

**AN INTEGRATED FREQUENCY SPECTRUM
LICENSING SYSTEM (IFSLS)**

BY

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12/02695

**A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF
SCIENCE IN DATA COMMUNICATIONS IN THE FACULTY
OF COMPUTING AND INFORMATION MANAGEMENT AT
KCA UNIVERSITY**

November 2014

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DEED OF DECLARATION

I declare that this dissertation is my original work and has not been previously published or submitted elsewhere for award of a degree. I also declare that it contains no material written or published by other people except where due reference is made and author duly acknowledged.

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ABSTRACT

Spectrum management has been a major concern in the telecommunication field. Regulatory authorities and other government agencies have been on the forefront trying to find appropriate solutions to address frequency spectrum management aspects that range from planning, licensing, monitoring and billing. Several solutions been presented with a common denominator being use of information and communication technologies.

Various systems have been developed for spectrum management with greater emphasis being placed on the efficiency with which spectrum is used and far more innovative ways like frequency re-use being fronted. Additional emphasis has been on Radio Frequency planning, Engineering analysis, and interference monitoring with a number of ICT systems such as ELLIPSE by Cril Telecom of France, Germanys SPECTRA system and Kyrgyzstan's SIRIUS system having been developed for spectrum management.

While effectively addressing RF planning, engineering analysis and RF interference, a number of these systems have failed to adequately address important administrative aspects of spectrum management that include application, processing, licensing and billing for the same spectrum.

This research utilizes the available ICT technologies to develop an integrated system with a central database that can be incorporated with technologies in the existing systems to deliver efficiency in spectrum management to regulatory agencies and users in key administrative aspects of application, processing, licensing and billing.

Simulation methodology was used with a prototype build and various aspects in spectrum management tested. The research has addressed the inefficiencies prevalent in the administrative aspects in spectrum management that range from application, approval, billing and licensing.

DEDICATION

I dedicate this work to my loving mum Margaret who has been quite instrumental in my education and my wife Marther for her emotional support. I shall forever remain grateful to them.

ACKNOWLEDGEMENT

I would like to extend my sincerest thanks and gratitude to all those who supported and encouraged me during my study.

First, I would like to express my gratitude to Professor Gatheri for his supervision and valuable guidance. Without his continuous encouragement and support, it would not have been possible for this thesis's completion. I would also like to thank Ms. Philomena for availing me resourceful information on visual basic that was core in this research.

Separate thanks to the spectrum management team at the Communication authority of Kenya (CAK) who gave me a lot of their working and personal time and Patrick Mwanamkuu of Vodafone Tanzania for his insightful information on Tanzania communication authorities operations.

My deep gratitude goes to my family and friends who have who have endured lonely moments when am working on my thesis. My daughter Patience particularly deserves a pat on the back for her understanding through this period.

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ABBREVIATIONS AND ACRONYMS

dB	Decibel
dBm	Decibel relative to one milliwatt
EM	Electromagnetic
EMI	Electromagnetic interference
FCC	Federal Communications Commission
KHz	Kilohertz
MHz	Megahertz
GHZ	Gigahertz
NTIA	National Telecommunications and Information Administration
RF	Radio frequency
DBMS	Database Management System
E.I.R.P.	Equivalent Isotropically Radiated power
FTP	File Transfer Protocol – a standard for transferring files electronically
GIS	Geographical Information System
.HF	High-frequency
IT	Information Technology
ITU	International Telecommunication Union
LAN	Local area network
MF	Medium frequency
S/N	Signal-to-noise ratio
SQL	Structured Query Language
TCP	Transmission control protocol
UHF	Ultra-high frequency
VHF	Very high frequency

CHAPTER ONE: INTRODUCTION

1.0 Background of problem

The radio frequency spectrum is a strategic asset for the economy of any nation. It finds application in a broad range of fields encompassing business and consumer communications e.g. mobile phone networks, wireless internet communication, aviation, shipping, defense, public safety, broadcasting, radar, astronomy and various other applications.

Unlike most natural resources, such as oil, coal, iron and others that can easily be depleted, radio spectrum's unique characteristics is that it is not consumed by use. This means that the resource is infinitely renewable. Since it is renewable, it cannot be accumulated for later use but must be properly managed. This therefore necessitates an efficient process for making radio spectrum available if and when needed for purposes which are useful to society (Cave *et al.*, 2006).

Sound and efficient management of spectrum is a key component in the performance of any communication sector. Flexible regulatory regimes and technologies that make spectrum use more accessible to operators offer significant potential to reduce lead times from innovation to market for communication products (Berggren et al. 2004; Chapin and Lehr 2007), and lend a competitive edge to operators and improved efficiency communication regulators.

As a public resource, radio spectrum is being managed by governments to ensure that it is shared equitably to promote the public interest, convenience, or necessity (Nunno, 2002). Across the globe, spectrum is tightly regulated by both the international and national regulators. The International Telecommunication Union (ITU) manages spectrum at the international level while The International Telecommunication Union-Radio (ITU-R) maintains a table of frequency

allocations which identifies spectrum bands for various categories of wireless services with the aim of avoiding interference among those services. Each country then allocates spectrum for various services within its own borders in compliance with ITU's table of frequency allocations. The table divides the world into three regions i.e. Africa and Europe, North and South America, and Australia and Asia.

The use of radio spectrum in most countries is managed by government agencies with Office of Communications (Ofcom) and the Federal Communications Commission (FCC) being responsible for radio spectrum regulation in the United Kingdom and United States respectively.

In Africa, Kenya has the Communications Authority of Kenya (CAK) which through an act of parliament of 2013 was transformed from communication commission of Kenya(CCK). South Africa has the Independent Communications Authority of South Africa (ICASA), Nigeria has the Nigerian Communications Commission (NCC) while Tunisia has National communications authority (NCA) as bodies responsible for radio spectrum regulation.

1.1 Causes of the problem in research area

In most countries, the primary approach to spectrum management by government is a licensing system. This involves spectrum being apportioned into blocks for specific uses, and assigned licenses for these blocks to specific users or companies. Users are assigned certain frequencies in such a manner as to ensure that the spectrum is used efficiently and without interference between users. Such assignments are through official authorization for users to use a certain frequency through a license. The license will usually state certain service criteria that must be complied with to avoid interference to other users and other conditions of operation for example indicating the expiry period.

The major disadvantage observed from this approach according to Olafsson *et al.* (2007) is that the allocation procedures are lengthy and bureaucratic, opening up the possibility that the decision-making process could be influenced by non-relevant factors such as political patronage, corruption and lack of accountability.

Apart from encouraging the sporadic usage of spectrum, the fixed spectrum assignment policy lacks elaborate mechanisms to account for issued frequencies as well as track usage of issued frequencies resulting in redundant frequencies from licensees who have long ceased operation which would have otherwise been issued to deserving users and interferences owing to double allocations to users operating in the same or adjacent locations.

Based on the aforementioned disadvantages of the current structures and spectrum assignment policies that include paper applications and lengthy periods of processing coupled with the increase in demand for radio spectrum; it's evident that there is need for a change in the operational framework of regulatory agencies and other spectrum custodians to adopt an integrated approach to spectrum management that will improve their operational efficiency.

1.2 Definition of terms

Integrated refers to combined and coordinated separate elements capable of achieving harmonious and interrelated functionalities as a whole.

Frequency is a description of the number of waves that pass a fixed place in a given amount of time

Spectrum management is the process of regulating the use of radio frequency with the aim of promoting its efficient use in order to achieve a net overall benefit.

A System is a set of interdependent entities designed to interact in such a manner as to form an integrated whole.

1.3 Problem statement

In order to meet the ever increasing demand in frequency, communication regulators need spectrum management systems and mechanisms that are efficient, accurate and transparent. In addition, the systems and mechanisms should not be too cumbersome for users and time consuming in terms of processing for the administrators.

Right now, most spectrum management systems and mechanisms are either manual or semi-automated and not user friendly. Delays are quite often in frequency applications and issuing of licenses to users. When applications are made, spectrum custodians have taken too long to analyze the spectrum and records to ascertain which frequencies are free in order to assign them to applicants and issue them with licenses. These procedures are time consuming and result in loss of revenue to governments from potential operators.

If spectrum regulators continue to use the existing mechanisms, they will not only be wasting time and money, which jeopardizes their overall efficiency and earning potential but will also be unable to track and account for the spectrum usage and consequently not able to meet the ever increasing demand

A new spectrum management system; integrated frequency spectrum management system (IFSMS) may surpass the manual license processing mechanisms in terms of efficiency in service delivery. This research was undertaken to develop an IFSMS for spectrum regulators with its efficiency and accuracy being tested as well.

1.4 Aims and objectives of the research

Main objectives

The main aim of this research was to develop an integrated spectrum management system that will enable regulatory agencies improve their operational efficiency in dealing with the various aspects of frequency allocation, license issuance, renewal and billing allowing operators and regulators to transact online through available ICT technologies like the web.

Specific objectives:

- i. Identify the existing mechanisms and approaches to spectrum management
- ii. Develop an integrated spectrum management system
- iii. Test the developed integrated spectrum management system
- iv. Validate the system in terms of accuracy and operational efficiency.

1.5 Significance of the study

The development of an integrated frequency spectrum management system will benefit regulatory agencies, frequency spectrum custodians and other users through timeliness and effectiveness in the following ways:

- i. E-licensing-automatic and decentralized on-line issuance and renewal of licenses and invoices also allowing for electronic signatures and digital certificates
- ii. Increased accuracy and optimized response to frequency assignment enquires, requests and interference complaints
- iii. A well establishment, expeditious, accurate and well documented billing mechanism for spectrum usage by operators.

- iv. Electronic submission of notifications from regulatory organizations to users and vice versa.
- v. Increased transparency and data availability to users of the frequency spectrum and custodians as well.

The next chapter is a literature review that discusses principles underlying spectrum management and case studies a number of developed systems in use as well typical licensing procedures for three East African countries

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

The issues of spectrum management are not new. A great deal of discussions has been on the subject, with increasing attention since the 1990s. The major themes in this body of literature are first the recommendations based on the ITU framework for designing and automating of spectrum management as well as monitoring systems. Second is an analysis of the state-of-art automated spectrum management systems that are compliant with the above mentioned publications and covering all of the ITU recommendations for frequency planning, licensing, fee collection, administration and engineering studies.

2.1 ITU recommendations and handbooks on spectrum management systems

ITU is the United Nations specialized agency for information and communication technologies and as such responsible for the allocation of radio spectrum and satellite orbits and the standardization and development of ICTs worldwide. Several journals provide a useful background in spectrum management policy and practice from various perspectives. Of particular importance are those from the ITU and member nations.

Periodic journals and handbooks from ITU conferences and publications are a major point of interest when discussing issues of spectrum management. Four major journals are considered in this research.

2.1.1 Recommendation ITU-R SM.1370 – Guidelines for designing and developing automated spectrum management systems that are automated and advanced.

This Recommendation provides guidelines that define operational requirements in terms of applications processing, frequency allocation plans, license processing, fee processing, as well as complaint processing. It also provides guideline son transaction processing, engineering requirements, border coordination, licensing fees and fee collection. It also gives an in-depth analysis of such aspects as monitoring, report generation user interface design and data processing requirements in terms of hardware and software

2.1.2 ITU-R SM.1537 Recommendation on automation and integration of spectrum monitoring systems with automated spectrum management.

The Recommendation notes that integrated and automated systems have the capability of processing large amount of information as well as carrying out measurements that draw the attention of monitoring service operators is important data which need further analysis by operators in their daily endeavors in supporting spectrum management.

It observes that automation through by use of computers and contemporary client/server architectures with remote communications tends to simplify administrative duties and enormous responsibilities of radio spectrum custodians. It notes and acknowledges that computerized systems enable rapid and accurate performance of repetitive tasks hence freeing personnel from more demanding tasks. The recommendation also puts a great emphasis on database usage and computer modeling to streamlining spectrum management functions and interference prevention.

The recommendation observes that an integrated system can be derived from coupling of spectrum management and monitoring makes functionalities that can automatically measure data

from the monitoring system and license information from the appropriate management database for detection of unlicensed transmissions and any other violations.

The recommendation further describes an integrated and computerized national spectrum management with monitoring capabilities as a complete one relying on one or several data servers within a network allowing workstations or clients throughout the network to access the database. The management system servers may include a main server and other servers for a database derived from the main database

2.1.3 Handbook on Spectrum Monitoring (edition 2002)

This Handbook offers a comprehensive reference on spectrum monitoring with the first chapter giving a brief overview of the spectrum management process and the role of spectrum monitoring as a key function in spectrum management. The second chapter describes the management information system as one consisting of database and associated reporting system.

The introductory section of the third chapter discusses the importance of automated, multi-channel direction finders while the later section discusses automation of monitoring. The last Chapter (4) provides more details on parameter measurements aspects.

2.1.4 Handbook on National Spectrum Management (edition 2005)

The first chapter of this Handbook – Spectrum Management Fundamentals – gives guidelines and discusses fundamental processes for effective management of the spectrum resource. It acknowledges that each administration can manage the spectrum differently, but underscores the fact that the fundamental elements are essential to any approach.

Other Chapters discuss at length such aspects as spectrum planning, frequency assignment and licensing, spectrum monitoring, Inspection and investigation. It also stipulates spectrum

engineering Practices, Spectrum Economics and automation for Spectrum Management Activities. The annexes of this handbook give examples of automated systems (case studies) that include Windows basic automated spectrum management system (WinBASMS) of ITU. They also provide Spectrum Management Training and give the best Practices for national spectrum management.

Other ITU-R Recommendations and documentations were also analyzed. ITU-R SM.182 recommendation for example provided a useful insight on how monitoring of radio-frequency spectrum occupancy can be achieved automatically. ITU-R SM.668 recommendations explains how electronic exchange of information can be applied in spectrum management while recommendation ITU-R SM.1047 provides a detailed description of the various aspects of National spectrum management.

Additionally, ITU-R SM.1048 recommendation was instrumental in providing useful guidelines for designing a basic automated spectrum management system (BASMS) whereas ITU-R SM.1604 recommendation came in handy in providing guidelines for a spectrum management system which is upgraded and quite useful for developing countries

2.2 State-of-the art spectrum management systems

State of the art is the highest level of development in terms of technology or scientific research achieved in any sphere at a particular time. It's also used to refer to the level of development in terms of artifacts, procedures, processes or techniques at any particular time.

Three state of the art spectrum management systems are analyzed below based on ITUs handbook on National Spectrum Management (edition 2005)

2.2.1 ELLIPSE SPECTRUM

This is an Automated Spectrum Management System designed and developed by Cril Telecom. Commonly referred to as Cril Telecom Software (CTS) it has the capability to handle different aspects of frequency planning, licensing, fee collection, administration and carrying out engineering studies. It's versatile hence ideal for spectrum regulatory authorities to carry out administrative and technical spectrum management tasks.

It has a high level of interactivity with spectrum monitoring systems in addition to the high quality of its spectrum management scope of functions while on the other hand addressing the financial and business aspects of spectrum management.

It's modularized with multi-user, multi-tasking and multilingual capabilities with a user-friendly GUI interface with ORACLE relational Database Management System (RDBMS) and an embedded geographical Information System (GIS).

It's based on a scalable Client/Server architecture, where the Server can be a UNIX sun Solaris, Linux or Windows. The multi-user client/server configuration allows different departments to work together on the same ORACLE relational reference database, while having appropriate data protection and security features and allowing user specific access roles

ELLIPSE Spectrum offers a unique flexible workflow module that allows any regulator's internal organization or processes to be entered in the system. It also allows easy customization of users on modules such as licensing, reporting, workflow and billing. ELLIPSE is designed to assist regulatory bodies and administrations in their daily tasks to achieve efficient frequency management in accordance with national and international related regulations.

The administrative and technical aspects of spectrum management activities offered by ELLIPSE are contained in the following modules:

Data entry and generation interface

This module offers a friendly graphical user interface (GUI) for technical and administrative data entry, reference data libraries and spectrum user management and associated accounts. It also provides statistics on database elements such as users, geographical areas, equipment, services and licenses

Geographical Information System (GIS)

This offers cartographic database availability, clutter maps and interface with External GIS tools like MapInfo. It also enables easy correlation between terrain, network and propagation models apart from providing fast and efficient user-friendly engineering process.

Licensing and billing module

This does license processing management providing user definable license format and layout, fee calculation and billing. It offers automatic application management allowing any internal process to be entered in the system. It also features an online license application form through web browser interface.

Engineering analysis and technical data management module

This module offers advanced engineering calculation features for radio services, e.g. fixed services, point-to-point, point-to-multipoint and broadcasting at LF, MF, HF and FM radio. It also has features for analyzing of fixed satellite services and HF communications. The module also does carrier to noise and inter modulation analysis. It has capabilities of analyzing receiver sensitivity and transmitter noise as well as plotting area coverage for any transmission.

ELLIPSEs powerful and scalable architecture makes it capable of managing hundreds of sites guaranteeing secured data sharing in multi user and multitasking environments. Several levels of

security at operating system, application and data level allows system sharing between various organizations e.g. civil and military working independently from one platform.

2.2.2 SIRIUS SYSTEM

This is an Automated National System for Spectrum Management developed in Kyrgyz Republic and has been in operation since 2003. Its simple design makes it quite effective for use under conditions of limited staff resources without any specialized training in radio technology. It can support simultaneous operation of up to a maximum of twenty workplaces with a possibility to increase the number of user sessions through upgrade of portions of the system providing multi-user access and simulations

. SIRIUS consists of the following modules:

Administrative module

This module performs a number of key functions that include verification of notified frequency assignment for compliance with international and domestic tables of frequency allocations and recording of frequency assignment notices in the system and verification of the information provided for completeness and correctness. It's also useful in invoice and fine generation as well as data back-up and restoration. It offers an adaptable system for calculation of fees and fines for spectrum utilization and registration of licenses for frequency assignments in the system. It's also useful in generation of administrative and technical reports and registration and auditing of system users. It's also from this module that licensing of frequency assignments takes place as well as domestic and international coordination and notification.

Database module

SIRIUS has an adaptable interface which allows the user to customize the entering and editing of data depending on technical characteristics and administrative requirements. The system is

capable of tracking any changes in status giving the date, operator and explanations regarding the change. Logging status changes makes it possible to determine the delays for administrative processing of applications received, and to formulate administrative queries to determine spectrum utilization effectiveness and efficiency.

Engineering analysis module.

This has spectrum planning tools that offer capabilities for entering and editing of new and existing tables of frequency allocations and allocation plans according to established schedules.

It also has analytical tools for the broadcasting, mobile and fixed services which help analyze and assess the effects of existing and planned stations on a given station at any geographical location within the service area of the station by service, using calculations based on digital terrain data. The tools also perform a quick calculation or a detailed analysis of the effect that a given station will have on existing and planned stations (by service) as well as analysis of inter modulation.

Monitoring module.

This is used for Interference complaints investigation and elimination such that if the source is not a licensed station, appropriate measures are taken to terminate the interfering emissions. The system also makes it possible to collect and store monitoring data so that changes in the characteristics of emissions can be tracked.

2.2.3 SPECTRA SYSTEM

This is a comprehensive and advanced automated spectrum management system developed by LS telecom AG covering a wide range of administrative and technical functionalities for all radio services. It has a proven integration with radio monitoring systems hence providing additional benefit to administrations

It has client server architecture with various modules connected to a central database that allows projects to be started with basic systems configurations which may be extended to more complex and comprehensive configurations in later project phases when required. The modularity of the system greatly helps to find an optimum balance between need, urgency and financial considerations in the country.

Digitalized Terrain Maps (DTM) are incorporated in the SPECTRA system as basis of administrative and technical procedures. Commonly used commercial GIS data formats can be migrated to internal formats for efficient data access. SPECTRA system can handle different types of layers, among others topographical, land usage and population data.

Key features of the system include administration of national and international frequency plans, workflows for the licensing procedures for specific radio services and deadline management of user roles with specific permissions on workflow actions. It offers frequency assignment procedures based on propagation models and technical data specific for particular radio service of one's choice and coordination procedures based on ITU recommendations or other international/national agreements for the particular radio service.

It features a central Spectrum Management database that includes administrative data, technical data, frequency plan data and monitoring data and is made up of the following modules:

Database module

This is a central oracle database that contains license, billing, monitoring and technical data as well as history.

Administration module

This administers license data for all radio services, does project tracing, offers work flow management and user guidance, automatic printing of licenses and other documents. It also provides deadline management, complaint processing, type approval, statistical and management reporting capabilities.

Billing module

This does fee calculation based on national fees structures does bookkeeping, automated invoice generation, credit notes reminder, income prediction. All billing procedures can be customized to the national financial rules and regulations.

Planning module

This is for creation and administration of national and international frequency plans

Web module

This is customized for e-licensing and e-reporting via web browser with a role based user management functionality. It's used for electronic entry of license application data by any web browser and the validation of application data.

Monitoring module.

This is an Interface function that connects the system with radio monitoring systems. This allows for measurements for investigation of spectrum usage, detection of unlicensed emissions and detection of emissions that are working with unlicensed parameters.

Multilink module.

This is a planning tool for point-to-point as well as point-to-multipoint fixed service networks.

Land mobile module

This is a planning and coordination tool for land mobile service providing frequency assignment according to coordination agreements.

Broadcast coordination module

Provides all planning and coordination tasks for broadcast services which range from FM radio, Television, Low Frequency, Medium Frequency and High Frequency broadcasts.

Satellite planning module

This helps in planning and coordinating of satellite services including databases for satellites, earth stations, terrestrial stations and ITU plans

2.3 State of practice

State of the practice basically means what businesses or individuals are doing in a particular field or time at particular geographical region. This section case studied three government authorities in East Africa charged with the responsibility of spectrum management as one of their key functions among their other regulatory roles

2.3.1 Communication Authority of Kenya (CAK)

Formerly The Communications Commission of Kenya (CCK), Communication Authority of Kenya (CAK) is the regulator for communications sector in Kenya. Established by the Kenya Communications Act (KCA) number two of 1998, and KICA amendment act of 2013, its mandate was to regulate telecommunications and postal sectors and also manage the country's radiofrequency spectrum. CAK is now responsible for facilitating the development of the information and communications sectors that incorporates i broadcasting, multimedia,

telecommunications and postal services as well as electronic commerce. This responsibility entails:

- a) Licensing of the communications sector i.e. telecommunications, postal, courier and broadcasting.
- b) Managing frequency spectrum and numbering plans for the country
- c) Facilitating the development of e-commerce.
- d) Type approving of telecommunication equipment to be used in the country
- e) Protection of consumer rights in the communications sector.
- f) Ensuring a level playing ground for all players in the field
- g) Managing the universal Access fund
- h) Monitoring of licensees and enforcing compliance to terms

In its service charter on licensing, the authority states ‘we will process applications for frequency licenses within 30 working days following receipt of complete applications from qualified applicants. We will assign frequencies within 60 days of receipt of a complete application subject to availability of frequencies’ (CAKs service charter pg. 11).

A close look however at the procedures for authorization and license administration paints a rather different picture. Let’s consider the two procedures below for issuance of a HF/VHF/ UHF license and for fixed, cellular mobile and paging services respectively.

Procedure of authorization of private HF/VHF/UHF radio networks

The process generally follows the process outlined here below:

- i. Applicants make applications to CAK for authority to establish a Radio Network, by completing an application form (RF1) giving details of the proposed network

configuration. They are to attach all the necessary documents and pay a non-refundable application fee of KSHS. 1,000 to accompany the application.

- ii. CAK receives applications and peruses them for completeness with applicants advised to provide the missing details/documentation if any.
- iii. CAK forwards applications requiring prior clearance from relevant government agencies
- iv. Applications are then subjected to verification by the Commission Licensing Committee (CLC) whose members are drawn from CAK departments and relevant government agencies.
- v. The CLC considers the applications and makes decision on the licensing eligibility of the applicants based on the legal, regulatory and policy requirements.
- vi. Any unfavorable finding by the CLC is communicated to applicants. In case of a favorable finding, CAK communicates the same and sends out a data form (RF3) to be completed by the applicant and returned with the requisite radio license fees. The form requests for the provision of detailed technical and operating data of the equipment in proposed network.
- vii. On receipt of the form (RF3) CAK checks whether the proposed equipment has been type approved. If the same has not been type approved, the applicant is requested to seek for type approval from the Standards and type Approval Unit of CAK. Type approval involves tests and evaluation of the technical and operating parameters of the equipment against CAK's specifications and international standards.
- viii. After ensuring the technical acceptability of the equipment, CAK carries out a technical analysis of the proposed network and assigns suitable frequency(s) to the applicant(s). The applicant then requests the equipment suppliers to program the radios to the assigned

frequency(s) and both the supplier and the applicant complete and returns a declaration form (RF6).

- ix. On receipt of the duly completed form RF6, CAK issues a license to the applicant which is renewed at the expiry of one-year period by returning it to CAK with appropriate renewal fee.

Procedures for obtaining a frequency license for fixed, cellular mobile and paging services

This category includes services such as low/medium/high capacity fixed telecommunications links, studio to transmitter links, fixed wireless access, cellular mobile and paging. The procedures for authorization and license administration are as below:

- i. Applicants file applications with the Commission by completing the prescribed RF3 form, detailing all the technical and operating data of the proposed equipment. A detailed network layout is also attached to the application.
- ii. The RF3 form together with any additional attachments is returned to CAK together with a non-refundable application fee of KSHS. 1,000.
- iii. CAK will examine the application in line with the national and ITU tables of frequency allocations in regard to the proposed frequency band and technical parameters. In case of favorable findings, CAK carries out technical analysis and consequently assigns suitable frequencies as appropriate and communicates the same to the applicant, together with relevant conditions of the frequency assignment. The applicant is also advised to remit the requisite frequency license fee as per the frequency fee schedule
- iv. CAK checks whether the proposed equipment has been type approved and if it hasn't, the applicant is requested to seek type approval from the Engineering Standards unit of the

Commission A frequency license is issued once type approval for proposed equipment is received and upon payment of the frequency license fee

- v. The period of validity of a frequency license is one year and must be renewed at the expiry of the period by returning to CAK the expired license with the requisite renewal fee

2.3.2 Tanzania Communications Regulatory Authority (TCRA)

Established by the TCRA Act No. 12 of 2003 the authority is responsible for the postal, broadcast and communication industries in the Republic of Tanzania. It's accountable to the Communications and Technology Ministry and mandated to regulate postal services, electronic communications and broadcast sectors in Tanzania. This includes among other functions:

- a) Licensing and enforcing license terms and conditions of broadcasting, postal and Telecommunications operators as well as regulating tariffs
- b) Managing the radio frequency spectrum
- c) Monitoring the implementation and performance of projects and applications in the ICT sector
- d) Promotion of effective competition and economic efficiency and Protecting consumer rights
- e) Promoting the availability of regulated services in the telecommunication sector

Application for licences for provision of telecommunication services is through the process below:

- i. The Authority makes periodic announcements in the media giving deadlines for submission of applications.
- ii. Received applications are categorised into respective categories that include network facility services, network services and content services and appropriate market segmentations i.e. international, national, regional, District or Community.
- iii. Applications received are scrutinised to establish if they have all required attachments i.e. application fee receipt, properly filled application form, well written business and roll out plan. Other important documentations include company registration, technical proposal of the services to be provided and previous experience.
- iv. Applicants who do not comply are notified to submit appropriate required documents while complied applicants are notified accordingly.
- v. The Authority conducts detailed evaluations of the applications based on defined criteria for a given category of license.
- vi. Applicants list is published and circulated in newspapers and posted in regulators website for public comments.
- vii. The Evaluation team then convenes to assess public comments against the applications. Applicants may be called and interviewed if and when necessary.
- viii. Recommendations of the evaluation team are forwarded to the Management for decision making
- ix. Recommendations of the Management are then submitted for approval to the board.
- x. Recommendations of the board are then submitted to the minister for consultation.

- xi. Licenses are then issued to applicants who are successful upon payment of appropriate fee i.e. initial fee, frequency user fee and numbering fee among other fees.

2.3.3 Uganda Communications Commission (UCC)

The commission is mandated by the Uganda communications act of 1997, to develop and promote efficiency in radio communications operations in Uganda. The commission is mandated among other functions to:

- a) Issue licenses for radio communications equipment
- b) Establish appropriate operating conditions and terms for licensees including payments for the same.
- c) Plan, monitor, manage and allocate radio frequency spectrum
- d) Establish technical requirements and standards in relation to radio communications apparatus, interference-causing apparatus or any class.
- e) Liaising with the International telecommunications Union and other bodies in matters related to planning, monitoring, managing and allocation of radio frequency spectrum

Office of Spectrum Management specifically helps in executing the above functions with the responsibility of frequency planning, assignment and enforcement. It's also mandated to establish regulations with regard to frequency fees structure, technical parameters and standards to govern the use of each spectrum band to ensure that current international regulations are met.

The office of spectrum management has put in place necessary procedures for spectrum issuance and licensing for the VSAT and access bands respectively as outlined below.

The process of VSAT frequency authorization

This is used for processing applications for VSAT frequency authorization after submission of an application.

- i. The Commission verifies the applicant's qualification for the VSAT radio frequency spectrum authorization. Appropriate formal responses are made if the applicant does not qualify.
- ii. If the applicant qualifies, the application is checked to verify that it's complete and meets the necessary requirements.
- iii. If an application is incomplete, the Commission will contact the applicant and requests for the missing information. On the other hand, if the applicant meets all the requirements for the assignment of VSAT spectrum, the Commission proceeds and processes the application.
- iv. The applicant is invoiced for VSAT spectrum authorization fees after processing the application and advised to pay within thirty days. Such application is cancelled if the fees are not paid within thirty days.
- v. After a license fee is paid, the applicant is issued with a letter of frequency assignment. For broadcasting frequency application, if the application meets the requirements and processing fees, the public is notified through the media for a period of two weeks within which if there is no objection to the application, the commission proceeds to assign a frequency to the applicant
- vi. After installations are completed within the period specified, the applicant invites the commission to inspect the installations and then a station frequency license issued to the radio station if the installations meet the licensing conditions.

For the case of radio and television broadcasts, broadcasters are required to seek the commission's permission to carry out on-air testing. They will then be granted permission to carry out testing on air for at least twenty-one days to ensure that their signal does not interfere with neighboring ones before being issued with an operational license.

2.4 Technological development in spectrum management

A typical spectrum management system consists of a database server with one or more workstations and software which:

- a. Manages the database of frequency assignments;
- b. Provides a variety of engineering analysis tools to analyze propagation and determine if a given path with given communications equipment will support the desired communications;
- c. Displays geographic maps superimposed with results of analyses, and
- d. Interfaces to a spectrum monitoring system to perform a variety of functions including automatic detection of licensing violations.

The spectrum management system includes a large relational database, accepts a variety of inputs including applications for licenses, issues a variety of notices and reports, and connects to monitoring stations.

Rapid technological developments in spectrum management gave way to recommendations by the ITU-R SM.1537-0-200107 for an automated, integrated system using common relational databases that can provide the following among other functionalities; automatic violation detection, frequency assignment and licensing and remote access to system resources. It also

proposes tools to support spectrum engineering and automated measurement of signal parameters. It also encompasses modern GUI features and automatic violation detection.

An automated, integrated spectrum management and monitoring system typically consists of a national spectrum management center and multiple fixed and mobile monitoring stations. The stations are interconnected via a network to allow voice and data communications. All of the stations in the network exchange information electronically and share common databases.

. An integrated, automated system can process large amounts of information, perform measurements and avail to service operator's data which can be further analysed and assist in spectrum management

Automated spectrum management systems are available to support such functions as administrative, licensing, engineering analysis, monitoring and any other activities of radio spectrum management.

Modern computer networks allow linking together of automated spectrum management and monitoring stations such that any user at a given locality in the system can have access to all other resources of the general spectrum management with appropriate authorization.

The use of databases and computer modelling simplifies spectrum management functions and help interference prevention. Joining of spectrum management and monitoring makes an integrated system possible.

2.5 Critique of the literature

After careful analysis of the literature it's evident that whereas substantive amounts of effort have been made to address challenges in spectrum planning, analysis and monitoring there's very little effort to address administrative challenges in four key areas.

- i. **Application**-most applications for spectrums are have not been automated and are still done manually on paper
- ii. **Processing** of applications goes through lengthy bureaucratic approvals by spectrum managers or boards
- iii. **Licensing** -Authorization and issuance is manual and takes considerable time before being available to applicants
- iv. **Billing**-there are delays in payments due to inaccuracies in generation and reconciliation of bills takes

The above aspects of spectrum management in the three East African countries of Kenya, Uganda and Tanzania have not been automated resulting in considerable delays that may have adverse effects on operations of regulatory authorities and operators as well.

Such delays are occasioned by:

- i. Lack of interactive systems through which applications can be made and tracked.
- ii. Lack of a central database for available frequencies, licensed operators and rates for the various frequency spectrum categories.

The present approach to spectrum management is inadequate as it does not take into account these key administrative perspectives. Spectrum management needs further research; it seems that researchers have overlooked the administrative aspects which are an integral aspect in ensuring efficiency in spectrum management.

Looking at this as a whole new field to be studied, research will be carried out to explore the possibility of developing an integrated frequency spectrum management system that will not

only assist in spectrum planning, analysis and monitoring but also alleviate the administrative challenges that arise in application, processing, licensing and billing of the spectrum.

2.6 Conclusion

The literature review links the engineering aspects of planning, analysis and monitoring to the allocation and licensing of frequency as a scarce resource. It looked at the ways in which this scarce resource is regulated with the administrative concerns serving as a source to explore the need for an enhanced spectrum management system.

Those findings are beneficial to the thesis: An integrated frequency spectrum licensing system aimed at creating a change in the operational framework of regulatory agencies and other spectrum custodians to adopt an integrated approach to spectrum management that will improve their operational efficiency

The Literature Review explores different aspects of spectrum management; it presents different tools, strategies and approaches to spectrum management, that act as an impetus to find out what is worth covering in the thesis.

It finds that application; processing, licensing and billing issues need exploring and evaluation. Linking the four administrative aspects of spectrum management and correlating the engineering aspects of spectrum planning, analysis and monitoring may be an eye opener to spectrum regulators.

The next chapter will focus on research methodology. It will analyze the various research methodologies available to ultimately arrive at one considered ideal for the implementation of the system under research.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0 Introduction

Research methodology refers to the ways in which research studies are designed and the procedure by which data is analyzed (Williams, 2012). A methodology outlines the various steps that are adopted by the researcher in studying a research problem and the logic behind them, (Kothari, 2004).

Quantitative and qualitative methods can be used in carrying out any research. Decisions regarding what, where, when, how much and by what means concerning a research study constitute a research design.

3.1 Experiment method

An experiment is an operation done under conditions that are controlled either to discover an unknown effect, test a given hypothesis, or to illustrate a known law. Experimental method relies on the degree of precision as well as the accuracy of observations from outcomes following changes in the factors being applied. They also involve close attention to the measurements of what is observed, Williams (2012).

Simulations and modeling also considered as experimental methods mostly applicable in ICT researches.

3.1.1 Strengths

Experiments allow the researcher to have control over variables hence creating new ideas and insights as well as contributing to cumulative knowledge.

3.1.2 Weaknesses

The sample under experiment may not be representative of the actual scenario. Experimental methods are also subject to human errors for example due to eye parallax. It also makes it difficult to devise or test situations that are similar to real life situations and its restriction to a single event limits generalization.

3.2 Simulation

Simulation provides an efficient way to monitor and study any situation under a variety of conditions. This is helpful in studying complicated models because it's cheaper than practical studies.

Depending on the system state being considered, simulation can be classified as below:

- i) Discrete simulation which makes assumption that system states change abruptly at points in time
- ii) Continuous simulation where elements of a system change state continuously over time in response to changing stimuli(Sivak,2003)

3.2.1 Advantages

Simulations offers considerable savings on cost of research validation and the ability to test various scenarios by changing parameters an exercise that would be quite elusive in the real world.

3.2.2 Disadvantages

The major disadvantage of simulation is that it may not capture all the conditions in spectrum management with regard to application, processing, licensing and billing.

3.3 Prototyping

This is a systems development method in which a prototype is built, tested, and then reworked until an acceptable prototype is achieved. It's from this that a whole system can be developed. A prototype is basically a sample implementation of a system that shows limited and main functional capabilities of a proposed system.

The following are typical steps involved in the prototyping model:

- i. Detailed definition of new system requirements. This usually involves interviewing users on aspects of the existing system.
- ii. Creation of a preliminary design for the new system.
- iii. Construction of the first prototype from the initial design usually scaled-down and a representation of the final products characteristics.
- iv. Thorough evaluation by users on the first prototype, noting its strengths, weaknesses as well as what needs to be added or removed.
- v. Modification of the first prototype following comments made by the users, and construction of the second prototype of the new system.
- vi. Evaluation of the second prototype in the same manner as the first prototype.
- vii. Iteration of preceding steps as many times as necessary to the satisfaction of users that it's a final products representation.
- viii. Constructing the final system based on the final prototype.
- ix. Thorough evaluation and testing of the final system and carrying out routine maintenance continuously to mitigate catastrophic failures and minimize on down time.

3.3.1 Strengths of Prototype model:

The major strength with this model is its ability to allow active involvement by users in the development as well as allowing for earlier error detections. It also gives users a better understanding any system under development by providing a working model of the system. It also avails quicker feedback from users leading to better solutions.

3.3.2 Shortcomings of Prototype model:

The major shortcoming arising from the prototype model is the potential increase in the system complexity with the possibility of expanding the scope of the system beyond original expectations. Additionally, Implementing and repairing model of building systems tends to consume immense resource resources in financial terms as well as time.

3.3.3 Appropriateness of Prototype model

Prototype model is ideal when there's need for multiple end-user interactions. It is also appropriate for systems with high interaction with end users as the case of online systems and web interfaces. It is also suitable when designing human computer interface systems as it allows end users to constantly interact with the system and therefore able to provide useful feedback that is essential for incorporation in the prototype to achieve a system that is useable.

3.4 Proposed Methodology

Simulation method was used to develop the integrated frequency spectrum licensing system (IFSLS) through the following stages:

- i. **Design of** the various elements that make up the system
- ii. **Coding and scripting** of codes and scripts respectively for each element that makes up the system.
- iii. **Testing of individual codes** for the various elements that make up the system
- iv. **Linking of codes and scripts** of the various elements to make up the system.
- v. **Testing of the system** to establish its suitability in the following areas of applications, Processing, Licensing and Billing. Testing will also be done on general interactivity with users and on the capacity of the database systems against system requirements.

Vi. **Validation** involves comparing test results with the expected reality

This chapter has explored the various methodologies that can be adopted in carrying out research and culminated to a choice of simulation as the most appropriate methodology for adoption. The next chapter will focus on the conceptual framework that underpins the overall design in order to achieve the desired system.

CHAPTER FOUR: CONCEPTUAL FRAMEWORK

4.0 Introduction

Miles and Huberman (1994) define a conceptual framework as a written or visual presentation that “explains graphically, or in narrative form, the main things to be studied – the key factors, concepts or variables -and the presumed relationship among them”.

Represented schematically, it conveys concepts and propositions through the use of boxes, arrows or other symbols. The discussions below are based on a symbolic representation that will help the researcher to express abstract concepts and relationships easily.

The conceptual framework is of great importance for the following:

- i) It clarifies concepts and proposes relationships among the concepts in a study.
- ii) It provides a context for interpreting the study findings.
- iii) It encourages theory development that is useful to the system design
- iv) It will help in explaining observations

The design of the IFSMS will be based on the conceptual model below:

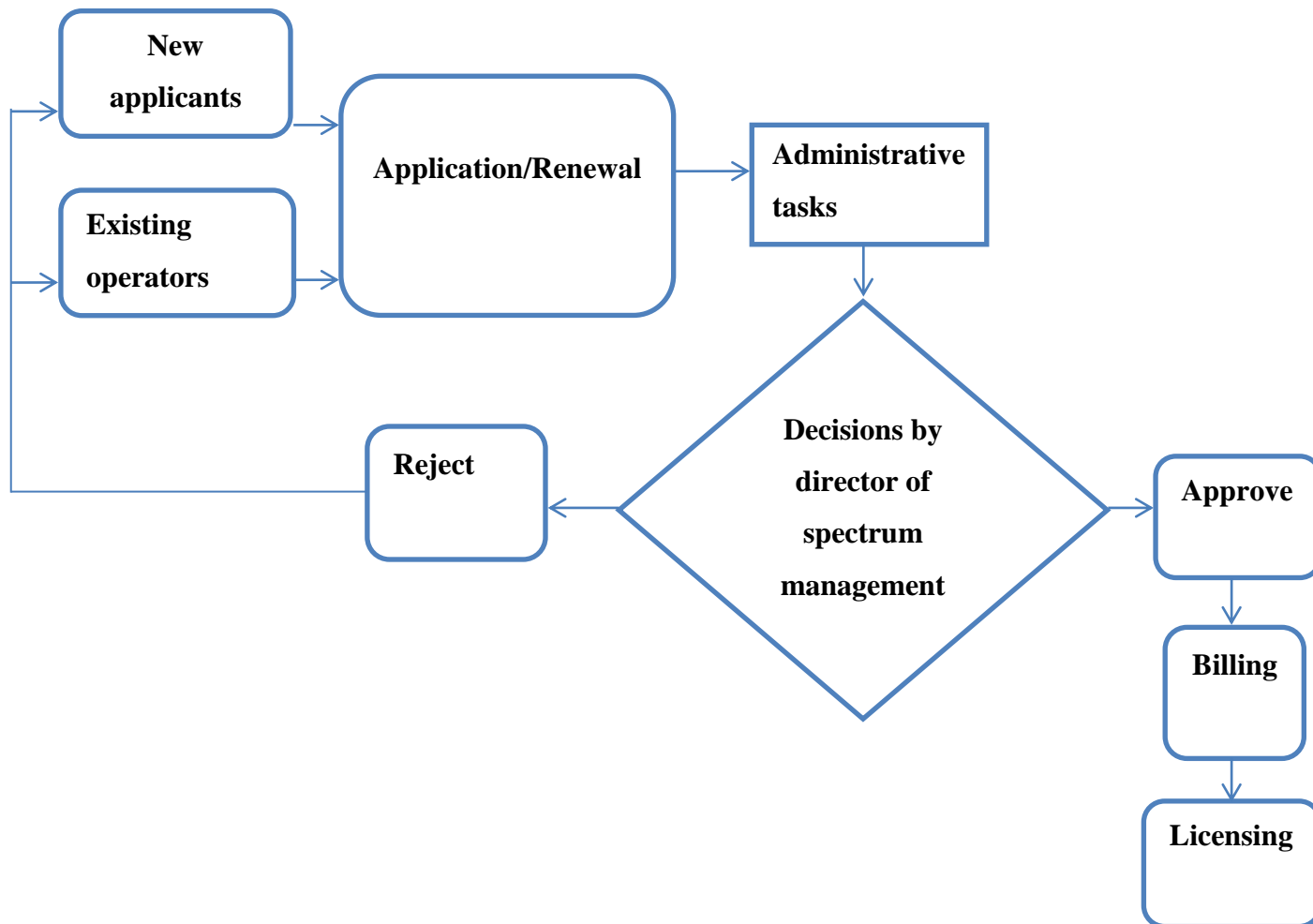


Figure 1: IFSLS conceptual model

The diagram above shows the various variables that will make the spectrum management system. This generally encompasses administration of license data, application tracing, and workflow management, automatic issuance of licenses and deadline management.

4.1 Application

New operators will be able to make online license application on forms through web browser interface. The client completes a form and submits it to the regulatory authorities' administration

in electronic form. Existing operators on the other hand will be able to login to confirm when their renewals are due in order to make payments for the same.

4.2 Processing

The processing will be based on transfer of records through predefined administrators. The spectrum administrator will check received records perform certain checkups regarding that data. When finished, he will transfer the record to the spectrum management officer (SMO) with his recommendations for further handling of the application. This will then be forwarded to the Spectrum management director who in consultation with a team will then approve or reject the application. Processing will also include deadline management of user roles with specific permissions on workflow actions

4.3 Licensing

Frequency assignment and ultimate licensing will be carried out after successful processing at predecessor stages. A Customizable e-licensing and notification module will avail printable licenses via a web browser.

4.4 Billing

This will be achieved through a module that will calculate fees based on applied or licensed frequency category and will include automated invoice generation payment due reminders with close reference to the database. It will also include Update for fee schedules and calculations

The next chapter will embark on the actual implementation of the conceptual model to realize the IFSMS under research.

CHAPTER FIVE: IMPLEMENTATION AND TESTING

5.0 Introduction

This chapter introduces the various blocks that make up the system under research and how each is developed individually and how they are collectively integrated into a single system. It also describes the various tests performed on the system to ensure it works as required.

5.1 IMPLEMENTATION

Implementation entailed moving the formulated idea from concept to the ultimate realization and deployment of desired technical specifications or an actual whole system through various stages. The successful implementation the system entailed carrying out a number of inter-related tasks in an appropriate sequence from configuration, running, testing, and making necessary changes.

Three tools were critical for the successful implementation of the IFSMS system as discussed below.

5.1.1 Visual basic

Basic stands for beginners' all-purpose symbolic instruction code, commonly used to refer to general purpose, high level programming languages designed to allow ease of use. It is a programming language that is event driven with an integrated development environment (IDE).It enables programmers to create GUI applications ranging from simple to complex ones. Programming in visual basic constituted visually arranging components as well as controls on forms and specifying attributes and actions for them and coding for more functionality.

Visual basic 2010 was downloaded and installed on a personal computer all owing the research to develop programs by writing codes

Forms were created using drag and drop techniques with an embedded tool used to place controls like text boxes and buttons which have attributes and handlers associated with them. Visual basics flexibility allowed easier modification of attribute values during run time.

5.1.2 My SQL offline server

This is an open source web server solution stack package that consists of the Apache HTTP server, My SQL database, and interpreters for scripts written in the PHP and pearl programming languages.

A Cross platform Apache HTTP server, My SQL, PHP, Pearl (XAMPP) proved quite ideal as a development tool allowing testing of the system from own computer without the necessity for internet access. It also has support for mechanisms allowing for creation and manipulation of databases in My SQL. Its Installation makes it possible to treat local hosts like remote ones by connection through an FTP client.

5.1.3 My SQL Connector

This is an open source driver that was downloaded from the internet that allows connection to a MySQL database server through the open database connectivity application program interface; a standard means for connection to any database. It is available for major operating systems like Windows, UNIX, Linux and Solaris .This is used to provide driver-manager based and native interfaces for the MySQL database supporting other MySQL functionalities that include stored procedures and transactions.

5.2 Implementation model

Implementation of the IFSMS is based on the conceptual model discussed earlier in chapter four with the figure below showing the various modules that make the system.

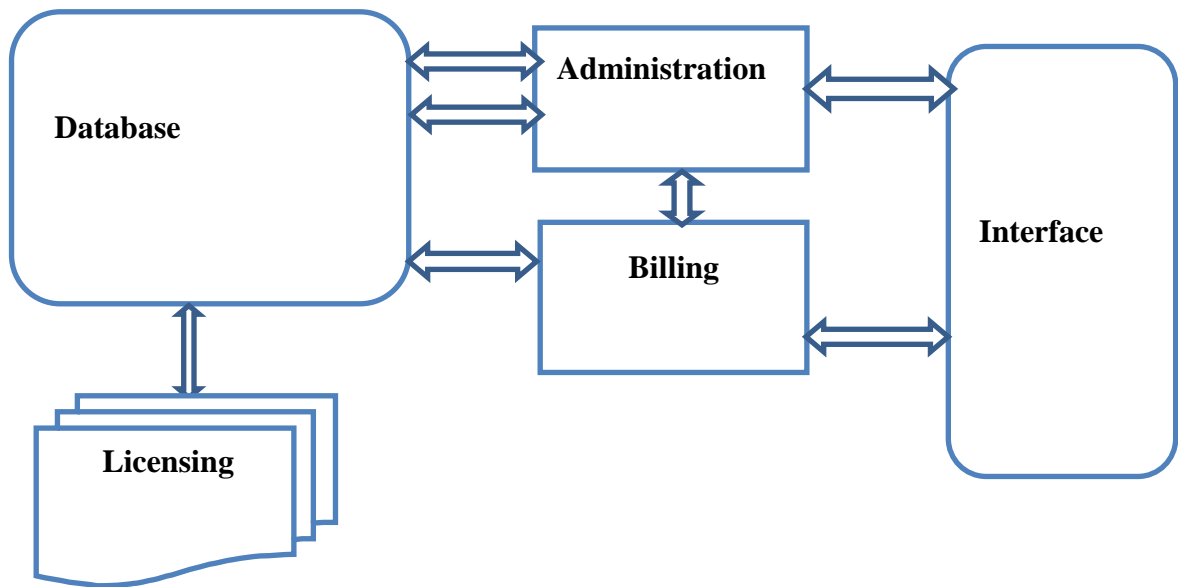


Figure 2: IFSLS Implementation model

5.2.1 Database

This consists of tables of frequencies, a list of administrators, operators and pricing category for the various spectrum categories.

Table of Frequencies

Three tables of frequencies were created; one for TV broadcast another for FM radio broadcast while the last one is for GSM frequency

174.00	174.25	174.50	174.75	175.00	175.25	175.50	175.75	176.00	176.25	176.50	Band 1
177.37	177.62	177.37	178.12	178.37	178.62	178.87	179.12	179.37	179.62	179.87	Band 2

Table 1: Television Broadcasting Frequency Bands

890.00	890.28	890.56	890.84	891.12	891.40	891.68	891.96	892.24	892.52	892.80	Band 1
893.68	893.96	894.24	894.52	894.80	895.08	895.36	895.64	895.92	896.20	896.48	Band 2

Table 2: Mobile Phone Frequency Bands

87.00	87.23	87.46	87.69	87.92	88.15	88.40	Band 1
88.50	88.73	88.96	89.19	89.42	89.65	89.90	Band 2

Table 3: FM broadcasting Frequency Bands

Administrators

Three administrators were created in the database i.e. the spectrum management administrator (SMA), the Principal Spectrum Management officer (PSMO) and the Spectrum Management director (SMD)

Operators

Three operators were also created in the database and were Safaricom, NTV and Radio Maisha

Pricing category

Pricing categories were used as below for three services

SERVICE CATEGORY	PRICING
FM radio broadcast	100,000
Television broadcast	500,000
Mobile telephony	1000,000

Table 4: Pricing category

To ensure the accuracy of data is maintained, validation checks were made to the data input process. Database output on the other hand consists of information provided directly to the user by query of the database, or to an application for analysis purposes. The database is designed with robust query capabilities through an easy-to-use interface.

Access control measures are in place through registration and definition of access levels to administrators and users to ensure that only authorized personnel have access to the database. This protects the system and users from such serious consequences like incorrect fees being charged to license-holders.

5.2.2 Administration module

This is for administration of license data for applicable frequency categories. It also offers workflow management for license approvals, deadline as well as complaint management functions

5.2.3 Interface module

This is an e-licensing and e-reporting tool via web browser with user management options that are role based and for electronic entry of license application data by any web browser and the validation of application data.

5.2.4 Billing module

This performs customized billing functions based on license category and generation of invoices among other functions.

5.3 TESTING

Testing involved confirmation of the systems working as specified defined in the objectives. Its main focus was to verify that the user requirements are met. The following types of tests will be carried on the system

5.3.1 Performance testing

The purpose of this test was to ensure the system met the specified performance criteria's. This was done by generating activities on the system with different user profiles being created and injected with different kinds of activities on the server to replicate different end-user environments.

System login

Applicants have access to the system via a customized workflow module for automatic application management through a web enabled interface with users being classified as either administrators or operators.

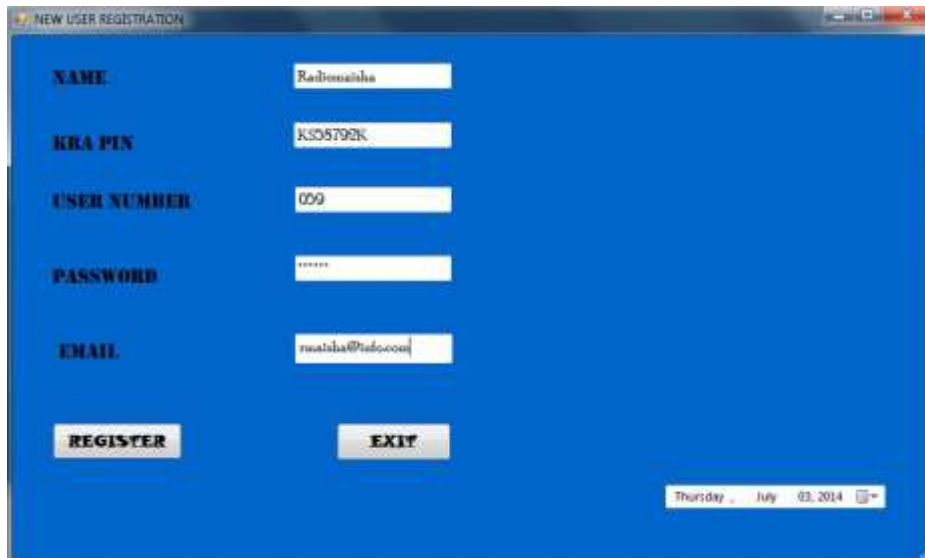


The image shows a web-based login interface titled "LOG IN INTERFACE". It features two main sections: "ADMINISTRATOR LOG IN" and "OPERATOR LOG IN". Each section has a "Name" field and a "Password" field, both represented by white input boxes. Below the "ADMINISTRATOR LOG IN" section is a "LOG IN" button. Below the "OPERATOR LOG IN" section is a "LOG IN" button and a "Register as a new user" button. At the bottom center of the interface is an "EXIT" button. The entire interface is set against a blue background.

Figure 3: Login interface

Administrators and operators will first be registered and have their user names stored in the database with definitions of different access rights. This will allow them access to the system as and when required to perform the necessary operations.

New users on the other hand will have an interface to register themselves on the system as shown below.



NAME:	Radimainaha
KRA PIN	KSD5792K
USER NUMBER	009
PASSWORD	*****
EMAIL	radimaha@info.com

Thursday, July 03, 2014

Figure 4: New user registration interface

As shown in the figure above, the new user who in this case is the applicant for the spectrum registered their names or names of their companies/organization with the KRA PIN which is unique to distinguish applicants or users. This was then being stored in the database and be referenced to grant them access if and when required upon successful registration.

A successful registration notification is availed on the screen on completion of registration as shown below.

The image shows a software window titled "NEW USER REGISTRATION" with a blue background. It contains several input fields and buttons. A smaller dialog box is overlaid on the main window, displaying a success message.

Field Label	Value
NAME	Radiomaisha
KRA PIN	KS58792K
USER NUMBER	059
PASSWORD	*****
EMAIL	rmaisha@info.com

Buttons: REGISTER, EXIT

Dialog Box: INTEGRATED FREQUENCY SPECTRUM MANAMEGENT SYST...
Successfully Registered!
OK

System Tray: Thursday, July 03, 2014

Figure 5: Successful registration

Service application

After successful registration, applicants have access to the operator menu shown below from which they can make application for licensing in the desired category.



Figure 6: Operator interface

On clicking the apply button, the interface below appears from which the applicant enters the necessary information attaching any relevant supporting documents. A notification for successful application is generated on the screen.

The screenshot displays a web application interface with a blue background. At the top, the title "APPLY FOR A SERVICE" is centered. Below the title, there are three input fields: "OPERATORNAME" with the value "Radio Maisha", "SERVICE" with the value "FM Broadcasting", and "LOCATION" with the value "Eldoret". At the bottom left, there is a button labeled "APPLY" and a button labeled "EXIT". At the bottom center, there is a date field showing "Wednesday, July 30, 2014". A dialog box titled "INTEGRATED FREQUENCY SPECTRUM MANAMEGENT SYSTEM" is overlaid on the right side of the screen. The dialog box contains the following text: "You have successfully applied for a service and we have your details in our database please wait for processing. You can check on the progress of your application in our website. Your transaction ID is G8954U". There is an "OK" button at the bottom right of the dialog box. Two red arrows are present: one pointing to the "APPLY" button and another pointing to the "OK" button in the dialog box.

Figure 7: Service application and successful application notification.

Processing

The system was tested through three approval stages as shown below:

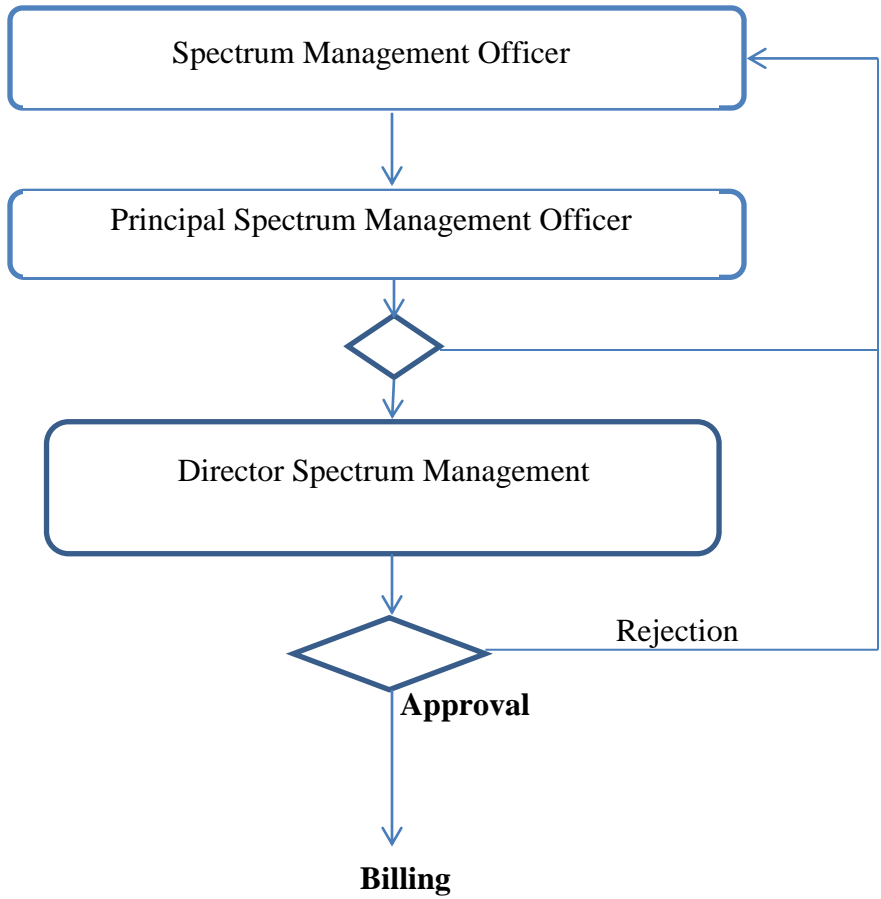


Figure 8: Application processing

The Spectrum management officer first validated that all fields and information entered by Radio Maisha applicant were correct and approved the application.

SPECTRUM MANAGEMENT OFFICER
SERVICE APPLICATION APPROVAL INTERFACE

OPERATOR NAME	RADIO MASHA
SERVICE	TV BROADCASTING
LOCATION	ELDORET
KRA PIN	KZ5804R
EMAIL ADDRESS	rmasia@info.com

INTEGRATED FREQUENCY SPECTRUM MANAGEMENT SYSTEM

Application has been verified and forwarded to the next level for further verification. Thank you!

OK

APPROVE REJECT EXIT

Friday, July 04, 2014

Figure 9: Spectrum management officer approval

The application was then automatically send to the Principal spectrum management officer who is next in the approval hierarchy. The application was checked and appropriate recommendations made based on analysis of the application and the available spectrum and approved as shown below.

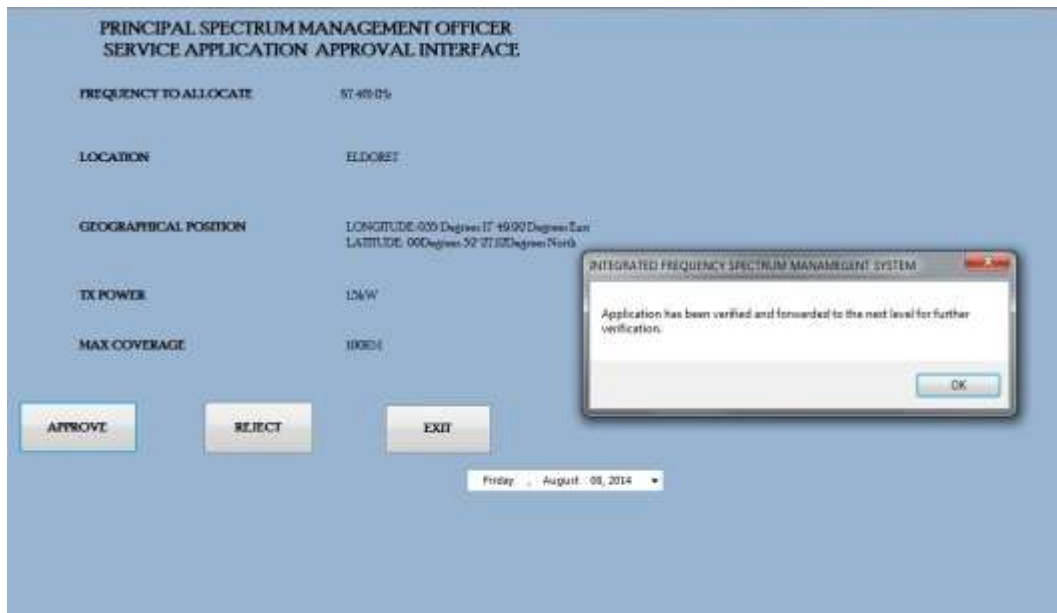


Figure 10: Principal Spectrum management officer approval

The application was then send to the director spectrum management (DSM) who approved it as well as shown below.

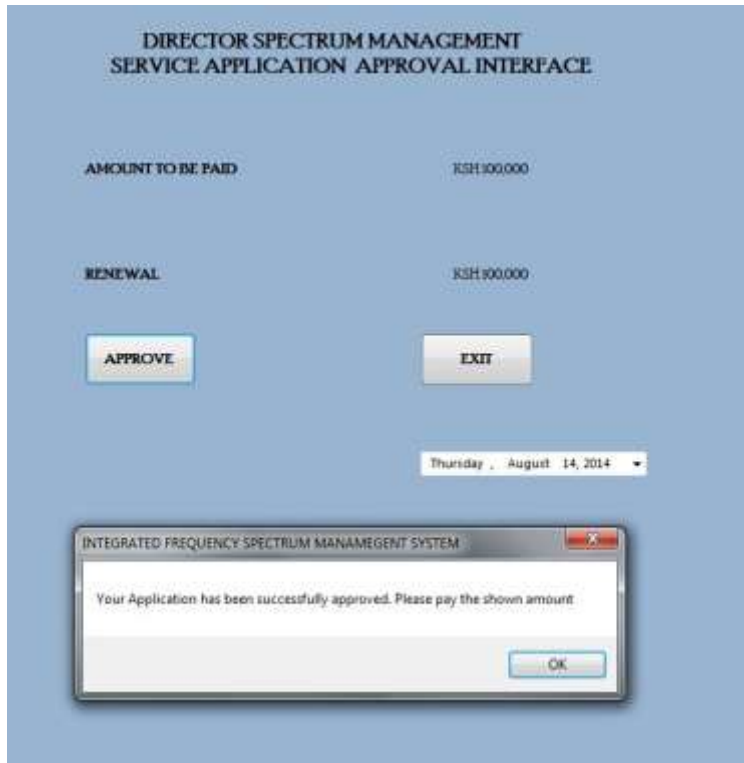


Figure 11: Director Spectrum management approval

The fully approved application was then forwarded to billing for generation of invoice. It's however important to note that the system has a programmed timer element will automatically forward the application to the next level in the approval chain after elapse of some set action period of inactivity to eliminate un-necessary delays and also flag cases of complacency in the application approval process.

Billing

Billing is triggered by a notification from the approval and undergoes a sequence of actions as indicated in the flow chart below.

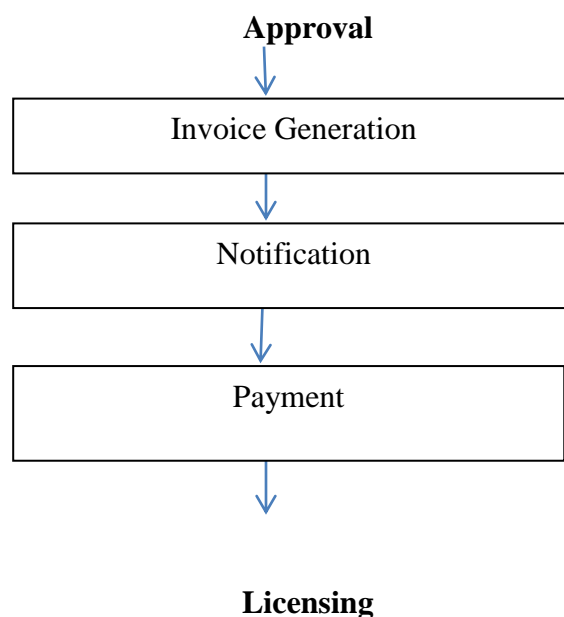


Figure 12: Sequence of actions in billing

An invoice is generated upon receipt of an approval notification based on spectrum category as shown below.

INVOICE 005091

COMMUNICATIONS AUTHORITY OF KENYA
P.O. BOX 564-00800
NAIROBI

DUE DATE: Monday , August 18, 2014

RADIO MAISHA

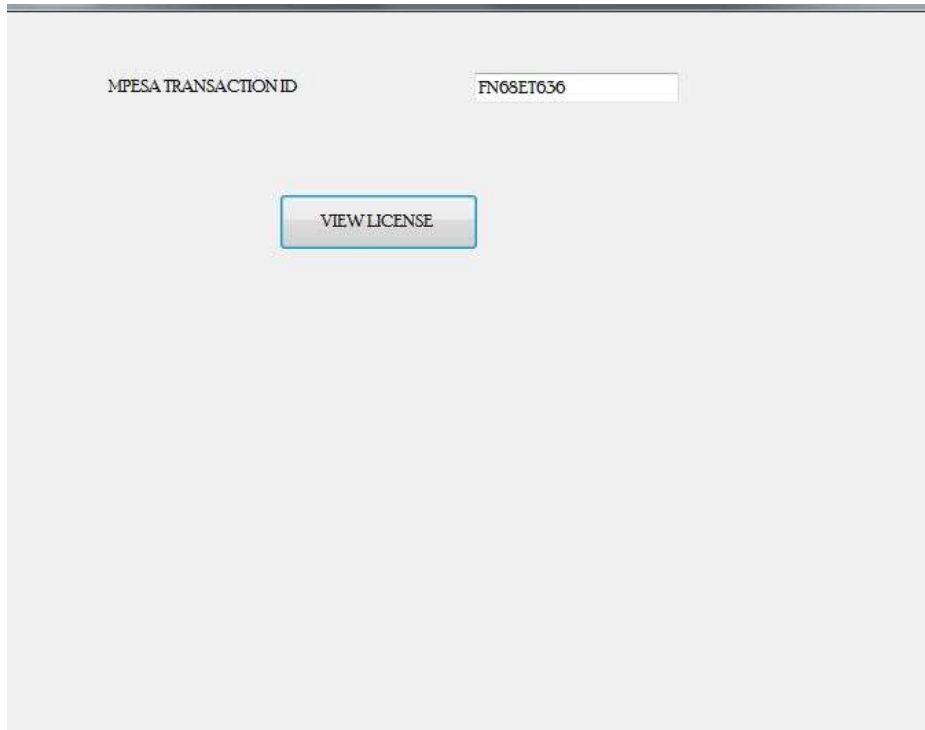
SERVICE	TYPE	PRICE	TOTAL
FREQUENCY ALLOCATION	FM BROADCASTING	KSH 100,000	KSH 100,000

AMOUNT DUE: KSH 100,000

PrintInvoice SaveInvoice

Figure13: Invoice generation

After invoice generation, a notification is sent to the applicant or operator via mail or SMS on the amount due for payment. The applicant makes payment via MPESA, logs in the system and enters the transaction ID as shown below.



The screenshot shows a web interface with a light gray background. At the top left, the text "MPESA TRANSACTIONID" is displayed. To its right is a white input field containing the alphanumeric string "FN6SET636". Below these elements, centered on the page, is a rectangular button with a blue border and a light gray gradient, labeled "VIEW LICENSE".

Figure14: Payments using MPESA transaction ID

The system then compares the transaction ID with pay bill number records to confirm payment and triggers license generation

Licensing

Upon receipt of license notification, the system populates a license in a standard format with nineteen fields containing all the relevant information based on the application made and approval granted as shown below:

COMMUNICATION AUTHORITY OF KENYA

LICENSE TO OPERATE A TELECOMMUNICATION SERVICE

THIS LICENSE NUMBER 2014/RA/08 FOR THE OPERATION
OF A RADIO/TV/MOBILE TELEPHONY/2-WAY FIXED/MOBILE RADIO
(HF/VHF/UHF) STATION IS AWARDED

TO MESSR: RADIOMAISHA

OFF P.O BOX: 427-030100 ELDORET

ON THIS DATE 21ST AUGUST OF THE YEAR 2014

THE LICENCEE IS HEREBY ASSIGNED A FREQUENCY OF 87.46MHz

TO BE TRANSMITTED FROM THE DESIGNATED AREA
HEREIN REFERRED TO AS KAPSOYA SITUATED IN ELDORET
TOWN AND AT A POINT IDENTIFIED BY

THE CO-ORDINATES LONGITUDE: 035 Degrees 17' 49.92 Degrees East
LATITUDE: 00 Degrees 32' 27.12 Degrees North
WITHIN THE REPUBLIC OF KENYA

SPECIAL CONDITIONS

1. LICENCE FEE PAID: KSH 100,000

2. MAXIMUM TRANSMITTED POWER 1.5 mW W KW

3. MAXIMUM COVERAGE RADIUS 100 KM:

4. ANNUAL RENEWAL FEE OF KSH: 100,000 TO BE PAID ON OR
BEFORE 21st AUGUST EVERY YEAR

5. THE AUTHORITY RESERVES THE RIGHT TO REVOKE AND/OR DECLINE
TO RENEW THIS LICENCE EITHER AT ITS OWN DISCRETION OR
NON-COMPLIANCE OF THE LICENCEE TO ANY OF THESE CONDITIONS

SIGNED *OKOROTER*

DIRECTOR SPECTRUM MANAGEMENT

Figure15: Generated license

From the figure the license contains the license number and category (Radio, TV, Mobile telephony etc.), name of the licensee and contact address and date and year of issue. It also contains the assigned frequency, designated area of operation, town and the geographical position in form of co-ordinates.

The license also shows the amount of license fee paid, allowed maximum power transmission and coverage radius as well as the annual renewal fee, due date, month and year. It also has special conditions stipulated which must be adhered to by the operator and lastly the signature of issuing authority.

5.3.2 Regression testing

This was done to detect defects arising due to code in the existing code which comprised of functional enhancements and configuration changes. This was to ensure that code changes to the system enhancements did not introduce defects in the system. Anytime changes were made to an existing working code, a test was executed to confirm that the new changes did not introduce any bugs in the system.

5.3.3 Usability testing

This tested the systems capability to be easily learned and understood by the end user. Features tested include easiness to learn and use the system and convenience its convenience to end users as shown below where an operator was able to make payment by submitting the MPESA transaction ID and renew the license for allocated spectrum

PLEASE ENTER YOUR TRANSACTION ID

TRANSACTION ID

INTEGRATED FREQUENCY SPECTRUM MANAMEGENT SYST...

Please enter the MPESA Transaction ID to view your license

Tuesday , August 19, 2014 ▾

Figure 16: Service payment

PLEASE ENTER YOUR DETAILS AND CLICK ON THE RENEW BUTTON TO RENEW YOUR SUBSCRIPTION

COMPANY NAME

KRA PIN

FREQUENCY

MPESA TRANSACTION ID

INTEGRATED FREQUENCY SPECTRUM MANAMEGENT SYSTEM

You have successfully renewed for your service, Your contract is valid for one year.

Friday , August 21, 2015 ▾

Figure 17: Spectrum license renewal

5.3.4 Security testing

This tested the system's ability to prevent unauthorized access to its resources and data. It involved the six basic security aspects of confidentiality, integrity, authentication, authorization, availability and non-repudiation.

Authentication

This involved establishing the identity of the user in the form of passwords where a user masquerading as an operator tried to gain entry to the system but was denied.

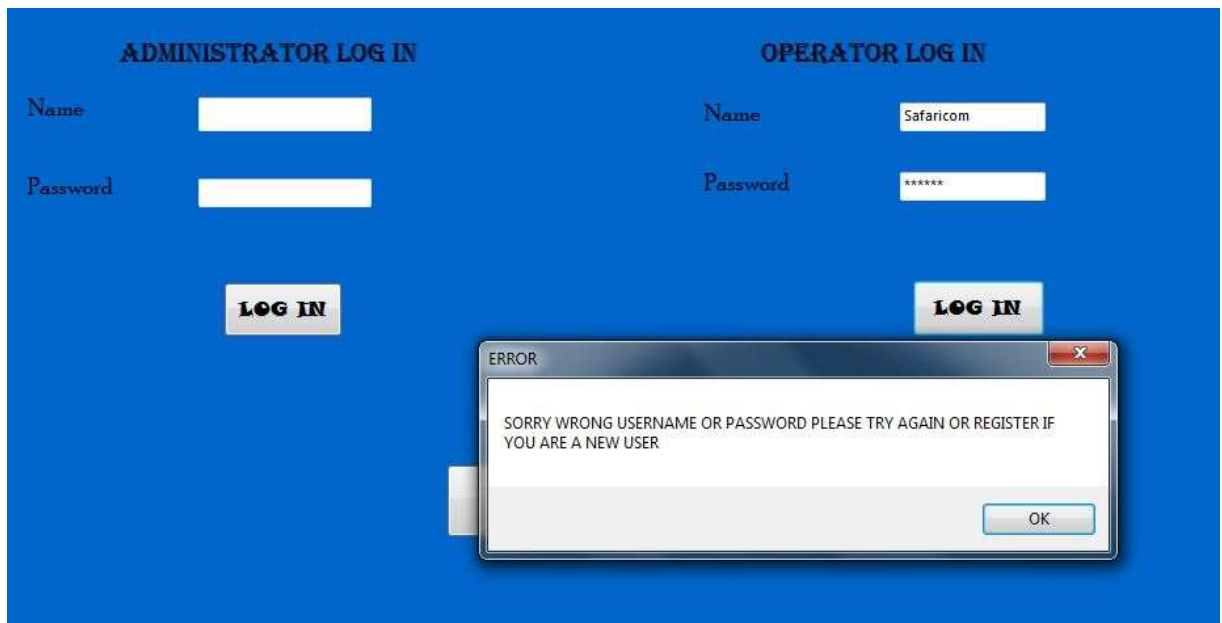


Figure 18: Operator authentication test

Authorization: This involved determining that a user is allowed to perform an operation system as shown below where an un-authorized entity was trying to access the system as an administrator but was unsuccessful.



Figure 19: Administrator security testing

Availability

This involved ascertaining the readiness of the system for use as and when needed. The application was able to be tracked by applicants any time they wished to check progress as shown below.



Figure 20: Status tracking after application



Figure 21: Status tracking after spectrum management officer's approval



Figure 22: Status tracking after spectrum management director's approval

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.0 Introduction

This chapter summarizes conclusions deduced from the study and presents recommendations that can be researched further to enhance the operation of the system.

6.1 Conclusions

The following conclusions were deduced from the research.

- I. Mechanisms and approaches to spectrum management include spectrum engineering, RF monitoring and lengthy licensing procedures by some regulatory authorities.
- II. IFSMS was successfully developed using appropriate technologies and tested on application, processing, billing and licensing functions of spectrum management.
- III. The system was validated for accuracy in terms of stored data and processed documentations and found to be consistent with design parameters.
- IV. IFSMS provides useful insight to spectrum management custodians on the desired aspects of managing spectrum in terms of efficiency, user friendliness, flexibility and timely delivery of services.

6.2 Recommendations

The research recommends future works on the system in the following areas.

1. Testing of the system online with regulators to determine its efficiency under real life environment

2. Interfacing administrative functions of application, processing, licensing and billing with other tools like radio engineering and monitoring to achieve a unified integrated system.
3. Interfacing of the system with mobile telephony functions to allow interaction through a USSD code.

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IFSLS CODES

1.SYSTEM LOGIN CODE

```
PublicClassForm1
```

```
PrivateSub Form1_Load(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs)
Handles MyBase.Load
```

```
EndSub
```

```
PrivateSub TextBox1_TextChanged(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs)
Handles TextBox1.TextChanged
```

```
EndSub
```

```
PrivateSub Label2_Click(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs) Handles
Label2.Click
```

```
EndSub
```

```
PrivateSub Label3_Click(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs) Handles
Label3.Click
```

```
EndSub
```

```
PrivateSub TextBox2_TextChanged(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs)
Handles TextBox2.TextChanged
```

```
EndSub
```

```
PrivateSub Button1_Click(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs)
Handles Button1.Click
If TextBox1.Text = "Admin" And TextBox2.Text = "PASSWORD" Then Form2.ShowDialog()
Else MsgBox("SORRY WRONG USERNAME OR PASSWORD PLEASE TRY AGAIN", MsgBoxStyle.OkOnly,
"ERROR")
```

```
EndSub
```

```
PrivateSub Label15_Click(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs) Handles
Label15.Click
```

```
EndSub
```

```
PrivateSub TextBox3_TextChanged(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs)
Handles TextBox3.TextChanged
```

```
EndSub
```

```
PrivateSub Label16_Click(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs) Handles
Label16.Click
```

```
EndSub
```

```

PrivateSub TextBox4_TextChanged(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles TextBox4.TextChanged

EndSub

PrivateSub Button2_Click(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles Button2.Click
If TextBox3.Text = "Safaricom" And TextBox4.Text = "SAF" Then
Form4.ShowDialog()
ElseIf TextBox3.Text = "Orange" And TextBox4.Text = "ORNG" Then
Form4.ShowDialog()
ElseIf TextBox3.Text = "Radiomaisha" And TextBox4.Text = "RMS" Then
Form4.ShowDialog()
Else :MsgBox("SORRY WRONG USERNAME OR PASSWORD PLEASE TRY AGAIN OR REGISTER IF YOU ARE A
NEW USER", MsgBoxStyle.OkOnly, "ERROR")
EndIf

EndSub

PrivateSub Button3_Click(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles Button3.Click
Form3.ShowDialog()
EndSub

PrivateSub Button4_Click(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles Button4.Click
Me.Close()
EndSub
EndClass

```

2. USER REGISTRATION CODE

```

Imports MySql.Data.MySqlClient

Public Class Form3
Dim MySQLConn As MySqlConnection
Dim operatorstableCommand As New MySqlCommand
Dim operatorstableadapter As New MySqlDataAdapter
Dim operatorstableData As New DataTable
Dim SQL As String
Dim connectionString As String = "Server=localhost;User Id=root;Password=;database=ifsms "

PrivateSub Form3_Load(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles MyBase.Load

EndSub

PrivateSub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles Button1.Click
Dim connectionString As String = "Server=localhost;User Id=root;Password=;database=ifsms"
Dim result As Integer
Using myconn As New MySqlConnection(connectionString)
Using spectrummanagementsystemCommand As New MySqlCommand()
Try

```

```

myconn.Open()

With spectrummanagementsystemCommand
    .Connection = myconn
    .CommandText = "INSERT INTO `ifsms`.`operatorstable`(`NAME`, `KRA
PIN`, `USER NUMBER`, `PASSWORD`) VALUES ('"& TextBox1.Text &"', '"& TextBox2.Text &"', '"&
TextBox3.Text &"', '"& TextBox4.Text &"');"
result = spectrummanagementsystemCommand.ExecuteNonQuery()
'if the result is equal to zero it means that no rows is inserted or somethings wrong
during the execution
If result = 0 Then
MsgBox("Data has been Inserted!")
Else
MsgBox("Successfully Registered!")
EndIf
EndWith
Catch ex As Exception
MsgBox(ex.Message.ToString)
Finally
myconn.Close()
EndTry
EndUsing
EndUsing
EndSub

PrivateSub Button2_Click(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles Button2.Click
Me.Close()
EndSub

PrivateSub TextBox1_TextChanged(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles TextBox1.TextChanged

EndSub
EndClass

```

3. ADMINISTRATOR LOGIN CODE

```

PublicClass Form8

PrivateSub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles Button1.Click
If TextBox1.Text = "SMO" And TextBox2.Text = "PASSWORD01" Then
Form12.ShowDialog()
ElseIf TextBox1.Text = "PSMO" And TextBox2.Text = "PASSWORD02" Then
Form13.ShowDialog()
ElseIf TextBox1.Text = "DSM" And TextBox2.Text = "PASSWORD03" Then
Form14.ShowDialog()
Else :MsgBox("SORRY WRONG USERNAME OR PASSWORD PLEASE TRY AGAIN", MsgBoxStyle.OkOnly,
"ERROR")
EndIf
EndSub
EndClass

```

4. SERVICE APPLICATION CODE

```
Imports MySql.Data.MySqlClient
Public Class Form5
Dim MysqlConn As MySqlConnection
Dim operatorstableCommand As New MySqlCommand
Dim operatorstableadapter As New MySqlDataAdapter
Dim operatorstableData As New DataTable
Dim SQL As String
Dim connectionString As String = "Server=localhost;User Id=root;Password=;database=ifsms "
Dim MySqlConnection As Object

Private Property cbxTypeofservice As Object

Private Sub Form5_Load(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles MyBase.Load
End Sub
Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles Button1.Click
Dim connectionString As String = "Server=localhost;User Id=root;Password=;database=ifsms"
Dim result As Integer
Using myconn As New MySqlConnection(connectionString)
Using spectrummanagementsystemCommand As New MySqlCommand()
Try
myconn.Open()

With spectrummanagementsystemCommand
.Connection = myconn
.CommandText = "INSERT INTO `ifsms`.`service
applications`(`OPERATOR NAME`, `SERVICE`, `LOCATION`) VALUES ('"& TextBox1.Text &"', '"&
TextBox2.Text &"', '"& TextBox4.Text &"');"
result = spectrummanagementsystemCommand.ExecuteNonQuery()
'if the result is equal to zero it means that no rows is inserted or somethings wrong
during the execution
If result = 0 Then
MsgBox("Data has been Inserted!")
Else
MsgBox("You have successfully applied for a service and we have your details in our
database please wait for processing. You can check on the progress of your application in
our website. Your transaction ID is G8954U ")
EndIf
EndWith
Catch ex As Exception
MsgBox(ex.Message.ToString)
Finally
myconn.Close()
EndTry
EndUsing
EndUsing
```

5. APPROVAL CODE

```
PublicClassForm12
```

```
PrivateSub Label19_Click(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs) Handles Label19.Click
```

```
EndSub
```

```
PrivateSub Button1_Click(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs) Handles Button1.Click
MsgBox("Application has been verified and forwarded to the next level for further verification. Thank you!")
```

```
EndSub
```

```
PrivateSub Button2_Click(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs) Handles Button2.Click
Me.Close()
EndSub
```

```
PrivateSub Form12_Load(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs) Handles MyBase.Load
```

```
EndSub
EndClass
```

6. SERVICE RENEWAL CODE

```
PublicClassForm7
```

```
PrivateSub Form7_Load(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs) Handles MyBase.Load
```

```
EndSub
```

```
PrivateSub Button1_Click(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs) Handles Button1.Click
MsgBox("You have successfully renewed for your service, Your contract is valid for one year.")
```

```
EndSub
```

```
PrivateSub Button2_Click(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs) Handles Button2.Click
Me.Close()
EndSub
```

```
PrivateSub TextBox2_TextChanged(ByVal sender AsSystem.Object, ByVal e AsSystem.EventArgs) Handles TextBox2.TextChanged
```

```
EndSub
EndClass
```