livery Street Birmingham B3 2PB, UK.: Packt Publishing Ltd., 2012.

[5] K. Chandrasekaran, *Essentials of Cloud computing*. 6000 Broken Sound Parkway NW, Suite 300 Boca Raton, FL 33487-2742: CRC Press Taylor & Francis Group, 2015.

[6] L. Hurwicz and S. Reiter, *Designing economic mechanisms*. 2006.

[7] N. M. Prize, E. Sciences, L. Hurwicz, E. Maskin, and R. Myerson, “Mechanism design,” *Foundations*, 2007. .

[8] N. Wang, H. Liang, Y. Jia, S. Ge, Y. Xue, and Z. Wang, “Cloud computing research in the IS discipline: A citation/co-citation analysis,” *Decis. Support Syst.*, vol. 86, pp. 35–47, 2016.

[9] C. Yung, “Chou’s Theories of Cloud Computing: The 5-3-2 Principle – Yung Chou on Hybrid Cloud.” 14-May-2011.

[10] M. Stieninger and D. Nedbal, “Characteristics of Cloud Computing in the Business Context: A Systematic Literature Review,” *Glob. J. Flex. Syst. Manag.*, vol. 15, no. 1, pp. 59–68, 2014.

[11] M. Armbrust *et al.*, “A view of cloud computing,” *Commun. ACM*, vol. 53, no. 4, p. 50, 2010.

[12] A. P. Mell (NIST) and A. T. Grance (NIST), “SP 800-145, The NIST Definition of Cloud Computing.” 14-May-2018.

[13] D. Linthicum, “Defining the Cloud Computing Framework | CloudEXPO Journal.” 12-May-2009.

[14] “ISO/IEC 17788.” 06-Jun-2014.

[15] A. Mas-colell, M. D. Whinston, and J. R. Green, “Game Theory,” in *Microeconomic Theory*, Oxford University Press, 1995, p. 219.

[16] “The 28th Jerusalem School in Economic Theory | The Institute for Advanced

Studies.” 09-Jul-2018.

[17] L. Hurwicz, “Economic design, adjustment processes, mechanisms, and institutions,” *Econ. Des.*, vol. 1, no. 1, pp. 1–14, 1994.

[18] “Definition of Mechanism Design Theory,” *Assignment Point*, Mar-2017. [Online]. Available: http://www.assignmentpoint.com/business/economics/definition-of-mechanism-design-theory.html.

[19] E. S. Maskin, “Mechanism design: How to implement social goals,” *Am. Econ. Rev.*, vol. 98, no. 3, pp. 567–576, 2008.

[20] A. D. Abubakar *et al.*, “Cloud migration process—A survey, evaluation framework, and open challenges,” *Glob. Bus. Rev.*, vol. 35, no. 4, pp. 377–393, 2014.

[21] N. Kshetri, “Cloud computing in developing economies,” *Computer (Long. Beach. Calif).*, vol. 43, no. 10, pp. 47–55, 2010.

[22] M. Armbrust, A. Fox, R. Griffith, A. Joseph, and RH, “Above the clouds: A Berkeley view of cloud computing,” *Univ. California, Berkeley, Tech. Rep. UCB* , pp. 07–013, 2009.

[23] K.-H. Ali, G. David, S. J. W., and S. Ian, “The Cloud Adoption Toolkit: supporting cloud adoption decisions in the enterprise,” *Softw. Pract. Exp.*, vol. 42, no. 4, pp. 447–465, Apr. 2011.

[24] UNCTAD, “The Cloud Economy and Developing countries,” 2013.

[25] “BSA Global Cloud Computing Scorecard.” 17-Jun-2018.

[26] Es. Africa, “Cloud Computing Strategy & Roadmap Project Readiness Assessment,” 2014.

[27] S. Singh, Y. S. Jeong, and J. H. Park, “A survey on cloud computing security: Issues, threats, and solutions,” *J. Netw. Comput. Appl.*, vol. 75, pp. 200–222, 2016.

[28] K. AlAjmi, “Is cloud computing appropriate for government?,” 2011, pp. 169–175.

[29] A. Khajeh-Hosseini, D. Greenwood, J. W. Smith, and I. Sommerville, “The Cloud Adoption Toolkit: Supporting cloud adoption decisions in the enterprise,” *Softw. - Pract. Exp.*, vol. 42, no. 4, pp. 447–465, 2012.

[30] A. Bandura, “Modeling,” *Corsini Encycl. Psychol.*, pp. 1–3, 2010.

[31] G. Celik, “Mechanism design with collusive supervision,” *J. Econ. Theory*, vol. 144, no. 1, pp. 69–95, 2009.

[32] R.Kenneth Mount and Stanley Reiter, “A model of computing with human agents.” Northwestern Univeirisity, 1990.

[33] J. Repschläger, R. Zarnekow, S. Wind, and T. Klaus, *Cloud Requirement Framework:*

Requirements and Evaluation Criteria to adopt Cloud Solutions. 2012.

[34] M. Mujinga and B. Chipangura, “Cloud Computing Concerns in Developing Economies,” *Proc. 9th Aust. Inf. Secur. Manag. Conf.*, pp. 1–9, 2011.

[35] M. A. Vouk, “Cloud computing - Issues, research and implementations,” in *Proceedings of the International Conference on Information Technology Interfaces, ITI*, 2008, pp. 31–40.

[36] O. Ali, J. Soar, and J. Yong, “An investigation of the challenges and issues influencing the adoption of cloud computing in Australian regional municipal governments,” *Journal of Information Security and Applications*, vol. 27–28. pp. 19–34, 2016.

[37] Cisco, “Cisco Global Cloud Index,” *Cisco*. 27-Apr-2018.

[38] “Cisco Global Cloud Index: Forecast and Methodology, 2016–2021 White Paper,” *Cisco*. 27-Apr-2018.

[39] A. P, Y. Devi, S. D. Dorairaj, N. Priya, and K. Vasantha, *Private Cloud for Organizations: An Implementation using OpenStack*, vol. 4. 2013.

[40] K. Chandrasekaran *et al.*, *Cisco Global Cloud Index: Forecast and Methodology, 2016–2021 White Paper*, 2nd ed., vol. 53, no. 1. Berlin, Heidelberg: CRC Press Taylor & Francis Group, 2018.

[41] G. M. Sullivan and A. R. Artino, “Analyzing and Interpreting Data From Likert-Type Scales,” *J. Grad. Med. Educ.*, vol. 5, no. 4, pp. 541–542, 2013.

[42] Y.-T. Sung and J.-S. Wu, “The Visual Analogue Scale for Rating, Ranking and Paired-Comparison (VAS-RRP): A new technique for psychological measurement,” *Behav. Res. Methods*, 2018.

[43] “Kruskal-Wallis H Test in SPSS Statistics | Procedure, output and interpretation of the output using a relevant example.” 23-Jun-2018.

[44] “Ethiopia Population (2018) - Worldometers.” 23-Jun-2018.

Appendices

Appendix I: Cloud computing concepts

On the discussions and experimentations in the context, we have taken the most usable definitions as follows:

What is cloud computing?

Cloud computing: A new style of computing in which dynamically scalable and often virtualized resources are provided as a service over the internet on demand.

What is virtualization?

A hypervisor, also called a virtual machine manager, is a program that allows multiple operating systems to share a single hardware host.

Appendix II: OpenStack

What is OpenStack?

OpenStack is a cloud operating system that controls large pools of compute, storage, and networking resources throughout a datacentre, all managed through a dashboard that gives administrators control while empowering their users to provision resources through a web interface.

OpenStack is a Cloud Operating System that provides one versatile platform for computing, networking and storage resources. i.e. Infrastructure as a service (IaaS) solution via a variety of complemental services.

OpenStack is open source python component to build clouds. It also includes java scripts. Written in python. So, we have shown the high light of python programming.

Addresses IaaS: API access to virtualized infrastructure (compute resources, networks, storage of various forms)- things we needed to build those virtualized infrastructure services (common libraries, authentication, virtual machine templet storage, and metering)- tools our users demand (web UI, and service orchestration)

OpenStack works on top of standard hardware.

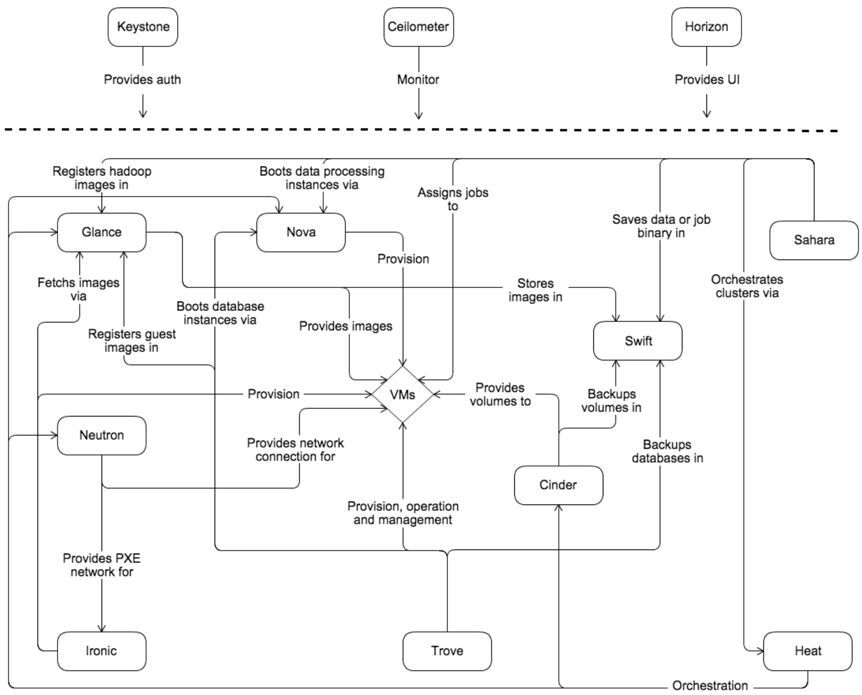


Figure: The conceptual architecture of a typical OpenStack environment.

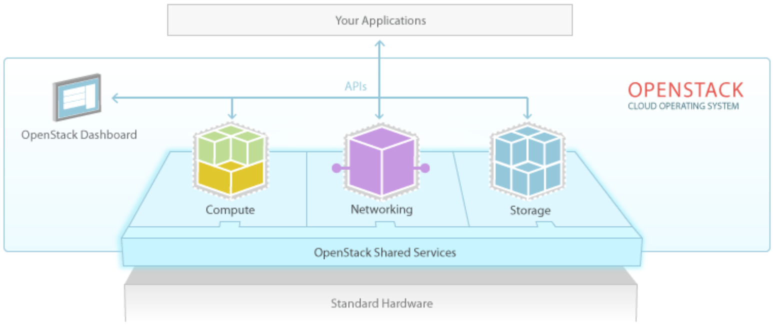


Figure: High level architecture of OpenStack software.

The have seen based on availability of the resource, design choice and technical skill the network layout of OpenStack can be in three forms:

4. All network, compute and controller can be in one node (single server) see Fig. need more network configurations. We use this during limited resources and the infrastructure capacity we needed.

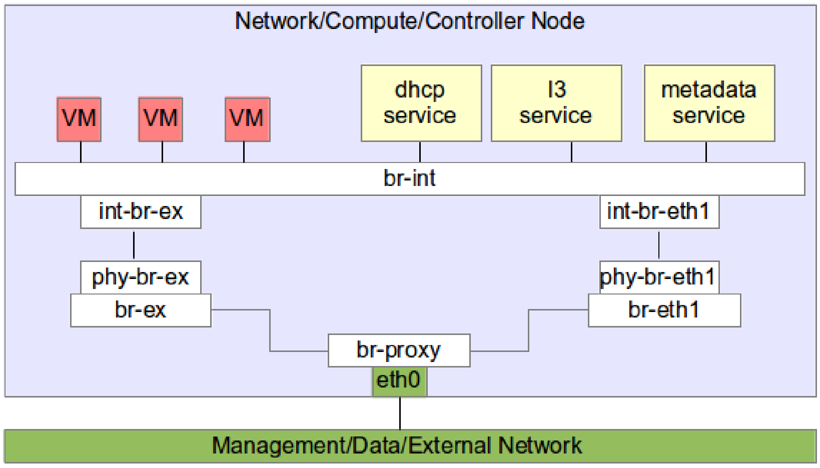
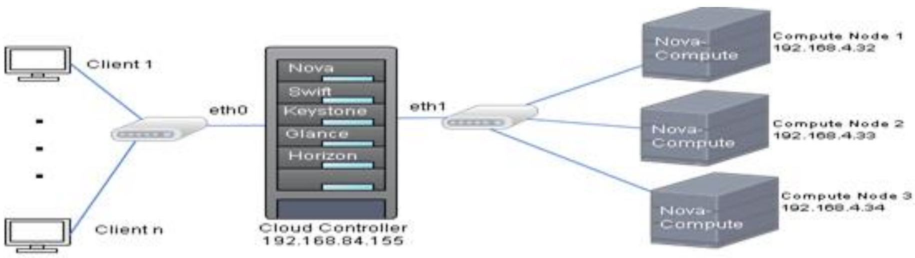


Figure: One node or single machine and single NIC OpenStack

5. Can be in two dedicated servers (network and controller in one node/cloud controller and one or more compute node). See Figure



6. Can be in three nodes

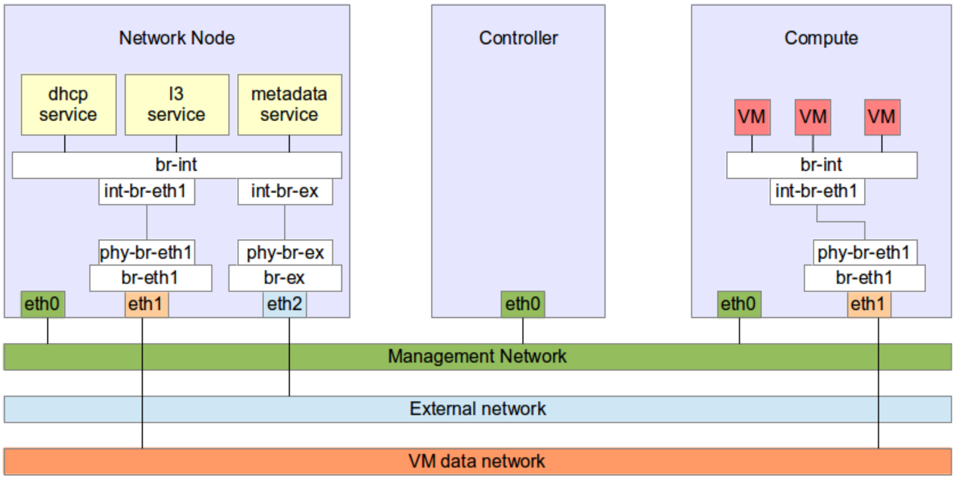


Figure: Three nodes architecture OpenStack networking layout using three machines

NICs: eth0(Ethernet interface1/10.10.10.11/24): management network: 10.10.10.0/24, eth1(interface2/10.10.10.21/24): VM data network/tunnel network. :10.10.11.0/24 - called tenant networks. eth2(interface3): external network: unnumbered: provider network/front-end(WAN) network for neutron router :203.10.113.0/24. Optional eth3(interface3 on compute node/10.10.12.31/24) storage network: 10.10.12.0/24.

eth0: all inter process communication happens. MySQL server, messaging queue server, etc are listening and this network used services exchanges information among themselves. If NICs resources are available this network should be isolated and secured and should not be added to the bridge. Eth0 connected to the LAN

eth1: instances talk to each other and to their network's l3 and DHCP services.

eth2: we used for two purposes: to expose the services (nova API, glance API, etc) to consumers outside of OpenStack/API network server access and to allow our instance to be accessible from outside of OpenStack via floating IP/ external network. Eth2 attached to the upstream ISP router/Internet. Based on our resource we can assign 2 NICs (see figure).

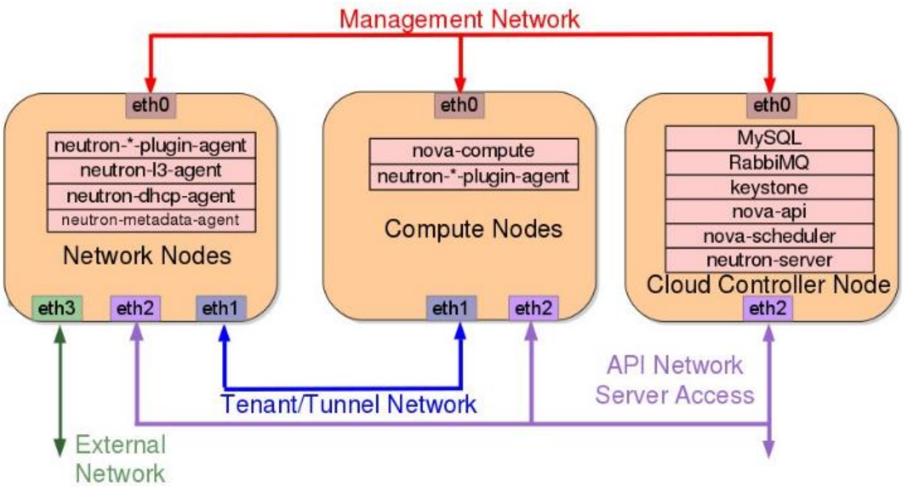


Figure r: Three Nodes architecture with 4-3-2 NICs on network, compute, and controller nodes respectively for more security.

Figure r depicts how two external networks used to expose the services nova API and glance API to consumers outside of OpenStack and to allow our instances to be accessible from outside of OpenStack through floating-ip. In this way, we can restrict all ports other than those on which our exposed services are listening.

The controller node runs the identity service, image service, management portions of compute and networking, networking plug in, and dashboard. It also includes supporting services such as a SQL database, message queue, and NTP.

The network node runs the networking plugin and several agents that provision tenant networks and provide switching, routing, NAT, DHCP services. This node also handles external (internet) connectivity for tenant virtual instances.

The compute node runs the hypervisor portion of compute that operates tenant virtual machines or instances. By default, compute uses KVM as the hypervisor. The compute node also runs the networking plugin and an agent that connect tenant networks to instances and provide firewalling (security groups) services. We can run more than one compute node.

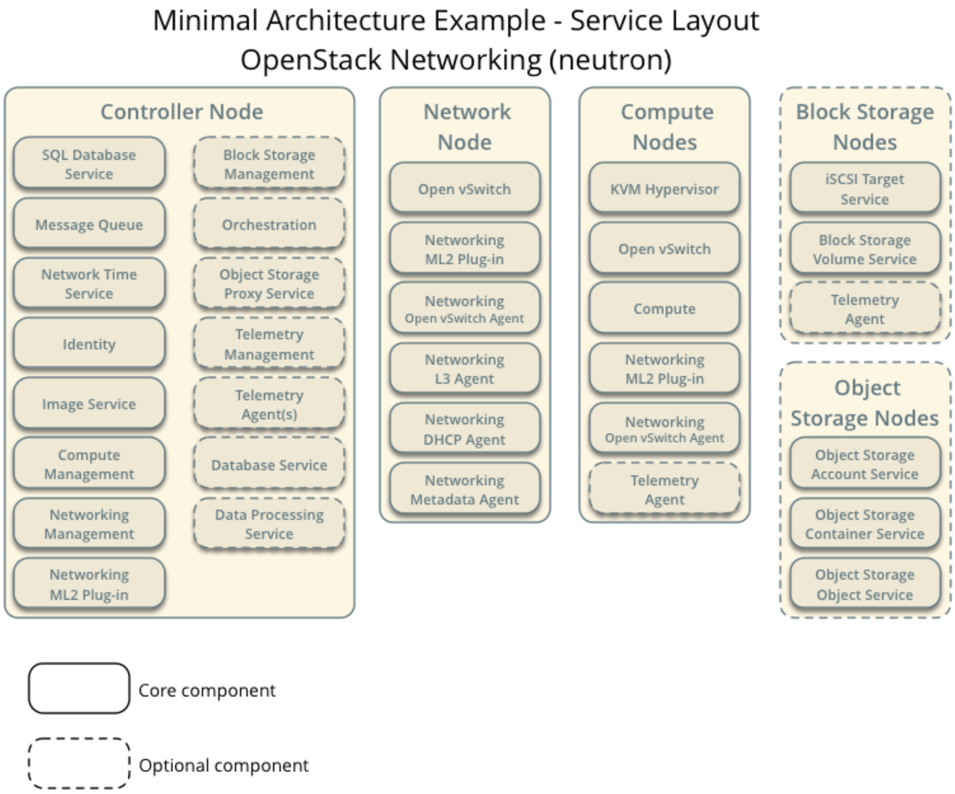


Figure: Service layout

During the experiment our work was focused around Open source cloud platforms, so we carried out installation, configuration and deployment of OpenStack (6 core services), as just the basic foundation and starting point with cloud computing in government organizations via hands-on practice with IT experts. Basically, to install OpenStack we were limited with knowledge of networking and virtualization.

To implement OpenStack, we used some enablers such as virtualization and web service; and we follow the 4-layered model of cloud computing architecture:

Cloud computing architecture: served as 4 layered model: HW layer, infrastructure, platform and application or SW layer.

HW layer bare metal layer: CPU, router, Hard disk, switches, etc . In this case, we used 2 severs and 1 switches, 2 client desktops.

Infrastructure layer responsible for managing the virtual server, storage media and balance the different nodes.

At first, we prepare all the required hardware and software based on the minimum requirement of OpenStack:

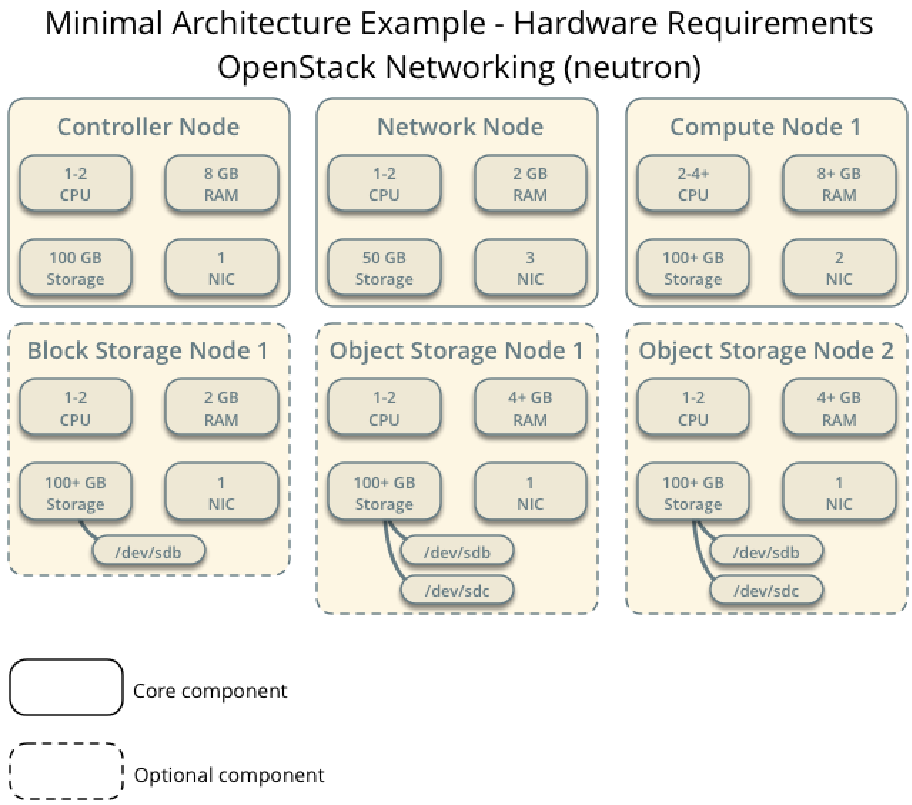


Figure: OpenStack works on top of standard hardware requirements.

Second, we started walking through OpenStack installation by cloning Devstack from GitHub repository (A shell script used for implementing OpenStack configuration environment) to see what it looks like the OpenStack environment-it was easy.

By default, the enabled core OpenStack services are: Nova (compute)- Manages the lifecycle of compute instances in an OpenStack environment. Responsibilities include spawning, scheduling and decommissioning of virtual machines on demand., Glance (image service/it has API registry and image store)- Stores and retrieves virtual machine disk images. OpenStack Compute makes use of this during instance provisioning., Cinder (block storage)- Provides persistent block storage to running instances. Its pluggable driver architecture facilitates the creation and management of block storage devices. And provide easily accessible permanent storage for all of our app., Keystone (identity)- Provides an authentication and authorization service for other OpenStack services. Provides a catalogue of endpoints for all OpenStack services. We have enabled additional services using local.config file. Like important services, Neutron? (Networking)- Enables network connectivity as a service for other OpenStack services, such as OpenStack Compute. Provides an API for users to define networks and the attachments into them. It has a pluggable architecture that supports many popular networking vendors and technologies. Manly interacts with OpenStack compute to provide networks and connectivity for its instances. Swift? (object storage)- Stores and retrieves arbitrary unstructured data objects via a RESTful, HTTP based API. Its implementation is not like a file server with mountable directories. Horizon (dashboard service)- provide a web based self-service portal to interact with underlying OpenStack services, such as launching an instance, assigning IP addresses and configuring access control.

Ceilometer (Telemetry)-Monitor and meters the OpenStack cloud billing, benchmarking, scalability, and statistical purpose.

Both swift and cinder are categorized under storage services. Keystone, Glance and ceilometer (optional shared service) projects are categorized and used as shared services of other OpenStack services. There are other high-level services, such as Orchestration (Heat), database service (Trove), and data processing service (Sahara).

Messaging: uses to coordinate/integrate operations and status information among services and it runs on controller node. OpenStack is compatible with several message queues services like: Qpid, ZeroMQ, and RabbitMQ. However, most distributions use RabbitMQ message queue services, therefore OpenStack uses RabbitMQ message queue service.

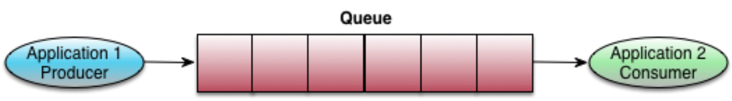


Figure: message queue

Initial setup:

We have used Ubuntu 14.04 LTS for installing stable release of devstack for demonstrating the OpenStack environment using the following steps and commands: 1) Run an update $ Sudo apt-get update, 2) Install git $ sudo apt-get install git 3) cloning step $ git clone https:// git.openstack.org/OpenStack-dev/devstack -b stable/kilo

The devstack is a good tool to get a simple environment of OpenStack for motivating IT's experts learning interest about the cloud. It is also easy to be up-to-date about a new change.

The devstack shell script is used to deploy one node OpenStack cloud (see Figure y) the architecture of one node OpenStack installed on laptop

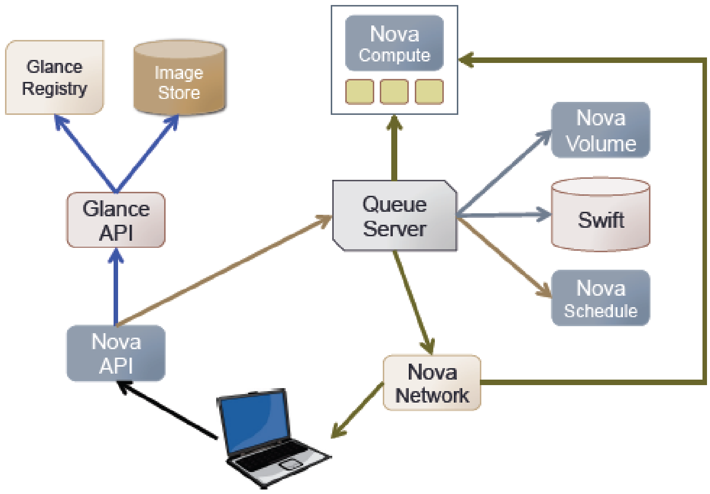


Figure: One node architecture of the OpenStack cloud deployed using devstack.

The following figures depict some services of OpenStack environment installed on laptop:

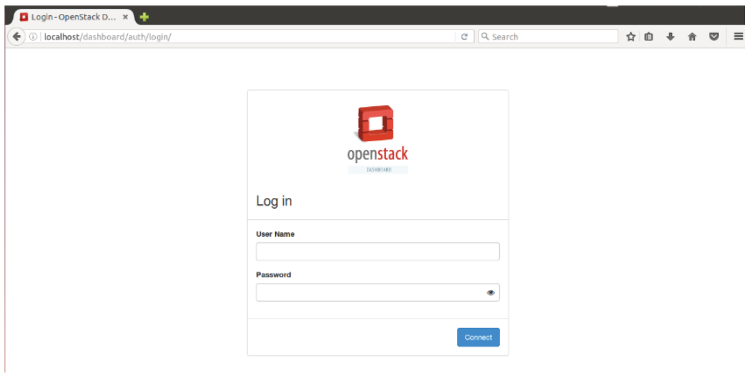


Figure: OpenStack Dashboard/ Horizon.

When we log in into the system identity service/Keystone provides authentication (see the Figure below)

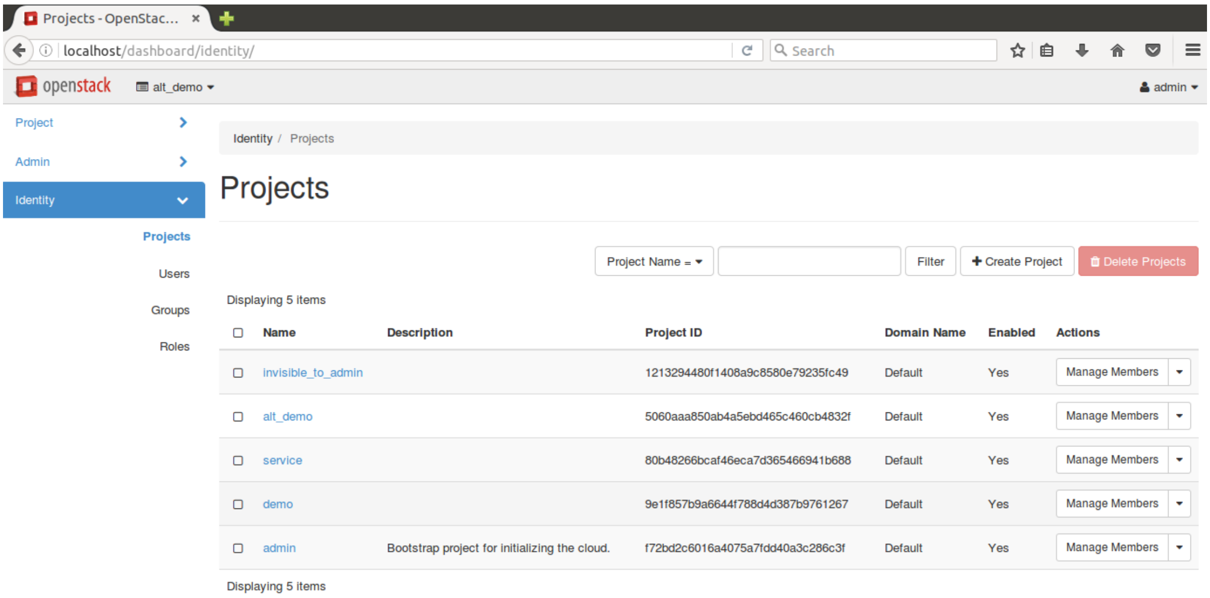


Figure: Identity service of OpenStack implemented in the Laptop.

However, Devstack is not used for realistic setup or production and difficult to get multi machines of OpenStack environment so that, we needed to install OpenStack from source and installing from the source was our second activity (It was very challenging due to limited knowledge and lack of skill of IT staffs about network components of the OpenStack). To implement OpenStack from source, we have design the following steps and requirements to deploy a minimal three-node cloud architecture in a flat network model with OpenStack Networking (Neutron) (See Figure x): For our experimenting, we used OpenStack kilo, the 11th release of the Open source cloud software, it has many components namely, Neutron, nova keystone, ceilometer, horizon, Glance, Cinder, swift, trove, Sahara, heat, ironic, orchestration, and many more.

- Three Ubuntu 14.04.5 LTS 64-bit Linux flavour distribution OS installed sever nodes involved in setting up cloud infrastructure using OpenStack cloud software. A 64-bit accepts both 32-bit and 64-bit images.
- We have used six client machines
- The three servers were with 1-3 network interface cards (NICs), 1-4+ CPU, 2-8+RAM, and 50- 100+GB hard disk for controller node, network node, and compute node.
- A dedicated switch to create a private cloud LAN

The flat network model provides us basic connectivity because scalability was not our concern and also the switch was unmanageable. Our network was in class c network category.

Server one (Controller Node) installation- 2 processor, 8 GB memory, and 250GB storage.

1. In the controller node Ubuntu 14.04.5 LTS 64-bit Linux flavour distribution operating system (OS) has been installed as the base OS. Server one runs the Identity service, Image Service, management portions of Compute and Networking, Networking plug-in, and the dashboard. It also includes supporting services such as a SQL database (MySQL, PostgreSQL, MariaDB, SQLit- we have chosen MySQL and installed it), message queue (RabbitMQ, ZeroMQ, qipd?- we have chosen RabbitMQ and we installed it), and Network Time Protocol (NTP). The rest services are optional and additional features of our cloud environment such as Block Storage, Object Storage, Orchestration, Telemetry, Database, and Data processing services. Server one has only one network interface card (NIC-eth0) for network management.

Network configuration:

1. Configure the first interface as the management interface (eth0): To provide internet access to all nodes for administration purpose such as installation, security updates, DNS and NTP.
   IP address: 10.10.10.11
   netmask: 255.255.255.0 (or /24)
   Default gateway: 10.10.10.1

auto eth0

iface eth0 inet static

address 10.10.10.11

netmask 255.255.255.0

gateway 10.10.10.1 change in the file /etc/network/interfaces

sudo ifup eth0

2. Reboot the system to activate the changes.

We have configured name resolution:

3. Set the hostname of the node to controller.
   Edit the /etc/hosts file to contain the following:
   # controller 10.10.10.11 controller
   # network 10.10.10.21 network
   # compute1 10.10.10.31 compute1

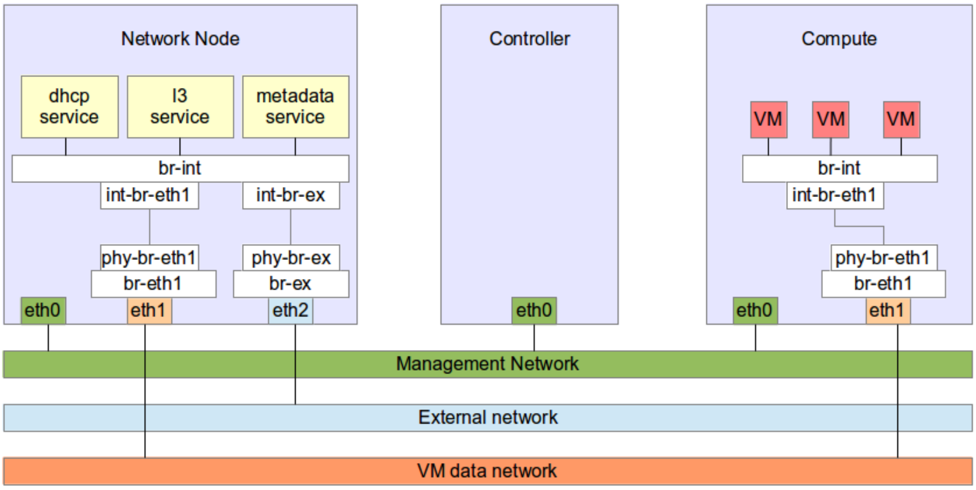


Figure: On controller node eth0 configured as a management network interface.

Server two (Network node) installation-2 processor, 4 GB memory, and 250GB storage

In the network node Ubuntu 14.04.5 LTS operating system (OS) has been installed as the base OS. Server two runs the Networking plug-in and several agents that provision tenant networks and provide switching, routing, NAT, and DHCP services. This node also handles external (Internet) connectivity for tenant virtual machine instances. The network node contains one network interface on the management network, one on the instance tunnels network, and one on the external network (3 NICs).

Network configuration:

1. Configure the first interface as the management interface (eth0):

IP address: 10.10.10.21

netmask: 255.255.255.0 (or /24)

Default gateway: 10.10.10.1

auto eth0

iface eth0 inet static

address 10.10.10.21

netmask 255.255.255.0

gateway 10.10.10.1 change in the file /etc/network/interfaces

sudo ifup eth0

2. Configure the second interface as the instance tunnels interface (eth1):

IP address: 10.10.11.21

netmask: 255.255.255.0 (or /24)

auto eth1

iface eth1 inet static

address 10.10.11.21

netmask 255.255.255.0

change in the file /etc/network/interfaces

sudo ifup eth1

Without a gateway because communication only occur among network and compute nodes in our OpenStack environment.

3. The external interface uses a special configuration without an IP address assigned to it. Configure the third interface as the external interface (eth2): provide internet access to VMs.

• Edit the /etc/network/interfaces file to contain the following:

The external network interface auto INTERFACE_NAME iface INTERFACE_NAME inet manual up ip link set dev $IFACE up down ip link set dev $IFACE down

4. Reboot the system to activate the changes.

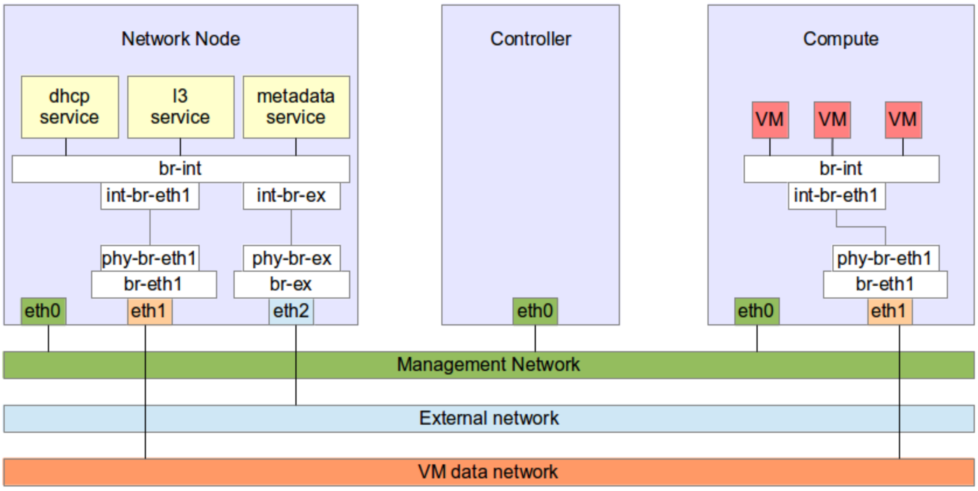


Figure: Network node configuration eth0 as the management interface, eth1 as tenant/tunnel interface for VM data network and eth2 as the external interface for WAN or internet.

We have configured name resolution:

1. Set the hostname of the node to network.

Edit the /etc/hosts file to contain the following:

network 10.10.10.21 network

controller 10.10.10.11 controller

compute1 10.10.10.31 compute1

Server three (Compute node) installation-2 processor, 8 GB memory, and 500 GB storage

In the compute node Ubuntu 14.04.5 LTS 64-bit operating system (OS) has been installed as the base OS. Server three runs the hypervisor portion of Compute that operates tenant virtual machines or instances. By default, Compute uses KVM as the hypervisor. The compute node also runs the Networking plug-in and an agent that connect tenant networks to instances and provide firewalling (security groups) services. We can run more than one compute node. The rest services are optional and additional features of our cloud environment such as a Telemetry agent to collect meters. Also, it can contain a third network interface on a separate storage network to improve performance of storage services. The compute node contains one network interface on the management network and one on the instance tunnels network.

Network configuration:

1. Configure the first interface as the management interface (eth0):

IP address: 10.10.10.31

netmask: 255.255.255.0 (or /24)

Default gateway: 10.10.10.1 Note: Additional compute nodes should use 10.10.10.32, 10.10.10.33, and so on.

auto eth0

iface eth0 inet static

address 10.10.10.31

netmask 255.255.255.0

gateway 10.10.10.1 change in the file /etc/network/interfaces

sudo ifup eth0

2. Configure the second interface as the instance tunnels interface (eth1):

IP address: 10.10.11.31

netmask: 255.255.255.0 (or /24)

auto eth1

iface eth1 inet static

address 10.10.11.31

netmask 255.255.255.0

change in the file /etc/network/interfaces

sudo ifup eth1

Without a gateway because communication only occur among network and other compute nodes. Note: Additional compute nodes should use 10.10.11.32, 10.10.11.33, and so on.

3. Reboot the system to activate the changes.

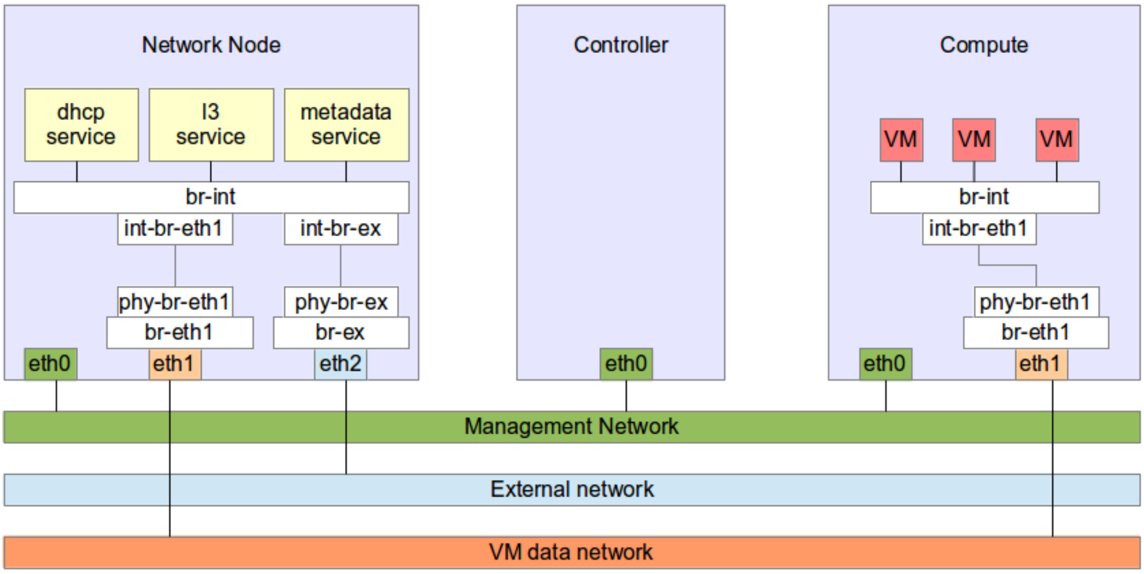


Figure: compute node configuration eth0 as management interface and eth1 as tenant/tunnel interface for VMs

configure name resolution:

1. Set the hostname of the node to compute1.

Edit the /etc/hosts file to contain the following:

compute1 10.10.10.31 compute1

controller 10.10.10.11 controller

network 10.10.10.21 network

We have verified network connectivity to the Internet and among the nodes before proceeding further.

From the controller server, ping a site on the Internet:

ping -c 4 openstack.org

From the controller server, ping the management interface on the network node:

ping -c 4 network

From the controller server, ping the management interface on the compute node:

ping -c 4 compute1

From the network server, ping a site on the Internet:

ping -c 4 openstack.org

From the network server, ping the management interface on the controller node:

ping -c 4 controller

From the network server, ping the instance tunnels interface on the compute node:

ping -c 4 10.10.11.31

From the compute server, ping a site on the Internet:
ping -c 4 openstack.org
From the compute server, ping the management interface on the controller node:
ping -c 4 controllers
From the compute server, ping the instance tunnels interface on the network node:
ping -c 4 10.10.11.21
Install OpenStack: Like: Amazone.com provides IaaS i.e. AWS CC platform, Microsoft Azure CC platform i.e. application platform as a service, and Google App engine CC platform i.e a web application platform as a service (python run time environment)

The test bed, that is, OpenStack cloud environment (in this case open source opportunity) is implemented based on kilo OpenStack version.

Nodes:

Compute node

Network node: Nova-scheduler, neutron-server

Controller node: MySQL DB for keystone, RabbitMQ, keystone, Nova-API

Message queue: to coordinate operations and status information among services.

Run on the controller node: RabbitMQ: message queue services.

Appendix III: Participant selection

Step 1: split the participants into government and private enumerator areas (EAs) The government sector will have 20 participants and the private sector will have 19 participants.

Step 2: sample for each stratum using PPS (probability proportional to size) for government and private sectors. In this case, 2 and 1.

Step 3: compile two listings for each EA (one for IT departments and one for other departments).

Step 4: 2 IT departments and 20 other departments will use simple random sampling for each selected EA.

Step 5: from all IT departments' staff network experts or cloud experts staying one year or greater, one will be randomly selected based on simple random sampling. Total= 19 from private sector.

Similarly, from government sector. Total= 20.

The minimum targeted sample determined to obtain the desired precision is equal to 39.

At first, we need to get IT experts' and end users' data through survey in order to deeply understand the hurdles, and then fit the data into the model. The model clearly shows the hurdles to design mechanism paired with an opportunity. The above sectors were surveyed to show digital technology is being widely acknowledged.

Appendix IV: Ethics application form

Application for Approval
Outline of Research or Related Activity

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Ethics Committee, Faculty of Computing and Mathematical Sciences

Note: add your project details to this document – do not delete any of the existing content

Details of Proposed Activity

1. Identify the project

1.1 Title of Project

Cloud Adoption Hurdles, Opportunities, and Competence Model in the African Context: Proof from Ethiopia

1.2 Researcher(s) name and contact information

Name: Melese Mulugeta Kebede

Department: Computer Science

Email address: melee.2007@yahoo.com

Phone number: 0220402621

Mailing address: Greensboro Street 25C Hamilton
New Zealand

1.3 Supervisor's name and contact information (if relevant):

Name: Dr.Vimal Kumar

Email address: vkumar@waikato.ac.nz

Waikato University, New Zealand

1.4 Anticipated date to begin data collection: May 30, 2016

1.5 Does your application involve issues of health or disability with human participants? If so, please refer to the guidelines as to whether your application needs to be submitted to the Northern Y Regional Ethics Committee.

No

2. Describe the research or related activity

2.1 Briefly outline what the project is about including your goals and anticipated benefits. Include links with a research program, if relevant.

The aim of this research is to investigate and suggest an innovative solution (Competence model) for the causes of the local isomorphic barriers to the adoption of cloud computing in the African context, focus in Ethiopia. Specifically, the key intention and goal of this research is to look at the effects of open source cloud computing resources on the reduction of cloud computing adoption hurdles via experimenting with the widely used platform i.e. OpenStack. OpenStack will be used for building a private cloud for target organization in order to examine and pave the way for the organizations. The model will be designed through the various context-based possibilities to mitigate the bottlenecks born from the lack of cloud concept, the lack of well-poised competent IT experts. That is, the lack of hands-on technical skills, under-utilization of the opportunities of open source cloud platforms, and a loose interpretation around the security, trust, legal and privacy issues. To design workable mechanism for Africa, this paper categorizes the cloud computing obstacles into three views: policy and business hurdles view, technical incompetence to the adoption view, and technical obstacle to the growth of the cloud view. The developed countries almost escaping technical incompetence view. However, many researches have proved that finding competent cloud experts is a chronic problem in developing countries. This research will add to the body of knowledge around cloud competence and the mechanism will minimize the cloud adoption barriers by maximizing cloud expert's competence.

2.2 Briefly outline your methods.

Research Approach:

1. Conduct a current state assessment and investigate the causes of local barriers of cloud computing using hard copy questionnaire (exploratory data) to lay the foundation and build evidence for further experimenting with OpenStack.
2. Further data collection via experimental, participatory demonstrations for potential cloud experts will be conducted by using open source "OpenStack" cloud computing management software.
    a. Conduct experimental demonstrations for the participant to observe and track their competence.
    b. Quantitative information will be collected using hard copy questionnaire after the practical participation of the experts, it is also a combination of face-to-face interviews and group discussions will be conducted.

3. Desk research, analysis and interpretation.
4. Design a mechanism for future state cloud competence as a solution.

2.3 Describe plans to give participants information about the goals of the research or related activity.

First, I will explain the goals of the research orally using local language. Second, the goal of the research is written on the questionnaire. In addition, during the experimental demonstrations first, I will describe the goal of the research by communicating with the organization via official letters and emails to the IT managers of the organizations. Second, I will explain the goal to the identified focus group (potential cloud experts/IT group) in the targeted organizations. (Attached).

2.4 Identify the expected outputs of this research or related activity (e.g., reports, publications, presentations).

The final deliverable of this research is a piece of written work that report on the findings. It is possible that publications and presentations may come out of the research.

2.5 Identify who is likely to see or hear reports or presentations arising from this research or related activity.

Waikato University, The Ethiopian Government Ministries (Education, ICT, and Agriculture), Universities, and Public Enterprises, Banks, ICT private sector companies, Internet service providers.

2.6 Identify the physical location(s) for the research or related activity, the group or community to which your potential participants belong, and any private data or documents you will seek to access. Describe how you have access to the site, participants and data/documents. Identify how you obtain(ed) permission from relevant authorities/gatekeepers if appropriate and any conditions associated with access.

Target sample size (n) is equal to three Ethiopia's government and private organizations and about 76 employees will be participating in this research for participatory demonstration and interview. For meaningful analysis the 3 organizations are grouped into two categories:

- Ministries (Education and Agriculture) (2)
- ICT Private Sector Company (1)

The physical locations of all of the above organizations are in the capital city of Ethiopia i.e. Addis Ababa. I work for the Ministry of Agriculture as an IT expert, so I have the right to access the site and deploy new knowledge to my office. In addition, all of the above organizations belong to either public sector or private service provider, so they are accessible for everyone. As an Ethiopian citizen I have the right to get any information from different organizations except sensitive military data. In this case, there is no need to capture sensitive military data, private data or documents. To access to the participants first, I will communicate with the employees' managers in Ethiopian bureaucratic procedure and culture (Usually, students are encouraged during their university thesis), so the manager will invite the staff members for my planned meeting to participate in the study through email, verbal communication or other communication medium.

3. Obtain participants' informed consent without coercion

3.1 Describe how you will select participants (e.g., special criteria or characteristics) and how many will be involved.

The participant organization are selected based on characteristics of current ICT usage and their expected potential to adopt the cloud, for providing the cloud and potential cloud experts. Their involvement systematically classified using stratified two-stage cluster sampling method and performed in five steps for target population:
Step 1: split into government and private enumerator areas (EAs).
Step 2: sample for each stratum using PPS (probability proportional to size) for government and private sectors. In this case, 2 and 1.
Step 3: Two listing compiled for each EA, one for IT departments and one for other departments.
Step 4: 2 IT departments and 20 other departments will sample using simple random sampling for each selected EA.
Step 5: From all IT departments staffs Network expert or cloud expert staying one year or greater, one will be randomly selected based on simple random sampling (6). And from all other departments staff's experts 28 years or older, user of networked computers (20). Total= 26 from private sector.
Similarly, from government sector. Total= 50.
The minimum targeted sample determined to obtain the desired precision is equal to 76.

3.2 State clearly whether this is an application under section 10 of the Ethical Conduct in Human Research and Related Activities Regulations: Large Random Sample Surveys.

No

3.3 Describe how you will invite them to participate.

First, I will communicate with the employees' manager via Ethiopia's bureaucratic and cultural procedure (usually, students are encouraged during their university thesis), and then the manger will invite the staff members for my planned date of meeting through email, verbal communication or other communication medium (The letter attached).

3.4 Show how you provide prospective participants with all information relevant to their decision to participate. Attach your participant information sheet, cover letter, or introduction script. See document on informed consent for recommended content. Information should include, but is not limited to:

- what you will ask them to do;

- the context in which information sheets and consent sheets will be used. When (e.g. just before the study, a week before etc), where (e.g. in a laboratory environment, in a field setting etc) and in what form (e.g. paper, email etc) information will be provided to prospective participants.
- how to refuse to answer any particular question, or withdraw any information they have provided at any time before completion of data collection;
- how and when to ask any further questions about the study or get more information.
- the form in which the findings will be disseminated and how participants can access a summary of the findings from the study when it is concluded.

This research will ask the participants to complete a hard copy (printed) questionnaire that will take about 45 minutes in their office and also I will ask IT experts to participate in the participatory demonstration of installing and configuring of a private cloud using open source cloud management software (OpenStack) in my office-training room (in the Ministry of Agriculture) at a given time within 5 weeks and I will track their suggestions. The complete information about the research and the information in the participant information and consent sheets will be provided just right before the survey in the form of hard copy in the participants work place At the same time, they have the democratic right (Article 29-Ethiopian Constitution) not to answer any single question, to hold, to refuse, to withdraw at any time of the survey/demonstrations within the data collection time and during the process; additionally, they have the right to request that the interviewer not use any of their interview or suggestion tracks. They have the right to ask questions for further clarification about this research study and to have those questions answered by me before, during or after the research. Finally, all participants can access a report on the web site called www.extensia-ltd.com.

3.5 Describe how you get their consent. (Attach a consent form if you use one).

I have attached a consent form that will be used with the survey, for both the managers and the staff participants.

3.6 Explain incentives and/or compulsion for participants to be involved in this study, including monetary payment, prizes, goods, services, or favours, either directly or indirectly.

No

4. Minimise deception

If your research or related activity involves deception – this includes incomplete information to participants -- explain the rationale. Describe how and when you will provide full information or reveal the complete truth about the research or related activity including reasons for the deception.

There is no deception. The complete information about the research is in the participant information sheet and this will be provided right before the survey. And the survey takes place only after the participants understanding and signing of the consent form.

5. Respect privacy and confidentiality

5.1 Explain how any publications and/or reports will have the participants' consent.

In the participant information sheet, I will give the information what will happen to the collected data, that is, the collected data from this survey will be anonymized and their response will be aggregated in a report. It is possible that publications and presentations may come out of the research.

5.2 Explain how you will protect participants' identities (or why you will not).

This research is anonymous, and questionnaires are numbered. Only the researcher will have the information about the translation of the questionnaires from numbers to identities. However, this will be stored in a file and this file will be securely destroyed by appropriate means once the research has been done.

5.3 Describe who will have access to the information/data collected from participants. Explain how you will protect or secure confidential information.

Only the researcher and supervisor will be privy to the questionnaires, forms, notes, documents, the paper written, and the soft copy files. The researcher will keep and treat them with the strictest confidentiality during the research. Afterwards, paper-based questionnaire, forms, notes, documents will be securely destroyed and the soft copy files will be irrecoverably deleted, once the research has been done. However, for protecting long-term retention of digital file integrity and identity, the converted soft copy or encoded information/data with a password protected file folder will be stored in the Faculty of Computing and Mathematical Science data archive for 5 years. After 5 years of storage life the stored data will be irrecoverably deleted from the data archive. No participants will be named in the reports or any publications and every effort will be made to disguise their identity.

6. Minimise harm to participants

'Harm' includes pain, stress, emotional distress, fatigue, embarrassment and exploitation.

6.1 Where participants risk change from participating in this research or related activity compared to their daily lives, identify that risk and explain how your procedures minimize the consequences.

This research will be conducted in the participants' office using the organizations' computers and hard copy questionnaires, so there is no harm compared to their daily life and work. There are no reasonable expected risks. There may be unknown risks.

6.2 Describe any way you are associated with participants that might influence the ethical appropriateness of you conducting this research or related activity – either favorably (e.g., same language or culture) or unfavorably (e.g., dependent relationships such as employer/employee, supervisor/worker, lecturer/student).   As appropriate, describe the steps you will take to protect the participants.

I am working with some of the employees who may participating in this research and we share the same national language (Amharic) and culture. However, these associations might not influence the ethical appropriateness of my conducting research. In contrast, positively influence to meet the goals of the research by participating according to the plan, coordination and procedure via the supervision of the managers.

6.3 Describe any possible conflicts of interest and explain how you will protect participants' interests and maintain your objectivity.

I am employed by the Ministry. So, this might raise possible conflict of interest. I will uphold the highest ethical and professional conduct. And I will declare to the participants without compromise, the standards and ethics of the research.

7. Exercise social and cultural sensitivity

7.1 Identify any areas in your research or related activity that are potentially sensitive, especially from participants' perspectives. Explain what you do to ensure your research or related activity procedures are sensitive (unlikely to be insensitive). Demonstrate familiarity with the culture as appropriate.

Potentially there are no sensitive areas in my research case. These days, IT is acceptable and not seen as socially and culturally sensitive. As Ethiopian I share the same national language (Amharic). Fortunately, I have traveled all over the Ethiopia and I know different modern and traditional cultures of Ethiopia.

7.2 If the participants as a group differ from the researcher in ways relevant to the research or related activity, describe your procedures to ensure the research or related activity is culturally safe and non-offensive for the participants.

At first, to be culturally safe I will follow traditional procedure and randomization to mix different local cultures. If it arises I will shuffle voluntarily group members and systematically regroup in ways relevant to my research with the help of their manager. Specially I have travelled all over the country I know the psychology of the participants how to reshape as a group.

Appendix V: Ethics approval letter and consents

Faculty of Computing and Mathematical Sciences
Rorohiko me ngā Pūtaiao Pāngarau
The University of Waikato
Private Bag 3105
Hamilton
New Zealand

Phone +64 7 838 4322
www.cms.waikato.ac.nz

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

20 May 2016

Melese Kebede
C/- Department of Computer Science
THE UNIVERSITY OF WAIKATO

Dear Melese

Application for approval under the Ethical Conduct in Human Research and Related Activities Regulations

I have considered your application to conduct a research project "Cloud Adoption: Hurdles, Opportunities and Competence Model in the African Context" with permission from the various Managers of Government Ministries in Ethiopa.

The procedures provided in your request are acceptable however we have approved the project as currently described. If an agreement is requested by any Ethiopian government authority, it can only be signed if it complies 100% with the project/program as described and approved by the University of Waikato. If any suggested agreement with the Ethiopian government suggests variations to the proposal/processes as approved, then the research cannot proceed without a new or modified ethics application being provided to us.

I note that participants involved in the study will not be identified in any resulting publications or the reports, and that at the conclusion of the project the data will be submitted to the FCMS Data Archive for secure storage for five years.

The Participant Information Sheets, Research Consent Forms and questionnaire comply with the requirements of the University's human research ethics policies and procedures.

I therefore approve your application to perform the research project.

Mark Apperley
Human Research Ethics Committee
Faculty of Computing and Mathematical Sciences

Research Consent Form
Ministry of Agriculture-ICT
Management Center, Ethiopia

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Ethics Committee, Faculty of Computing and Mathematical Sciences

Cloud Adoption: Hurdles, Opportunities, and Competence Model in the African Context.

Consent Form for Managers

I have read the participant information sheet and the research study has been explained to me. I have been given the opportunity to ask questions and my questions have been answered. If I have additional questions, I have been told whom to contact. I agree to my staff members to participate in the research study described in the participant information sheet and will receive a copy of this consent form. I will receive a copy of this consent form after I sign it.

Signed: ____

Name: ____

Date: ____

Researcher's Name and contact information:

Name: Melese Mulugeta Kebede

Department: Computer Science

Email address: melee.2007@yahoo.com

Phone number: 0220402621

Mailing address: Greensboro Street 25C Hamilton East 3216
New Zealand

Supervisor's Name and contact information:

Name: Dr.Vimal Kumar

Email address: vkumar@waikato.ac.nz

Waikato University, New Zealand

Appendix VI: Questionnaires

Cloud adoption questionnaire ID No ____________

1. The Aim and General Questions

The aim of this survey is to investigate the hurdles to the adoption of cloud computing in the Ethiopian context and to show how each hurdle is paired with an opportunity.

Please tick your answers.

1. Which one of the following applies to you?

- ◯ IT expert of the organization
- ◯ Other expert of the organization

2. What is your highest qualification?

- ◯ Certificate
- ◯ 10+3
- ◯ 10+4
- ◯ University degree (BSc., BA, MSc., PhD, other)

Please specify e.g. Certificate in Electronics, BSc. in IT

3. How old are you?

- ◯ 18-30
- ◯ 31-50
- ◯ 51-70
- ◯ 70+

4. Do you currently own at least one IT device (including mobile, tablet, laptop, desktop, etc)?

- ◯ Yes
- ◯ No

If your answer is yes please specify

1

5. Are you familiar with the organization's IT systems?

◯ Yes

◯ No

2. General awareness

Question 6 up to 13 can be answered by all participants.

6. Have you heard of cloud computing?

◯ Yes

◯ No

If yes about what you have heard?

7. Have you ever used cloud computing services (like Dropbox, Google drive, OneDrive, AWS, MS Azure, IBM cloud, Google App engine, GoGrid, FlexiScale, Salesforce, Zoho, etc)?

◯ Yes

◯ No

If yes please specify

8. Based on Q7 above do you know their policies?

◯ Yes

◯ No

If yes please specify

9. Are you aware of free open source software (FOSS)?

◯ Yes

◯ No

If yes please specify two more

10. Based on Q9 do you know their licencing policies?

◯ Yes

◯ No

If yes please specify their licencing policies

11. Are you aware of free cloud services (like storage service, software service, etc)?

◯ Yes

◯ No

If yes please specify

12. Based on Q11 do you know their agreements?

◯ Yes

◯ No

If yes please specify?

13. Do you think cloud computing would be helpful in your organization?

◯ Yes

◯ No

◯ I don't know

3. Awareness, readiness and competence questions

From Q14 up to Q29 are for IT Experts only.

14. Have you learnt cloud computing at university?

◯ Yes

◯ No

If yes please specify the course contents as much as you can and the place?

15. Have you used virtualization (ESXi, Xen, Hyeper-v, KVM, etc)?

◯ Yes

◯ No

if yes please specify

16. Based on Q15 for what purpose are you using virtualization?

17. Are you aware of open source cloud management platforms (including OpenStack, CloudStack, Eucalyptus, Open nebula, etc)?

◯ Yes

◯ No

If yes please specify

18. Based on Q17 have you seen any private or public cloud setup environment using one of the open source platforms?

◯ Yes

◯ No

If yes where?

19. Based on Q18 do you think you can setup a private or public cloud?

◯ Yes

◯ No

If your answer is No why? if your answer is Yes please tell us what tools and techniques you will use?

20. Based on Q18 do you think it is suitable for an organization?

◯ Yes

◯ No

please specify?

21. Are you aware of closed source cloud platforms (including IBM cloud, MS-Azure, AWS,etc)?

◯ Yes

◯ No

If yes please specify?

22. Are you aware of other types of computing? (like Grid computing, distributed computing, cluster computing, etc)

◯ Yes

◯ No

◯ Others computing

please specify

23. Are you aware of cloud users or Essential user entities(like Cyber infrastructure developer, end user, etc)?

◯ Yes

◯ No

If yes (please add more)

24. Are you aware of enabling technologies of the cloud (like virtualization, web services, service oriented architecture, workflows, web 2.0, service flows, component-based systems, etc)?

- ◯ Yes
- ◯ No

If yes please specify and write something about?

4. Awareness, readiness and competence questions

25. Have you ever setup cloud computing environment earlier for any organization?

- ◯ Yes
- ◯ No

If yes using what cloud software or platform?

____

26. What is the greatest achievement for your setup related to the cloud?

____

27. Was the design of the cloud adequate to achieve the result, purpose and over all objectives?

- ◯ Yes
- ◯ No

28. What do you think are the benefits to adopt the cloud computing from Ethiopia's perspectives?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Reduce cost	○	○	○	○	○
Reduce IT overhead for the end-user	○	○	○	○	○
Quality of platforms and software increase	○	○	○	○	○
Quality of services increase	○	○	○	○	○
Delivery of services increase	○	○	○	○	○
Speed or performance of the system increase	○	○	○	○	○
Dynamic scale ablity increase	○	○	○	○	○
Backup and restore or disaster recovery improve	○	○	○	○	○
On-demand and pay as you go	○	○	○	○	○
It changes capital expenditure to operational expense	○	○	○	○	○

29. What do you think are the barriers to the adoption of cloud computing from Ethiopia's perspectives?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Lack of cloud education	○	○	○	○	○
Lack of cloud research	○	○	○	○	○
Shortage of Finance	○	○	○	○	○
Lack of awareness	○	○	○	○	○
Lack of security	○	○	○	○	○
Lack of data privacy	○	○	○	○	○
Lack of trust and reliance	○	○	○	○	○
No quality and availability of the Internet connectivity and infrastructure	○	○	○	○	○
Lack of awareness of open source cloud platforms	○	○	○	○	○

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	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Licencing problems	○	○	○	○	○
Lack of cloud policy and legal framework	○	○	○	○	○
Lack of standards	○	○	○	○	○
Lack of competent cloud experts	○	○	○	○	○
Lack of service concept/ lack of utility concept (like x as a service)	○	○	○	○	○
Lack of readiness	○	○	○	○	○
Affect the operations of the organization	○	○	○	○	○
It creates IT unemployment	○	○	○	○	○
Cloud providers have a full control of the platforms	○	○	○	○	○
Generic platform/providers do not design platform in a context of specific countries, companies, and their business practices.	○	○	○	○	○
Lack of government initiatives	○	○	○	○	○
Costly	○	○	○	○	○

30. Is there any additional information for the cloud awareness, readiness, and skill that you would like to discuss as part of this questionnaire?