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PRIVATE CLOUD NETWORK MANAGEMENT SYSTEM

By

Samuel Opae: P53/28792/2019

Supervisor

Dr. Andrew Mwaura Kahonge

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DECLARATION

Researcher's Declaration

This project report is my original work and has not been presented in any other institution for an academic award. All sources, references, literature used or excerpted during the elaboration of this work are properly cited and listed about the respective source.

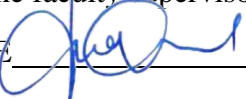
SIGNATURE  DATE 4-12-2021

Samuel Opa

Registration Number: P53/28792/2019

Supervisor's Approval

This research project has been submitted as partial fulfillment of the requirements for the award of the Degree of Master of Science in Distributed Computing Technology at the University of Nairobi with my approval as the faculty supervisor.

SIGNATURE  DATE 06-Dec-2021

Dr. Andrew Mwaura Kahonge

School of Computing and Informatics

University of Nairobi

ABSTRACT

Network Automation is the game-changer in Network Management in most organizations and across the world. This is bring about change and shift in the way network configuration, design deployment, and monitoring have been done in the previous years. The emergency of a Software-defined network is shifting the Network vendors to produce devices that can be integrated and run as infrastructure as a code. This emergency and evolution of technology will assist an organization to reduce operational costs and provide a customizable way of architecture the Network for the novice ways while reducing the complexity of managing the Network Infrastructure. Network management is one area that the approach of Network automation using infrastructure as a code is taking high precedence. While leveraging on Network automation, Network engineers and Information Technology Support Team will be able to interact with systems in a friendly way while managing. This study focused on a Network management tool that is meant to assist Network engineers and helpdesk to deploy, manage and configure network switches in a multi-vendor environment. The Network Management is proof of concept to showcase how automation can simplify network complexities in a multi-vendor environment to present a solution to the existing challenge of manual configuration and specialized skills geared towards a particular vendor in the Networking industry. Hence it fits in the gap analysis that was established in the literature review as it was identified the existing solutions reviewed could not provide centralized configuration management for the multivendor environment.

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DEFINITION OF TERMS

- Software-Defined Network: is a network architecture design with capabilities to be programmed
and to be centrally controlled using a software application.
- Network Automation: This is the approach of automating manual tasks with the end goal being a simplification of the complexity of management of network infrastructure
- Virtual Local Area Network: This refers to the logical separation of Network devices by use of
grouping into subnets
- IP : Refers to a set of standards and rules that dictate how data is sent on the Network
- Local Area Network : refers to a group of computers connected on a network that spans abuilding.
- Network: A connection of two computer devices or systems using communication media

ABBREVIATION/ACRONYMS

IP	–	Internet Protocol
GNS3	-	Graphical Network Simulator 3
CLI	–	Command-line interface
SSH	–	Secure Shell
HTTP	–	Hypertext Transfer Protocol
SAS	–	Software as A service
LAN	–	Local Area Network
VLAN	–	Virtual Local Area Network
O&M	–	Operation & Management

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CHAPTER ONE: INTRODUCTION AND BACKGROUND INFORMATION

1.1 Background

Network Automation which relies on a Software-defined network is a process of using software to automate a particular Network task by understanding, interpreting, and creating logic. This improves efficiency and the capabilities of manual tasks while limiting the error rate providing a space for focusing on the scalability of the task with less effort. (Ratan,2017, p 7). Networking is essential in any organization as it provides interconnectivity and communication in an enterprise environment and the outside world Devices that are majorly used in networking are Routers switches and firewalls. Every Network device vendor has a different syntax of commands for Network Management. Each vendor plays a role in the network. (Patricia & James, 2014, p 29) States that to make changes in network behavior, it is necessary to access each router in the network and issue a set of commands to the operating systems in the language that has been defined by the vendor of the network equipment. The overall objective of this is to change the device's results. In such a closed environment networking devices, cannot easily interact with other components existing in the network.

1.2 Research problem

Network Automation refers to the process and procedure of automating tasks that are executed manually such as configuration, management deployment. A survey carried out by (Wenfeng, Yonggang, Chuan, Dusit & Haiyong, 2017, p 29) states that during provisioning of a network device in the environment, there is a need to have proper configurations for synchronization and to achieve coherence in network operation. The existence of heterogeneity of network vendors and configuration management has facilitated the decentralized architecture typically involving a certain level of manual processing. As the end goal is met, it is worthwhile to note that the manual configuration process is tedious and subjected to errors which in turn increases the amount of time require t to troubleshoot a network that has misconfiguration. With this manual and decentralized architecture and existing network designs, it proofs hard to attain automatic and dynamic reconfiguration in the Networking field. The emergence of Network automation is the solution in such given circumstances This provides a way in which the network can be programmatically configured using a Software-Defined Approach. There is a need to reduce the

time for deployment and provisioning of network devices. Network Automation has been a problem for many since skilled talent remains a challenge even though we have tools that can be used. This has led to increased cost of Maintaining deploying and management of the network as an organization is seeking consultants service to maintain the network to shift risks associated with network downtime.

1.3 Research questions

The research questions included:

1. What are existing approaches are being used for Network Management?
2. What are the challenges facing the automation of Networks?
3. What are the benefits realized by adopting network automation?

1.4 Objectives of the study

1.4.1 Overall objective

This study aimed to provide a Network Management Prototype to assist manage and configuring Network devices in a multi-vendor environment by interacting with a user-friendly interface.

1.4.2 Specific objectives

1. To research and establish existing network configuration approaches that have been adopted to configure the network and deployment of new services.
2. To research and establish challenges facing Network automation and benefits that can be realized by automating the network
3. To design a prototype for Network configuration Tool for Configuration deployment for Local Area Network switches.
4. To implement and test the developed prototype for the Network Configuration

1.5 Justification of the research

Software-defined network and Network automation will be beneficial in such cases, as it can take care of all the preceding aspects and perform the tasks in parallel. Hence, if it takes 30 minutes of manual effort for one router, and in the worst-case scenario the same minutes for automation to

perform the same task, then leveraging on parallel execution it is possible to attain a result in all 1,000 routers being upgraded within the same 30. minutes. (Ratan, 2017.pg7). This has been attributed to the fact that the network is becoming big and complex to maintain. The use of scripts can be a solution, but this exposes the code to users. By employing A web framework, will ensure that scripts are used by multiple end-users using just the browser. This provides the programmer the ability and independence to script on their preferred platform (such as Windows or Linux), and people can use the scripts on their choice of browser. They don't need to understand how the code has been written, or what functional call or used in the backend, and of course, this ensures that the code is hidden from being directly visible to end-users. (Ratan,2017. pg. 109).

1.6 Scope of the research

The Scope involved 3 networking Vendors. Cisco, Aruba, and Arista. Since the images for emulation were readily available for use and they are supported in the Simulation environment. The scope encompassed the switch LAN functionalities. For configuration parameters, VLAN configuration was the point of focus on the LAN section. Interface configuration. Static route configuration on switches

1.7 Assumptions

1. The assumptions included: Network stability will provide optimal routing in the simulated environment.
2. All other vendors can be provisioned in the simulated environment for testing.
3. The system developed will require optimal resources during deployment and testing.

CHAPTER TWO: LITERATURE REVIEW

In this section, we will be looking at reviews of network Automation and how it can assist in an Enterprise environment. The emergence of REST API has played a key role in software Defined Network. This is meant to simplify the task. Most major vendors in the Networking Industries like Huawei and Cisco are adopting this new technology to simplify networks and increase efficiency, According to Mihăilă et al.,(2017,p95-96) state that the concept of network Automation will bring about dynamic infrastructure configuration by automation deployment. This has been attributed to the fact that the network is becoming complex due to the heterogeneity of the device. They also state that Traditional Methods for Configuration are time-consuming given that the learning curve is steep due to vendor-specific languages and commands to be configured on the device. Leaning towards the SDN brings a new paradigm shift that downplays vendor dependency on standard protocols. Adopting a network automation organization will be able to realize savings on OPEX and improve efficiency and easy maintenance of the network infrastructure.

2.1 Levels of Network Automation

While looking at emerging issues from this literature review (David,2020) states that other areas to be considered while moving towards Autonomous driving Networks In order provides to achieve an Autonomous driven Network there are five levels to be considered by any organization. The first level which is also referred to as **Level 0 manual Operational and Management(O&M)**, at this level monitoring capability, and all dynamic tasks must be executed manually this is where the traditional approach on configuration management is based and it is a decentralized way of management. As we approach **Level 1 Assisted O&M** some subtasks are executed based on existing rules that provide an increase in execution efficiency which can be based on triggers such as scheduled tasks and scripts. **Level 2 is semi-autonomous**, with inclinations towards enabling a closed-loop O&M for certain units that resided in the external environment which facilitates reduction of the bar for personnel skill sets. **At L3 Conditional Autonomous networks**, the network should be able to adapt to real-time changes, optimize and adjust to any other external factors to facilitate intent-based closed-loop management. **L4 Highly Autonomous Networks** which is built on top of Level 3 features seeks to accommodate more complex cross-domain ecosystems. At this level, the system should provide predictive management of services that result in the resolution of network faults before the customers can

raise any complaints. This is the level where the number of downtimes is reduced to provide improvement in users' experience. **The L5 fully autonomous network** is the highest level and is the goal of network evolution while providing automation that covers various domains.

2.2 Building Infrastructure as a Code

While building automation for a Network there is a need to build an infrastructure as a Code. Masek et al.,(2018) provide more details stating that this is a way of representing the Management of Network infrastructure which includes Network Devices Load balancers, and interconnectivity by providing an architecture that depends on versioning that the DevOps engineers consume from the source code repository. They also present to us the available approaches and tools that can assist in building Infrastructure as a code. They present tools like Chef, puppet, Ansible, SaltStack, CloudFormation, and Terraform which are open source. From their work, they were able to achieve automation by leveraging the use of Ansible which is python based and using YAML. While. The systems run on the webserver that provides front End administrators with a user interface that facilitates easy administration.

2.3 Alternative approaches to Network Management

Eric. P (2019, p2-4) states that some network devices or vendors have not provided documentation for configuration or managing devices possess challenges to network Engineers. However, as the adoption of REST API is taking place or traditional approaches towards automation, the main challenge is the automation of legacy devices that do not support REST APIs this involves the use of SNMP, Netconf. However, the presence of SSH and telnet can be an approach towards solving this by employing other Python libraries that can leverage interaction utilizing a legacy protocol such as ssh.

2.4 Challenges facing Network Management

The network device in such as Routers and Switches were initially designed to be configured as standalone hence configuration is by one by one by utilizing terminal which was the simplest method available at the time (Shamus, 2019) Over time there has been advancement in technology such that and all network devices have shifted towards IP technology, however, as this advancement is being realized configuration and management of these devices remains to be

manual and per device basis. With time various devices with different functionalities are introduced in the environment that have a unique command line that requires a different skillset to manage and Maintain by the Network Operation Center this has been attributed to the advancement and introduction of new protocols. This has led to a complicated network in that changes are performed during planned downtimes to avoid risks associated with the manual configurations. (Shamus, 2019)

According to (Shamus, 2019). Most organizations are facing challenges to realize automation with 96% of the organizations admitting that the main challenge is price. This has been attributed to the fact that many enterprise solutions being bought are hard to budget for.

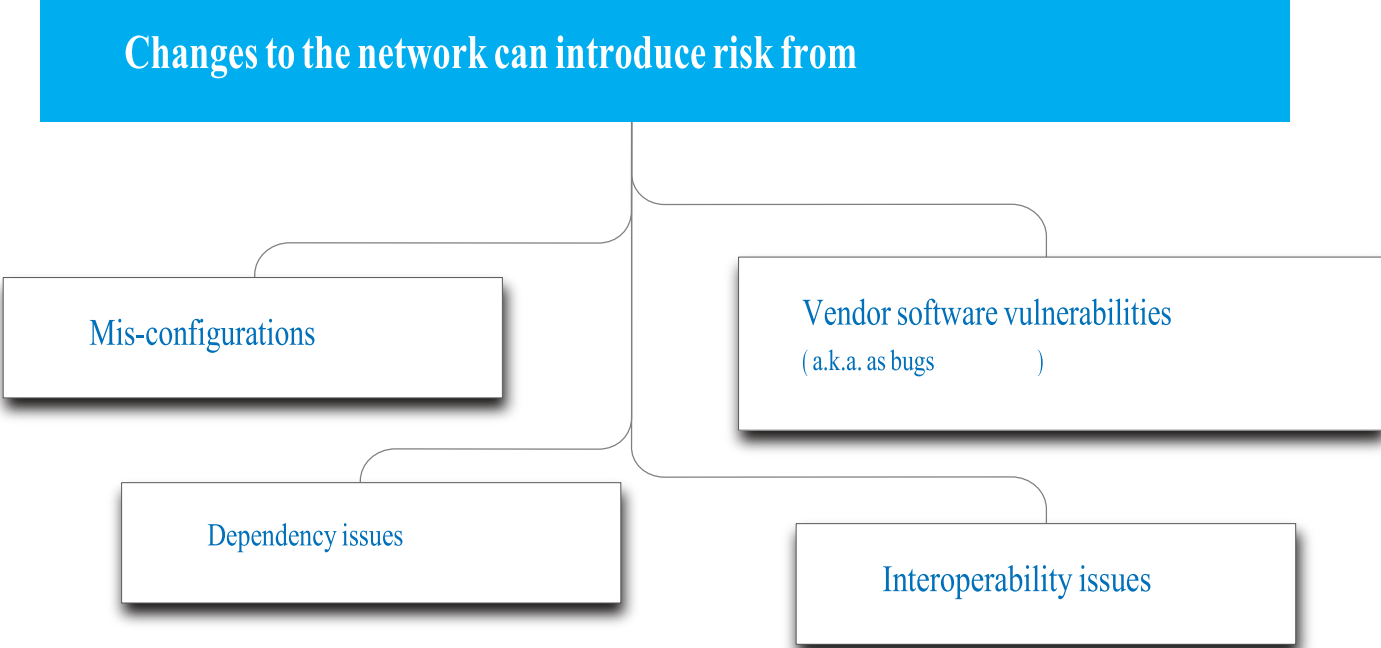


Figure 2. 1 Showing risk on Network Change

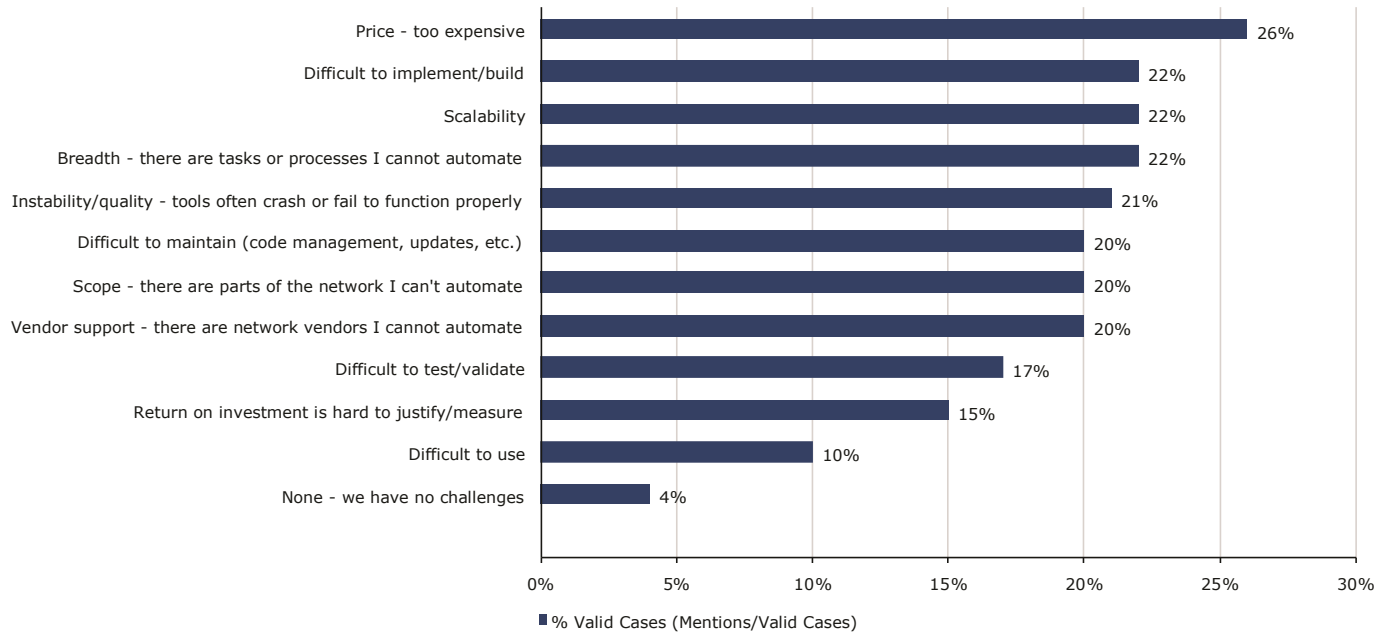


Figure 2.2 Source © 2019 Enterprise Management Associates showing challenges facing network automation

2.5 Automation Hierarchy

According to research carried out by AGC, (Mark,2020) states that the hierarchy of automation is bottom-up such that task automation becomes the atoms of the process. This is to say that various manual tasks e.g. network device configuration. The domains are collection is seen as a collection of devices managed as one and at cross-domain automation also known as orchestration where the process is applied across domains. The process of automation requires input at the initial or top-level in terms of Operations Support Systems (OSS) not forgetting the key player that buys in the idea which is Business Support Systems (BSS).

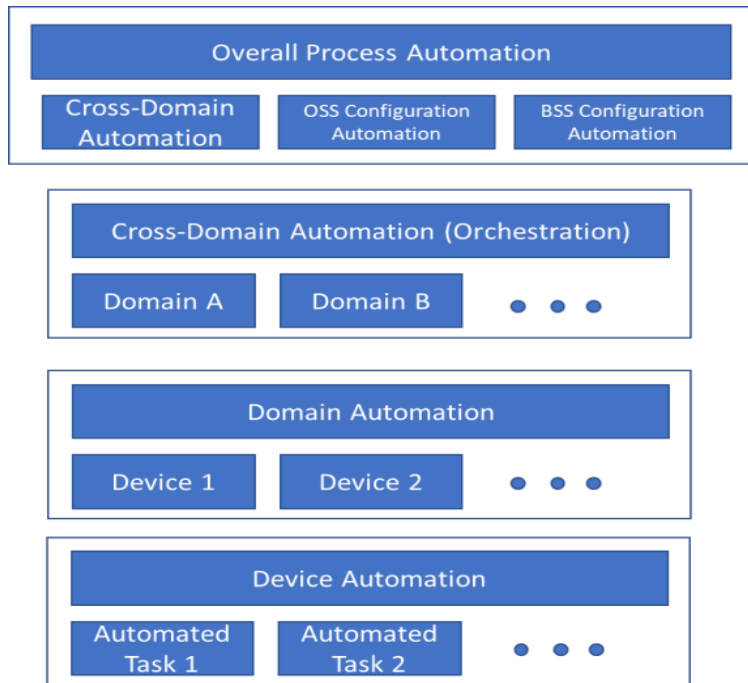


Figure 2.3 Showing The Automation process(Source: ACG Research, 2020)

2.6 Existing Solutions for Network Management

1. SolarWinds Network Configuration Manager

SolarWinds has provided a leading edge when it comes to network Automation. It is one of the top players in the niche when comes to network Management. According to SolarWinds (2018). The tools can perform network performance, scripting for management of devices, and track deviation. Ability to check the synchronization of configuration, provide information on tracking changes. However, performing these changes requires the administrator to create scripts that will be utilized while explicitly specifying Required attributes to be added or removed in the configuration. This is an alternative approach. However, it has some limits especially when change is needed within a short time. It will require specialists to provide input to create a script to be loaded as a template to be used or scheduled for change to be realized.

2. ManageEngine Opmanager

ManageEngine is another product that has been widely used to manage networks. According to ManageEngine, C. (n.d.). it has capabilities to carry out Scheduled configuration, ensure devices are backed up, provide restoration of configuration from backup. It also offers the ability to Detect

changes in real-time including configuration changes providing the ability to schedule tasks through templates and scripts while providing security and compliance during configuration change while providing reports.

However, it's worth noting that most tasks are done based on written scripts that need to be uploaded to the systems. Configuration deployment is on the script-based approach.

3. PRTG Network Monitor

According to the PRTG network monitor . (n.d.) PRTG is another Network Monitor used to monitor devices, network traffic, and applications by the organization. It provides functionalities to monitor, provide analyze and by specified service level agreement.. Be it for an individual device or an entire network. The presence of a Centralized Console for Management and customizable dashboards is one of the advantages of this tool. It also provides functionalities that enable remote patch management for Network devices. However, it cannot deploy configuration

2.7 Conceptual Model

Ravitch and Riggan (2011) define this as an argument as to why the identified topic of study has an impact while citing that another element of the Conceptual Model can be derived from a theoretical framework.

There are 3 sources for building a conceptual model. Ravitch & Riggan (2011) provides three sources that can:

1. Experience
2. Literature
3. Theory

This research proposal was based conceptual Model citing the literature as the source.

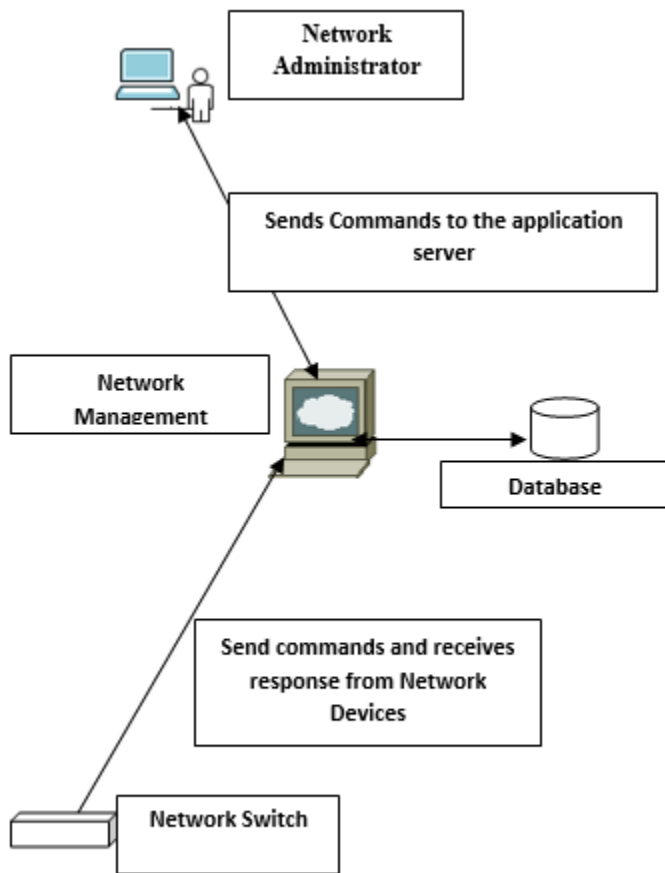


Figure 2.4 shows the conceptual framework

2.8 Conclusion

Having reviewed the literature sources the following gaps were identified. Configuration of Network from command lines has its limitations due to human error. It requires more time to provision the Network no to mention specialized skill sets are needed to manage the. Network Automation has been challenged by the fact the cost of implementation remains high. The existing solutions identified from the above literature have good capabilities to manage networks. It is worth noting that configuration deployment provided by the solution is script-based. Network automation brings about reduced downtime and reduced errors while saving costs on support and consultation for specialized skills.

CHAPTER THREE: METHODOLOGY

The objective of the research is to bring new knowledge by establishing insight or know-how regarding a certain issue. For one to get different outcomes it requires one to use different methods, techniques for different situations to provide answers that address an area of interest. Experts in the research field have provided standardized methodologies that help researchers with different techniques they can utilize to meet the divergent nature of research. These methods are utilized based on the scope or the depth of the area or subject of study. (Kothari, 2004; Rajasekar et al., 2013) states that a Research methodology is a step-by-step approach or systematic approach towards finding a way of solutions. With a scientific approach of doing an investigation that is aimed at arriving at some findings

3.1 Research Design

It is concerned with the transformation of the identified research questions in the interesting project. (Trochim,2006) states that hourglass design is one option of making research conceptual design. The hourglass starts at the top where the researcher states the problem that he intends to study. Currently, the problem is widespread. hence need to narrow down to the specific question that the researcher intends to address in the study. This might include a hypothesis or focus questions.

This research leveraged the use of Design science research to design, build, and evaluate a prototype for Network Management Tool. (Peffer, Tuominen, Rothenberger, & Chatterjee, 2007). As stated below:

1. **Identifying the Problem-** for this research this will be achieved by reviewing the literature review on Network automation and
2. **Defining Objectives of a Solution.** – Derived from the problem statement and identified research questions
3. **Design and Build or implementation-** This will involve designing a low-level diagram and transforming documents to the implementation of the Network Automation Layer 3 switch prototype.
4. **Evaluation of the system-** This was achieved by carrying various system tests.
5. **Communication-** This involved communicating the results and conclusion drawn from the

study not forgetting the implication and future work.

The above process and approaches describe activities that will be carried out in each section with a clear explanation of what it will entail.

3.2 Research Type

According to (Kothari 2004) Research methods are categorized into 5 categories: Descriptive vs analytic, applied vs Fundamental, Quantitative vs Qualitative, Conceptual vs Empirical, and others which are variants of the four categories mentioned above.

From the above categories presented above. This research will focus on Applied Research/Action. The choice for the above type is because this research approach is based on the development of the Network Management Prototype which will be used by Network or IT support to replace the traditional Command-line approach which has limitations. Bruce et al. (2005) categorize the nature of IT research into seven distinct categories. These are: Information practice, Human-technology interaction, Applications to other disciplines, Impact, Sanctioned, Constructed and Software Development

This research is categorized under the Software development category. This is geared towards system development, enhancing systems such as designing new algorithms. Logic design and software engineering. As the focus is on developing Network Management too as proof of concept.

3.3 Research Method

The research was Qualitative Research and the Prototype method was used to achieve the set objectives. Olivier (2009) highlights commonly used research methods that are used in information technology. This includes Literature review, Modelling, Prototypes, mathematical proofs, Experiments, Languages, Surveys, Case studies, and Arguments. For this research, we chose to use a prototype.

Classification of research methods falls under two categories: Quantitative or Qualitative. The quantitative research method involves the study of natural phenomena from a natural science which also requires the collection of Quantitative data that is subjected to statistical methods. Qualitative research methods are used to conduct studies that explain phenomena in social sciences. Qualitative research is subjective, exploratory, and open-ended. The use of an interview is one

used by defining a specific set of questions that needs response based on opinions or attitudes while addressing the issue in the study.

3.4 Sampling from Population

Purposeful sampling was used to identify research participants as this requires individuals who will provide credibility when it comes to findings. (Suri, 2011). The strategy used to achieve this is which persons were picked out deliberately to provide vital information which cannot be collected from other choices. In this case, we picked Network administrators in the sample because they warrant inclusion As this research was qualitative. The purposive sampling method was considered. Hence statistical data was not required. Any sample size selected can be utilized. For this study, we selected 10 Network Administrators who were part of the Sample size during the evaluation of the prototype.

3.5 Data Collection Techniques

Data collection refers to various techniques used to get the required information and provide measurement on interesting variables systematically to provide feedback on research questions while carrying our evaluation of the outcome (Kabir, 2016). Data classification can fall into two categories: qualitative and quantitative. A qualitative approach was considered.

For this project interviews, discussions, and observation were used as sources of data collection. Unstructured interview sessions were used during testing as a direct technique of obtaining more information on views, feelings, and touch about the prototype. There was physical interaction with the developed Prototype, hence observations were used during testing of the developed prototype and evaluation

3.6 Data analysis

Collected data was qualitative, content analysis was employed to identify common patterns of Network configuration uptake by Network Engineers. Table 1 below shows summarizes the data analysis.

Inquiry	Description
Whereabouts of Network Management systems	Adoption of Network Automation and Software-Defined Network
Extent of implementation to include multi-vendor configuration	None of the respondent could demonstrate 100% implementation of such System
Any knowledge on any implementation of Graphical users interface tools for Network Administration.	Ansible playbook which is based on Red hat was suggested by one of the respondents.
Network Management Techniques used	Mostly done through a scripting language such and use of command line for specific vendors

Table 3.1 Content analysis for Interview

3.7 Development methodology

Prototype development employed the use of the DevOps d methodology. (Synopsys Editorial Team,2017) shows cases that DevOps development methodology leverages on the combination of a set of practices that are geared towards an organizational culture. The methodology leverages organizational change to facilitate enhancement, the collaboration between different departments that have different responsibilities for different segments of the development life cycle, such as development, quality assurance, and operations.

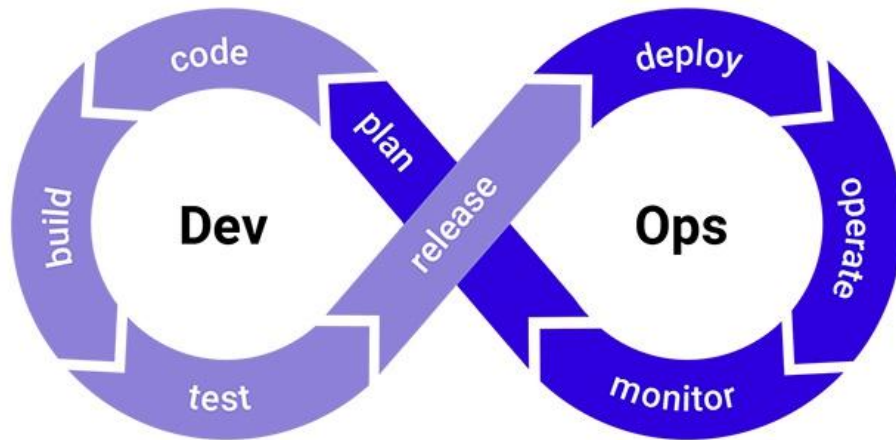


Figure 3.1 Figure from Synopsys shows DevOps methodology

According to (Chellamalla,2018) the DevOps methodology presents several benefits that can be realized. The presence of Strong collaboration between development and operation teams not to forget Synchronization when it comes to deployment on various platforms. Improving end-user capability levels.

3.8 Ethical considerations

Participants were informed to adhere to ethical standards. They were to be transparent during testing of the system since this will help provide information to improve the systems and also they were informed to maintain the integrity and also to demonstrate confidentiality of the information

CHAPTER FOUR: RESULTS AND DISCUSSIONS

This chapter focuses on procedures and processes that were followed to implement Network Configuration Tool. And evaluation results were obtained during the tests that were carried out on the Network Management Tool. These tests were performed by Network Engineers who were selected from various industries such as banking, telecommunication, and Technology. The Network Engineers/Administrators compared the outcome from the toolkit and as compared to the Manual configuration.

4.1 System analysis

During this analysis phase, we were able to investigate prototypes and existing gaps for analysis, identify existing gaps which were later used to propose improvements that can be adopted.

This also provided a chance to identify the benefits that can be realized from the development of the prototype.

At the initial stages of development Feasibility study and analysis was conducted, requirement gathering and modeling was also considered

4.1.1 Feasibility Study/Analysis

During this phase project feasibility was measured to ascertain if the proposed system was viable in terms of economic, schedule, technical, and operation feasibility. This also provided a way to test the solution if it can meet operation and objectives with efficient resource utilization

4.1.1.1 Economic feasibility

The cost was deemed of value and this was measured in terms of time finance and the human factor. For this project, some resources were readily available while others required monetary resources required was for getting infrastructure as a service for Deploying servers

4.1.1.2 Technical feasibility

This was covered by checking the availability of hardware capacity for the server, software availability to provide a simulation environment, and skilled resource which was key towards ensuring development and managing deliverables of the prototype. The presence of Networking

skills and Development made it easy since they were readily available.

4.1.1.3 Operational feasibility

This covered the area of providing the solution to the existing problem being addressed by the system that was developed. During this phase the main concern was to be sure whether if the prototype that was developed could adequately solve the problem. This was justified from the problem statement and stated project objectives.

For this study, it was discovered that the system was providing the required solution to the existing challenges that are faced by Network Administrators and the IT help desk. It should be noted that the adoption of the network management was highly dependant on the willingness of the users to buy in.

4.1.1.4 Schedule feasibility

This was done to determine the project deadline based on the Gant chart. This provided guidance on the deliverables of projects and ensured that the solution could be designed and implemented within an acceptable period.

4.1.2 Requirement elicitation

This was done for classification requirements into two major functions. These are functional and non-functional requirements. For the development of this Prototype literature review and work experience were given considerations while doing requirement classification.

4.1.2.1 Functional requirement

Below are the functional requirements for the Prototype :

- a. Login module
 - A landing web page where created users on the systems can access the systems
 - The ability of the user to view the number of devices, VLANs, and interfaces available.
- b. System Management module
 - Provides the capability to add and delete users

- Management of the role user has on the system.
- Permission Management
- Department Management which allows mapping users with respective departments

c. Network Management module

- Device onboarding and Offboarding of devices
- Vendors listed supported by the systems
- Basic Show commands provided for verification
- Show Interfaces for the selected vendor.
- Ability to shut down the interface
- Ability to default interfaces
- Ability to attach VLAN to the selected interface
- Ability to create Trunk interface
- Changing interface from switch port to Route Mode
- List interfaces and the Number of Interfaces assigned to the Interfaces.
- Ability to assign an IP to associated VLAN
- Ability to list trunk Interfaces configured for Verification purposes and status
- Ability to create static Routes
- Ability to view interface configuration in detail for verification

d. System Monitoring Modules

- The ability of the system to list online users.
- The ability of the system to list logged in IP address
- The ability of the system to list Logged in device Operating System
- The ability of the system to use a browser to login
- Ability to list last time of the user.
- The ability of the Admin to lock the user.
- The ability of the user to blacklist the IP address

4.1.2.2 Non-Functional Requirements

This is not the main functionality of the system. This includes functionalities that provide criteria of which system can be judged.

a) accuracy

The Capability for the prototype to deploy correct commands with no error.

b) speed – Ability to deploy command and respond at an expected speed in times of time

c) efficiency – Proper resource utilization of resources such as computing resources.

4.1.3 System modeling

4.1.3.1 Use case diagrams

Use Cases are used to provide summarized user activities to the systems. They consist of actors and use cases. Actors are represented by various entities that interact with the system to enable the users to access and Use Network Management Tool to login Configure Monitor the system.

For this system, the actors are Network Administrator Super Admin, IT helpdesk Super Admin, Figure 6 & 7 shows the design for these actors for the Network Management Tool

The activities of the Network Administrator included:

1. Login
2. Onboard Vendors
3. Onboard New devices
4. Manage configuration
5. Role Management

The activities of IT helpdesk super admin included:

1. Login
2. Configure Devices
3. Verify Configuration
4. Save the Configuration
5. Monitor logged in users
6. Unlock users
7. Monitor IP and blacklist unknown IPs

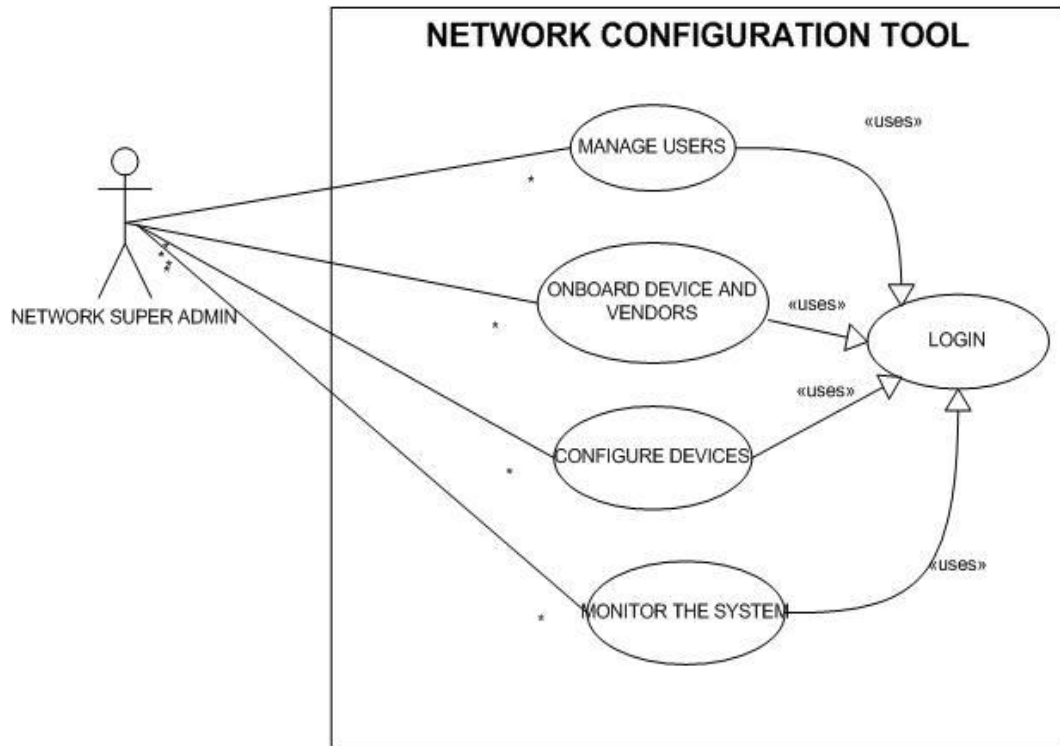
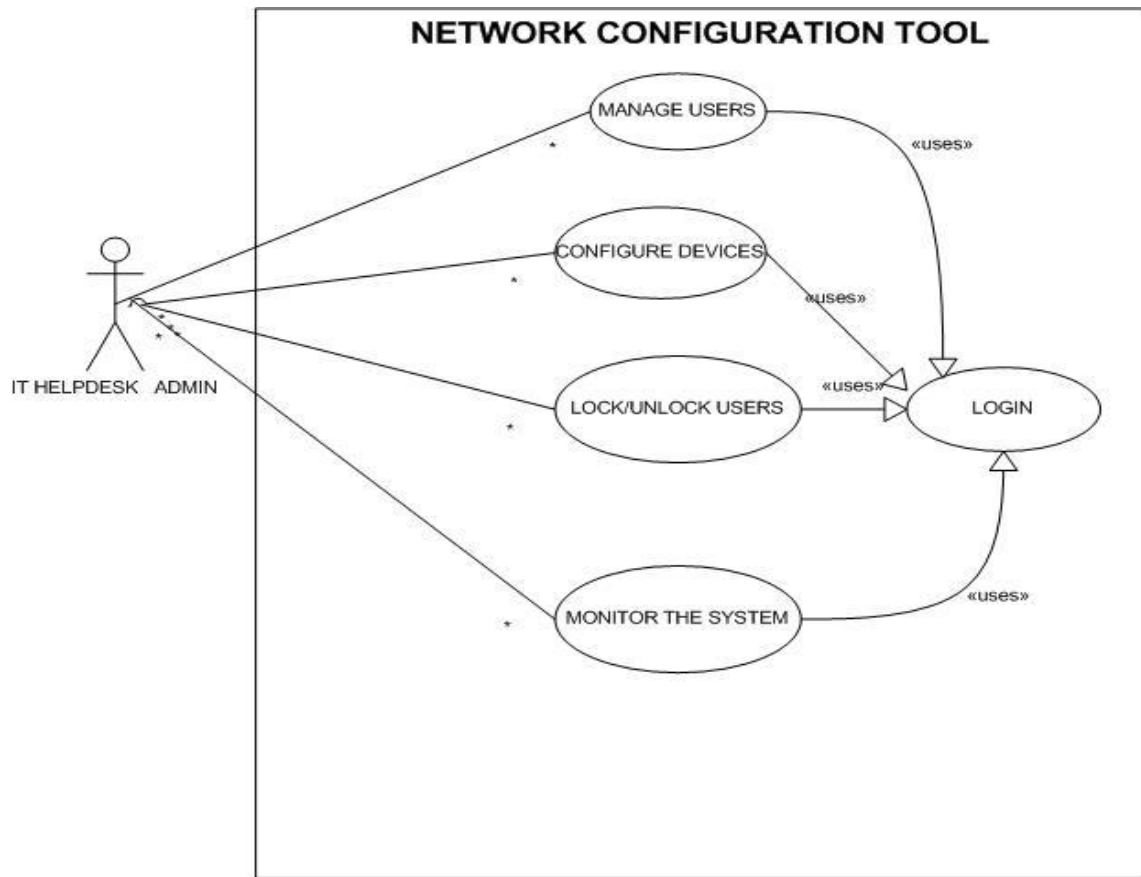


Figure 4.1 Shows Network Super Admin use case diagram

Figure 4.2 shows the IT helpdesk Use Case



4.1.3.2 Context diagram

Provides information on external agents performing interactions with the system and data flow based on the level of interaction. providing clarity on system boundaries

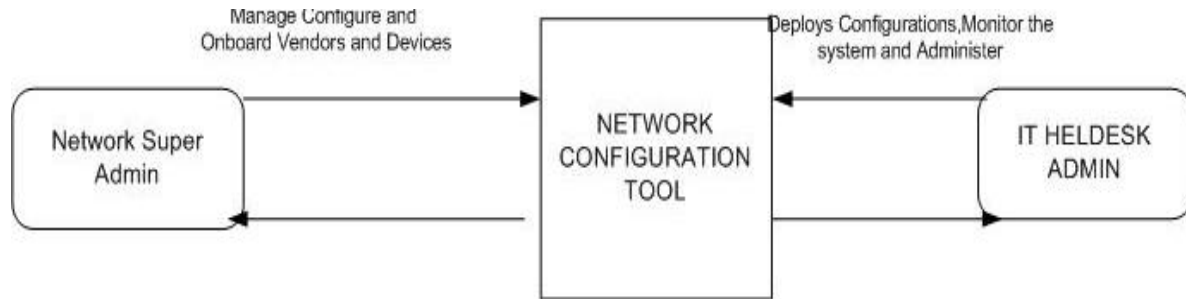


Figure 4. 3 Context Diagram

4.2 System design

System design involved the designing of elements of the prototype such as the user interface screens. The objective of the design process was to provide sufficient information about the prototype and its elements to enable implementation.

4.2.1 Conceptual design

This defines system behavior and architecture. Figure 4.4 conceptual design of the Cloud Network Management tool.

PHYSICAL NETWORK HIGH LEVEL DESIGN

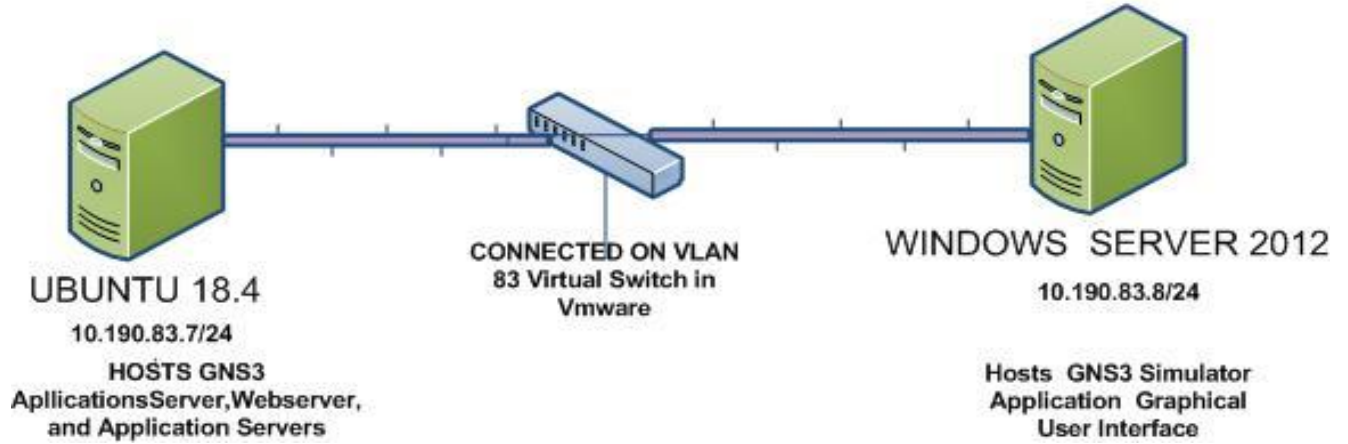


Figure 4. 4 The High-Level Diagram Network Design

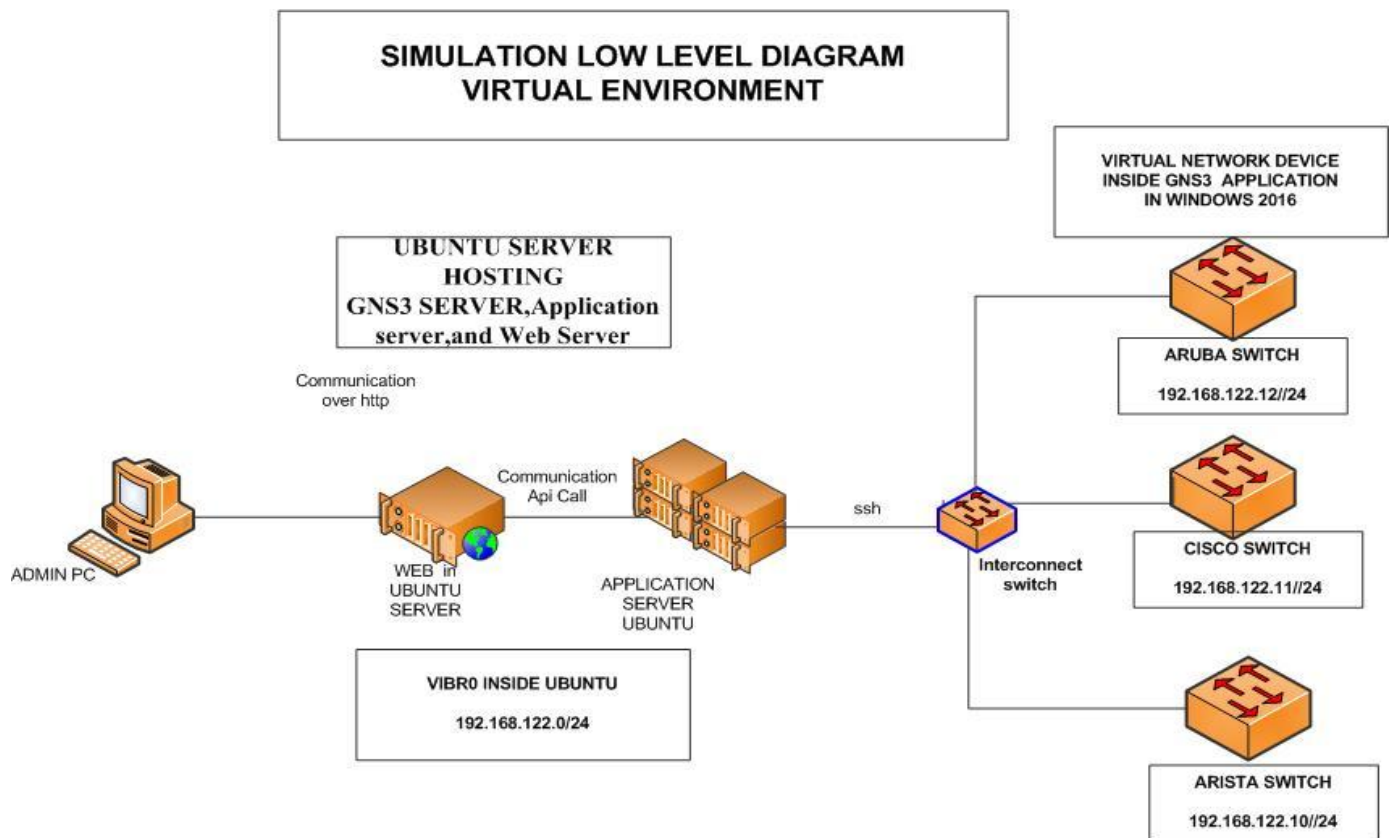


Figure 4. 5 Low-Level Network Diagram inside a virtual Simulated Environment

4.2.2 Database Design

The Database Design was designed to store data that needs to be stored off the devices. The system uses two databases. One for the local device. Local Network devices have internal storage for credentials. The MySQL Database holds user data. This was done after the determination of data to be stored and how elements are interrelated. For this project, SQLite relational database was used, and the table below depicts the entities of different tables in the database.

Provider's device config	Security devices
Provider's device	Systems permission
Network devices	User Auth
Accounts	Users Group
Django session	Providers company

Table 4.1 showing entities that were used to design the database schema

4.2.3 User interface design

User interface was designed based on factors such as usability and user experience while performing functions on the system.. In order to achieve usability of the system user interface design and experience has to be simple and captivating. The figures below show some of the screen designs that were developed for the Network Management Prototype.

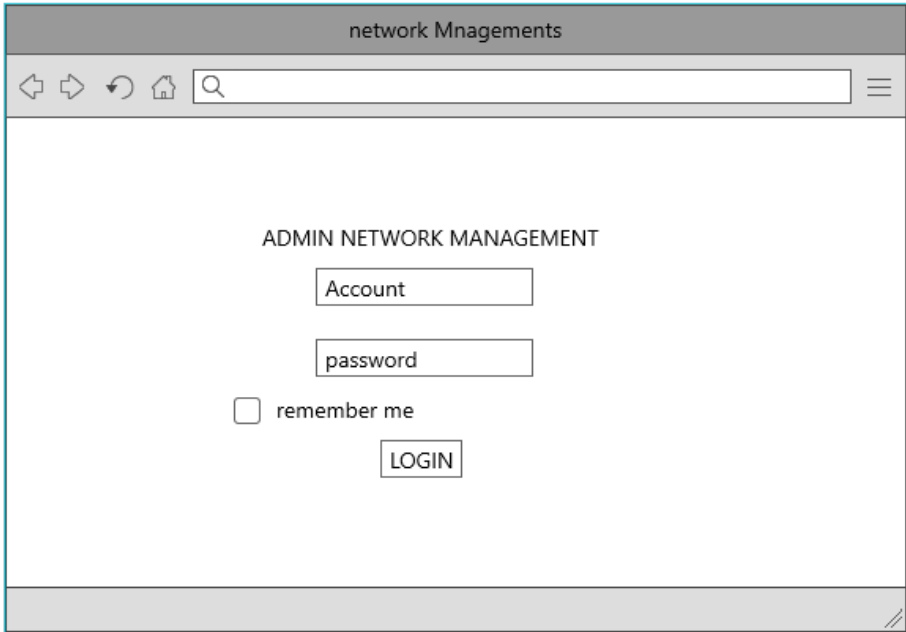


Figure 4.6 Above showing User interface design -Login screen

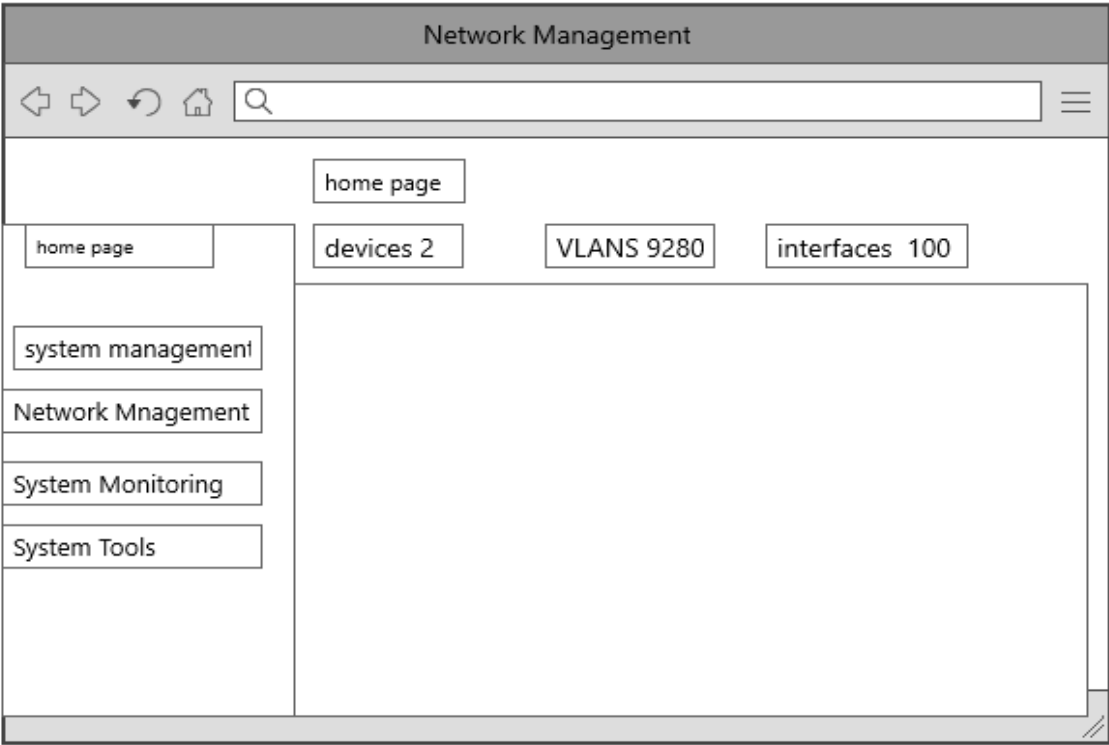


Figure 4.7 above shows User interface design device configuration interface

4.3 System implementation

This section provides a detailed description of the implementation and testing of the prototype with selected users. It shows the resources that were used, software tools, choice of programming technology, and testing of the Network Management Prototype

4.3.1 Hardware Resources

- HP Spectre –Laptop
- Processor – 8 CPUs; 2.3GHz.
- RAM – 18GB
- Hard disk-500 GB (SSD)
- HPE Gen 9 with Vmware 64 GB

4.3.2 Software Resources

Below are software resources that were leveraged during the development of the toolkit.

- Mysql database.
- Visio professional 2019
- Microsoft word 2019
- Visual studio
- Microsoft PowerPoint 2016
- Operating system: Windows OS and Linux (Ubuntu)
- Git for version control
- Netmiko Python Library
- Gns3 Vmware
- Arista Eos VMware
- Aruba OS HP VMware image
- Cisco ios Vmware
- Vue JS

4.3.3 Programming Approach and Tools and Technologies.

Network configuration technologies expertise, API development, and web technologies

were utilized to perform the setup and development. The below listed technologies we used.

4.3.3.1 API development Framework

The use of the spring framework was based on the ability to write APIs that are intuitive very fast and easy to debug which in turn reduces the development period. This backend API was developed using a spring boot framework, a java framework using Swagger.

4.3.3.2 DataBase

Mysql was selected as the database. The purpose of this database was for user management and holding vendors Configurations.

4.3.3.3 Front End

The front end of the system was designed using Vue JS a JavaScript Library, This was for building user interfaces since its library has the capabilities to create an interactive interface with ease of navigation.

4.3.3.4 Python Netwmiko Library

Netmiko is a library used to Manage Multi-vendor Network devices by initiating connection via SSH and deploying configuration as it has capabilities to deploy for various vendors. It has the capability for stability tuning for slower devices.

4.4 System testing

This is the process that ensured that the result captured is correct for every input function. It involves validating the output against the input to check for consistencies and also checking that the toolkit both the framework and the prototype executes without logical and/or syntax errors.

The techniques below were used during system evaluation:

4.4.1 System Walkthroughs with Network Administrators.

Based on the development methodology DevOps. Testing was done continuously throughout the

development lifecycle. The prototype was presented to the Network Engineers who were selected randomly to test functionalities and share feedback on the prototype.

4.4.2 Module testing

This was done by Testing each module developed independently as a component of the system individually. Each component of the module developed was subjected to various tests. This was done to ensure correctness and accuracy while Validating and verifying functionalities for each component

4.4.3 Regression testing

Regression testing was done to test for Bugs that could be existing in the system as a result of combining all components to form a single functional system.

4.4.4 Integration testing

Integration testing was done to ensure proper interfacing of modules in the prototype to build a whole system and ensure the collaboration of modules while meeting the overall system specifications.

4.4.5 System testing.

After all, components were tested and verified. All modules are compiled and subjected to various tests and later build as the full functional unit, to ensure that functional requirements specified are met. All the errors discovered were corrected as desired ensuring that all the modules were operating correctly.

4.4.6 User acceptance testing

Validation of the developed Network management prototype was performed by the end-users. Selected 10 users who are Specialized Network Administrators were chosen to confirm that the system was ready for operational use. During the acceptance test, end-users i.e., Network Engineers experts tested the prototype by conducting sample configurations and then compared that with the existing solutions.

4.4.7 Test cases

This was done to verify the developed prototype meets the expectations by verification of stipulated functionalities provided.

#	Module	Test	Expected Result	Actual Output
1	Login Module	Verify user can log in to the device using provided credentials	The ability for a user to access the system landing page	The Login module was accessible.
3	System Management module	ability to manage Permission Management	Management of privilege access	It was possible to manage user rights
5	Network Management module	Device onboarding and Offboarding	Ability to add new devices from the three vendors.	This was confirmed to be working as expected
6	Network Management module	Verify Show commands provided for verification, Configure interface parameter, Shut and Unshut port, create access and trunk port, Attach VLAN to an Interface for Selected Device	Ability to configure interface parameters and defaulting for each selected device.	Configuration was successful
7	Network Management module	List interfaces and the Number of Interfaces assigned to the VLAN. Ability to assign an IP to associated VLAN. trunk Interfaces configured for Verification purposes and status.	Ability to configure Vlan parameters and verify the configuration for each vendor	It was possible to deploy the VLAN configuration and verify the status.
8	Network Management module	Ability to create static Routes	Create Static Routes to different destination	It was possible to create static routes on the switches
9	Network Management module	Ability to view interface configuration in detail for verification	Ability to list all interfaces for selected devices displaying detailed configuration for the selected vendor	It was possible to view interface details.
10	System Monitoring Module	the ability of the system to list online users is logged in IP address, logged in device Operating System, which browser was used to log in,	The ability for the prototype to display Online users, logged in the browser, and IP	Positive results were obtained. The system could list online users, IP addresses and
11	System Monitoring Module	list last time of the user, the ability of the Admin to lock/unlock the user, ability of the user to blacklist the IP address	Ability to lock and Unlock user, blacklist the users IP	It was possible to list IP users and identify the browser used to login

Table 4.1 showing Test cases

The figure below shows the prototype site that users can access the systems over the Brower.

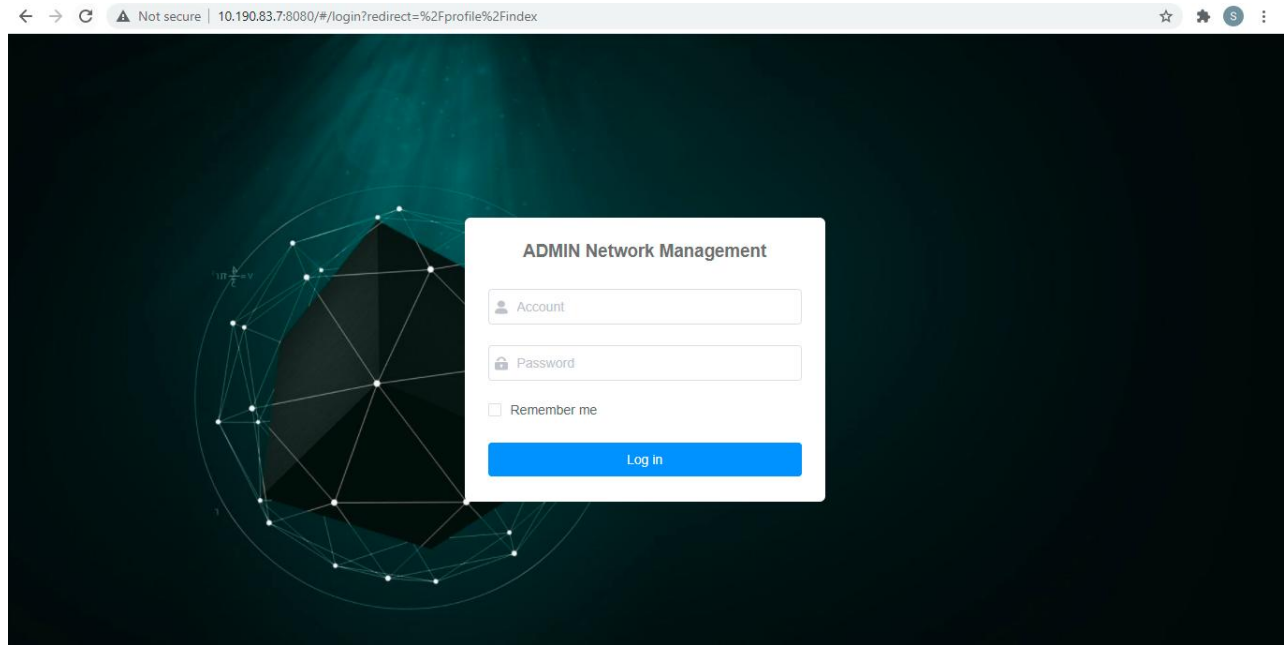


Figure 4. 8 Prototype login page

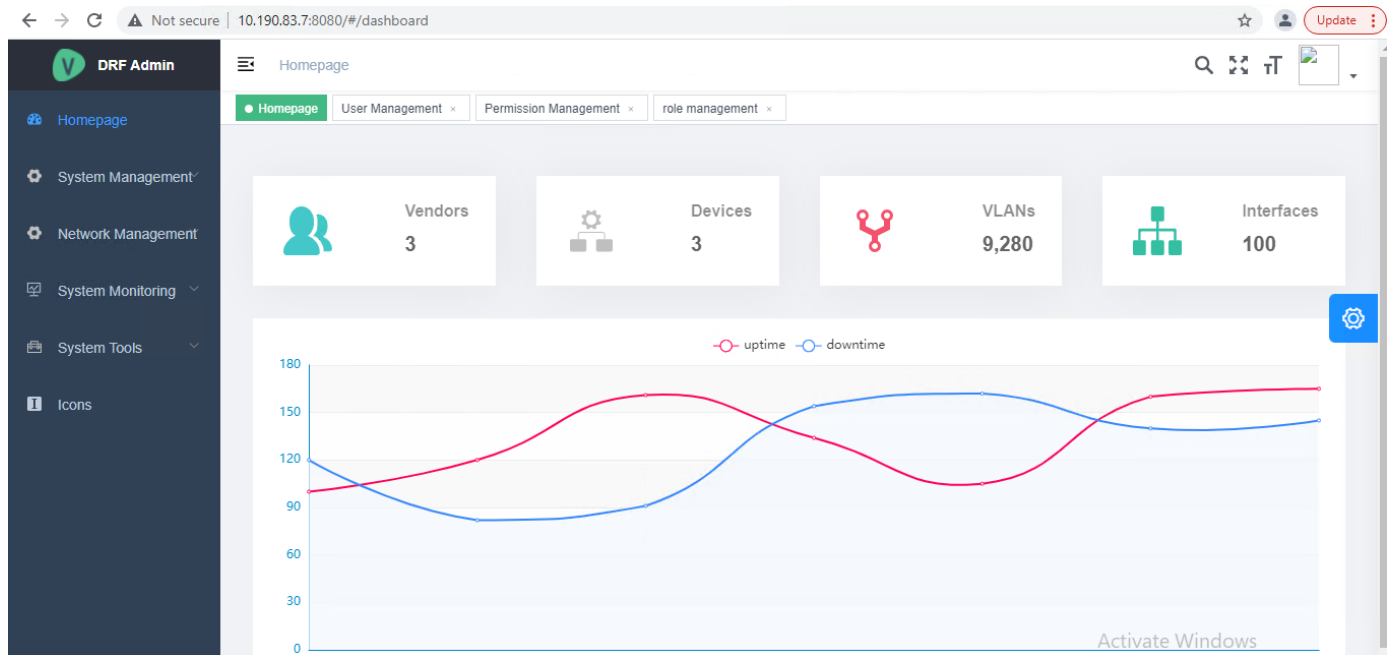


Figure 4.9 shows the user landing page to Network Management Tool.

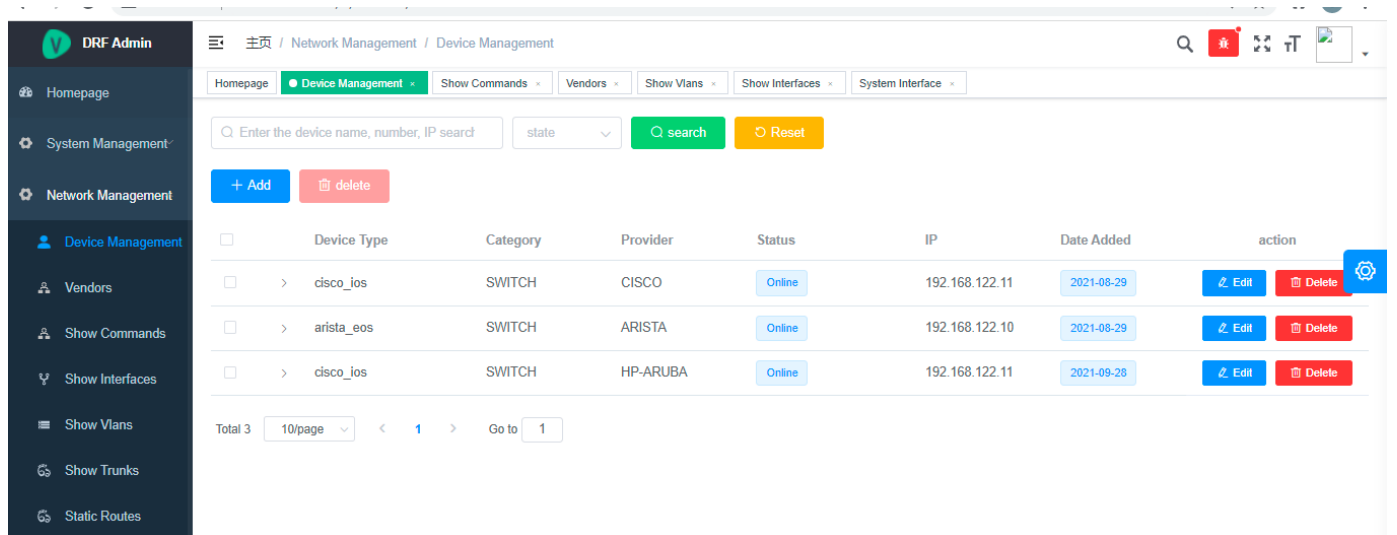


Figure 4.10 below shows the Device management section where users can onboard devices

Figure 4.11 Device Management section shows Vendor management where different vendors are configured to the system for this case this is Cisco, Arista, and HP-Aruba

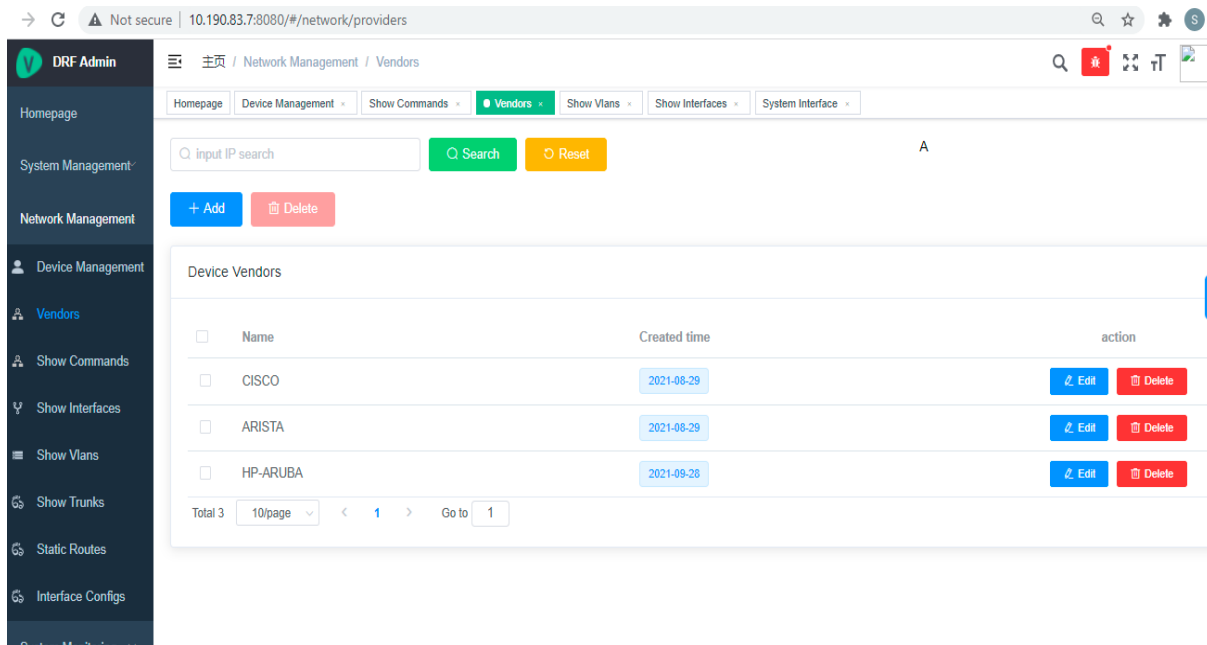


Figure 4.12 shows the device onboarding section

The figure below shows the interface where users can list interfaces from different vendors, configure interface parameters such as setting, trunk ports, assign Vlan to port, default port assigned to switch port

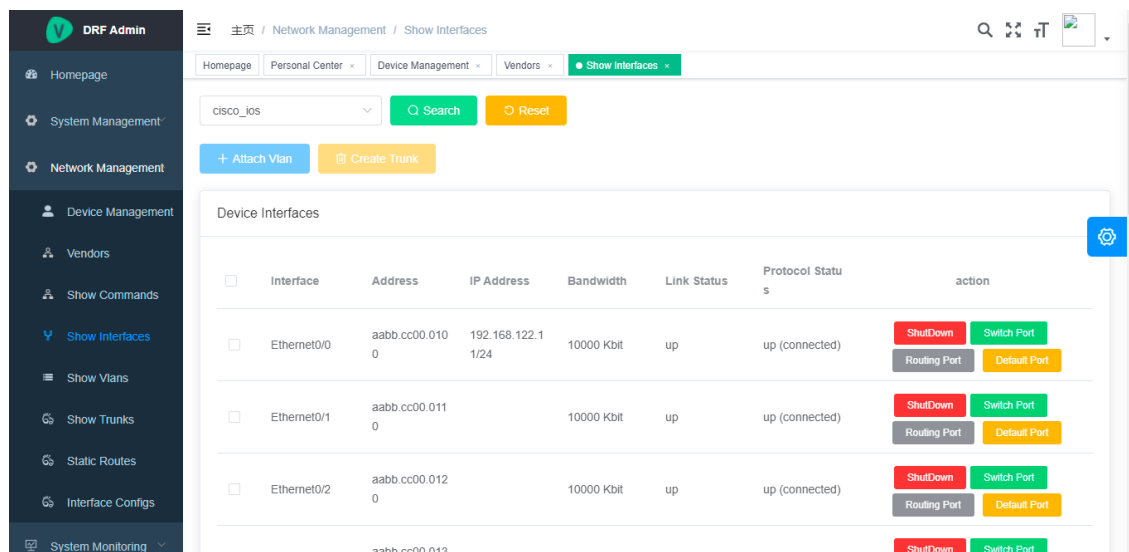


Figure 4. 13 shows the listing of all interfaces and parameters that can be configured.

The figure below shows the VLAN section. Here a user can create a new VLAN, assign an IP and be able to get to know the number of interfaces that have been assigned to a particular VLAN

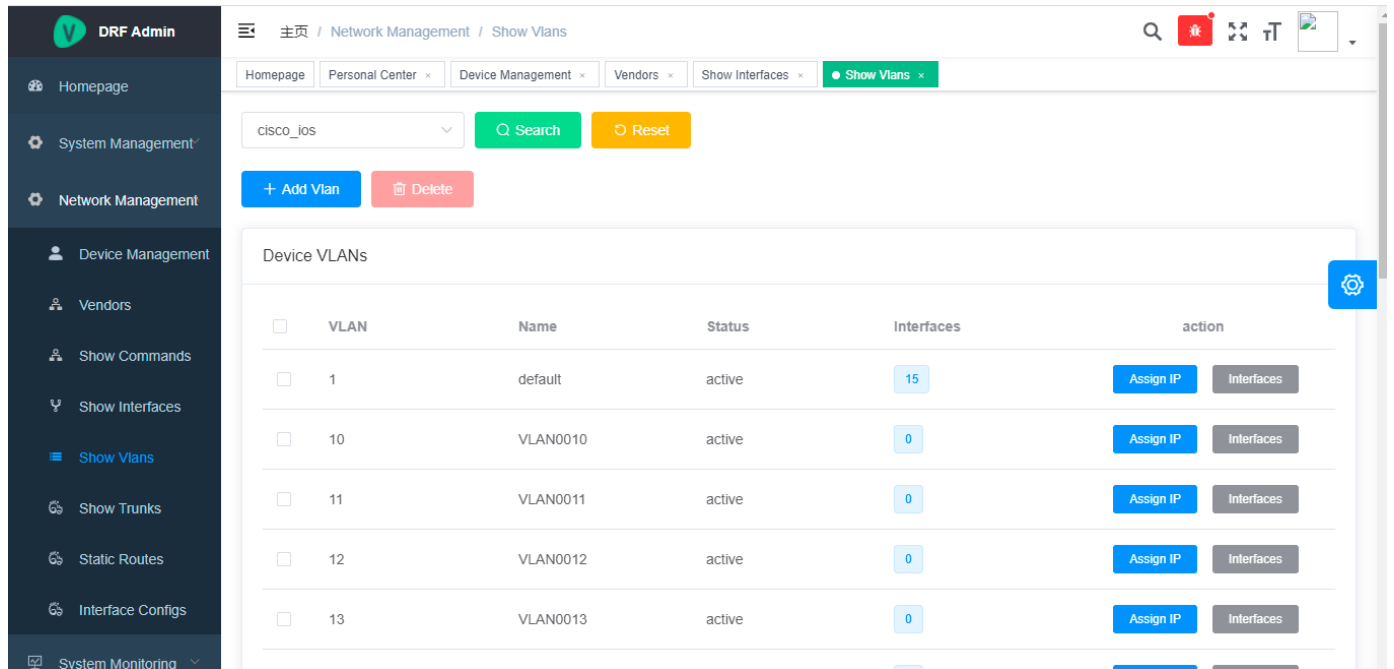


Figure 4.14 Figure showing VLAN configuration Section

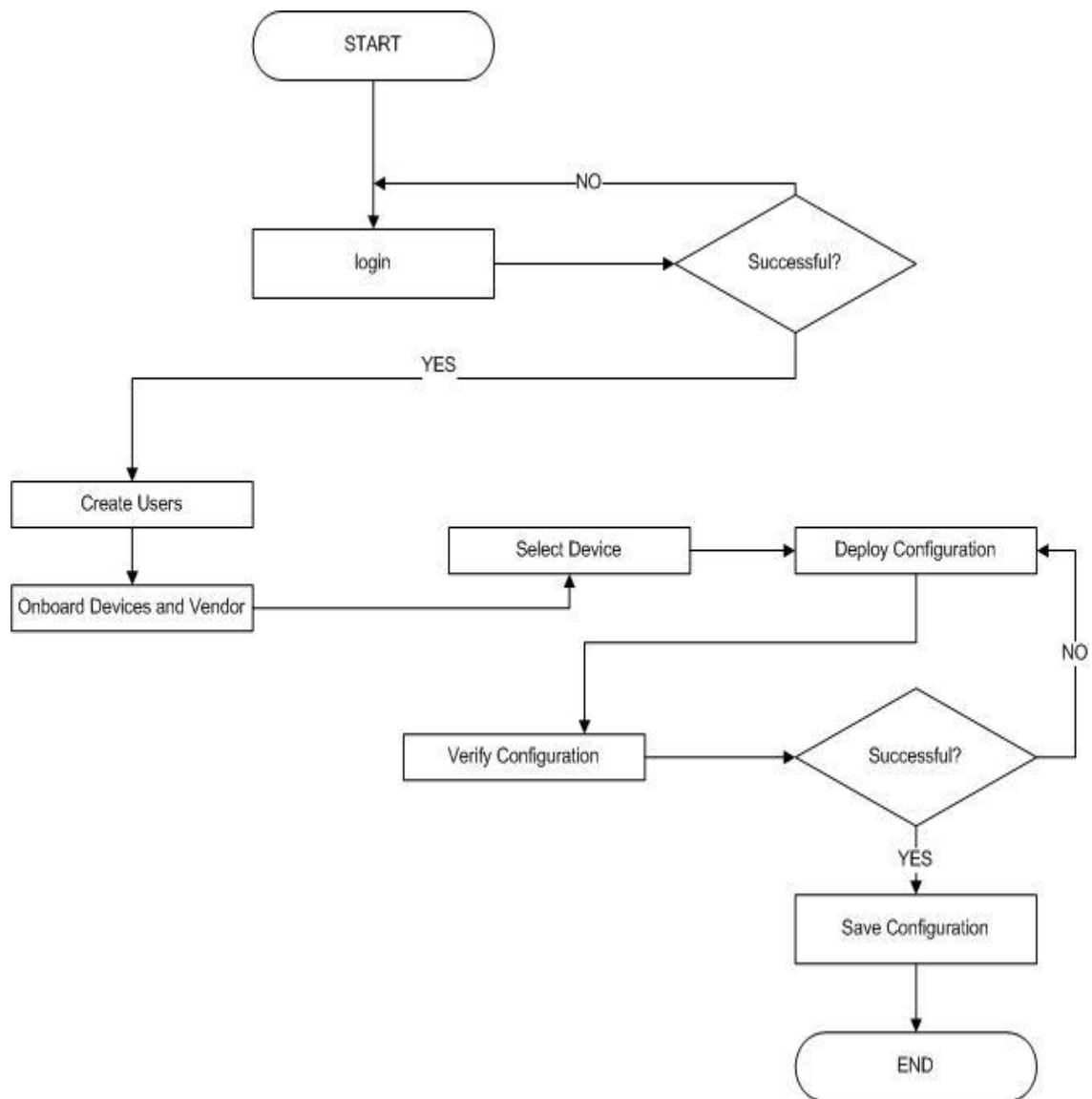


Figure 4.15 The flowchart showing how network Management tool Works

4.5 Prototype evaluation and results

4.5.1 Functional evaluation

Table 4.3 below shows the evaluation and results of the modules that are exposed to a customer who would wish to subscribe to the service.

Module	Evaluation	Results
Login Module	Verify user can log in to the device using provided credentials	This was successful.
System Management module	Verify ability to manage Permission Management	This was successful.
Network Management module	Verify the ability of Device onboarding and Offboarding	This was successful.
Network Management module	Verify Show commands provided for verification, Configure interface parameter, Shut and Unshut port, create access and trunk port, Attach VLAN to an Interface for Selected Device	This was successful.
Network Management module	List interfaces and the Number of Interfaces assigned to the VLAN. Ability to assign an IP to associated VLAN. trunk Interfaces configured for Verification purposes and status.	This was successful.
Network Management module	Ability to create static Routes	This was successful.
Network Management module	Verify Ability to view interface configuration in detail for verification	This was successful.
System Monitoring Module	Verify the ability of the system to list online users is logged in IP address, logged in device Operating System, which browser was used to log in,	This was successful.
System Monitoring Module	Verify list last time of the user, the ability of the Admin to lock/unlock the user, blacklisting of the IP address	The result was successful.

Table 4.3 End-User Functional Evaluation Results of the System

4.5.2 User testing results

Further to the testing, the Network administrators were asked to provide feedback on the User experience based on the observation they made during the Testing process. Figure 5.1 below shows a chart with their responses.

This was based on capabilities of productions in the literature review could not provide Comprehensive solution for network configuration and they relied more on scripting which was Tedious also to mention that required technical knowledge for the programming language to support multi-vendor.

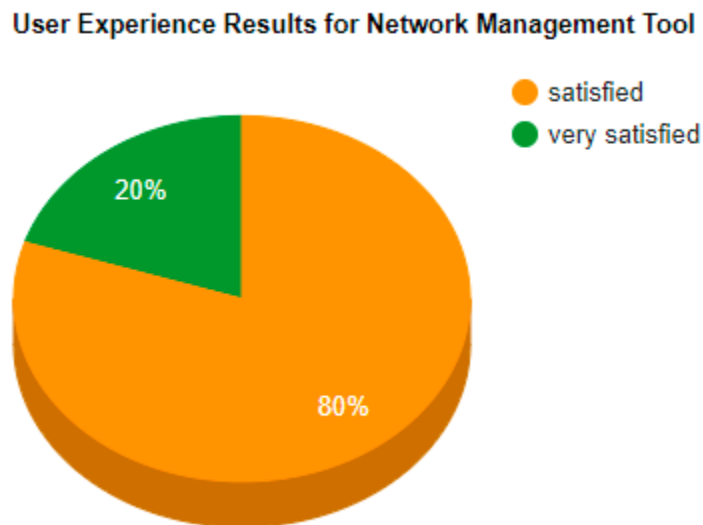


Figure 4.16 User Experience results

In terms of usability and correctness to reduce errors performed during manual processes the experts were asked if this was the solution that can improve the ease of network management in a multi-vendor environment and Ease the deployment of Configurations for help-desk

4.6 Discussion

From the review, it was evident that most engineers were dependent mostly on the Command-line interface for Network Management and administration. This required them to understand syntax from different vendors and the learning curve was very steep. Some had gone further to creating static scripts to configure the various device. Given the sensitive nature of the Network, such scripts contained usernames and passwords that in the event they fall into bad hands the network can be compromised through attacks by malicious users. During configuration or deployment of Devices. It was also discovered that the possibility of committing errors was higher while using a command-line interface or by using the scripts. This could lead to Network outages.

The use of the Network Management tool comes in handy to reduce the burden of Network administration as it provides user-friendly interfaces that do not require users to memories commands other than following documentation on how to use the system. This will help the novice user with no technical background to manage the network and execute changes without bringing down the network or relying on the specialized skills of Network administrators

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

In this chapter, we discussed findings obtained in summary form while focusing on conclusions of the study and recommendations that will spearhead research in this field.

The research questions below led to the findings:

a) What are existing approaches are being used to configure the network??

Through the literature review, it was established that one of the approaches towards configuring networks is using vendor-specific terminals. This requires the Network engineers to obtain relevant skills from different manufactures to support the network. Alternatively, use of scripting language. This involves the creation of static scripts that are executed by the use of libraries in a python programming language. With the emergence of rest APIs, Some vendors are developing network devices that can handle Rest API requests.

b) What are the challenges facing the automation of Networks and Network Configuration?

The challenge facing network automation is the lack of skills to cut across programming and Network administration After careful review of literature sources and the feedback from the Network Engineers. There is still a gap for DevNets as this is still a new field.

c) What are the benefits realized by adopting network automation?

Having reviewed literature sources and feedback obtained during evaluation and testing of the Developed prototype. The possibility to reduce deployment period and network configuration in an environment are high while embracing automation. It is possible to reduce manual administration of the network creating a dynamic and user-friendly way of interacting with the systems and enabling the help desk to Administer the Network.

With the use of Automation. Anyone with information technology can manage the network given clear documentation as it eliminates the need to learn the vendor-specific language.

5.1 Contributions of the study

The developed Prototype will be of great assistance to Network Engineers who are still novices in the industry and also to the IT helpdesk. Since it eliminates the command line and

scripting. With a graphical user-friendly interface that is web-based. The admin can deploy commands to devices from different vendors by clicking buttons and inputting values and the rest will be taken care of by the backend systems.

5.2 Implications for practitioners

The solution will come in handy improving efficiency and bridging the gap especially in Network technologies that require specialized skills for administration. Reduction of complexity in a network lowers the period required for Network administration. It is possible to have a system hosted and presented to manage the system in a cloud-based. The implication is that network administration can be performed from anywhere remotely using portable devices. The rate of committing errors is reduced as all functionalities are well tested

5.3 Limitations

The resulting prototype from the study only covers how to configure and manage Network Devices switches from Three vendors this are Cisco, Aruba, and Arista, using a web-based portal only. This study focused on VLAN configuration and Interface configuration which are initial and essential configurations required in Network Administration.

5.4 Future Works

The future work is to extend capabilities to include more functionalities at the switching levels other than the ones implemented on this prototype. Include machine learning This can be extended to the Cover the Routing Domain of the Networking layer to provide capabilities such as self-healing network and the ability to track and give recommendations to the user on best practices of network configuration factoring in Security aspects.

5.5 Conclusion

The Emergency of Software-defined Networking is a positive move to ensure operation cost of organizations is lowered. As to the Administrators, this will ensure a reduced number of downtimes and error rates committed when deploying configuration or executing a change in the environment. With the emergency of Rest API in the Networking field, it is possible to integrate a multi-vendor environment and have a centralized management console. Adoption of

Network Automation will reduce the steep learning gap and vendor specialization. This will ensure that Network engineers have the capabilities to administer devices from Different vendors. The Network Management is proof of concept to showcase how automation can simplify network complexities in a multi-vendor environment. This tool aims to present a solution to the existing challenge of manual configuration and specialized skills geared towards a particular vendor in the Networking industry. Thus, achievement of the objectives of this study.

These Network Management Tools can be used and deployed in various industries to reduce the operation cost that most organizations realized due to misconfiguration of devices that causes Downtimes This software has been presented as a Private cloud service. The Prototype is controlled by the service provider who is responsible for updating configurations and adding more functionalities based on user requirements. This includes adding new vendors to the Network Management tool and adding functionalities

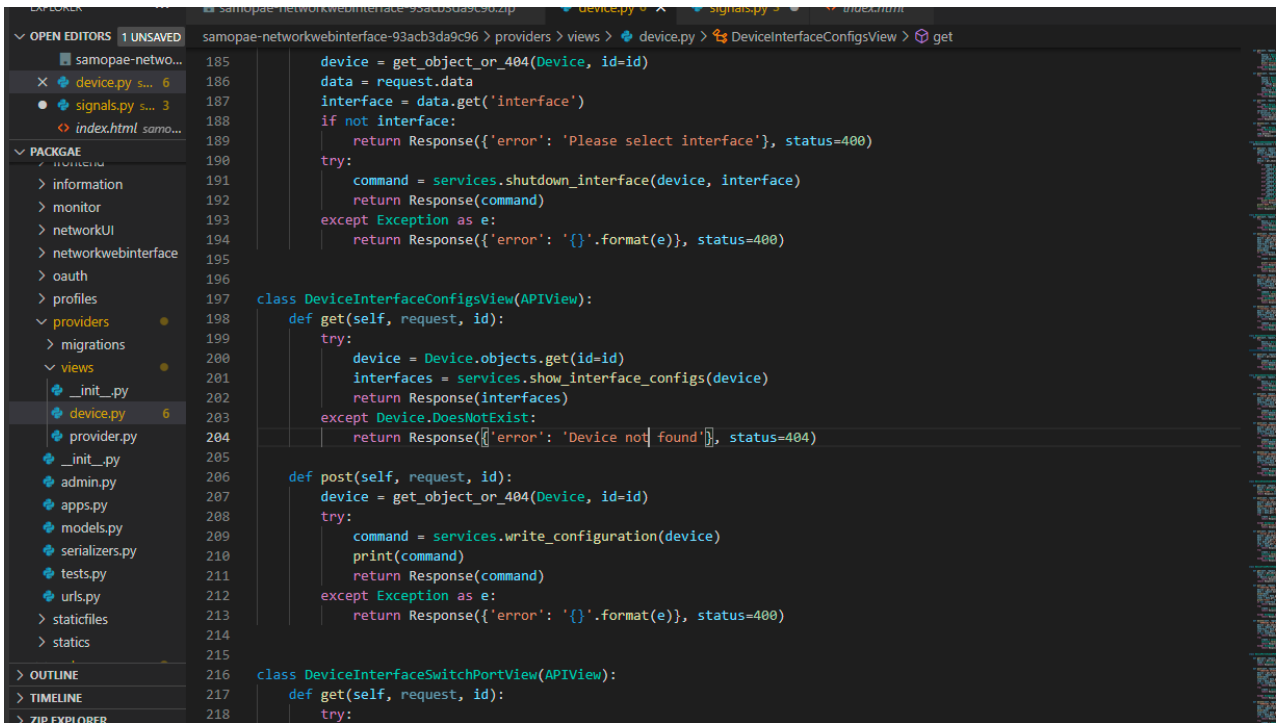
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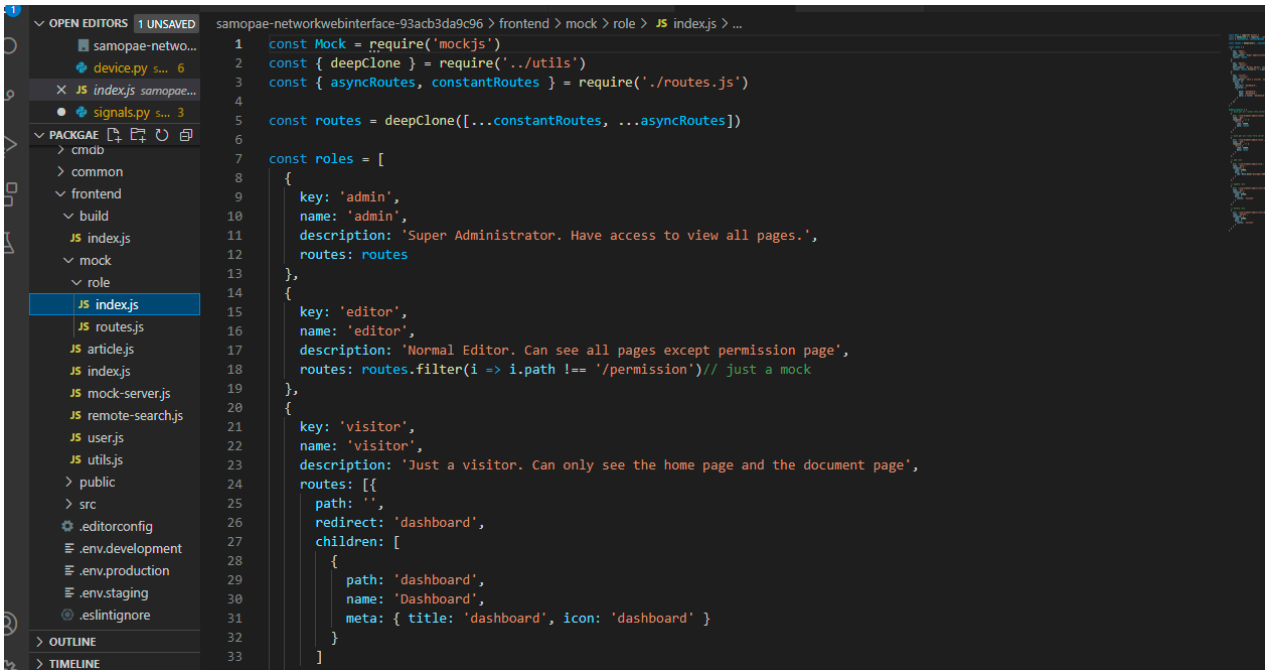
APPENDIX

Code Sample



```
185     device = get_object_or_404(Device, id=id)
186     data = request.data
187     interface = data.get('interface')
188     if not interface:
189         return Response({'error': 'Please select interface'}, status=400)
190     try:
191         command = services.shutdown_interface(device, interface)
192         return Response(command)
193     except Exception as e:
194         return Response({'error': '{}'.format(e)}, status=400)
195
196
197 class DeviceInterfaceConfigsView(APIView):
198     def get(self, request, id):
199         try:
200             device = Device.objects.get(id=id)
201             interfaces = services.show_interface_configs(device)
202             return Response(interfaces)
203         except Device.DoesNotExist:
204             return Response({'error': 'Device not found'}, status=404)
205
206
207     def post(self, request, id):
208         device = get_object_or_404(Device, id=id)
209         try:
210             command = services.write_configuration(device)
211             print(command)
212             return Response(command)
213         except Exception as e:
214             return Response({'error': '{}'.format(e)}, status=400)
215
216
217 class DeviceInterfaceSwitchPortView(APIView):
218     def get(self, request, id):
219         try:
```

Front End Sample Code



```
1 const Mock = require('mockjs')
2 const { deepClone } = require('../utils')
3 const { asyncRoutes, constantRoutes } = require('./routes.js')
4
5 const routes = deepClone([...constantRoutes, ...asyncRoutes])
6
7 const roles = [
8   {
9     key: 'admin',
10    name: 'admin',
11    description: 'Super Administrator. Have access to view all pages.',
12    routes: routes
13  },
14  {
15    key: 'editor',
16    name: 'editor',
17    description: 'Normal Editor. Can see all pages except permission page',
18    routes: routes.filter(i => i.path !== '/permission') // just a mock
19  },
20  {
21    key: 'visitor',
22    name: 'visitor',
23    description: 'Just a visitor. Can only see the home page and the document page',
24    routes: [{
25      path: '',
26      redirect: 'dashboard',
27      children: [
28        {
29          path: 'dashboard',
30          name: 'Dashboard',
31          meta: { title: 'dashboard', icon: 'dashboard' }
32        }
33      ]
34    }
35  }
36 ]
```