AN INTELLIGENT MODEL FOR QUALITY SERVICE IN OPEN DISTANCE ELECTRONIC LEARNING

by

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ABSTRACT

Quality of service (QoS) in the open distance electronic learning (ODeL) environment, in general, becomes a part of the entire assessment of all services provided by the institution. High-quality service delivery in a virtual environment is one of the most significant challenges, as it is required to become the primary competitive institutional strategy in service-oriented organizations. However, critical quality of service elements in ODeL are not optimal in providing high quality requirements. Authentication as a critical QoS element in ODeL has been considered in numerous research but an optimal cheating-free, non-venue-based assessment has not yet been realized. Bandwidth resource, another critical QoS element in the ODeL platform, is scarce when services performed by many users contend for bandwidth, causing congestion in the network. Through intelligent systems ODeL can be made smarter to achieve QoS; however, the challenge is that many conflicting issues affect the implementation of smart education in ODeL.

This research proposes an intelligent QoS framework capable of reorganizing and adapting to changes within ODeL to provide smart education. The framework constitutes a fused multimodal biometric authentication model based on facial recognition, voice recognition, and keystroke dynamics to provide cheating-free examination in ODeL. It is a predictive framework of bandwidth management, which integrates a sustainable hidden Markov model (HMM) and a normalization policy coupled with SolarWinds technology for prior network data feeder, is incorporated. It is a model that relies on the classified critical conflict factors in the smart education environment and the possible resolution strategies. The QoS elements modeled in the research are validated with a confirmatory factor analysis on a survey of the research participants. The framework will benefit open distant electronic learning institutions, examination agencies, organizations with limited network bandwidth, and quality assurance agencies.

KEYWORDS

Quality of Service, Open Distance Electronic Learning, Fused Multimodal Biometric, Authentication, Online Examination, Bandwidth, Normalization, Learning Management, Smart Education, Smart Conflict Management.

DECLARATION

Student number: 57640777

I declare that "An Intelligent Model for Quality Service in Open Distance Electronic Learning" is my own work and that I have referenced and acknowledged all the sources that I have used by means of complete references.

I further declare that I submitted the thesis to originality checking software. The result summary is attached.

I further declare that I have not previously submitted this work or part of it for examination at UNISA for another qualification or at any other higher education institution.

February 15, 2023

Signature

Amoako Prince Yaw Owusu

Date

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DEDICATION

I dedicate my PhD to my wife (Abigail Owusu Amoako), my mother (Hannah Sarben), and my late father (Augustine Amoako Atta). A special recognition goes to my children (Oheneba, Osaa and Nyamekye) for their steadfast support throughout this journey. Ultimately, this is dedicated to God, my creator and sustainer.

ACKNOWLEDGEMENTS

My journey in this PhD degree has been full of challenges and at some point, it was not hopeful that I would complete the program. As a father and with many responsibilities at home and the workplace coupled with external family commitments, the journey was quite tough.

I must admit that the assistance UNISA provided to students pursuing their post-graduate degree is immeasurable. A comprehensive resource made available to students, seminars and workshops led by highly resourceful personnel sharpened my thoughts on writing quality research. These resources have contributed so much on the outcome of this thesis and the completion of my degree, and I sincerely acknowledge that.

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My wife, Abigail, and our children, Oheneba, Osaa and Nyamekye, have been my backbone of support from the beginning to the end of this journey.

Finally, I believe in the words of Philippians 1:6 that my God who began the good work in me has accomplished it. May His name be forever exalted.

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LIST OF PUBLICATIONS

Journal Articles:

- P. Y. O. Amoako and E. Mnkandla, “Fused Multimodal Biometric Authentication for an Open Distance Learning Environment Online Examination”, *International Journal of Smart Technology and Learning (IJSMARTTL)*, vol. 3, no. 3, 2023, ISSN: 2056-4058, doi: 10.1504/IJSMARTTL.2023.10059328.
- P. Y. O. Amoako and I. O. Osunmakinde, “Emerging bimodal biometrics authentication for non-venue-based assessments in open distance e-learning (OdeL) environments”, *International Journal of Technology Enhanced Learning*, vol. 12, no. 2, 2020, doi: 10.1504/IJTEL.2020.106287.

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- P. Y. O. Amoako, Conceptual Framework on Proactive Conflict Management in Smart Education, 11th Sustainable Education and Development Research Conference - Sustainable Industrialization and Innovation: Proceedings of the Applied Research Conference in Africa (ARCA), August 24-27, 2022, Springer Nature

- P. Y. O. Amoako and I. O. Osunmakinde, “Sustainable Markov Model Bandwidth Planner Enhancing Learning Technologies in Constrained Distance Learning Environments – a Pandemic Response, IEEE 20th International Conferences on Information Technology Based Higher Education and Training 7-9 November 2022, Side, Antalya, Turkey

LIST OF ACRONYMS

ACCJC	Accrediting Commission for Community and Junior Colleges
AI	Artificial Intelligence
AMOS	Analysis of a Moment Structure
AR	Augmented Reality
BRP	Borrow-Return-Preempt
CFA	Confirmatory Factor Analysis
CHOKe	CHOose and Keep
CP	Complete Partitioning
C-RAC	Council of Reginal Accreditation Commission
CS	Complete Sharing
DEAC	Distance Education Accrediting Commission
DLSTM	Deep Long Short Term Memory
DNA	Deoxyribonucleic Acid
DTF	Discrete Fourier transform
EFA	Exploratory Factor Analysis
EM	Expectation-Maximization
FACKD	FACial and Keystroke Dynamics
FAR	False Acceptance Rate
FN	False Negative
FP	False Positive
FR	Facial Recognition
FRR	False Rejection Rate
GMM	Gaussian mixture model
GTEC	Ghana Tertiary Education Commission
HLC	Higher Learning Commission
HMM	Hidden Markov Model
HMM-NP	Hidden Markov Model and a Normalization Policy
IQSODeL	Intelligent Quality Service in Open Distance Electronic Learning
KD	Keystroke Dynamics
KM	Knowledge management
LA	Learning Analytics

LMS	Learning Management System
LTSD	Long-Term Spectral Divergence
MAE	Mean Absolute Error
MAP	Maximum A Posteriori
MFCC	Mel-frequency cepstral coefficients
MSE	Mean Square Error
NC	Network Capacity
NP	Normalization Policy
NPM	Network Performance Monitor
ODeL	Open Distance Electronic Learning
OFDMA-PONs	Orthogonal Frequency Division Multiple Access Passive Optical Networks
QM	Quality Matters
QoS	Quality of Service
RFID	Radio-Frequency Identification
RMSE	Root Mean Square Error
RNN	Recurrent Neural Network
ROC	Receiver Operating Curve
SaaS	Software as a Service
SCORM	Shareable Content Object Reference Model
SEM	Structural Equation Modeling
SNMP	Simple Network Management Protocol
SPSS	Statistical Package for the Social Sciences
TN	True Negative
TP	True Positive
UI	User Interface
VAD	Voice Activity Detector
VPT	Virtual Partitioning
VR	Virtual Reality
VR	Voice Recognition
xAPI	Experience Application Programming Interface
XML	eXtensible Markup Language

CHAPTER 1

INTRODUCTION

1.1 Introduction

Technical quality and functional quality, according to Gronroos (1982), a pioneer in the proposal of the Service Quality Model, are the two-dimensional elements that determine users' perception and final satisfaction of quality. The service's technical quality dimension focuses on what the user receives, emphasizing the technical result of the process. Contrarily, functional quality deals with how the user experiences the technical result (Dudovskiy, 2022).

In order to increase the standard of service, several intelligent models have been applied in recent years to address various technical issues in the field of education. These sophisticated methods are built using several Artificial Intelligence (AI) modeling techniques (Zhang & Aslan, 2021) . A framework is constructed using the Internet of Behavior and AI to provide personalized smart, flexible education (Embarak, 2022) . In the music education of college students, artificial intelligence is employed in a system to boost the student's enthusiasm and effort, which is helpful for good student performance and knowledge absorption (Wei et al., 2022) . Quality of service models based on AI techniques have been developed to enhance the performance of communication network systems (Li et al., 2022). Based on a comprehensive examination on AI technology-based services, a study identified four categories of AI technology-based service encounters: AI-supplemented, AI-generated, AI-mediated, and AI-facilitated. It concluded that AI technology-based services are the solution to customer and staff satisfaction (Li et al., 2021). By extension, an intelligent model based on AI techniques can be employed for quality of service in open distance electronic learning (ODeL) to supplement, generate, mediate or facilitate the teaching and learning services.

Open distance electronic learning (ODeL) is learning by synchronous and asynchronous means transferred through internet technologies (Saleem et al., 2022). Such means of learning are mostly referred to as online learning. The quality of ODeL is described as access to just-in-time support systems and ease of usage for students, lecturers, and administrators of an institution leading to all students' satisfaction (Saleem et al., 2022) . Quality of service (QoS) in open distance electronic learning is a challenging issue to solve by institutions engaged in such education. Quality in higher education is conceptualized by Harvey and Green (1993) as outstanding, perfection (or consistency), appropriateness for purpose, and value for money as five distinct but linked quality orientations. It is difficult to achieve service quality in ODeL because it encompasses so many different factors, such as course design and content, learning context, rapid feedback, learning outcomes assessment, learning environments, and support services (Hénard & Roseveare, 2012). According to Zuhairi et al. (2020) , maintaining quality in ODeL requires a thorough, integrated online system for student support.

The QoS in ODeL involves the implementation of smart education. Smart education can be achieved through the implementation of intelligent techniques to regulate the systems and activities of users to provide intelligent quality service. Intelligent quality service in ODeL depends on modeling the smart education infrastructures to incorporate AI methods to secure users, manage bandwidth, and manage conflict.

Quality of service in the online environment, in general, becomes a component of the institution's overall evaluation of all services supplied by the institution. High-quality service delivery in a virtual environment is one of the most critical challenges, because it must become the main institutional competitive strategy in service-oriented companies (Kim & Kim, 2020). According to Demir et al. (2020) , most universities in recent times attempt to comprehend the financial and strategic implications of learners' perception of value for money as the key determinant of the success of ODeL platforms and the educational system in general; and further claims that due to the impact on students' motivation and their success rate, most investigations have mainly focused on the proper levels of learners' pleasure in the e-learning system (Demir et al., 2020).

As opined by Sadikin and Hamidah (2020), a unique challenge faced by ODeL is the distance between lecturers and students who are far apart, such that direct interaction, guidance, and supervision of students' activities in the learning procedure are limited. In the view of Balasubramaniam et al. (2009) , the generic and possible challenges faced by a service-oriented system such as ODeL are that the system and its compositions meet end-user quality requirements. Understanding the cost and risk of meeting quality standards is important for service providers, who should also be aware that system characteristics typically necessitate built-in trade-offs. Service providers need enough information on choosing between alternative services with the same functional capability as well as QoS procedures to check and implement service level agreements. Therefore, it is essential to develop standards for QoS in ODeL.

Palvia et al. (2018) indicate that ODeL is on track to assume the mainstream of education. They do however, highlight a number of variables that affect the quantity and quality of ODeL, including the economy, the government, national legislation, infrastructure for information and communication technology, the spread of the internet and mobile technology, and the digital divide (Palvia et al., 2018).

Research conducted by Gallego Sánchez et al. (2021), presents a high-level relational coordination as the driving force behind better educational quality, in accordance with the relational coordination and its relationship with the quality of institutions' online education systems. When examining functional organizational boundaries, relational coordination is a verified method of assessing the effectiveness of participant communication and relationships in any activity. It suffices that coordination among factors such as security, network bandwidth, and conflict resolution in ODeL is necessary for QoS. They further characterize achieving QoS in two areas. First is the universal quality of the learning platform and methodology, suggesting the consideration of efficient organizational processes in decision making. The second is the technical quality under two dimensions including navigation and design, and multimedia resources (Gallego Sánchez et al., 2021).

During the COVID-19 pandemic's peak, many or almost all schools at all levels introduced online learning, which propelled research to evaluate the QoS in online education. For example, Shahzad et al. (2021) evaluated the impact of QoS on systems and information on users' satisfaction, system use, and success of e-learning portals. The findings indicated that system quality significantly affects users' satisfaction and will provide success to e-learning portals. Online learning using WhatsApp Group was suggested by Wargadinata et al. (2020) as the best in the COVID-19 pandemic period due to its ease of use and minimal data requirement. However, an assessment by Adnan and Anwar (2020) on the success of online teaching and learning during the COVID-19 pandemic based on students' views revealed that the desired output in underdeveloped countries could not be achieved due to some conflicting issues.

It is stated by Ortiz-López et al. (2020) that a crucial component and assurance of the implementation and growth of education in recent years on virtual platforms is quality assessment initiatives, programs, and strategies. Therefore, establishing quality evaluation standards on the processes, phases, and tools in ODeL will guarantee more reliable and effective smart virtual teaching and learning.

In this study, frameworks for user authentication, bandwidth control, and conflict management are proposed for use by various businesses that are adopting or plan to implement virtual learning systems. This will include a broad quality of service framework called IQSODeL as well as more specific ones for examinee authentication, bandwidth control, and conflict management.

1.2 Background and Motivation

The ODeL environment faces many challenges that hinder the quality of service, which can be categorized under three main subheadings: security, specifically authenticating users; bandwidth management; and conflict management.

The goal of authentication is to confirm that the agents are who they say they are. Authentication seeks to confirm the identification of ODeL students and plays a significant part in security in a non-venue-based exam scenario (an examination given for candidates to take from their locations without a common center). Unlike face-to-face analysis, authentication in ODeL exams is unsupervised, and invigilation is fundamentally different in an unrestricted remote context (Moini & Madni, 2009). When an examinee poses as someone else, impersonation dangers, specifically in e-assessment, occur in virtual organizations. It might take the form of a student giving their security information to an impostor who then answers the exam on their behalf; a student simply logging in to an exam and allowing another to continue on their behalf; or a student logging in and answering the exam on their own while getting help from a helper with the right answers.

Many organizations and examination bodies have been plagued by the issue of examination misconduct in its different manifestations. In a study on malpractice, exam boards penalized students 2,430 times in the summer 2016 exam series in England, Wales, and Northern Ireland, as well as in other parts of the UK and abroad, and 2,460 times in the same exam in 2015 (Vikas, 2016). As presented in Björklund and Wenestam (1999), the following are instances of university cheating rates measured in research in a North American context: rates were reported in 1941 at 23%, 1952 at 38%, 1960 at 49%, 1964 at 64%, 1980 at 76%, and 1989 at 23%. The normal rate was estimated to be between 40% and 60%, while other percentages as high as 82% and 88% were noted. Even in a location with invigilators, this issue is very concerning.

Tens of thousands of students have allegedly been discovered cheating on examinations and papers at institutions all around Britain. According to "The Independent" study, the habit is growing (Moini & Madni, 2009); and, according to the additional statement, over the course of the last three years, more than 45,000 students from 80 different institutions have been hauled before college authorities and found guilty of academic misconduct, which can range from using cheat sheets or mobile devices during exams to hiring private companies to write essays for them (Moini & Madni, 2009).

On October 21, 2015, the Ghanaian Times published a report about eight law students who had been found cheating on an exam, and the campus informer published a report about 24 students from a polytechnic in Ghana who had been caught cheating on an exam during the second semester of the academic year 2013/2014. As reported by The Point newspaper, a southern university in Nigeria expelled 21 students and rusticated 33 others on September 11, 2016, for exam malpractices. On November 12, 2015, Pulse TV in Nigeria reported that 31 students were expelled from a northern university for engaging in examination malpractices.

The COVID-19 epidemic has affected education at all levels and across all continents; and because of lockdown regulations in many nations, e-learning is now a necessity for ongoing education. A study by Noori (2021) on how the pandemic affected Afghan university students' learning found that they were unable to receive continuous online instruction, which was catastrophic. The challenge was mainly due to poor and low-speed internet connections. A study on the COVID-19 pandemic's effects on Nepalese teaching and learning also highlighted the limited availability of online resources (Pal et al., 2021). The negative effects of the epidemic on education were offset through open distance electronic learning, but the main issue is the constrained network capacity that many educational institutions have.

In an ODeL platform where massive numbers of users run many services on the network, bandwidth management helps allocate better performance to enhance teaching and learning quality.

Many organizations set up high-speed internet services to facilitate the entire workflow among various departments and business parties. However, the network drain has led to decreased workflow efficiency, resulting from inappropriate use of the network resources. An ODeL environment with many students and instructors accessing a single repository simultaneously poses critical network bandwidth allocation challenges(Buthmann, 2021). A statement made by Intel Canada indicates that students at college have online access about one-third of their education time through their mobile devices (Exinda Staff Writer, 2016).

Figure 1.1 presents the poor network performance of private and public universities with limited bandwidth. The transmission rate decreases for both upload and download when the number of users/loads increases.

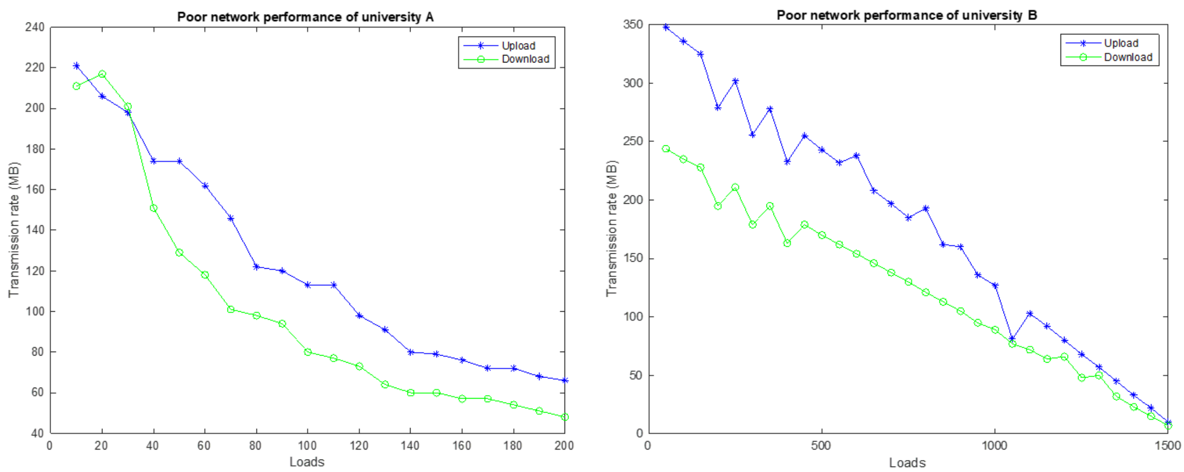


Figure 1.1: Network performance of two universities

According to Casado (2020), constant reliance on high-speed internet has led to a 40% increase in bandwidth usage, indicating that the monthly data consumption of a typical household was 600Gb or 700Gb and was over 1000Gb in the COVID-19 pandemic. Since the outbreak, broadband communication services demand has soared, and some operators’ experiences with internet traffic are currently over 60% more than before the crisis (OECD, 2020).

Another dimension of challenge limiting the quality of service in ODeL is the conflict issue. Conflicts in ODeL may arise from non-functional requirements of systems such as portability and usability. To resolve such conflicts requires ODeL to exhibit the characteristics of smart education because smart technologies are capable of reorganizing to adapt and meet user requirements (Scardamalia & Bereiter, 2014).

Smart education typically helps teachers deliver effective and resourceful learning experiences to students by blending cutting-edge learning analytics methods with granular domain expertise that transforms current learning models into universal and contextualized education. Technology is used by smart education platforms to ensure non-venue-based education and incorporates models to enhance the "smartness" of the content and pedagogy by addressing issues like the degree of customization, the degree of ubiquity, and the degree of self- or co-regulation (Hoel & Mason, 2018).

There is a clear trend in the contemporary educational environment of movement toward smart education, which provides the opportunity to build up smart personnel for the current smart society (Semenova et al., 2017). This is evident from the emerging new smart universities employing smart technologies in their educational process and management (Semenova et al., 2017).

Conflict is currently an academic life factor, and learning institutions frequently experience tension in some cases. There exist varying forms of conflict due to its source, which have revealed different thoughts as to its definition. Thomas, (1976) defines conflict as “the process that commences when one agent perceives that the other has frustrated or is about to frustrate some of his interest”. Conflict is inevitable and inherently good because it raises and addresses challenges, energizes operations on the most relevant issues, makes agents “be real,” and motivates participation

(Smriti et al., 2013). This aids a user to learn and identify the differences and how to make them beneficial.

According to Lyapina et al. (2019), the operating system's compatibility with several smart educational procedure programs of varying teaching directions ensures the establishment of current fundamental science built on mobility and rapidity of flow of information. Hence, this demand creates new ground-breaking and technological dimensions of study to support diversified teaching and learning agents to prevent their conflicting interest in smart education in ODeL.

A systematic review of the study landscape of smart education conducted on a bibliometric analysis revealed the complete silence of investigation on the concept of conflict issues hindering the advancement of smart education in ODeL (Li & Wong, 2021). It was noted that the majority of research on smart technology for teaching and learning had little to do with hot-button concerns like the Internet of Things, big data, flipped learning, and gamification. Therefore, the QoS needed to be rendered by ODeL for smart education is limited.

The open distance learning environment presents a challenge because many of them are not adaptable and dynamic enough to offer first-rate user support. This necessitates the creation and implementation of plans for service quality in these online learning settings. According to Lee and Chong (2002), several centralized learning management systems are too rigid to adapt to the changing and fluctuating learning requirements of individual students. To support sharing and collaborative learning environments, more advanced learning management systems that can dynamically alter the content and display instructional modules based on the learner's needs are preferred (Lee & Chong, 2002). The key elements for achieving quality service in ODeL in this research are centered on secured cheating-free examination, appropriate bandwidth allocation, and conflict management. Research contributions on ODeL have been significant, but issues on quality of services remain a predominant challenge.

The foundation of Virtual Corporation is technology. Because this technology is networked, the boundless property given to that kind of organization is guaranteed. This suggests that some kinds of geographical barriers are disappearing. These businesses usually operate exclusively online, indicating that they are not bound by any certain location or time zone (Stratigea & Giaoutzi, 2000). Therefore, it is challenging to validate users on such platforms.

A virtual business can be both fully global and locally focused at the same time, even when only employing a small number of people. However, a limited bandwidth situation limits the virtual organization to a local or even personal level. As a result, managing bandwidth is crucial in a virtual workplace. Due to the information transmission delay, employee excitement was deteriorating, the CEO was preoccupied, and senior leadership was disgusted (Horton, 2009). These and numerous other issues surrounding crises in virtual organizations must be addressed.

As stated by Kovoor-Misra and Misra (2007), failures of websites are considered technical crises since they occur in the technical infrastructure of online businesses. These errors could be the result of several things, like software bugs or poor system architecture. Internet-based businesses' websites are similarly susceptible to heavy traffic and issues with their external networks (Kovoor-Misra & Misra, 2007). These provide difficulties for providing virtual organizations with excellent service, necessitating the requirement for a system to improve service quality.

A cursory review of the crises discovered in the preliminary studies of the research area identified groups including the capabilities of the communications network, compatibility problems with software and hardware, computer security, and the changing nature of technology. Figure 1.2 below illustrates this in a graph with a percentage weighting.

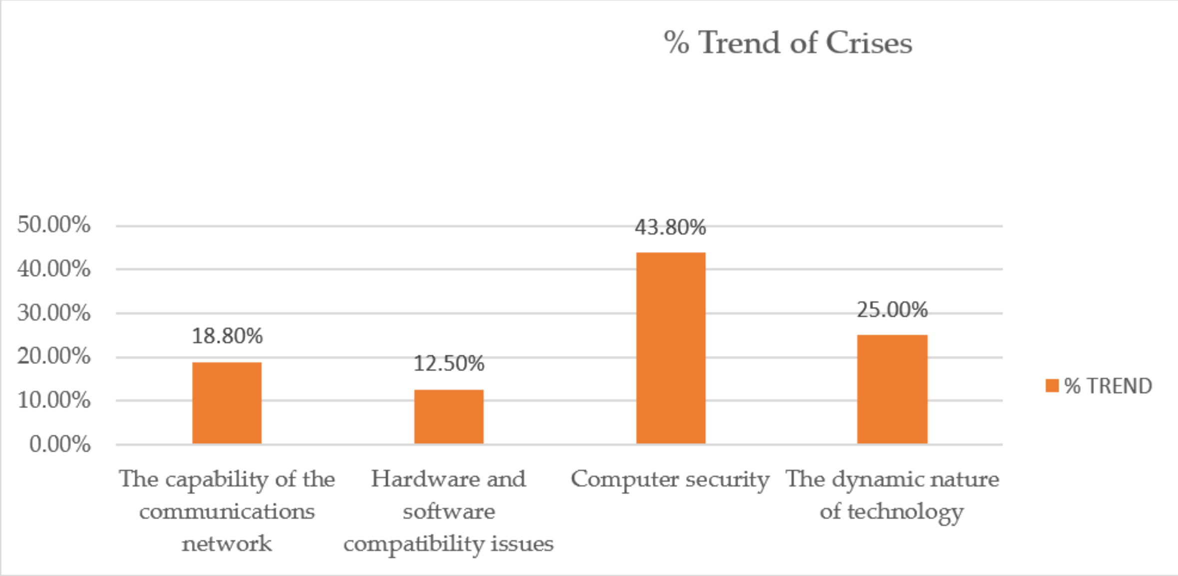


Figure 1.2: Percentage trend of crises in virtual organizations

Against this background, it is desirable to construct an intelligent model that incorporates intelligent methods and protocols to provide quality of service in ODeL.

1.3 Problem Statement

The research problem is categorized as follows:

a) There is no intelligent quality of service model for open distance electronic learning that can reorganize and adapt to changes to provide smart education.
b) The extent to which authentication is established in ODeL for a non-venue-based assessment is not optimal and affects the QoS.
c) The extent to which bandwidth management based on capacity efficiency for massive users in ODeL lacks proactiveness and limits QoS.
d) QoS in ODeL to achieve a smart education environment is affected by limited proactive conflict management.
e) There is no significant research on determining and modeling QoS in ODeL based on critical quality elements for smart education.

1.4 Research Questions

The main research question desired to be answered is:

How can an intelligent quality of service model capable of reorganization and adapting to changes be fabricated within open distance electronic learning?

The following specific questions will need to be answered in order to discuss the aforementioned core research question:

1. To what extent can authentication be established in ODeL for a non-venue-based assessment for QoS to achieve smart education?
2. To what extent can ODeL manage bandwidth based on capacity efficiency for massive users of virtual surroundings for QoS for smart education?
3. How can conflict be managed proactively within ODeL to achieve a smart education environment?
4. How can the quality of service (QoS) in ODeL be determined and modeled for smart education?

1.5 Research Objectives

The main objective of the research is:

To use methods and techniques to develop an intelligent quality of service model capable of reorganization and adapting to changes within open distance electronic learning (ODeL) for smart education.

In the quest to achieve this universal objective, the following sub-objectives are to be realized:

1. To develop a model for authentication in ODeL on a real-time execution in non-venue-based assessment for smart education. The main challenge in an open distance electronic learning environment is authenticating examinees

during examination since existing technologies cannot provide accurate authentication.

2. To develop a sustainable bandwidth planning strategy to reduce bandwidth requirements for massive users with competing services in a constrained network capacity of an ODeL environment for QoS for smart education. Considering the degree to which ODeL can regulate bandwidth based on capacity efficiency for massive virtual environments, users require appropriate management techniques to make ODeL smarter for quality teaching and learning.

3. To propose a framework for proactively managing conflict for QoS to make open distance electronic learning smarter. Smart education is the new paradigm of virtual education, but appropriate management of elements that are catalysts of conflict remains unattended. A framework serving as a guide to managing conflict in smart education is required to enhance open distance electronic learning quality.

4. To propose a framework incorporating methods and schemes to implement QoS adaptation in an ODeL. Quality of service is a key component of making the current educational system smarter. Still, methods and schemes are not organized appropriately to achieve it in an open distance electronic learning environment.

1.6 Research Design

The idea of quality has traditionally placed a strong emphasis on the creation and adoption of an institution-wide culture that prioritizes a customer-focused approach, ongoing development, empowering employees and using data to inform decisions. The alignment of product and service design with consumer expectations is what drives this philosophy, as well as from a commitment to quality across all stages of development, manufacturing, and delivery. The process-centered mindset places a strong emphasis on lowering variability and continuously enhancing the functionality of the finished good or service. Quality must be anticipated, prepared for, and integrated into products and services, as it is commonly acknowledged (Kenyon & Sen, 2015).

This research employs the mixed method to identify, prepare and integrate key quality elements in ODeL to propose a framework for intelligent quality of service in ODeL. Quantitative and experimental methods are employed for authentication and bandwidth management. Qualitative method is used for conflict management and quantitative survey for validation of the quality of service framework. Data were collected from a university learning management system and a survey for simulation and validation, respectively. Python program was used for the simulation.

A multimodal biometric authentication framework based on facial recognition, voice recognition, and keystroke dynamics is proposed, and detailed experiments are carried out to assess and validate the model's implementation.

Considering the inherent workload constraints among ODeL services competing for scarce resources, the intention is to forecast future bandwidth demands that will assist in preventing online class disruptions. A predictive framework of bandwidth management, which integrates a sustainable hidden Markov model and a normalization policy (HMM-NP), coupled with SolarWinds monitoring technology for prior network data feeder, is developed. Extensive experimental evaluation is conducted on the model.

A qualitative investigation of conflicting situations that hinder the smartness in ODeL warrants the development of a model to resolve conflicts in ODeL to promote smart education.

The final model consists of a unified framework integrating the various models for authentication, bandwidth management, and conflict management and is further validated. This is designed to showcase the implementation protocols to enhance the QoS in an ODeL environment.

1.7 Ethical Considerations of the Research

The University of South Africa's (UNISA) requirements for ethical behavior have been adhered to in full throughout this research.

The research and ethics committee of the College of Science, Engineering, and Technology (CSET), UNISA, has granted their approval for this work with reference number 2021/CSET/SOC/050.

The researcher affirms that the dissertation is his own work, that all references and quotations from sources were properly acknowledged and cited, and that neither the data nor the results were falsified.

There is not a single instance of plagiarism or forgery in this dissertation. Any instances of plagiarism were corrected using the Turnitin program. Mendeley's referencing software was used to manage reference and citations.

1.8 Scope and Limitations of the Study

1.8.1 Scope of the Research

Considering that the diversity and current advances of ODeL in particular and in the virtual organization at large have introduced a wide area of research frontiers, however, this research scope extends to the following aspects of open distance electronic learning:

- Authentication – Providing a cheating-free examination in the ODeL platform. This prevents an impersonation and a third-party assistant dictating to the examinee.

- Bandwidth management – In an ODeL environment massive users run many applications in which most consume high bandwidth under scarcely available capacity. An intelligent bandwidth consumption determiner and planner is considered.
- Conflict management – Multi-user systems generate conflict. Examples include resource conflict and goal conflict. For smarter ODeL platforms conflict resolution is key. A framework to resolve conflict in smart education models to make ODeL smarter is the focus.
- Quality of service – Identifying, classifying, and evaluating quality elements in ODeL environment is the basis for users' satisfaction. The quality elements are those that "must be", "dimensionality (single or multiple)", and "attractive". The focus on the QoS elements must be security, all dimension bandwidth access, and an attractive conflict-free learning environment.
- As part of this research a prototype of the IQSODeL framework is developed.

1.8.2 Research Limitations

The virtual organization comprises vast areas of concentration. Such areas include financial virtual platforms (such as electronic banking), business virtual environments (such as electronic commerce), and virtual learning environments (such as open distance electronic learning). This study is limited to open distance electronic learning. The specific areas of concentration in ODeL are towards the attributes that make it smarter to provide quality service.

The focus of this research is limited to assessing a tertiary institution's real-time data for evaluating the proposed models. Some existing state-of-the-art frameworks were compared with the researcher's models and the publicly available dataset.

Quality of service framework, IQSODeL is proposed as a prototype for virtual organization limited to authentication, bandwidth management, and conflict management as quality elements and then validated.

1.9 Research Synopsis

Table 1.1 provides a breakdown of the dissertation's structure.

Table 1.1: Outline of the dissertation

CHAPTER	TITLE	DESCRIPTION
Chapter 1	Introduction	This chapter deals with the general introduction for readers to gain a basic understanding of the research focus. It constitutes the background and motivation, research question, research objectives, research scope and limitations.
Chapter 2	Literature Review and Theoretical Background	Related literature survey conducted in this research revealed the works done in the following areas: • Authentication - varying techniques to provide a cheating-free examination in ODeL environment are discussed. • Bandwidth management – a myriad of bandwidth management models in virtual platforms are discussed. • Conflict management - factors of conflict in virtual organizations with emphasis on smart education are reviewed. • Quality of service elements and their implementations in virtual platforms are discussed. • Learning management systems as a key component of ODeL platform are discussed • The theoretical background on machine learning techniques employed in this study is presented. In this chapter, the gaps in the body of literature are shown.
Chapter 3	Research Design and Methodology	The chapter explains the methods and strategies for designing this research.
Chapter 4	Experimental Evaluations of ODeL Frameworks	This chapter discusses the experiments conducted on bimodal authentication, multimodal authentication and intelligent bandwidth planning models.

		Construction of conflict management model and the overall ODeL QoS model (IQSODeL).
Chapter 5	Comparative Analysis and Validation of IQSODeL model	The models constructed in this research are benchmarked with existing techniques and validation is presented in detail.
Chapter 6	Conclusions and Future Directions	The theoretical and methodological contributions of this study are discussed in this chapter along with how they answer the research questions. The research's shortcomings are emphasized, and additional future developments are suggested in this study.

1.10 Chapter Summary

Open distance electronic learning is significantly revolutionizing into smart education. Such virtual organizations face many challenges, which compounded during the COVID-19 pandemic. These challenges must be addressed by implementing intelligent frameworks that model the approaches to tackling them. This chapter generally introduced open distance electronic learning highlighting the critical challenges in virtual organizations substantiated by real-life statistics. The research objectives indicated the focused area leading to answering the outlined research questions. The scope and limitations of the study are presented to clarify the specific areas included and those excluded. In addition, this chapter presented the entire research outline by chapters.

The next chapter presents detail literature review of related works to realize the extent of considerations in the research scope and identify the gaps in literature.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The survey of the literature that is relevant to the research topic is covered in this part. Journal publications, conference proceedings, periodicals, reports, and books were primary sources of focus in this literature review. Websites and webpages were included as extra sources of information in some cases as part of the study's dimensions of information sources.

The literature covered the aspects of quality of service in ODeL focusing on the various elements that contribute to the quality concepts. Much emphasis is given to the key contributing elements, secured cheating-free ODeL examination, optimal bandwidth management, and conflict management. Learning management systems (LMSs) are reviewed as a common tool used in ODeL to ensure the level of implementation of the quality-of-service elements for smart education. The research data for experimental evaluations were obtained from LMSs. The machine learning theories used in this research as intelligent concepts to make ODeL smarter employed in the research are reviewed.

2.2 Quality of Service in ODeL

Quality in higher education is conceptualized by Harvey and Green (1993) as outstanding, perfection (or consistency), appropriateness for purpose, and value for money as five distinct but linked quality orientations. It is difficult to attain service quality in ODeL because it involves so many distinct variables, such as course design and content, learning context, rapid feedback, learning outcomes evaluation, learning settings, and support services (Hénard & Roseveare, 2012). According to Zuhairi et al. (2020), a thorough, integrated online student assistance system is required for preserving quality in ODeL.

The overall evaluation of all services offered by the institution now includes a section on the quality of service in the online environment. One of the most important issues is providing high-quality services in a virtual setting since service-oriented firms need it to become their main institutional strategy for competition (Kim & Kim, 2020). According to Demir et al. (2020), most universities in recent times attempt to comprehend the financial and strategic implications of learners' perception of value for money as the key determinant of the success of ODeL platforms and the educational system in general. The statement goes on to say that because of the effect on students' motivation and success rate, the majority of researchers have solely focused on suitable levels of learners' satisfaction in the e-learning system.

ODeL environment provides benefits necessary for quality of service in education. One benefit from the lecturers' perspective is that multiple instructors from different locations with varying profiles can participate, enriching them with cultural and educational knowledge. The access to a wider range of educational options, current knowledge trends in various fields of expertise, the required benefit from the opportunities in information and communication technology, and the chance to balance the academic, professional, and personal life effectively and comfortably are the main advantages mentioned by online educational practitioners in the BestColleges.com report on the trends in online education for 2022 (Foto et al., 2022).

According to Sadikin and Hamidah (2020), the distance between students and lecturers, which limits direct engagement, guidance, and supervision of students' actions in the learning process, is a particular problem faced by ODeL. Only via dependable internet connectivity and effective bandwidth control can this gap be closed.

In the opinion of Balasubramaniam et al. (2009), a service-oriented system like ODeL may face a variety of issues, including ensuring that the system and its components fulfill end-user quality standards. The cost and risk of meeting quality standards should be understood by service providers, who should also be aware that system characteristics usually call for trade-offs or are built in. In order to monitor and enforce service level agreements, service providers need to have enough information to compare alternatives with the same functional capabilities (Balasubramaniam et al., 2009). As a result, it is crucial to create QoS standards for ODeL.

In the view of Palvia et al. (2018), ODeL is on track to assume the mainstream of education. They do, however, highlight a number of variables that affect the quantity and quality of ODeL, including the economy, the government, national legislation, infrastructures for information and communication technology, the digital divide and the spread of the internet and mobile technology (Palvia et al., 2018).

High-level relational coordination appears to be the driving force behind higher educational quality, according to a study on the examination of interactive coordination and its relationship with the institutions' online education systems' quality (Gallego Sánchez et al., 2021). Interactive coordination is a proven method for evaluating the effectiveness of relationships and communication across functional organizational boundaries in any activity. For QoS, it is sufficient to say that coordination is required among variables like security, network bandwidth, and conflict management in ODeL. They go on to describe obtaining QoS in two additional ways. The first is the general caliber of the learning environment and technique, which suggests that decision-making should take into account effective organizational processes. The second is the technical quality, which is divided into two categories: multimedia resources and navigation and design (Gallego Sánchez et al., 2021). Hence, designing appropriate technique for security, bandwidth, and conflicts resolution in ODeL cannot be overemphasized.

In the heat of the COVID-19 pandemic, many or almost all schools at all levels introduced online learning, which propelled research to evaluate the QoS in online education. For example, Shahzad et al. (2021) evaluated the impact of QoS on systems and information on users' satisfaction, system use, and success of e-learning portals.

The findings indicated that system quality significantly affects users' satisfaction and will provide success to e-learning portals. Online learning using WhatsApp Group was suggested by Wargadinata et al. (2020) as the highly effective in the COVID-19 pandemic due to ease of use and minimal data requirement. However, an assessment by Adnan and Anwar (2020) on the success of online education in the COVID-19 pandemic as viewed by students revealed that the desired output in underdeveloped countries could not be achieved. This may be attributed to network bandwidth limitations or some other technical conflicts.

Ortiz-López et al. (2020) claim that quality evaluation initiatives, programs, and strategies are a key success element and guarantee the recent deployment and development of education on virtual platforms. Therefore, adopting high standards for evaluating the procedures, stages, and resources used in online education would provide smart virtual teaching and learning that is more dependable and efficient. In the section that follows, this study reviews the QoS standards.

2.3 Quality of Service Standards

A myriad of accredited institutions for QoS in online education focuses on diverse criteria for accreditation. Through its member organizations, the Council of Regional Accreditation Commission uses a peer evaluation procedure to assess QoS at various educational levels (C-RAC, 2020). The Western Association of Schools and Colleges' Accrediting Commission for Community and Junior Colleges assesses online learning QoS based on the availability of accurate application of procedures to determine whether substantial interaction is provided between the teacher and the learner in courses offered by distance education (Accjc, 2022). The Higher Learning Commission uses a checklist to assess the quality of programs and learning objectives across all delivery channels and locations (HLC, 2019). The Distance Education Accrediting Commission provides relevant criteria for online learning in a handbook that includes adequate materials are designed and delivered using easily available and trustworthy technologies (DEAC, 2022). The Online Learning Consortium is a membership-based resource organization that promotes quality of service (QoS) in online teaching and learning through workshops, consultancy, and research.

The Ghana Tertiary Education Commission (GTEC) has expressed its requirement for accrediting full open distance education and pointed out the network bandwidth challenges, and some other conflicting issues that affect the quality of service (GTEC, n.d.). The commission has, therefore, approved blended learning, which requires tertiary institutions to conduct teaching online for some periods and have face-to-face meetings at some other periods.

The majority of regulatory bodies that accredit ODeL develop their standards and evaluation criteria using evidence-based methods. The Quality Matters (QM) framework, which establishes national QoS norms for schools to adapt using rubrics that match the demands of various sectors in online education, is one of these evaluation criteria (Butcher & Wilson-Strydom, 2020).

According to Delva et al. (2019), Standards and evaluation norms for accrediting educational institutions are created using evidence-based methodologies. The Quality Matters (QM) framework of quality frameworks and rules is a well-liked evaluation criterion with checklist and commission. An evidence-based instrument or rubric is typically used in a faculty-oriented peer review process for ODeL course evaluation. The eight categories used by the QM standards are: course overview; learner objectives and measurement evaluation; materials and resources; learner support; learner engagement; course technology; and accessibility (Quality Matters, 2021).

Although research has shown that QM standards can be used to properly monitor and deliver QoS in ODeL (Adair & Shattuck, 2015; Hollowell et al., 2017), there are no intelligent frameworks for ensuring a secured cheating-free learning environment, bandwidth management, and conflict management. All the above agencies and framework fail to point out clearly the major quality elements for ODeL quality of service for successful smart education. This study points out the major QoS elements in ODeL as reviewed in the next section.

2.4 Quality of Service Elements in ODeL

To evaluate the QoS elements in online learning, Baradaran and Ghorbani (2020) proposed reliable infrastructure, government support, benefits and financial support, perception and knowledge, educational facilities, quality class engagements, entrance conditions, educational process, meeting students' needs, planning and flexibility of courses, information sharing, and professors' opinions as part of the 13 latent variables. A model is proposed for assessing the higher distance education quality, identified to have information and communication technologies as the major element (Mejía-Madrid & Molina-Carmona, 2016). The model constitutes five criteria that include; Relevance, Institutional environment, Curriculum plan, Academy, and Students. The model employed 36 pointers (of which 24 are quantitative and 12 are qualitative) providing explicit assessment elements. Further validation of the model was undertaken to ascertain effectiveness in evaluating the Central University of Ecuador's distant learning program's quality (Mejía-Madrid & Molina-Carmona, 2016).

Research conducted by Du et al. (2018) employed a service blueprint method to determine the elements of service process in online learning systems. The contribution is to identify the key elements affecting the quality of users' feelings and construct evaluation indicators of QoS in online education. The users' feelings are defined by how secure they feel, accomplishing their activities that require continuous bandwidth availability with conflict-free operations in the learning environment.

The University of Texas-Pan American considers the QoS elements in ODeL in three facets that constitute course materials quality, presentation quality, and student service quality. The individual quality aspects are addressed independently but prioritize the synergistic interplay among them (Davies et al., 2000). This means that conflict management as a collective measure of all other QoS concerns needs a complete synergistic interplay of all individual QoS elements.

Mursidi and Soeharto (2016) proposed the DIECU Model, which stands for the cycle of deciding, implementing, evaluating, checking, and upgrading. The model is intended for ongoing development for long-term quality assurance. The underlining concept of the DIECU Model is Internal Quality Assurance, which requires academic institutions to implement a cyclic activity quality assurance system that begins with deciding on established standards or measurements of quality assurance by the universities. Implementation of the established standards of quality assurance is the next activity in the cycle. It follows with evaluating the standards to ascertain the fulfillment of quality assurance. Then continue checking the outcome of the standards on educational quality and make the necessary upgrade if there are deficiencies in them (Mursidi & Soeharto, 2016). However, the existing standards have not established key QoS elements in ODeL to provide smart education. There is a need to decide on the main quality elements, implement them appropriately, conduct frequent evaluations, and constantly check and upgrade to meet current technological requirements in ODeL. This study identifies security, network bandwidth, and conflict management as the key elements for QoS in ODeL for smart education. The following subsections present a detailed review.

2.4.1 Secured and Cheating-Free Examination as ODeL QoS Elements

One of the main issues with attaining QoS in the ODel environment is security. It is realized in the framework of Graf (2002) depicting two concrete solutions for providing an improvement on specific security requirements in ODeL. The first part of the framework introduces secure testing on the part of the student and the second deals with confidentiality and copyright. It is revealed that one significant security issue with ODeL is successfully conducting online assessments and examinations (Glorin, 2021). For the learning certificate's validity to be guaranteed, online exams must be properly administered. According to Glorin (2021), rigorous research must be conducted to ensure effective techniques are employed to prevent cheating in ODeL. Authentication is an important security concern for QoS in ODeL among availability, integrity, and confidentiality (Huu Phuoc Dai et al., 2016). According to Graf (2002), authentication of users is a basic feature for an ODeL system since it is the foundation for access control, billing, maintenance of learning materials, user profiles, and certification. All other security issues faced by ODeL platforms are minimized by implementing appropriate and secured authentication mechanisms (Costinela-Luminita, 2011). Although research has shown that security is one of the critical QoS elements and emphasizes on authentication in ODeL dealing with security element of QoS, there is no framework that incorporates effective and efficient authentication techniques to ensure cheating-free examination in ODeL. Therefore, there is the need to establish a framework with the state-of-the-art authentication techniques to enhance QoS in ODeL.

2.4.2 Authentication as an ODeL QoS Element

The goal of authentication is to confirm that agents (users) are who they say they are. Authentication seeks to confirm the identification of ODeL students and plays a vital role in security in a non-venue-based assessment scenario (an assessment conducted for candidates to take tests from their locations without a common facility). Unlike in-person analysis, ODeL evaluation does not oversee authentication, and invigilation is fundamentally different in an unrestricted remote context (Moini & Madni, 2009). When an agent poses as someone else, impersonation dangers, specifically in e-assessment, occur in virtual organizations. It can appear on a form when a pupil gives the impostor their security information. This impersonator answers the exam on the student's behalf, or when a student simply signs into an exam and permits another to continue on his behalf, or when an examinee logs in and completes the exam on his own while receiving assistance from a helper.

Numerous schools and testing organizations have struggled with the issue of examination malpractice, which has a negative impact on educational quality. According to a report on malpractice, exam boards in England, Wales, Northern Ireland, and the UK regions awarded 2,430 fines to candidates for the summer 2016 exam series, compared to 2,460 penalties for the same exam in 2015 (Vikas, 2016b). Even in a location with invigilators, this issue is very concerning. If contact institutions recorded so much, there is a need to pay serious attention to distance assessment and make it more secure.

The need for reliable student authentication in non-venue based evaluation has prompted researchers to suggest a number of different approaches. By using "what you know", knowledge-focused authentication verifies identity (Moini & Madni, 2009). To confirm individual access to the ODeL environment, personal knowledge is required. Another technique is object-based authentication, which assumes that people who own identity items are legitimate. Presenting or utilizing tangible objects, such as electronic chip cards, magnetic cards, and digital keys, enables users to be recognized (Ullah et al., 2012).

Other strategies now being used to prevent examination misconduct in ODeL environments include, for instance, lecturers giving students exams that may be research-based and have a short deadline, making it challenging for students to get help (Sabbah, 2012). Additionally, they might be given a quiz with a time limit, which would prevent them from looking elsewhere for the answers.

These strategies have proved helpful, but they are insufficient in an ODeL atmosphere when students are under pressure and could easily enter the wrong identity, misplace tangible goods, or impersonate. More detailed authentication measures are considered in the section below.

2.4.3 User Authentication Measures

(a) Knowledge-based Authentication

By using "what you know", knowledge-based authentication validates identity. To authenticate a person's access to the online environment, they must have personal information (Bates, 1999). A legitimate user may be considered an imposter if the knowledge is forgotten.

(b) Password Systems

Password requirements have been researched in various implementations (Sabbah, 2012; Stevens, 2001). Some researchers have examined the effect of usability and security of password composition policies and management (Al-arimi, 2014; Abhishree et al., 2015). This requires constant update in order to remain secured.

(c) Passwordless System

As an improvement to the traditional username and password combination, passwordless authentication was introduced (Abhishree et al., 2015). In this user authentication measure, a password or token is generated and valid for one login session and therefore not exposed to the replay attack; also, the authentication transmission on an open and unsecured channel would not pose any apparent threat since such credentials are worthless after each login session. A fundamental problem with this authentication measure is a denial of service attack.

(d) Profile-based Authentication

As a result, students are asked profile questions that are used to develop and polish each student's profile as they study. The challenge questions are generated by the second step of verification when a student seeks access to the online exam and are taken from the student's profile (Ahmad et al., 2006; Ullah et al., 2012). However, the results of the current study suggest that usability issues that lead to the failure of profile-based authentication may be caused by memorability, question clarity, syntactic diversity, and question relevance (Ullah et al., 2014).

(e) Virtual invigilator for Authentication

Another plausible way of dealing with online examination malpractice is to introduce a virtual invigilator during the examination. Video streaming, also referred to as remote proctoring, is a mechanism that aids the examiner to track all the agent's activities while taking the exam in real-time. This mechanism does not only provide real-time monitoring of the agent but also aids in preventing impersonation. A system developed by Swapnil (2020) provides the above-stated solutions.

The challenge with these methods is that they require high bandwidth for live video streaming and, more importantly, do not provide solutions to malpractice through dictating answers by a third party. This study proposes a fused multimodal biometric authentication model applying facial recognition, keystroke dynamics, and voice recognition.

(f) Biometrics-based Authentication

Identification of a person based on physiological or behavioral traits is called biometrics. The face, hand (fingerprint, hand geometry, palm print), eye (iris and retina), ear, skin, odor, dental, and DNA are examples of often used physiological traits. In virtual organizations, voice, gait, keystroke, signature, mouse movement, and pulse are often employed behavioral traits. This section provides a discourse on, the target methods.

- **Face-based**

Face-based authentication may be a reliable authentication for a candidate in examinations in an ODeL environment. Verification of the presence of candidates in a distance education course may be done through face recognition with images captured by the use of a webcam in an online environment (Jones & Viola, 2003). The face biometric trait for recognition uses algorithms for pattern matching and image recognition to confirm the user's identity. Remarkable research has successfully contributed to face-based authentication (Li et al., 2015; Ouloul et al., 2012). This measure's difficulty may be severe facial damage after training of sample data; else it provides more accurate results.

- **Voice-based Authentication**

Extensive investigations have been done on voice authentication (Saquib et al., 2010). The work of Barbu et al. (2016) indicates that fusing multiple biometrics is a vital process for any multimodal agent authentication system for performance and accuracy enhancement. They proposed a text-dependent voice authentication technique that recognizes the sequence of same-speech vocal expressions. The speech feature extraction employs the popular cepstral and Mel-cepstral analysis presented by Zheng et al. (2001). A short-time analysis of each vocal expression is performed on the features that divide the speech signal into overlapping segments.

A voice recognition system is characterized by two primary states of operation, training, and testing. As depicted in Figure 2.1, during training, the agent's voice is captured and digitized to derive a "voiceprint", which is enrolled and compared over a length of time to ascertain its uniqueness. The voiceprints are saved in a repository for future assessment during authentication. The testing state extracts the agent's voice, matches it against the voiceprint in the repository, and then determines the agent's authenticity for acceptance or rejection into the system (Morgan, 2012).

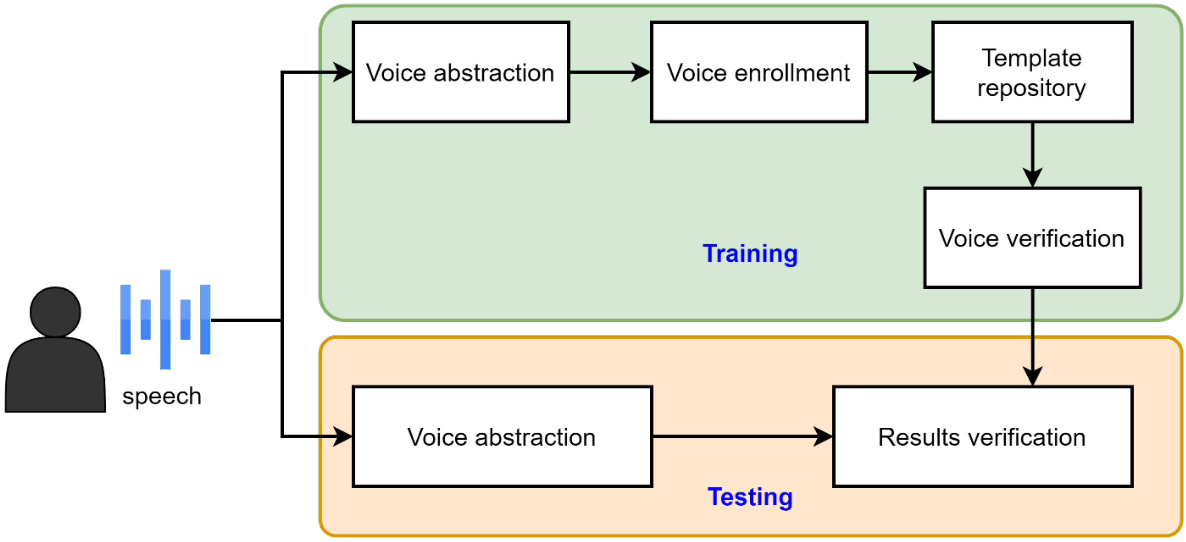


Figure 2.1: Voice recognition system

Voice recognition has been employed in many applications for authentication. Several techniques have been presented in research on voice recognition. The work of Barbu et al. (2016) employed the Mel-Ceptral technique for voice recognition in which text-dependent featured a sequence of same-speech vocal utterances for recognition. Voice authentication for the confidentiality of data for traffic security in communication with voice over internet protocol calls is proposed (Elshamy & Hussein, 2017). A study implements a voice biometric authentication system in an Android smartphone environment. After introducing the speech features database, voice recognition, and authentication system flow, a random shuffling mechanism for creating a voice cipher is introduced. Following that, speech feature extraction based on mel-frequency cepstral coefficients (MFCC) is used, and the voiceprint feature model of voice segmentation data is successfully trained using the Gaussian mixture model (GMM) (Zhang et al., 2018).

According to You et al. (2010), the Gaussian mixture model is realized to be effective and scalable for modeling the spectral distribution of speech dealing with text-independent speaker recognition. Hidden Markov Model (HMM) based voice authentication has been employed for storing the voiceprint of an agent uniquely and then applied for recognition. HMM has been used widely in speech recognition, but its implementation in voice authentication is employed on text-independent to recognize a speaker with no reliance on a specific spoken text but solely on the speaker’s voice (Jayamaha et al., 2008). An authentication technique for recognizing an agent’s unique digital voice portrait capable of functioning in direct streaming in real-time and in on-Board telecommunication components is developed for use in cloud networks (Melnik & Smirnov, 2019). The Cyber Security Research Center at London Metropolitan University has developed a number of research prototypes on the use of voice assistants to support financial and commercial activities with high-security level authentication in banking and online payment (Vassilev & Lane, 2020).

It is therefore, realized that the benefits of using voice authentication in many services are significant. The efficiency and user acceptance of the technology has been proven across many implementations involving many enrolled users (Smallman & Consulting, 2020). The challenge in this method is the inability to distinguish between the user’s speech, other people's speech, and background noise, which could result in confusion and mistakes during transcription. Also, people now make deep fakes using the recent developments in artificial media technology. These are false human voices that are created synthetically and sound just like the real thing. This research realized the fusion of methods to eliminate such deficiencies.

- **Keystroke Dynamics Based**

Analyzing typing rhythms to discriminate among agents is a mechanism to detect imposters or unauthorized users of a system. Keystroke dynamics is the name of the analysis. Keystroke dynamics is a behavioral biometric method to recognize a person's keyboard typing style. Keystroke dynamics have been successfully used in a significant amount of research for authentication (Giot et al., 2010; Alves et al., 2014; Liu et al., 2015).

Keystroke dynamics is regarded as a unique biometric technique that is transparent, affordable, and unobtrusive (Gupta et al., 2015). The most desirable qualities of a verification system are produced by the combination of keystroke dynamics and face recognition.

A continuous authentication of a multimodal biometric method is proposed to verify students in an e-learning platform (Fenu et al., 2018). This method combines facial, voice, keystrokes, touch, and mouse for continuous user authentication. It is obvious that multiple authentication methods increase accuracy but also increase the complexity of the verification system, requiring high processing time and network bandwidth in an ODeL. The combination of facial, voice, and keystroke features is optimal since touch and mouse features are duplicates of a keystroke.

Although decision-level fusion strategies are seen to be more superficial and too stiff given the scant information at hand. But the majority voting approach at the decision level may be the fusion strategy (Korves et al., n.d.). Significant authentication methods include weighted voting based on Dempster-evidence Shafer's theory, AND/OR rules, and the behavior knowledge space technique (Lam & Suen, 1995). In this research, the weighted voting approach combined with AND/OR rules. The challenge with keystroke dynamics authentication is that a user under certain emotional conditions may exhibit inconsistent rhythm and cause failure in authentication. Analysis of the authentication measures is presented in the next section.

2.4.4 Analysis of Authentication Measures

Table 2.1 summarizes the authentication measures used in virtual organizations, highlighting the measures, types, and examples, suitable for distance learning assessment and its vulnerabilities.

Table 2.1: Comparison of authentication measures for ODeL

MEASURES TYPE	EXAMPLES	SUITABLE FOR ODeL	VULNERABILITY

Knowledge-based Authentication (Al-arimi, 2014; Abhishree et al., 2015)	User-ID and password scheme	Suitable	1. Share of login credentials with a third party. 2. Dictionary attacks & brute-forcing attempts. 3. Impersonation is possible
	Challenge questions or security questions	Suitable	1. Brute force attacks 2. Impersonation is possible
	Passwordless authentication	Suitable	1. Denial of service attack 2. It is expensive 3. Impersonation is possible
Profile-based Authentication (Bates, 1999)	Personal information, education, professional experience, activities, learning activities, hobbies, and future objectives.	Suitable	1. Sharing of login credentials with a third party. 2. Impersonation is possible
Object-based Authentication (P. Zhang et al., 2015)	Electronic chip cards, RFID tag, digital keys, and magnetic cards,.	Not suitable	1. Items could be compromised or transferred to a third party. 2. May require special purpose devices
Biometric Features Authentication (Li et al., 2015 (Vassilev & Lane, 2020)	Physiological characteristics: hand (hand geometry, fingerprint, palm print), eye (iris and retina), skin, ear, dental, odor, DNA, and voice	Suitable	1. Error correction coding is required because biometric measurements are fuzzily defined. 2. May require special purpose devices 3. Difficult to impersonate
	Behavioral characteristics: keystroke, voice, gait, mouse movement, signature, and pulse	Suitable	
Location-based Authentication Swapnil (2020)	Geo-location based	Suitable	1. May require continuous connection to the location. 2. Impersonation is possible
Proxy-based Authentication (Bukkawar & Pathan, 2017)	User's device or terminal	Suitable	1. Can be easily compromised 2. Impersonation is possible
Time-constrained and Disabled	Research-based exams with limited time making it difficult for a student to seek assistance.	Suitable	1. May not be implemented in most critical authentication schemes.

Software Method Swapnil (2020)	A student takes a quiz under insufficient time to complete	Suitable	2. Students can be smarter and faster
	A software that disables access to all online applications during the examination	Suitable	

Almost all the authentication methods discussed are suitable for ODeL. However, each of them is limited to providing optimal cheating-free examination for quality of service in ODeL. This research considers fusion of the most appropriate and efficient techniques to provide cheating-free examination in ODeL for QoS.

2.4.5 Bandwidth Management as ODeL QoS Element

Much research conducted over the years concerning bandwidth management has revealed different techniques. For example, Random Early Detection and Stabilized Random Early Detection queue-based bandwidth estimation schemes maintain a data structure for estimating the number of active connections and determining inappropriate candidate flow. However, it fails to provide a simple router technique for penalizing (Victor, 2007). Another queue-based bandwidth management technique, CHOKe introduced as a stateless queue management method that bridges fairness and simplicity (Pan et al., 2000). These suggest future research into algorithms' performance with a broader range of parameters, varying topologies of network and absolute traffic traces, attaining more precise theoretical models, and hardware implementation issues.

Other bandwidth management schemes include those based on sharing (Huang et al., 2016), and gaming theory (Fang & Bensaou, 2004), which demand an enhanced traffic prediction for the bandwidth allocation model. There is a wide range of traffic prediction schemes for bandwidth management, including the Linear time-series model (Box et al., 2015), L-PREDEC (Wei et al., 2010), and Fractional Auto Regressive

Integrated Moving Average (FARIMA) (Sadek et al., 2003). The Least Mean Square model is another traffic prediction model for bandwidth management (Fu et al., 2012). Further research will require complex protocols for bandwidth management and security for massive access networks on these techniques. Other future intentions are to employ efficient but straightforward machine learning techniques to predict and allocate bandwidth appropriately.

Although the linear model and the Least Mean Square have significantly affected bandwidth management, Recurrent Neural Network models with more complex time-series data can provide better bandwidth management. A RNN variation called Deep Long Short Term Memory (DLSTM) is used for bandwidth management (Cenggoro & Siahaan, 2016). For Sleep/Doze-Mode Passive Optical Networks, a Bayesian Estimation and Prediction-Based Dynamic Bandwidth Allocation Algorithm is provided (Pubuduni et al., 2014). The Borrow-Return-Preempt (BRP), a technique bandwidth management, which can be used to distribute bandwidth to specific requests of each type of application is proposed (Xu et al., 2016). Further application of the model in a variety of data centers stated as a consideration in the future.

Although there is quite a significant amount of research on bandwidth management schemes, not much has been done in managing bandwidth in the ODeL environment, and no appropriate estimated required bandwidth for services and users. Coping with this requires appropriate technology for managing bandwidth to satisfy all users with a massive number of services in a constrained resource environment.

This study employs proactive sustainable bandwidth planning based on HMM and normalization. Prior knowledge of off-peak and peak periods used to train HMM for predicting network performances. Allocation of bandwidths normalized based on constraints. The purpose of emerged HMM (HMMα) is to optimize the bandwidth allocation to many services based on interaction with SolarWinds Network Performance monitoring technologies and performance databases.

2.4.6 Bandwidth Management Schemes

The following subsections present the conventional bandwidth management techniques:

(a) Traffic Management

The ability of the network to give particular classes of traffic preference is referred to as traffic management. For instance, it's necessary when there are one or more delay-sensitive, learning-critical applications and rare bandwidth availability. Preferential treatment in this context might entail reducing the bandwidth that particular applications, like email, received while also maintaining fairness for all the agents of some learning-critical, delay-sensitive application. Making sure all agents of a specific application receive at least a certain amount (for example, 25 Kbps) of bandwidth is one technique to assure fairness.

Additionally, any anomalous traffic must be immediately reported to administrators via a real-time alert. System administrators can then put in place the necessary policies to address the problem immediately. The administrator can simply allot fixed bandwidth to each user during peak hours to guarantee that each user has a steady connection to the main systems and the internet.

(b) Complete Sharing (CS)

In Complete Sharing, as opined by Gavious and Rosberg (1994), it is impossible to exert any control over how well each agent performs. It is the simplest prospective method and performs well with light loads. However, a well-designed network shouldn't be constantly lightly laden.

(c) Complete Partitioning (CP)

In Complete Partitioning, strict regulation over an agent's performance is exercised, but resources wastage is a subject of critical concern. Nevertheless, this technique works very well under high load conditions except for different agent's demands that can be estimated accurately (Jordan et al., 2010).

(d) Virtual Partitioning (VPT)

VPT is regarded as combining CS and CP methods. It does not waste resources, but how effectively different agents share resources depends on the capacities that have been assigned to them. Additionally, other agents' blocking rates are not strictly regulated, particularly when the traffic is not stationary (Alwakeel & Prasetijo, 2014).

(e) Caching

About the work of Cenggoro and Siahaan (2016), accelerating the delivery of content and optimizing WAN bandwidth use motivate the current application of caching. When viewed in this light, caching may be considered a technique where storage resources are used in a way that makes the WAN appear to have received a bandwidth improvement. However, only increasing bandwidth won't be enough to improve underperforming applications. As a result, learning-critical programs will still need to be protected because bandwidth will continue to be limited. Utilizing bandwidth-enhancement strategies like caching in conjunction with traffic management is the answer.

(f) Compression

Compression's main purpose is to reduce a file's size so that it may be transmitted over a WAN. In this regard, caching and compression might be viewed as being extremely similar. Particularly, compression can occasionally make the WAN behave as though it had undergone a one-time bandwidth increase (Cenggoro & Siahaan, 2016). However, implementing compression does not address subpar application performance, as was the case with caching. As was already said, the solution to that issue is to combine traffic management with bandwidth enhancement strategies like compression.

All the above conventional bandwidth management techniques may be efficient in smaller network systems because they do not optimize bandwidth on predictive demand. ODeL needs to deliberately construct their network 'smarter' and not just 'fatter' to optimize bandwidth truly. ODeL will make the most of its network infrastructure if it handles the issue in this manner. Table 2.2 presents a comparison of the bandwidth management methods.

Table 2.2: Comparison of bandwidth management methods

Bandwidth management techniques	Specific model used	Data set used	Strength	Weakness	Accuracy (%) concerning the data used	Administrative control	Effectiveness on Network load	The efficiency of Bandwidth usage
Complete sharing (CS) (Gavious & Rosberg, 1994)	A stochastic knapsack problem with a restricted complete sharing strategy in B-ISDN	Traffic classes of homogeneous and heterogeneous importance indices	Performance is quite close to optimal for equal importance indices	Significant improvement only in heterogeneous indices	70% – 78%	Some level of admin control required	Effective under light loads	Less efficient
Complete partitioning (CP) (Jordan et al., 2010)	The recursive algorithm based complete bandwidth partitioning	The bandwidth of fixed classes of revenue generated by admitted connections	Often employed for simplicity and provides the capacity to determine optimal complete partitioning policy on bandwidth with comparatively fewer complexities.	It does not apply to multiple resources among multiple services, specifically when bandwidth allocation is on multiple intersecting routes simultaneously.	96%	Strict admin control required	Effective only if high load demand can be estimated	Moderately efficient
Virtual Partitioning (VPT) (Alwakeel & Prasetijo, 2014)	A VANET's based Virtual Persistent bandwidth partitioning manager in	Packet simulation based on NS-2 Network Simulator software.	When the network is congested, it offers better performance for higher-priority messages.	Real-life data accuracy is not guaranteed.	95%	Some level of admin control but not over blocking rates	Practical only when traffic is non-stationary	Moderately efficient

	broadcast channel							
Caching (Natarajan & Das, 2018)	Cache based popularity rank computed using the MooD	Current demand estimation for the content.	Compared to current ideas of non-caching standard architecture, it offers decreased latency.	Due to the delivery path's increased number of processing nodes and transmission lines, there are significant additional processing expenses.	27% improvement in latency	High admin control required	Effective under light loads	Less efficient
Compression (Sun et al., 2017)	Bandwidth utilization in 5G networks based on scalable header compression technique	The capacity, the flow table size, and the lookup Delay.	Allows for the compression of a large number of data flows and offers effective and efficient bandwidth use.	Lookup delay could not be significantly improved.	The relative error of less than 6%	High admin control required	Require other techniques to be effective	Less efficient
Proposed HMMα-Planner	HMM and normalization policy	Peak and off-peak bandwidth utilization of a university	Capable of providing a sustainable bandwidth plan	Not yet identified	94%	No admin control is required to plan under bandwidth constraint, as supported by Figure 3.5.	Effective under all types of loads as revealed in Figures 4.19 and Figure 4.20	Comparatively highly efficient, as indicated in Figure 4.22 – Figure 4.30

The review indicates that existing state of the art techniques for bandwidth management are deficient in providing optimal allocation for massive users in ODeL for QoS. Such gap is filled with a proactive bandwidth allocation model in this study.

2.4.7 Conflict Management as ODeL QoS Element

Conflict management is a critical issue in every establishment since it is a key element in the quality of service. Managing conflict in ODeL is to make ODeL institutions smarter. It is important that smart universities providing smart education need to pay much attention to conflict management. This section discusses smart education and the concept of conflict and its management and the gaps in literature.

(a) Smart Education in ODeL

By analyzing smart education projects conducted by some developed countries, Zhu et al. (2016) established some general concepts on smart education. They indicate that smart education attempts to help the workforce develop knowledge for the twenty-first century and skills for societal needs and challenges. In order to enable timeless and boundary-less learning, which encompasses a variety of learning styles, including formal and informal learning, personal learning, and social learning, and aims to achieve continuity of learners' learning experiences, intelligence technology is a significant key player in the construction of smart educational environments. Again, Zhu et al. (2016) define ‘smart’ regarding the educational environment as engaging, intelligent, and scalable. In order to support customized and individualized learning, the environment must include features like context awareness, content adaptability, collaborative and interactive tools, quick evaluation, real-time feedback, and eventually handling every dispute. Soaring to engage the learner in meaningful learning with effectiveness and efficiency is paramount to QoS. It must be possible to integrate cutting-edge interfaces, smart devices, and a variety of learning data in a conflict-free operating learning environment, which is one of the prerequisites for open system design.

(b) Basic Requirements of Smart Education in ODeL

To consider ODeL systems as fit for smart education, researchers have specified some basic requirements for smart education as QoS standards.

- *Information-oriented Teaching Environment*

Smart technologies including big data, cloud computing, IoT, and mobile internet are used in an information-oriented teaching environment to create the entire teaching and learning environment (Cui, 2020). The big data in education should compose a fusion of large-scale integrated educational resources in the educational information system, realize the accurate and detailed resources distribution, personalized information pushing, and generate data intelligence-driven ecological closed-loop information in the teaching and learning information system platform (Liu 2019).

- *Teaching and Learning Data Collection*

According to Hu et al. (2020), to elicit the learning data, course data, and student interaction data from classes, techniques for gathering teaching and learning data must be built on IoT and mobile internet. The IoT-based data collection is useful for obtaining and studying IoT data for classrooms, including data on the hardware used in classrooms, video monitoring data, data on human bodies, and other IoT content data. Large-scale data collection on teaching and learning is important because it may be used to determine numerous factors and models that are based on real-world circumstances and demands. Therefore, this will promote the knowledge of students learning situations from different aspects and dimensions.

- *Application Systems Integration*

The educational institutions service system providing smart education includes scientific research, community life, and teaching and learning processes. The creation of a distributed application system based on interactive cloud computing helps to facilitate management staff decision-making, all-around, real-time teaching and learning. Data fusion and big data technology must be integrated into the service information system (Liu, 2019).

- *Teaching and Learning Resource Sharing*

One of the vital requirements of smart education is making resources available to all agents in the educational environment in real time. The service platform needs to accumulate, integrate, and share teaching and learning resources of every discipline (Hu et al., 2020). In context-aware ubiquitous teaching and learning, standard and resource libraries for sharing, communication, and teaching resource accumulation require construction. In supporting learning activities both online and offline, this will discuss design and development considerations for smart learning environments.

- *Smart Learning Analytics*

Clow (2013) stated that learning analytics can create a unique learning experience based on strengths, weaknesses, and individual preferences. By estimating, organizing, analyzing, and reporting contextual learner data to comprehend and improve learning and learning platforms, learning analytics (LA) is regarded as important to education (Siemens & Baker, 2010). Learning analytics can, therefore, reveal the conflicting issues among learners and trainers in smart education. Smart LA can be useful in preventing conflict in smart education since it can intensify the customized teaching and learning experience at levels of observing all learning activities at a finer granularity consisting of instructors teaching episodes, students' study episodes, completion episodes, and assessment preparation.

The works of Kumar and Vivekanandan (2018) study a number of exemplary Smart LA implementations and highlight their key components to show how instructors may use Smart LA to better understand the efforts their students are making to improve learning experiences. Testing on various learning platforms, learning sensors, and learning fields is all included in smart LA. Research considerations on Smart LA have centered on ways instructors can better understand competence in designing smart environments and existing technologies applications (Kumar &

Vivekanandan, 2018; Trætteberg et al., 2016). However, no consideration of it in applying Smart LA as a criterion for conflict management in virtual learning environments is found.

It is opined by Zhu et al. (2016) that achieving a personalized learning experience in smart education requires the smart learning environment to offer precise and comprehensive learning services facilitated by learning analytics. As a result, they list the following ten characteristics of a smart learning environment: interoperability, seamless connectivity, adaptability, ubiquitousness, whole record, natural interaction, and high engagement. These features require proper conflict management to enhance the smart learning environment.

This study considers Smart LA as a practical component in modeling conflict management framework in smart education in the sense that it encourages self-regulated and collaborative learning by recognizing areas in need of improvement and recommending appropriate instructional strategies and materials.

- *Data Governance*

As presented in the work of Hu et al. (2020), high integrity, a global perspective, homogeneity, and standardization are necessary for the implementation of big data technology in order to avoid data challenges such as a lack of data criteria, data loss, a lack of authoritative sources, data redundancy, a lack of accuracy, data unavailability, and other data conflicts. In order to provide a worldwide data center and software system for the whole data management life-cycle, proper data governance strategies must be applied in smart education. As a result, this will provide data support for the environment of the smart education service and ensure long-term system validity for QoS.

(c) Conflict in Smart Education

In the perspective of Ozturk and Simsek (2012), conflict is the perceived overt or hidden events generated from a different group of agents, triggered by dynamics of the conflict having a role in the smart education process. When agents work together to achieve a common goal, they mostly come together in different relationships with varying life conditions; they can generate diverse certainties, logic patterns, and values (Gergen, 2003). The agents' differences in smart education are critical issues in the emergence of conflict. The dynamic nature of agents in virtual organizations and specifically in smart education does not necessarily indicate that conflict exists among them as it is possible to avoid. On the contrary, when agents suggest opposing arguments, they may not even experience differences. Thus, if the participating agents' activities and culture in the educational environment accommodate the differences, the knowledge production and acquisition processes and anxieties are expressed on approaching deadlines, coupled with an internal dynamic of ontological insecurities that may cause conflict to arise.

Research on the role of conflict in general centers on the two contrasting views, emphasizing the negative or positive. However, some other research considers the neutral approach to explore the concept openly to avoid bias. Conflict in teaching and learning may have an impact on students' learning preferences, involvement in collaborative and cooperative learning, and chaos. Typically, conflict has the potential to result in resolution, compliance, disintegration, and dropouts (Ozturk & Simsek, 2012). In the context of democratic pedagogy, the study further investigates the practical appearance of conflict and students' experiences in virtual learning settings. Conflict dynamics play a significant role in the emergence or avoidance of conflict in teaching and learning and require much attention to achieving smart education for QoS.

The research conducted by Semenova et al. (2017) indicates that the characteristics of a university providing smart education include:

- the presence of a unique intellectual platform for the continued development of proficiencies of the subjects and the objects of education processes that presume formal and informal education.

- an active implementation of smart devices and smart technologies in the educational process based on the highly developed technical infrastructure of the university.
- a unified data description standard-based education content design.
- a portable software developed to meet varying operational systems to guarantee equal usage for all agents of the educational procedure without device type limitations.
- a whole range of adaptive educational programs to create a comprehensively tailored education.
- an application of neuro-agents for data collection and processing concerning the commencement and completion of academic programs. Therefore, knowledge control and learning analytics are required to provide maximum adaptation of the teaching and learning procedure.
- a smart curriculum designed by practical experts with efficacy evaluation.

Smart technology-based e-learning and mobile learning systems give students widespread access to instructional content from around the world, regardless of time or location. The integration of social networks into the educational process, a well-built electronic university, a highly managed network, and cloud storage for instructional content are thus necessary.

It is emphatic that only a few universities have these characteristics, suggesting that many conflicts exist in many smart educational institutions; hence, the need to establish a framework for conflict management for smart education in ODeL to improve the QoS.

Agents and other resources in a smart learning environment are likely to be shared, as are the systems that control them. The decisions made by one agent may have an impact on others when taking into account a shared bandwidth. Each agent may need a separate stage configuration because each agent's intentions can change at any given time. However, because these various contexts demand different conditions, they frequently cannot be active simultaneously on the same bandwidth. Therefore, it suffices to claim that a conflict scenario exists. There is potential for more friction because of the collaboration of applications in smart education platforms. The conclusion is that for a system to successfully resolve conflict, it must be able to deal with user ownership and priority in order to modify its behavior. User interaction in a multi-user system, such a smart education platform, may require categorization control layers, much like in human organizations. This is especially true when the task environment is dynamic, complicated, and uncertain, as described by Lee (2010).

Systems must be able to handle a variety of conflicts on behalf of users, or else they will have to accept their limitations and tell users that the conflict has been addressed directly, which is not a proactive approach. Although influenced by several causes, each agent is fundamentally unique and constantly evolving, leading to different goals and mental models that are less predictable and, in some instances, in contradiction. Context inference becomes considerably more difficult in smart schooling. It presents difficulties in separating the interests of each actor and resolving conflicts between those desires (Hasan et al., 2006). The difficulty of tracing the objectives and, consequently, the context of each agent, severely limits the system's capacity to react correctly. Resolution of a conflict between multiple agents is more difficult than one agent. As a result, the number of agents varies in direct proportion to how challenging context inference and conflict resolution are.

According to Park and Lee (2005), the notion of conflict varies from context-aware application to application, and each actuator on a ubiquitous system may influence the context by altering the actual environment in which it is located. User or application conflict is defined as "... a context change that results in a state of the environment that the application or user considers inadmissible" (Tuttlies & Schiele, 2007). In a smart education environment, compared to other systems, the likelihood of conflict is higher because of a variety of factors, including the services used and the movement of entities (Syukur & Loke, 2005).

According to a study, measuring the smart education readiness index in Bandung, Indonesia, which is a city with a high concentration of educational institutions and is strategically located for the development of the smart education concept, scored 64.46% ready (Indrawati et al., 2018). Hence, this suggests that about 35% of conflicting issues hinder the readiness for smart education implementation. The work of Xiangwei. Zheng et al. (2009) proposed a simulated annealing technique for course scheduling. The most significant conflicts are the timetable elements and average distribution of courses for each class, classroom, teacher, campus, and others per week. Resource conflict is, therefore, a significant issue in smart education for QoS in ODeL. This research addresses network bandwidth as a major resource conflict in ODeL, which has not been indicated in literature.

(d) Conflict Classification in Smart Education

As previously mentioned, many conflicts can arise in various dimensions based on their origin, intervenient, detection time, and resolvability. Concerning the source, according to Carreira et al. (2014), a conflict can occur at the resource level when multiple users access a given resource, the application level when multiple users access an application, the policy level when multiple users access a given application, the profile level (also known as the role level) when multiple users have conflicting user profiles and preferences in the same context, or any other level in between. On the basis of intervenient, they once more proposed that conflict situations can either be single-user—where one user's intentions are at odds with one another—or user vs. user (multi-user). They also suggested that user vs. bandwidth—where user actions are at odds with any established bandwidth allocation policies—falls under the category of resource-related conflict.

Conflicts that are detected as priori anticipated to occur are classified as such in their submission on the detection time as another method of classifying conflicts. This is referred to as a possible conflict in some writings (Ibrhim et al., 2021; Kempter & Danciu, 2005). More frequently, it can also be a conflict that will definitely happen if the agent is in the right situation, or it can be a conflict whose likelihood of happening is lower than that of a specific probable conflict because it might still not happen even if the user is in the right situation and at the right time. Additionally, if a conflict arises, it can be identified (also known as an actual conflict), either by using the context-awareness features of the structure or by getting user feedback. The last situation is when a conflict is detected only after enough time has passed to resolve it, maybe as a result of limitations on context awareness or sensing delays (Lee, 2010). They contend that, in the best-case scenario, conflict is addressed before detecting it and is considered avoidable, classifying situations according to their capacity to resolve conflict. If not detected prior to the occurrence, then the resolution technique is applied.

In most cases, a conflict is detected when it really occurs, at which point the system either tries to resolve it or recognizes that it is unable to do so. Another possibility is that the system may not detect a conflict early enough to resolve it, but rather realizes it later, perhaps due to a delay in a sensor's response. In this case, the system can only acknowledge the conflict's occurrence, include it in routine learning processes, and even alert system administrators to the issue to make future improvements. Figure 2.2 summarizes the conflict classification in ODeL.

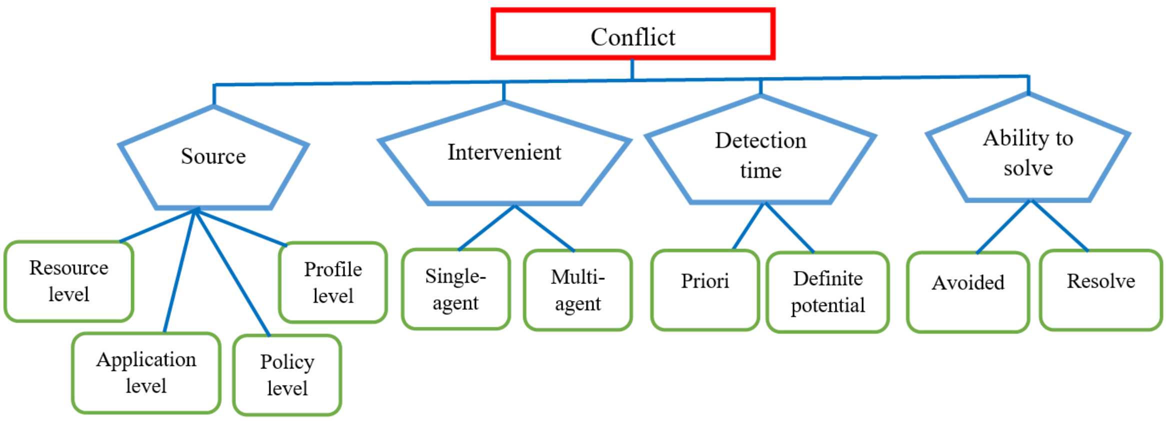


Figure 2.2: Conflict classification (author's compilation)

This classification reveals the various possible conflicts affecting the progress of smart education in ODeL for QoS. The classification leads to the identifying models useful for managing the conflict to enhance smart education in ODeL.

(e) Conflict Management Model for Smart Education in ODeL

Meng et al. (2020) proposed a smart pedagogy framework based on the "SMART" key elements model "(situated learning (S), mastery learning (M), adaptive learning (A), reflective learning (R) and thinking tools (T))," curriculum design method and detailed teaching strategy. A significant result revealed that smart pedagogy promotes learning outcomes but fails to address the conflict between teaching and learning agents and their environment.

Also, Tentori and Rodriguez (2011) present a multi-agent architecture that supports subjective coordination by allowing activity awareness and including elements that allow independent agents to broadcast activity events and gain context from activity recognition. Users keep track of changes in activity characteristics declared in a common language and use a context model to represent e-activities and support specific inquiries. Users are able to perceive coworkers and items when they are in use, which suggests that a cognitive component will estimate activity and, as a result, take the proper action.

Education 4.0 requirements respond to the technological commitment influenced (Hartono et al., 2018), proposed a smart hybrid learning technique and architectural framework with a three-layer architecture approach. This system provides a platform for all inclusion learning in smart education and solves the problem of remote areas without continuous internet access. The smart hybrid learning approach combines case-based learning, challenge-based learning, and the flipped classroom approaches. Although the framework points out solutions to essential issues in smart learning, specifically providing an all-inclusive learning platform, it does not consider the inevitable management of conflict in such an all-inclusive platform. The model is, therefore, reconstructed with the inclusion of conflict management presented in Figure 2.3.

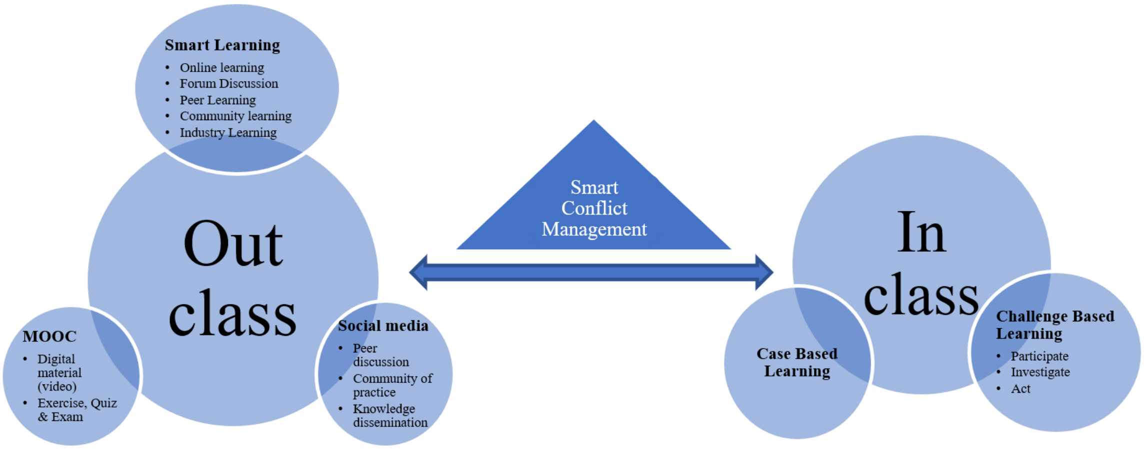


Figure 2.3: Enhanced smart hybrid learning method model (Hartono et al., 2018)

Apart from improving the smart hybrid learning method to resolve conflicting situations, the proposed conceptual model of the smart hybrid learning technique is enhanced and Figure 2.4 shows that.

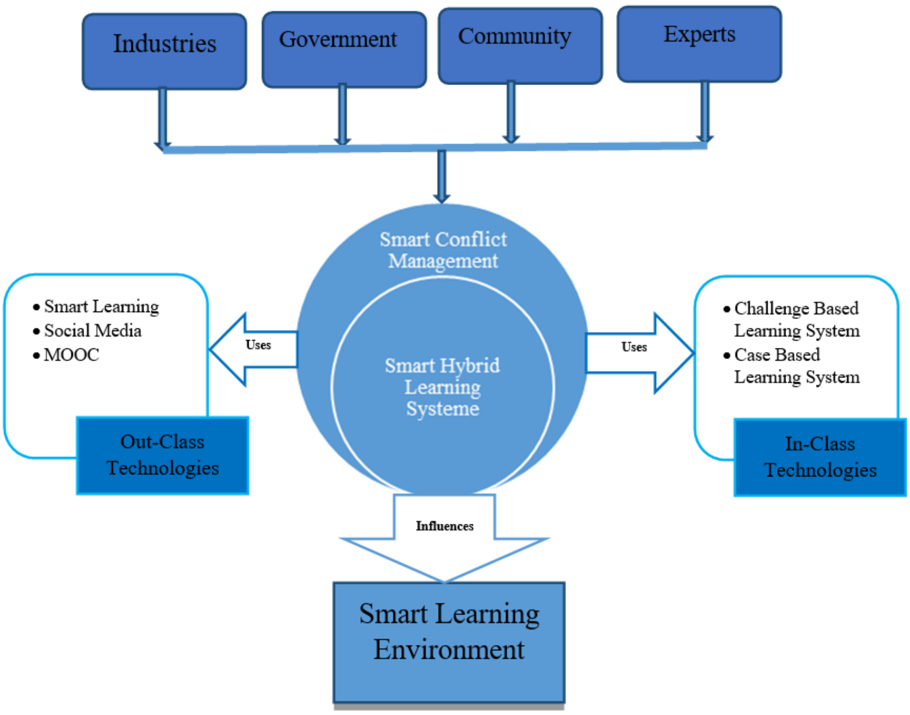


Figure 2 4: Conceptual framework of smart hybrid learning technique (Hartono et al., 2018)

In the previous study, Indrawati et al. (2018) provides a summarized smart education and improved model for measuring its readiness index. This research, therefore, further improves the model to include conflict management, which is not incorporated but is very significant, as shown in Figure 2.5. The readiness index is the indicator for commencing smart education in a smart campus of a smart city.

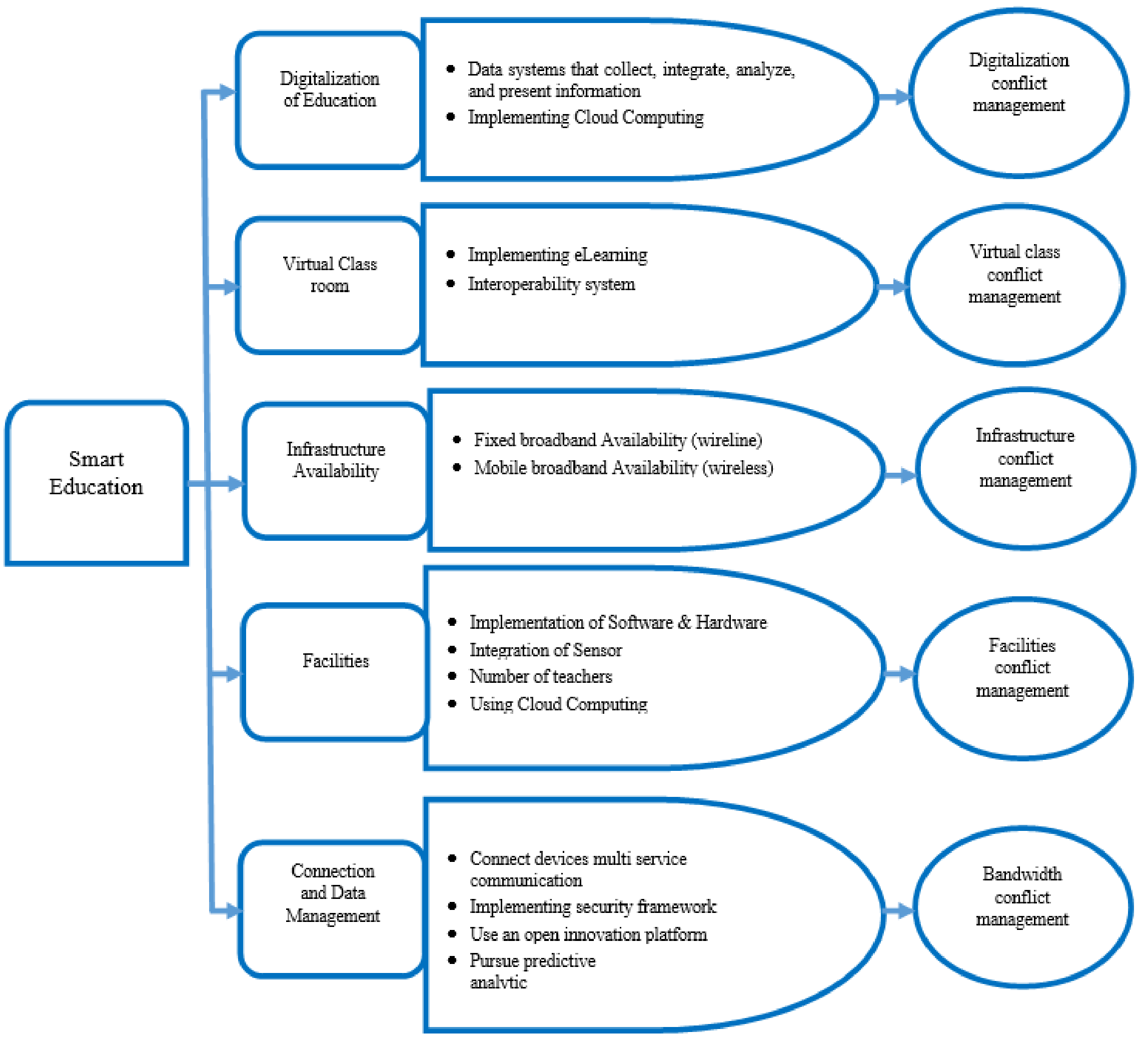


Figure 2.5: Improved model for measuring smart education readiness index Indrawati et al. (2018)

They came to the conclusion that in order to execute smart education as effectively as possible, stakeholders must continually improve their practices. Each indicator features a different set of advantages, disadvantages, and conflicts. Each indicator requires immediate settlement of every issue that becomes the focal point of conflict.

Considering the broad trends in smart education across nations and what it means to be "smart", Zhu et al. (2016) proposed a conceptual a structure for smart education. Three key elements of smart education are described in the framework: a smart environment, a smart learner, and a smart pedagogy. These three essential components need not have conflicting issues to provide effective and efficient smart education. Hence, Figure 2.6 presents an improved framework that considers conflict management with the three essential components.

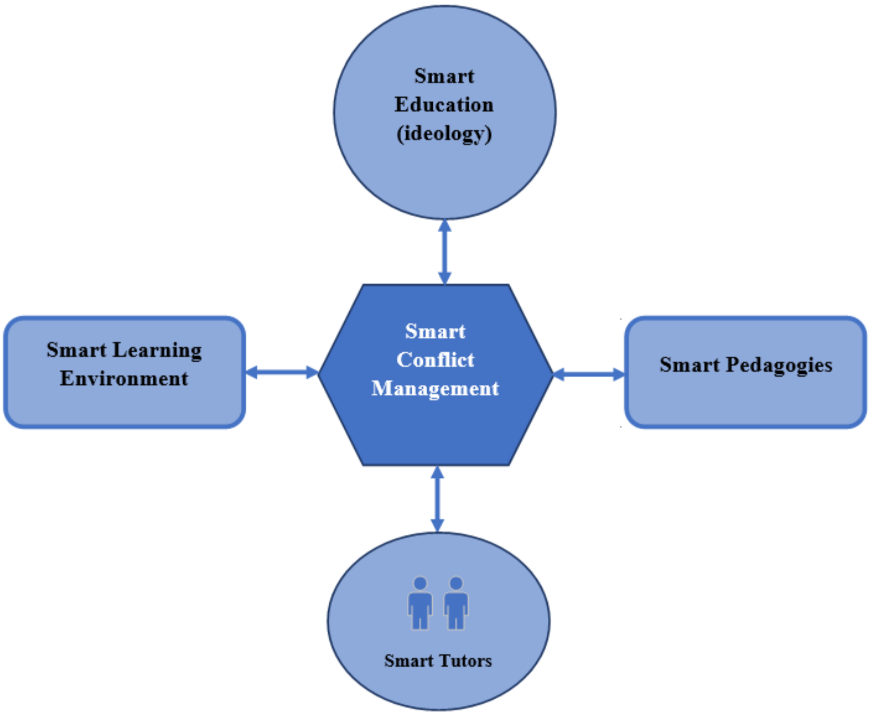


Figure 2 6: Conceptual framework of essential components for smart education Zhu et al. (2016)

The framework for smart pedagogy that has been proposed by Zhu et al. (2016) includes mass-based generative learning, group-based collaborative learning, individual-based personalized learning, and class-based differentiated instruction. The idea is a technology framework for smart education that emphasizes the function of smart computing. Critical functionalities and the tri-tier architecture are all presented. The difficulties of smart teaching are then highlighted (Zhu et al., 2016). Table 2.3 shows a summarized analysis of the models employed for smart education in ODeL for QoS.

Table 2.3: Comparison of conflict management models in smart education *(author's compilation)*

Author	Model	Strength	Weakness
(Meng et al., 2020)	Smart pedagogy framework	Learning outcomes are highly promoted	It does not consider conflict management
(Tentori & Rodriguez, 2011)	Multi-agent framework for activity awareness	Identify activity estimation on the component for the next appropriate action.	Conflicting activities are not considered and managed
(Hartono et al., 2018)	Smart hybrid learning model	Continuous access to the system at a remote site without internet	Only accessibility conflict is addressed and fails to include other smart education conflicts.
(Indrawati et al., 2018)	Smart education readiness index	Provides an indicator for establishing smart education	Conflict management is not considered a readiness index factor
(Zhu et al., 2016)	A conceptual framework for smart education	Point out three vital components of smart education.	No conflict management concept is implemented in the framework.

The review on smart education models reveals that conflict management is missing in literature. This study reconstructs the models to incorporate conflict management as a key element to characterize ODeL as smart education for QoS. The next section discusses the methods for managing conflict in ODeL for smart education.

(f) Resolving Conflict Proactively for Smart Education in ODeL

Conflict is not always harmful, according to numerous academics. Because more options are generated and analyzed before deciding, conflict is a crucial emergent state that enables agents to make better decisions (Jehn & Mannix, 2001). Different techniques to conflict resolution may be necessary depending on the type of dispute that could arise in smart education and impact ODeL QoS. This study establishes proactive conflict management framework to promote smart education in ODeL for QoS considering the following conflict resolution approaches:

- *Goal-based Conflict Resolution*

Each agent in smart education strives to accomplish a different purpose. Conflict between these several aims arises and must be resolved at each goal's or interest's level.

The approach used by Tuttlies and Schiele (2007) primarily on conflicts resulting from disparate user interests, focuses on a priori conflict detection and resolution through avoidance. The strategy was based on the PCOM component model, which uses contracts containing components' functionalities and requirements to choose services and devices and assess their suitability. Applications must disclose how they affect other applications and agents to avoid conflicts and promote a resolution, possibly by adopting the incompatible applications. It has a conflict manager module that is connected to a database that holds a context model describing the state of the environment, and another database that keeps track of the situations that are deemed to be conflicting. This allows conflict management to recognize conflicting circumstances in real time.

Another strategy like the one above is put forth by Armac and Kirchhof (2006), which employed a different infrastructure. It introduced a rule-based conflict discovery method that works under the premise that all resources and performance are measured as weighted automata and combined with a set of rules that keep an eye on the components to spot conflicts as they arise.

Concerning a goal-based resolution of conflict, Silva and Ruiz (2010) define a collective conflict as a state of inconsistency that a shared application may experience while assessing collective settings, where the application runs into difficulties in achieving multiple conflicting individual goals at once. They suggest an approach for conflict identification and resolution that uses a client-server architectural paradigm to pick and set up the most effective conflict resolution algorithm currently available. The application's requirements for quality of services (QoS) and resource usage will determine which option is selected. The collective pleasure of agents with the achieved resolution results constitutes the QoS criteria realized in their job.

Once more, a dynamic dispute resolution method suggested by Park and Lee (2005) integrates agents' preferences and aims to resolve conflicts amongst various context-aware apps in responsive settings. Agent preferences are expressed as cost functions over the gap between objectives and resolved values, with agent goals modeled as the value assigned to a context attribute by the actions they requested from applications. The set value is chosen to minimize the cost of all agents engaged in conflicts based on these statistics.

- *Resource-based Conflict Resolution*

Conflict over resources addressed by Retkowitz and Kulle (2009) used a technique that investigates dependencies between services realized as bindings. It highlights resource concurrency issues and introduces a method to prevent them through more dynamic and effective resource sharing. A configuration process prioritizes previously established binding policies and constraints while attempting to provide a service configuration that concurrently fits agent requirements, device environment, and service dependencies. To examine service bindings and handle access control taking priority groups into account, they used service method tagging and communication interception. This method is consequently not totally automatic but does provide agents with a tool to visualize and manually change the system status.

Conflict settlement using resources was suggested by Huerta-Canepa (2008), which focused on an ad hoc interaction-based management strategy for smart spaces. They agreed that only two jobs could be conducted at once, and that conflicts could be avoided through area device management and resource allocation based on the priorities of the agents, the duration of the jobs, and other similar pre-defined parameters.

- *Policy-based Conflict Resolution*

Considering a policy-based approach to resolving conflicts, Syukur and Loke (2005) investigated methods for conflict identification and avoidance based on context changes. They developed a policy-based application model where application actions are explicitly governed by policy. As suggested by Kawsar (2007), it is necessary to distinguish clearly between policy-based conflict in terms of their causes, detection, and resolution procedures, and different temporal approaches for resolution. Rules with priority schemes among agents are the most prevalent techniques for resolving conflict. The best functioning strategies, according to their findings, were a hybrid of reactive and proactive-based conflict recognition and proactive instantaneous conflict resolution. They contend that the suitability of each method depended on the specifics of the system.

By defining conflict as the differences that occur when the same application requests opposing actions in response to a context change or when collaborating applications disagree with an application of an everyday action, Capra and Emmerich (2003) defends the identification and resolution of run-time dynamic policy conflicts. They contend that conflicts require execution-period rescue since they cannot be resolved statically during the application design phase. This method distinguishes and addresses two different kinds of conflicts: intra-profile conflicts, which happen within the profile of an application that is currently running on a specific device; and inter-profile conflicts, which happen between the profiles of applications that are currently running on various devices. Additionally, it uses a microeconomic strategy that relies on a sealed-bid competition amongst applicants to achieve a fairly impartial dispute resolution process.

In addition, Lupu (1997) investigates policy conflict and instead of focusing on run-time conflict detection and resolution methods that help the agents define policy and roles and connections, they stress offline conflict detection and resolution strategies. They outline management guidelines for object domains and describe a conflict analysis tool that integrates with a Role-Based Management paradigm. They believe that conflicts may arise when these domains overlap, or when various policies are applied to the (subject, action, and target) tuples. They use a domain nesting method based on precedence to reduce the amount of overlaps that agents are provided with as well as roles and inter-role linkages to reduce the scope of regulations that require monitoring.

- *Authorization-based Conflict Resolution*

Before access to the smart education system can be granted, any agent—even the overall administrator—will need authorization. As a result, there may occasionally be some conflicts. For instance, if the system gives an agent access to a single login account, the actual agent may not be able to log in if another agent accidentally uses their credential and resets it. As evidenced by Masoumzadeh and Amini (2007), this is strongly tied to conflict based on policy. They claimed their method's strength is the static conflict recognition and conflict resolution limited to run-time. Essentially, setting priority amongst competing policies is a workable approach to this. To accomplish this, they formalize the application of context limitations in a rule-based, context-aware multi-authority policy model, allowing the justification of precedence establishment principles. Furthermore, they provided a thorough graph-based strategy to enable precedence among authorizations in a conflict state and evaluated timing techniques and resolution algorithms. The detection phase can be resolved by creating a probable conflict graph statically and using it in the actual conflict situation.

- *Automatic Conflict Resolution*

The above-discussed techniques to conflict resolution are important steps useful in a smart education environment to improve conflict management. However, they are not automatically proactive concerning the meeting and averting possible conflicts. There is, therefore, the need to fashion a model that integrates them to build an automatic conflict management framework.

According to Hasan et al. (2006), an environment context information is supplied into a system that performs spontaneous context-aware conflict resolution. The system then checks for conflicting situations and creates a new context in the environment to satisfy conflicting demands or provide advice about the conflicting scenario. Additionally, they claim that developing actuators to support brand-new demands of agent-performed tasks is necessary for the automatic resolution of conflicts. The expressed requirements about limits on environmental variables served as the foundation for the automated conflict identification and resolution method. When there is no assignment to the environment variables that fulfills all the constraints describing those requests, for instance, the demands of agents may conflict with one another. Services are similarly represented as limitations that account for their potential impact on environmental variables. Activities have pre- and post-conditions, which are restrictions on environment variables; and space zones have constraints as well, which are restrictions (perhaps enforced by a policy) on environment variables. These are factors surrounding smart conflict management and modeled as presented in Figure 2.7.

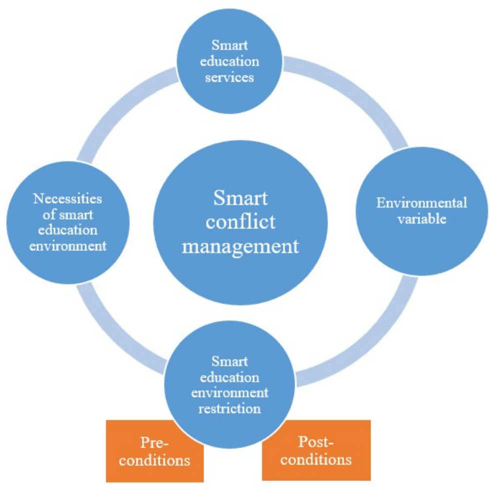


Figure 2.7: Factors of smart conflict management, Hasan et al. (2006)

2.5 Learning Management System (LMS) in ODeL

An intelligent learning management system (LMS), a platform that makes it possible to provide content online for educational purposes, is a major component of ODeL services. An LMS is a web-based tool used to expedite the delivery of blended, online, and in-person courses in both commercial and academic settings, to give a more technical description (Barreto et al., 2020). A piece of software or web-based technology called an LMS is utilized to plan, carry out, and assess a specific learning activity. It is utilized for eLearning processes and, in its simplest form, comprises of two parts: a server that manages the crucial operations and a user interface that is managed by teachers, students, and administrators (Brush, 2019).

Because it is created to support learner-centered techniques with integrated learning activities founded in learning objectives, independent of the delivery medium, an LMS is purportedly the most advanced tool for fostering learning. However, there are certain issues with the LMS ideology. The LMS structure, according to detractors, is built to support traditional ideas about education, such as a teacher-centered approach or a tool for administration (Bousbahi & Alrazgan, 2015). Since they are in charge of the design of the education (for example, content sequencing) and the kind of interactions, the course designer or teacher can determine how the LMS will function (i.e., with whom, when, and how learners interact). Designers and teachers can create learner-centered courses using a variety of methods, including open discussion forums, learner choice in assignments, and video chat, to name a few. Despite criticism, one study found that LMS are "currently the pinnacle to which educational technology is applied in the planning and execution of transformational teaching-learning experiences interactively and collaboratively to best capture and maintain the students' attention via a wide range of platforms that most suit the rapidly changing world of globalization and internationalization" (Kpolovie & Akpelu, 2017). Therefore, a platform for ODeL, requires incorporating QoS elements to optimize the services in ODeL.

The way that instruction is given has been redefined by LMS. In 1924, a device known as the teaching machine marked the beginning of the LMS. The typewriter-like teaching tool with the potential to support multiple-choice testing was created by Sidney Pressey (Quizworks, 2017). There is the need for cheating-free feature in the LMS to provide QoS.

The invention of the teaching machine led to an explosion in advances in what is now known as learning management systems. LMS innovations did not take off till the HP computer was created. It's interesting to note that the first software-based LMS ever existed with the 1990 SoftArc release of the HP rival Macintosh. Martin Dougiamas introduced the first open-source internal network for promoting learning on a worldwide digital platform together with the creation of Moodle in 2002. But LMS didn't switch to the cloud until 2012, lessening the strain of server upkeep (Quizworks, 2017). The network Bandwidth management is needed to lessen the strain on LMS for QoS in ODeL.

Using a learning management system, an instructor can frequently produce and deliver content, monitor student engagement, and assess student achievement. Through a learning management system, students may also have access to interactive features like message boards, video conferencing, and threaded discussions. Large and small businesses, as well as regional, state, and federal governments, as well as traditional and ODeL educational institutions, regularly use LMSs. The solutions can improve traditional education methods while also saving enterprises time and money. If the system is operational, instructors and administrators will be able to successfully manage a variety of system components, such as user registration, content, calendars, user access, communication, certificates, and notifications. Such QoS platforms can be achieved with proactive conflict management among all LMS users and resources. This study aims at proposing a proactive conflict management framework, which is suitable for making LMS smarter for QoS in ODel.

2.5.1 Uses of Learning Management Systems

LMSs have benefits for a range of industries, including for-profit corporations and institutions of higher learning. Knowledge management is the main purpose of a learning management system (KM). The process of gathering, organizing, communicating, and analyzing the knowledge contained in an organization's resources, documents, and human capital is known as knowledge management. However, the specific role of the LMS will vary based on the organization's training goals and plan. Some of the uses of LMS with respect to areas of implementation include the following (Brush, 2019):

- Employee onboarding and training are some of the most often used applications for an LMS in a business context. In this case, the LMS is used to help train new staff by providing them with access to training materials via a range of devices. Employers can reward new hires who contribute their knowledge and insight and discover more about how well the training sessions are going and what areas new hires require further assistance.
- LMSs can also be utilized for extensive company training. Training for members, partners, and clients is included. For consumers to use a new product, they must first be educated on how the system works; hence, customer training is frequent in software and technology organizations. Continual customer education will also enhance the client experience and foster more brand loyalty.
- LMS is frequently used in corporate settings for staff retention and development. The LMS can be used to assign necessary courses to current employees to ensure that they are developing the skills necessary for their jobs, remaining informed about product changes, and maintaining current knowledge through new product and compliance training.
- As previously said, the two most common LMS applications are employee onboarding and training. When students use an LMS for these purposes,

instructors can create immersive learning experiences that enable them to master new skills and problem-solving strategies. For example, classes combining training for augmented reality (AR), virtual reality (VR), and even artificial intelligence (AI) could be offered through an LMS AI. As a result, the workforce will probably see an increase in creativity and innovation.

- Another example is the use of an LMS for sales training. Onboarding and training fall under this category, but it also includes the creation of seminars on product knowledge, instruction in customer service, and case study-based tutorials that draw on previous client experiences to improve current interactions.
- Using an LMS is another option to provide blended learning to students. Blended learning combines traditional classroom instruction with online learning resources. By enhancing the learning environment in the classroom with additional digital content that can be customized to match each student's specific learning needs, this method is more effective than traditional face-to-face training.

LMS is typically used in ODeL, or online distance learning, where teaching and learning take place. The wide range of uses of LMS calls for enhancement by employing critical QoS element.

2.5.2 Characteristics and Operation of Learning Management Systems

A large repository that enables users to manage and store information centrally can be compared to an LMS. Anyone with a secure login and password can access the system and its online learning resources. Alternatively, if the system is self-hosted, the user will need to install the application on their computer or connect to the company server to use it. Common characteristics of an effective LMS include (Brush, 2019):

- *Responsive design:* Any platform, including desktop, laptop, tablet, and smartphone, should be able to access the LMS. The most suitable version for the user's chosen device should always be displayed by the LMS. For users to access content even when offline, the LMS should also permit content downloads.
- *User-friendly interface:* The user interface of the LMS platform should make it simple for learners to navigate it (UI). The UI should also work with the user's abilities and the goals of the business. A confusing or annoying user interface makes the LMS ineffective and increases the risk of user loss.
- *Analytics and reporting*: Instructors and administrators must be able to observe and track their online training programs to determine their efficacy. This can be used by both individuals and groups of learners.
- *Course catalog and management*: All the eLearning courses and the related course materials are kept in the LMS. Administrators and teachers should be able to create and manage these catalogs and courses to offer a more tailored learning experience.
- *Integration and content interoperability*: The packaging of content created and saved in an LMS must adhere to interoperable standards like SCORM and xAPI.
- *Support services*: Different LMS vendors offer varying levels of assistance. Many websites include forums where users can communicate and offer support to one another. Additional support services, including a dedicated toll-free service line, are made available at a cost.
- *Support for certification and compliance*: This functionality is a requirement for systems used for online compliance training and certifications. Instructors and administrators should assess a student's skill set to identify any performance gaps.

- *Social media features*: The use of social media technologies for social learning is supported by several LMS platforms. This allows users to collaborate, communicate with their colleagues, and share their knowledge.
- *Gamification*: Some LMS contain built-in gamification features or game mechanics that enable instructors and administrators to create more engaging and motivating courses. This can help students who need extra encouragement to finish the course, perhaps in the form of leaderboards, points, or badges.
- *Automation*: Learning management systems should enable administrators to automate time-consuming, repetitive tasks. Examples include user grouping, new user population, user deactivation, and group enrollments.
- *Localization*: LMS must have multilingual support features so that language barriers do not affect the learning and training materials. Some LMS can display the appropriate version of the course upon entry thanks to the incorporation of geolocation information.
- *Artificial intelligence (AI)* - Finally, AI may help an LMS provide tailored learning experiences for users by giving course formats that are suitable for their needs and by suggesting topics based on the user's prior course completions. AI in tools can be leveraged to provide smart support to LMS such as authentication in e-assessment, managing limited bandwidth of massive users, and conflict management.

These characteristics of LMS are very significant for the quality of service in ODeL. However, much emphasis is needed on automation, and AI features to provide solutions to the critical quality factors that this research has identified to be security, bandwidth management, and conflict management.

2.5.3 Types of Learning Management Systems

Depending on the technology on which the LMSs are established, are categorized under the following types (Brush, 2019).

- *Cloud-based*: Cloud-based LMS are frequently hosted using the business model known as "Software as a Service" (SaaS). Cloud-based LMS providers manage system maintenance and perform any required technical updates or upgrades. Online users can access the system at any time and from any location by entering a username and password.
- *Self-hosted*: Users of this LMS type are required to download software. The self-hosted platform allows for more customization and creative freedom, but users must constantly pay for updates and maintain the system.
- *Desktop-based*: On the user's computer, LMSs for desktop programs are set up. On some devices, the program might still work, though.
- *Mobile-based*: These LMSs are accessible whenever, whenever, and on any mobile device. They make mobile learning possible. With this platform deployment type, users can take part in and monitor their online learning activities while on the go.

The recommended LMS type that can provide an optimal platform in ODeL is cloud-based, but it needs to incorporate the QoS elements. The next section discusses the crises in LMS that may hinder the QoS in ODeL.

2.5.4 Crises in Learning Management Systems

A set of guidelines known as the Shareable Content Object Reference Model was developed by the Advanced Distance Learning group, which is supported by the US Department of Defense, to encourage the standardization of learning management systems (Brush, 2019).

According to Lwande et al. (2021), learning management systems like Moodle, Claroline, and Blackboard are used in educational institutions to make teaching easier, however these platforms do not have the tools for analyzing data or identifying behaviors like learning preferences and cognitive traits. Instead, they use the daily access records to compile specific statistics reports solely. Therefore, there is a lack of quality of service in LMS used in ODeL to achieve smart education.

Although a potential benefit is the growing availability of open-source technologies, which spread the resource burden for developing, upgrading, and supporting these systems across a large developer community rather than one or two private corporations. In the end, Watson and Watson (2007) reports that LMSs must:

- provide more constructivist-based training with an emphasis on adaptable, learner-defined objectives,
- broaden the scope of the learning environment to the home and further involve the parents, promoting teamwork both inside and outside the school,
- personalized assessment, tracking of progress, reporting, and sensitivity to learner requirements should all be improved,
- become truly systemic, seamlessly connecting systems to enable increased communication between systems and among stakeholders,
- enhance cost-effectiveness and better utilize currently available resources in schools, and
- improve support for professional diagnosis and development for stakeholders, especially teachers.

However, these and other quality features are non-existing in LMS, thereby limiting the quality of service needed for ODeL smartness. There is a need to evaluate the LMSs to ascertain the provision of QoS, and this is presented in the next section.

2.5.5 Evaluation of Learning Management Systems

It is reported by eLearning Industry (2022) that there exist 880 LMSs used by institutions and industries. An evaluation of the best 20 LMSs is provided based on customer experience and user experience. Table 2.4 obtained from eLearning Industry (2022) presents an exhaustive ranking of the top 20 LMS created with actual users input who were ready to discuss their LMS usage as of September 1, 2022. The reviews have all been evaluated independently by eLearning Industry. The following metrics determine the appearance order:

- *Customer Satisfaction (CSAT Score)*: evaluates the level of consumer satisfaction with a certain good, service, or transaction.
- *Customer Effort (CEF Score)*: identifies the effort necessary to contact the LMS vendor for customer service.
- *Customer Expectation (CEX Score)*: the gap between what customers anticipate from an LMS vendor and what they really get.

Utilizing a 5-step Likert scale from "Strongly Disagree" to "Strongly Agree," these metrics were generated.

Table 2.4: Top 20 LMS rankings

LMS	SCORE	CSAT SCORE (%)	CEF SCORE (%)	CEX SCORE (%)
LearnUpon LMS	91	100	98	100
360Learning	90	98	98	98
TalentLMS	89	98	96	96
Adobe Learning Manager	88	96	94	98
GyrusAim	87	96	96	94
iSpring Learn	87	96	94	94
Academy Of Mine	86	94	96	92
hosstinn	86	94	96	94
Absorb LMS	85	92	94	92
Docebo	85	94	92	94
Eduflow	85	96	90	92
LearnWorlds	84	92	92	92
iTacit Front-line Employee Platform+LMS	84	92	92	92
The Brainer LMS	84	92	94	88
Schoox	83	94	96	82
Tovuti LMS	83	92	90	90
Skypiom knowledge MS	83	92	90	88
Coassemble	82	90	90	90
Digits LMS	81	88	92	86

Further evaluation is provided in Table 2.5 (eLearning Industry, 2022) with the following metrics:

- *System usability scale (SUS)*: this is the most widely used and thoroughly proven metric for evaluating usability.
- *Perceived Utility (PU)*: this reflects how much the user believes the application maximizes their ability to do their task.
- *Net Promoter Score (NPS)*: the Net Promoter Score (NPS) statistic determines how likely individuals are to suggest a product on a scale of 1 to 10.

Table 2.5: Top 20 LMS ranking (based on SUS, PU, NPS)

LMS	ALL SCORE (%)	SUS (%)	PU (%)	NPS (%)
Adobe Learning Manager	87	96	96	92
Talent LMS	86	92	96	96
LearnUpon LMS	86	92	94	98
Absorb LMS	85	92	94	94
GyrusAim	85	90	96	96
Docebo	84	90	94	92
Xperiencify	84	88	94	96
360Learning	84	90	92	94
iSpring Learn	83	88	96	96
inquisiq	83	86	96	96
Coassemble	83	86	94	96
CanopyLAB	82	86	94	92
Nimble LMS	82	88	86	94
LearnWorlds	81	82	96	98
Gurucan	82	80	94	94
Eurekos LMS	80	80	94	96
Tovutu LMA	79	78	96	94
Digits LMS	78	80	88	92
Skillcast LMS	77	78	90	94

System quality depends on general quality elements, non-functional requirements, and technical quality features, which are functional requirements (Gallego Sánchez et al., 2021). The quality criteria employed in both rankings consider only the general quality elements, and therefore, the best LMSs are deficient in providing optimal quality service in ODeL.

2.6 Selected Machine Learning Schemes

In this section, the machine learning algorithms employed in this study for constructing the intelligent model for QoS in ODeL are reviewed. Machine learning has gained popularity in its implementation in many fields. There are numerous methods for managing bandwidth and authentication. Because of their biological significance and technical capabilities for user authentication, machine learning techniques were used in this study, specifically Gabor filtering and Haar feature-based cascade classifiers. Also, Hidden Markov Model is utilized due to its ability to apply observed states to detect hidden state data for bandwidth management.

2.6.1 Gabor Filtering

Images of the agents were filtered using the Gabor filter, which combines a sinusoidal wave with a Gaussian function. According to information, the Gabor filter is used to process facial photographs because of its biological importance and technical capabilities (Chung et al., 1999).

Equation (1) depicts the 2-dimensional Gabor function g(x, y).

$$g(x, y) = \left(\frac{1}{2\pi\sigma_x \sigma_y}\right) \exp\left[-\frac{1}{2}\left(\frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2}\right)\right] + 2\pi jWx \quad (1)$$

with Fourier transform G(u, v) given in equation (2)

$$G(u,v) = \exp\left\{-\frac{1}{2}[\frac{(u-W)^2}{\sigma_u^2} + \frac{v^2}{\sigma_v^2}\right\} \quad (2)$$

where $j = \sqrt{-1}$, $\sigma_u = \frac{1}{2\pi\sigma_x}$, $\sigma_v = \frac{1}{2\pi\sigma_y}$, u and v are the spatial frequencies, and W is the twiddle factor.

Cosine waves provide the real component, while sine waves produce the imaginary component. A complex number is produced by combining the two elements as written in equation (3).

$$h(x, y, \lambda, \theta, \sigma_x, \sigma_y) = \frac{1}{2\pi\sigma_x\sigma_y} * \exp\left\{-\frac{1}{2}\left(\frac{x'^2}{\sigma_x{}^2} + \frac{y'^2}{\sigma_y{}^2}\right)\right\} * \exp\left\{i\frac{2\pi x'^2}{\lambda}\right\} \quad (3)$$

where x' and y' are:

$$x' = x\cos\theta + y\sin\theta$$

$$y' = y\cos\theta + x\sin\theta$$

The θ represents the orientation of a Gabor filter and λ indicates the wavelet. The Gaussian envelope's standard deviation is represented by σ in a one-dimensional plane by. The following phase involved considering various scales of resolution and orientations for face images, and then extracting the feature map by convolution with the images and then applying equation (4) for the various scales and orientations;

$$Feature\ Map(x, y) = \sum_{k_1=-\infty}^{\infty} \sum_{k_2=-\infty}^{\infty} Im(k_1, k_2)\ h(x\text{-}k_1, y\text{-}k_2, \lambda, \theta, \sigma_x, \sigma_y) \quad (4)$$

the scaling factor being k.

Literature provides a detailed presentation of a comprehensive and effective computation of the Gabor feature (Ilonen et al., 2005).

2.6.2 Haar Feature-based Cascade Classifiers

The Haar feature-based cascade classifier shown in equation (5) was used to categorize the filtered images;

$$H(x) = \sum_{t=1.....T} c_t(x) \quad (5)$$

where, $c_t(x) = \alpha_t h_t(x)$ are scaled by the corresponding weights the set of thresholded Haar-based classifiers chosen during AdaBoost training. When extracting facial features from an integral image using Haar wavelets, which are represented as box classifiers, equation (6).

$$II(x\,,y) = \sum_{x' \leq x\,, y\prime \leq y} i(x, y) \tag{6}$$

where the sum of the pixels above and to the left of (x, y), inclusive, makes up the integral image at point (x, y) (Chaudhari et al., 2015).

2.6.3 Mel Frequency Cepstral Coefficients

Voice recognition as an augmented authentication feature is based on Mel Frequency Cepstral Coefficients (MFCC). The MFCC represents the short-term spectral-based feature used for voice recognition. The voice signal must first be divided into frames, usually by applying a windowing function at fixed intervals. This activity, in the process, aids in modeling small sections, usually 20 microseconds, of the signal that is statistically fixed. Edge effects are eliminated, however windows still have functionality, particularly Hamming windows. The next step is to create the cepstral feature vector for each frame.

Each frame's discrete Fourier transform (DTF) is performed afterward, with only the logarithm of the amplitude spectrum being kept. The importance of the amplitude spectrum's logarithm relative to the phase as revealed by perceptual tests that loudness of a signal is roughly logarithmic influences the choice of the logarithm.

The next step in the procedure is to emphasize perceptually evocative frequency while smoothing the spectrum. To do this, 256 spectral components must be divided into 40 frequency bins. Since it has been determined that the lower frequencies in speech are significantly more important than the higher ones, the bin spacing is based on the "Mel" frequency scale. The Mel scale relies on a mapping between actual frequency and perceived pitch that is roughly linear below 1kHz and logarithmic above, although the human auditory system can only perceive pitch linearly. For each frame, the Mel-spectral vectors' highly correlated components are determined.

The method ends with the decolorization of the Mel-spectral vector's components in order to reduce the number of parameters in the system. Karhunen-Loeve transform or principal component analysis can be used to achieve this. Comparable to the discrete cosine transform is the Karhunen-Loeve transform (Logan, 2000).

The derivations of the MFCC are obtained as follows (Hosom, 2003):

- The frequency f of the signal spectrum is scaled into Mel-frequency f' according to the relation in equation (7).

  $$f' = 2595 \times \log_{10}\left(\frac{f}{700}\right) \quad (7)$$

- By determining the logarithm of the Mel-frequency coefficients and using the discrete cosine transform, the requisite MFCCs can be obtained.
- Initially, deduce V = 16 MFCCs from individual speech utterance.
- The MFCC feature matrix has a size of K x V for K frames per utterance.
- Create a vector using all of the utterance's frames' first MFCCs (v = 1) where v = 1, 2, 3, …, V. The expression is $L_1 1$, $L_2 1$, $L_3 1$, ..., $L_k 1$.
- On the other hand, feature vectors of MFCC for v = 2, v = 3,…, v = 16 are molded and expressed as:

$$[L_{11}, L_{21}, L_{31}, ..., L_{k1}], [L_{12}, L_{22}, L_{32}, ..., L_{k2}],…, [L_{1V}, L_{2V}, L_{3V}, ..., L_{kV}] \quad (8)$$

where $u = 1, 2, 3, …, U$ being utterances number in a voice state.

According to Reynolds (2009), a weighted sum of the component Gaussian component densities defines a Gaussian Mixture Model (GMM), which is a parametric probability density function. The probability distribution of continuous scales or characteristics in a biometric system, such as vocal-tract-related spectral data in a speech recognition system, is typically modeled parametrically using GMMs. The iterative Expectation-Maximization (EM) technique or Maximum A Posteriori (MAP) estimate from a properly trained prior model are used to project GMM parameters from training data.

The weighted sum of the component Gaussian densities makes up a Gaussian mixture model (Ω) expressed in equation (9).

$$p(x|\lambda) = \sum_{i=1}^{\Omega} \omega_i \, g(x|\mu_i, \Sigma_i \qquad (9)$$

where x is a continuous-valued, D-dimensional data vector (representing measurement or features), w_i, $i = 1, \ldots, \Omega$, are the weights' mixture, and $g(x \mid \mu_i, \Sigma_i)$, $i = 1, \ldots, \Omega$, are the Gaussian densities of the components. Equation (10) defines each component density as a D-variate Gaussian function.

$$g(x|\mu_i, \Sigma_i) = \frac{1}{(2\pi)^{D/2}|\Sigma_i|^{1/2}} \, exp\left\{-\frac{1}{2}(x - \mu_i)' \, \Sigma_i^{-1}(x - \mu_i)\right\} \qquad (10)$$

given the covariance matrix Σ_i and the mean vector μ_i. The combination weights adhere to the restriction that $\Sigma_{i=1}^{\Omega} \omega_i = 1$

All component densities' mean vectors, covariance matrices, and mixture weights are used to parameterize the entire Gaussian mixture model. Together, these variables are stated in equation (11),

$$\lambda = \{\omega_i, \mu_i, \Sigma_i\} \; i = 1, \ldots, \Omega \qquad (11)$$

Equation (11) indicates several variants on the GMM (Reynolds, 2009).

2.6.4 Basics of Hidden Markov Model (HMM)

The following elements specify the essentials of the Hidden Markov Model used in constructing the framework for network bandwidth management:

- Individual states denoted as $S = s_1, s_2, s_3, \ldots, s_N$: N denotes the hidden states.
- The sequence of observations given as $\Omega = \Omega_1, \Omega_2, \Omega_3, \ldots, \Omega_T$: T denotes the

number of observations.

- State transition matrix, given as $A = \{a_{ij}\}$, where a_{ij} indicates the likelihood of a change from state *i* to state *j*.
- Observation probability matrix, given as $B = \{b_j(\Omega_T)\}$, where $b_j(\Omega_T)$ indicates the probability of observing Ω_T at state *j*
- Initial state probability, given as π
- The HMM compact notation, given as $\lambda = (A, B, \pi)$

1. *Decoding Problem* – method determines the model λ state sequence most likely to have produced the given observation $\Omega = \Omega_1, \Omega_2, \Omega_3, \dots, \Omega_T$. The Viterbi algorithm is commonly employed to solve this problem. Given the current state *i*, a supplemental variable created to forecast the maximum likelihood for incomplete observation sequences and state sequences up to *t* = *T* given as:

$$\delta_t(i) = \max_{s_1, s_2 \dots s_{t-1}} p\{s_1, s_2 \dots s_{t-1}, s_t = i, \Omega_t, \Omega_2, \dots, \Omega_{t-1} \,|\, \lambda \qquad (12)$$

It follows that

$$\delta_{t+1}(j) = b_j(\Omega_{i+1}) \left[\max_{1 \le i \le N} \delta_t(i) a_{ij} \right], \ 1 \le i \le N, \ 1 \le t \le T-1 \qquad (13)$$

with $\delta_1(j) = \pi_j b_j(\Omega_1), 1 \le j \le N$

2. *Learning problem* – this identifies how, given a model λ and a series of observations $\Omega = \Omega_1, \Omega_2, \Omega_3, \dots, \Omega_T$, the model parameters {A, B, π} may be adjusted to maximize $p\{\,\Omega \,|\, \lambda\}$.

   An iterative method for estimating λ from just Ω is called Baum-Welch. It works by increasing a log-likelihood proxy and bringing the present model closer to the ideal model. Baum-Welch is just the process of repeating the actions below until convergence.

   Definition of forward and backward auxiliary variables are required.

The first of the two variables is:

$$\xi_t(i,j) = p\{s_t = i, s_{t+1} = j \mid \Omega, \lambda\} \tag{14}$$

This can as well be expressed as:

$$\xi_t(i,j) = \frac{p\{s_t = i, s_{t+1} = j \mid \Omega, \lambda\}}{p\{\Omega \mid \lambda\}} \tag{15}$$

Applying forward and backward variable to this will result in:

$$\xi_t(i,j) = \frac{\propto_t (i) a_{ij} \delta_{t+1}(j) b_j(\Omega_{i+1})}{\sum_{i=1}^{N} \sum_{j=1}^{N} \propto_t (i) a_{ij} \delta_{t+1}(j) b_j(\Omega_{i+1})} \tag{16}$$

The second variable referred to as a posteriori probability expressed as,

$$\Pi_t(i) = p\{s_t = i \mid \Omega, \lambda\} \tag{17}$$

Applying forward and backward variables, we can obtain:

$$\Pi_t(i) = \frac{\propto_t (i) \delta_t(i)}{\sum_{i=1}^{N} \propto_t (i) \delta_t(i)} \tag{18}$$

Deducing the relationship between $\Pi_t(i)$ and $\xi_t(i,j)$, we obtain:

$$\Pi_t(i) = \sum_{j=1}^{N} \xi_t(i,j),\ 1 \le i \le N, \quad 1 \le t \le M \tag{19}$$

HMM is popular in diverse implementations and has been successful in prediction purposes.

In a dynamic and stochastic network traffic environment, an HMM's proposed definition of traffic states on orthogonal frequency division multiple access passive optical networks (OFDMA-PONs) (mean and contrast of the bandwidth request observations) as two parameters to predict throughput and end-to-end delay. HMM's application improved the throughput by 15%, which was made possible by efficiently sharing the surplus bandwidth through an accurate separation of the heavily loaded optical network units and light-loaded optical network units (Lim et al., 2017).

A study by Zaki et al. (2019), provides a model based on HMM and Contrast for characterizing the traffic conditions during peak hours in two-dimensional space, where mean speed and contrast were used to capture traffic patterns variability. The empirical evaluation indicated an improvement in prediction error of 91.2%.

This work considers varying the HMM parameters to emerge best fit HMM model for the ODeL platform dataset.

2.7 Gaps in the Literature

It is revealed in literature that ODeL institutions are concerned with providing quality services; however, there is no specification of critical QoS elements to fashion out a model to provide quality service in ODeL.

Although studies have revealed that QM standards can be employed to monitor and adequately provide QoS in ODeL (Adair & Shattuck, 2015; Hollowell et al., 2017), however, the existing standards have not established key QoS elements in ODeL to provide smart education.

The existing authentication measures employed in ODeL optimal cheating free examination due to fact that they use either single authentication measures or multimodal authentication, which have deficiencies such as impersonation and inability to provide solutions to malpractice through dictating answers by a third party. Even those that provide some levels of authentication do not resolve malpractice in all forms completely in online assessment.

ODeL platforms such as LMS are compacted with massive users with many services. The challenge this poses is network drain, which affects the QoS in all services provided to users in ODeL. There is no proactive network bandwidth management scheme for appropriate allocating of bandwidth to make ODeL platform smarter in the literature.

Conflict is inevitable in every establishment that deems QoS as a priority. The literature has revealed that ODeL should be characterized as smart education environment to provide QoS, however none of the smart education models reviewed in literature considers conflict management in principle and practice.

There is a need to decide on the main quality elements, implement them appropriately, conduct frequent evaluations, and constantly check and upgrade to meet current technological requirements in ODeL. This study identifies security, network bandwidth, and conflict management as the key elements for QoS in ODeL for smart education and the following chapter present detailed methodologies for authentication to ensure cheating-free non-venue based assessment. Effective bandwidth allocation method and proactive conflict management framework are proposed.

Many researchers expressed interest in the quality of service models in ODeL, of which the major concentration has been on making ODeL smarter. However, some areas still need much research, for example, identifying the major quality of service elements in ODeL. Bridging the gap, this research constructs an intelligent model (IQSODeL) by incorporating the key quality of service elements in ODeL, which can serve as a prototype for quality service in virtual organizations.

2.8 Chapter Summary

This chapter reviews the major challenges of QoS in ODeL and identifies the key elements and the implementations in the existing works to resolve problems in user authentication, bandwidth management, and conflict management. The LMSs as the primary platforms for ODeL activities are reviewed extensively to ascertain the level of QoS implementation mechanisms.

Machine learning methods considered for constructing an intelligent model for ODeL in an attempt to provide solutions to the QoS challenges were presented while introducing an axis for the research paradigms. The preceding chapter details the design and methodology of this research.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

Methods and tools employed in the research are the focus of this chapter. The methodologies for evaluating the QoS elements for establishing the framework for ODeL service quality are discussed. It also takes into account the research's ethical considerations, the data sources used, the data analysis techniques used, and the validity and reliability considerations.

3.2 Method

In order to present a framework for intelligent quality of service in ODeL, this research uses the mixed method to identify, prepare for, and integrate essential quality factors in ODeL. Approaches for user authentication and bandwidth management are based on quantitative and experimental. Conflict resolution techniques are based on qualitative. The overall QoS for the ODeL framework (IQSODeL) is established based on the merge of the three models, which are identified as the main QoS factors in ODel. A quantitative approach is then used to validate the framework for service quality. For simulation and validation, data was gathered through a university learning management system.

A researcher or research team mixes elements of qualitative and quantitative research procedures in mixed methods research (such as the use of qualitative and quantitative viewpoints, data collection, analysis, and inference techniques) for the basic aims of increasing the breadth, depth, and consistency of understanding (Johnson et al., 2007). Distinguishing the aim for mixing in mixed methods research, Greene et al. (1989) indicated that complementarity aims to elaborate, improve, illustrate, and clarify the findings of one approach with those of another method.

Based on an examination of the justifications for integrating qualitative and quantitative research that the authors of mixed methods studies have suggested, Bryman (2006) developed the following list of more specific justifications for doing mixed methods research:

- Credibility – refers to claims that using both methodologies improve the reliability of results. A qualitative approach is used to identify and ascertain the credibility of the QoS elements in ODeL.
- Illustration – putting "flesh on the bones" of "dry" quantitative conclusions, or using qualitative data to illustrate quantitative findings. The qualitative identification of the QoS elements is illustrated with quantitative experiments.
- Confirm and discover – in a single project, this comprises developing hypotheses using qualitative data and testing them with quantitative data. A quantitative survey is employed to confirm the QoS element based on qualitative research.
- Utility, also known as improving the usefulness of findings - is the idea that combining the two methodologies will make the results more valuable to practitioners and other people. This idea is more likely to be prominent in papers with an applied focus. A QoS model fashioned out of the combined methods serve as a prototype for ODeL institutions and other virtual learning platforms.

This research, therefore, explores experimental and survey techniques on quantitative methods and qualitative methods to propose a framework for QoS in ODeL.

3.3 Participants

The research was carried out at a university that engaged in most of the teaching and learning activities in open distance electronic platform. The university has three campuses and three learning centers with a total student population of 6270. There are 127 full time lectures with over 200 part-time lectures, and 105 administrative staff. The participants involved in the research from the above population are categorized as follows:

- *For bimodal biometric user authentication*

The sample comprises of 75% males and 25% females, with 20% majoring in computer science and 70% majoring in information technology. Students majoring in information technology who are majoring in education make up the remaining 10%. We used 20 third-year IT students as the imposter data set during the authentication step to evaluate the system's FAR.

In the first database, 520 data samples were recorded, of which 200 were movie images of the agents when they were in different locations around campus and 320 were still pictures of the agents. 315 still photos and 195 video images totaling 510 samples were recorded for the second database. These were gathered from students both on and off campus, at various points in their residence halls. These served as the algorithm's training data. When the pupils were out of the classroom, 480 samples—290 still photographs and 190 motion images—made up the data set for a third database.

- *For multimodal biometric user authentication*

The experiment participants consisted of 245 undergraduate students of bachelor of Education in Information Technology on the Moodle learning management system in an online course. These participants were from three different campuses of the affiliated institution of the researcher. Out of the 245 students, 220 were registered into the system and 25 non-registered represented as imposters.

- *For bandwidth management in ODeL*

On evaluating the bandwidth management model, the University's lecturers (or Professors), students, and administrators participated in the experiment. The three campuses in three regions of the country and three learning centers in other three regions participated in the experiment. The student population used were over four thousand from five different schools and faculties, of which two-thirds of them are distance and sandwich students who do most of their learning activities online, over six hundred faculty members and staff working at the University. About two hundred and fifty constitute the University's teaching staff, of which the remaining are the non-teaching staff who were involved in the experiment.

The administrators in charge had to designate lecturers for the courses, add students to them so they could enroll in the class, and then finalize the courses. Students of the various classes were from different parts of the country and some international students.

- *For IQSODeL Validation*

A total of 551 participants constituting 476 students, 53 lecturers, and 18 university administrators participated in the study. The study carried out during the first session of 2022/2023 academic year. The participants were from the three campuses and two learning centers of the university. Confirmatory factor analysis (CFA) and structural equation modeling (SEM) were used for data analysis. Due to the analytic approach, it is required to take the participants' number into account. Researchers have proposed varying criteria for determining the study group size. Bayram (2000) opine that size of the participant should be over 200. According to Preacher and MacCallum (2002), the minimum sample size should range from 100 to 250 while Schumacker and Lomax (2012) indicated that many studies used participant range from 250 to 500 and are appropriate for SEM analysis. Consequently, it was decided that the sample size for this investigation was adequate.

3.4 Data Collection Instruments

Different instruments were used for data collection. Data for the user authentication experiments were obtained using a client-server on ODeL platform to gather male and female real-life data sets through the user machine-enabled web camera and keyboard.

SolarWinds bandwidth monitoring tool interfaced with an application based on the proposed model to monitor the network bandwidth. The e-Tutor learning management system was hosted on a single server that provides access to services. This research used such tools due to real-time tracking and network performance monitoring. Alerts are easily configured for correlated events, sustained situations, and complicated blends of device states. Monitoring network device and interface availability as well as performance metrics of bandwidth usage is the key to its acceptance.

A literature survey was conducted to identify smart education models useful for ODeL for reconstruction to incorporate conflict management to make ODeL platform smarter. Data collection for validation of the QoS elements in ODeL was through a questionnaire administered using the Microsoft office form.

3.5 Development of Bimodal Biometrics Authentication for ODeL

In order to ensure that exams are free of cheating, this section discusses the procedures for user authentication on the ODeL platform.

3.5.1 Phase 1: Establishing a Framework for Users' Authentication

It is essentially impossible to plan and provide the best authentication of candidates in a non-venue-based examination in an ODeL environment due to variety of issues. A model that illustrates the many activities at all levels necessary in such setting is developed and shown in Figure 3.1 in an effort to offer a common backplane for authentication.

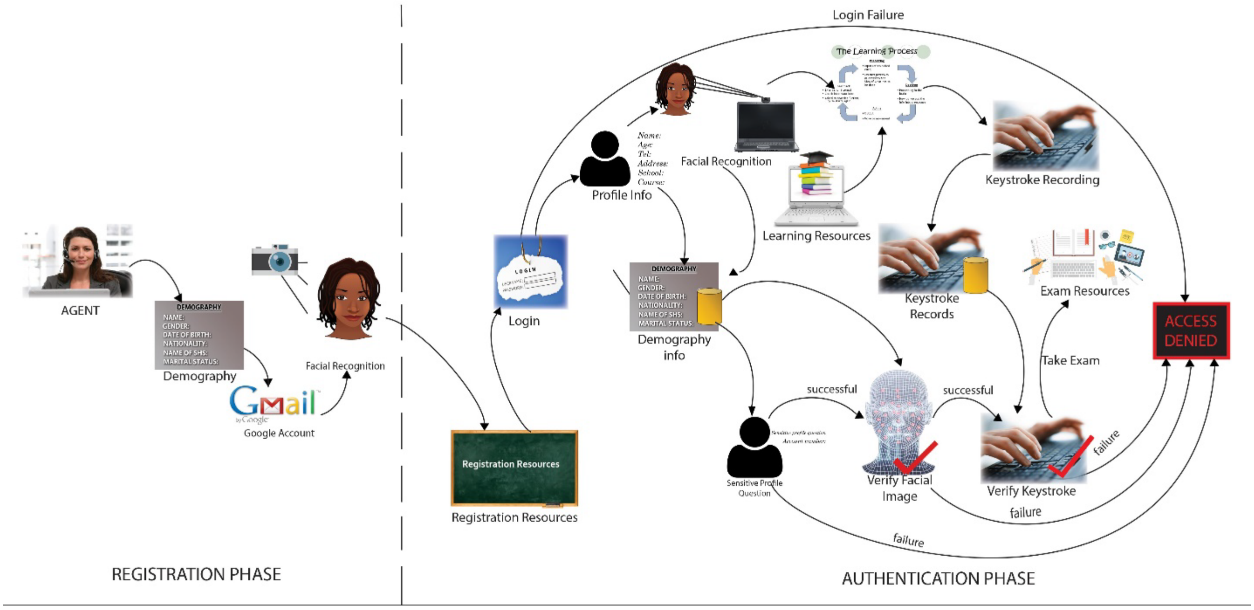


Figure 3.1: Bimodal biometric authentication framework

There are two parts to the framework: The registration phase, which a user must complete in order to join the learning system, is shown on the left. It involves the submission of demographic data, such as a Gmail address (to identify location), facial picture capture (using the webcam of users' laptop), and database-stored keystroke features. Processes for learning and assessment are a part of the second phase, or authentication phase. The database records and updates the student's (user's) facial image and keystrokes each time they use the system during the learning process. Algorithms for machine learning are used to train the system. Prior to taking an exam, a user is authenticated using data that has been gathered over time. The use of both facial recognition and keystroke dynamics as authentication principles is referred to as "bimodal biometrics authentication".

While taking into account all the requirements for a virtual examination, the architecture in this method enables the following benefits:

- Determining the standard requirements for authenticating users
- Establishing consistency when a non-venue-based test is given in an ODeL environment
- Ensuring strong scalability for assessment in big contexts with numerous users

- Assisting in avoiding illegal access from people or malicious software

In addition to the aforementioned, this authentication framework's verifications are very specific to each user and extremely challenging to copy or steal. Also, if the location of the examination and registration are the same, the user's Gmail account uses that location to identify each user.

3.5.1 Phase 2: Users' Registration and Learning

A crucial part of the entire structure is the registration process. Since authentication is necessary for all activities, including learning, evaluation activity, and reporting (more particularly, students grades checking other information), this procedure is linked to all other processes. The activity flow in this phase is depicted in Figure 3.2.

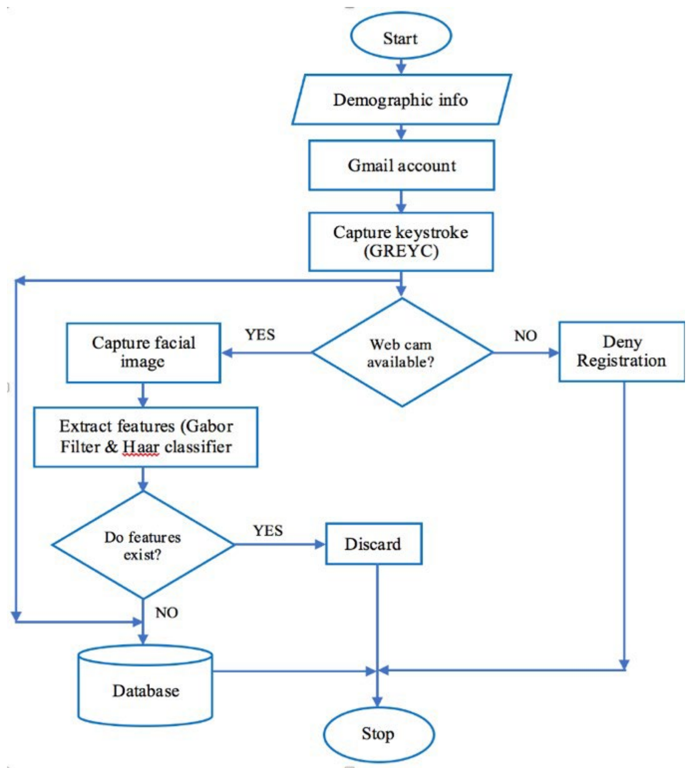


Figure 3.2: Flowchart for registration and learning

According to the flowchart above, a user's necessary information is recorded upon registration and updated as the learning progresses.

3.5.2 Facial Features Learning of User as a Security Measure

Every user who enrolls in the system must have a web camera in order to record their facial image, as shown in Figure 3.1 and Figure 3.2. The learning of facial traits is described in Algorithm 1.1.

Algorithm 1.1: Learning of facial feature

INPUT: Face image (f_i) OUTPUT: Facial features(f_f)

STEP 1: For Access < Exam period
STEP 2: Capture f_i
STEP 3: Filter $fi = Equation3(fi)$
STEP 4: Determine $f_f = Equation4(fi)$
STEP 5: Classify $f_f = Equation5(f_f)$
STEP 6: IF access != exam period
    IF f_f != f_x (existing images features)
      Save f_x
      ELSE
        Discard f_x
    ENDIF
  ENDIF
STEP 7: END FOR

Any time a specific characteristic of a person is obtained, and for an extended period of time shown to remain unchanging, it offers a strong prediction likelihood of the presence of that individual and can be useful feature for authentication. Additionally, its absence will indicate as proof for authentication system to show that the person's physiological appearance has changed. In this study, learning a user's physiological pattern basically entails identifying the user's distinctive features by use of a procedure for accumulating the characteristics for a set amount of time at various locations, in various environments, from various perspectives, and with various intensities (brightness) of the user's features. The recordings of these physiological parameters are kept in a database and can be utilized or compared for authentication.

3.5.3 Learning of Users' Keystroke Dynamics as a Security Measure

In this study, a substantial additional authentication technique is implemented based on the behavioral feature shown in Algorithm 1.2.

Algorithm 1.2: Keystroke dynamics learning (using GREYC Software)

INPUT: Key release time (*r*), Key press time (*p*), Previous key release time (r_p), Same key press time (p_s), Previous key press time (p_p), OUTPUT: Keystroke dynamics (k_d)
STEP 1: For Access < Exam period STEP 2: Capture p, r, p_p, r_p, p_s STEP 3: Key Hold Time (k_h) = $r - p_s$ STEP 4: Down Down Key Latency (k_{dd}) = $p - p_p$ STEP 5: Up Up Key Latency (k_{uu}) = $r - r_p$ STEP 6: Up Down Key Latency (k_{ud}) = $r - p_p$ STEP 7: Down Up Key Latency (k_{du}) = $p - r_p$ STEP 8: IF access != exam period Determine keystroke dynamics, k_d (k_h , k_{dd} , k_{uu} , k_{ud} , k_{du}) ENDIF STEP 9: END FOR

This algorithm analyzes user activity over a predetermined time period to identify patterns that may stand the test of time. The user's actions are tracked throughout time in a database at various times, under various conditions, and under various constraints. By doing this, the user's behavior can potentially be predicted as purpose for authentication, due to the learned behavior over time. The keystroke dynamics of each user who logs in to the system are recorded starting from the moment they registered with the system, and this information is added to and updated in the database.

3.5.4 The Bimodal Biometrics Authentication Scheme

The environmental criterion for non-venue-based assessments stipulated in this scheme is the presence of a webcam that can capture the entire room in a constrained, controlled setting.

a. Facial authentication process

As demonstrated in Figure 3.1, the face is initially compared to the training data from the learning phase to validate the agent before the assessment. Equations (3) and (4), which are stages in Algorithm 1.1, are utilized to extract the face features and map them onto the database image in order to do this. Algorithm 1.3 establishes the combined face recognition and keystroke dynamics (FRAKD) authentication. If the currently acquired image finds a match in the database, the user is taken via keyboard authentication; otherwise, the agent is denied access. The two "give access to assessments" have been combined, so the agent must pass both authentication checks.

b. Keystroke dynamics as complementary evidence

Keystroke dynamics support the authentication of face feature in the bimodal authentication system. According to Figure 3.1 and Algorithm 1.3, an agent can only move on to the exam after successfully complete authentication of keystroke following the facial recognition. It is discovered that applying Manhattan distance provides straightforward to use, accurate results, and low error rates (Ilonen et al., 2005).

Computing the score represented with Manhattan distance is given by equation (20):

$$\mathrm{M} = \sum_{i=1}^{n} (|x_i - y_i|) \tag{20}$$

Where test vectors are denoted by $x = (x_1, x_2, x_3, \ldots, x_n)$ and training samples mean vectors are denoted by $y=(y_1, y_2, y_3, \ldots, y_n)$. Additionally, it was found that string length greatly affects how different users' typing techniques affect outcomes at the

Manhattan distance (Chaudhari et al., 2015). For a massive user environment like the ODeL environment, this classification works well.

Accomplishing keystroke authentication takes into consideration the preceding periods, as shown in Algorithm 1.3.

i. Key hold time: It is the duration for a single key pressed and its released computed as:
   Key hold time = Key released duration – Key pressing duration
ii. Down down key latency: The duration of two consecutive presses obtained as:
   Down down key latency = Key press duration – Previous key press duration
iii. Up up key latency: The duration of two consecutive releases computed as:
   Up up key latency = Key release duration – Previous key release duration
iv. Up down key latency: The duration of current key release and the next key press obtained as:
   Up down key latency = Key release duration – Previous key press duration
v. Down up key latency: The duration of current key press and the release of next key obtained as:
   Down up key latency = Key press duration – Previous key release duration

A truth table for the keystroke dynamics process is shown in Table 3.1, where it is assumed that for all latencies—down, up, and hold—a key press is represented by value of 1 and a value of 0 represents a key release.

Table 3.1: Truth table for keystroke dynamics procedure

Latency	Key Press (KP)	Key Release (KR)	Result (R)
Key Hold Duration	1	0	0
Down Down key	1	1	1
Up Up Key	0	0	0
Up Down Key	1	0	0
Down Up key	1	0	0

The various combinations obtained for key pressing and releasing presented in Table 3.1 is used to design the corresponding AND logic output shown in Figure 3.3.

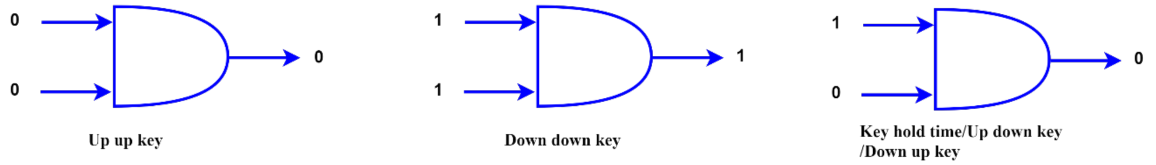


Figure 3.3: AND gates for keystroke dynamics

Algorithm 1.3: FACKD authentication procedure

INPUT: Face image (f_i), Keystroke dynamics (k_d), Key press duration (p), Key release duration (r), Previous key press duration (p_p), Previous key release duration (r_p), Same key press duration (p_s) OUTPUT: Access Granted or Denied

STEP 1: For Access = Exam period
STEP 2: Capture f_i
STEP 3: Filter $fi = Equation3(fi)$
STEP 4: Determine $f_f = Equation4(fi)$
STEP 5: Classify $f_f = Equation5(f_f)$
STEP 6: IF f_f != f_x existing image features
Access Denied
ELSE
STEP 7: Capture p, r, p_p, r_p, p_s
STEP 8: Key Hold Time (k_h) = $r - p_s$
STEP 9: Down Down Key Latency (k_{dd}) = $p - p_p$
STEP 10: Up Up Key Latency (k_{uu}) = $r - r_p$
STEP 11: Up Down Key Latency (k_{ud}) = $r - p_p$
STEP 12: Down Up Key Latency (k_{du}) = $p - r_p$
STEP 13: Determine keystroke dynamics, k_d (k_h , k_{dd} , k_{uu} , k_{ud} , k_{du})
STEP 14: IF k_d = Match
Take Exam
ELSE
Access Denied
ENDIF
ENDIF
ENDFor
STEP 6: END

3.5.6 Evaluation and Scoring Instruments

The experimental results evaluation and validation mechanisms used are discussed in this section.

a. Leave-p-out cross-validation method

To address overtraining in the validation situation, the leave-p-out cross-validation approach is employed for authentication (Arlot & Celisse, 2010). Six experiments were conducted at three separate locations for students' facial authentication with 520 at the first, 510 at the second, and 480 at third locations. This study used intervals of 40 between training and testing for facial feature authentication and 20 for global keystroke dynamics authentication for each batch of location data that was gathered. Five times each was done in the experiment.

b. ROC

The y- and x-coordinates of a receiver operating characteristics (ROC) curve constructed for the experimental data are, respectively, the identification rate (sensitivity) and false acceptance rate (specificity).

c. FRR

The experiment's false rejection rate (FRR) is determined by:

$$FRR = \frac{\text{Rejected number of positive faces}}{\text{Sum of all positive faces introduced}}$$

The results of the experiments' average FRR are shown.

d. FAR

The false acceptance rate (FAR) is determined by the following:

$$FAR = \frac{\text{Number of accepted negative faces}}{\text{Sum of all negative faces introduced}}$$

The averages of all FARs in the experiment's findings are summarized in the research.

e. *Confusion matrix*

With reference to the definitions of the entries, a confusion matrix is presented in showing the effectiveness of the categorization used in this study (Santra & Christy, 2012).

3.6 Development of Fused Multimodal Biometric Authentication for ODeL

Strengthening the authentication of users by preventing dictator assistance in an ODeL platform, requires improvement on the bimodal biometric authentication model. Figure 3.4 presents a fused multimodal biometric authentication model.

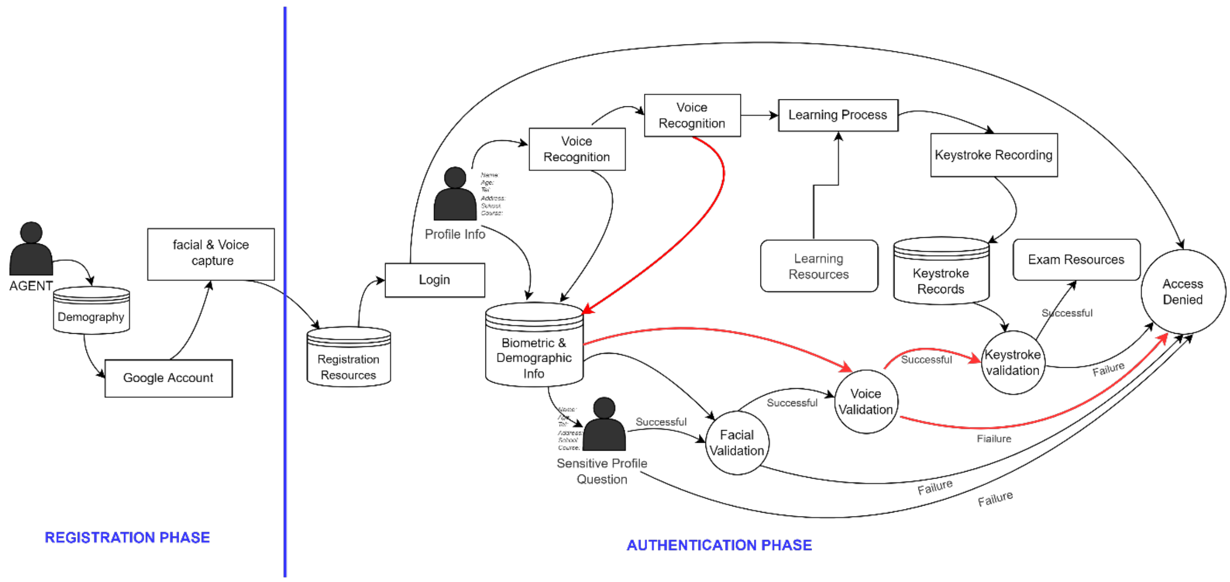


Figure 3.4: Fused multimodal biometric authentication model

The two phases of the framework replicate the bimodal authentication model with an additional voice recognition in the second phase that deals with the prevention of the dictator's assistance. The user's records are updated each time within the learning process, and during the assessment period, machine learning techniques are employed. This aids in implementing the authentication mechanism through facial, voice recognition, and keystroke dynamics. The framework achieves the merits of standard authentication requirements, enhancing consistency and scalable online examination of large users' assessment and preventing unauthorized access and assistance.

This section focuses on the augmented voice recognition component of the framework. Algorithm 1.4 illustrates the steps for performing voice feature learning of the process.

Algorithm 1.4: Voice feature learning

INPUT: Voice signal (v_i)
OUTPUT: Voice features(v_f)

STEP 1:For access < examination period
STEP 2: Record environment noise
STEP 3: Capture v_i
STEP 4: Identify the agent's voice by LTSD
STEP 5: Filter v_i by VAD
STEP 6: Extract v_f = *Equation 1*(v_i)
STEP 7: IF access != exam period
    IF v_f != v_x (existing images features)
        Save v_x
            ELSE
                Discard v_x
    ENDIF
ENDIF
STEP 8: END FOR

Learning an agent's voice comprises distinguishing the agent's voice from the environmental noise and a third party's voice. It requires identifying unique characteristics through content recognition and feature extraction over a period of time.

3.6.1 Fused Multimodal Biometric Authentication

The fused biometric multimodal authentication process requires a user to pass the three authentication tests: facial, voice, and keystroke dynamics for the examination completion. As revealed in Figure 3.4, Algorithm 1.5 presents all the steps for the fused authentication scheme.

Algorithm 1.5: Fused authentication algorithm

```
INPUT: Facial image (f_i), Voice signal (v_i), Keystroke dynamics (k_d)
       Key press time (p), Previous key press time (p_p), Key release
       time (r), Same key press time (p_s), Previous key release time
       (r_p)
OUTPUT: Access granted or denied
-----------------------------------------------------------------
STEP 1: For Access = examination period
STEP 2: Capture f_i
STEP 3: Filter fi = equation5( fi )
STEP 4: Determine f_f = equation6( fi )
STEP 5: Classify f_f = equation7( f_f )
STEP 6: IF f_f != f_x existing image features
              Access denied
        ELSE
STEP 7: Record environment noise
STEP 8: Capture v_i
STEP 9: Identify the agent's voice by LTSD
STEP 10: Filter v_i by VAD
STEP 11: Extract v_f = equation 1(v_i )
STEP 12: voice matching = equations 2-4(v_i, v_f)
           IF v_f != v_x (existing images features)
             Access denied
              ELSE
STEP 13: Capture p, r, p_p, r_p, p_s
STEP 14: Key hold time (k_h) = r - p_s
STEP 15: Down down key latency (k_dd) = p - p_p
STEP 16: Up up key latency (k_uu) = r - r_p
STEP 17: Up down key latency (k_ud) = r - p_p
STEP 18: Down up key latency (k_du) = p - r_p
STEP 19: Determine keystroke dynamics, k_d (k_h , k_dd , k_uu , k_ud , k_du)
STEP 20: IF k_d = Match
           Take examination
           ELSE
           Access denied
         ENDIF
      ENDIF
    ENDIF
  ENDFor
STEP 21: END
```

3.7 Development of HMM-based Model for ODeL Platform Bandwidth Management

This section presents the methods employed in constructing the framework for bandwidth management as QoS element in ODeL.

3.7.1 Problem Formulations

This paper formulates the optimization problem that aims to minimize bandwidth allocation to many services and the corresponding bandwidth consumption to share bandwidth among ODeL services considering network constraints.

For all services,

Given,

$B_{s1}, B_{s2}, B_{s3} \ldots B_{sn}$: bandwidth services requests of various agents on the network.

B_{sh}, B_{sm}, B_{sl} : predicted bandwidth services requests for high, medium, and low demand.

Practically, user n's overall upload service request is obtained by:

$$T_n^{sup} = \max \{B_{sh}^{up} + B_{sm}^{up} + B_{sl}^{up}\} \quad (3.2)$$

Moreover, user n's overall download service request is obtained by:

$$T_n^{sd} = \max \{B_{sh}^{d} + B_{sm}^{d} + B_{sl}^{d}\} \quad (3.3)$$

Thus, our formulated joint ODeL services and bandwidth allocation (OSBA) expressed as follows:

$$(OSBA): min \sum_{k=1}^{N} \{T_n^{sup}\}_k + \{T_n^{sd}\}_k \quad (3.4)$$

subject to: $\sum_{k=1}^{N} [B_{sh}^{up}]_k \leq B_{sh}^{up.max}$

$\sum_{k=1}^{N} [B_{sh}^{d}]_k \leq B_{sh}^{d.max}$

$[B_{sh}^{up}]_k , [B_{sh}^{d}]_k \geq 0, \forall_k$

Where T_n^{sup} and T_n^{sd} refer to total upload service request and total download service request, respectively, taking the maximum (max) values, and this research seeks to minimize (min) the sum of the two. The parameters B_{sh}^{up} , B_{sm}^{up} , B_{sl}^{up} represent upload service for high, medium, and low bandwidth demand, respectively, while B_{sh}^{d} , B_{sm}^{d} , B_{sl}^{d} denoting download service for high, medium, and low bandwidth demand.

The constraints indicate that the total upload service bandwidth demand for all users cannot be more than the maximum available upload bandwidth, and additionally, the total download service bandwidth request for all users is limited to the maximum download bandwidth capacity.

3.7.2 Establishing a Framework of Sustainable HMM Model

In establishing a sustainable HMM model framework, this research considers the various n-Services that consume bandwidth on the ODeL platform: virtual classroom via the internet, registration load, assignment submissions, online exam submissions, e-tutoring, video conferencing, course material upload and download, and more. The bandwidth demand for the various services is monitored and recorded by the SolarWinds bandwidth monitoring tool. These are fed into HMM to predict future bandwidth, which serves as a feeder to Normalizer to plan bandwidth, as indicated in Figure 3.5. Each bandwidth predicted on service by HMM serves as an input to the Normalizer planner to allocate the bandwidth demand on each service for three days. This collaborative planning is an iterative process.

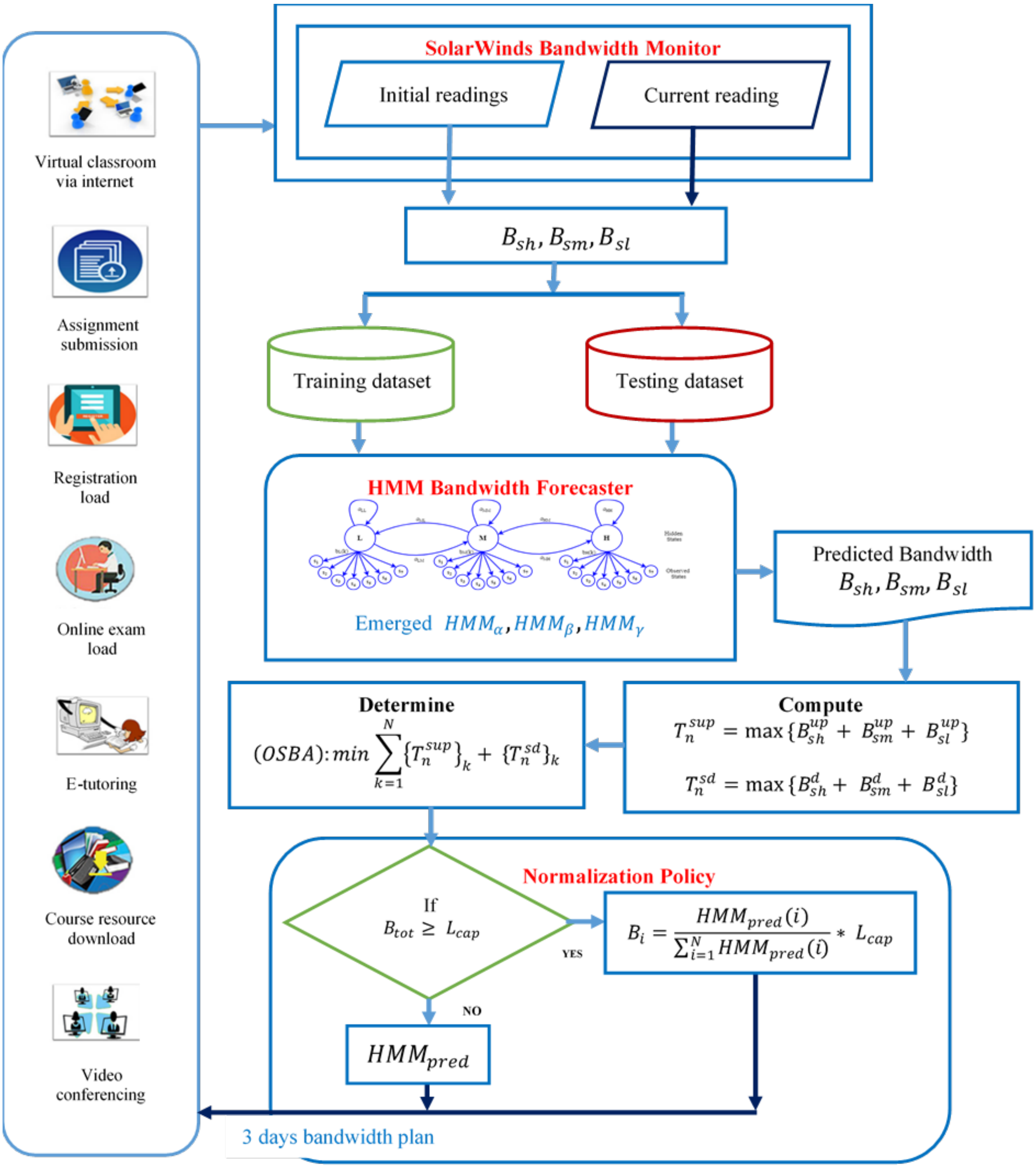


Figure 3.5: Framework of sustainable HMM for managing ODeL platform bandwidth

Thus, the model first monitors the ODeL network bandwidth consumption of massive users' services by SolarWinds network performance monitoring tool. Next, the collected data is supplied to the HMM to predict bandwidth demand. Finally, the predicted results fed into the Normalizer-Planner generate bandwidth consumption plan for all services.

3.7.3 SolarWinds Network Performance for ODeL N-services

SolarWinds network performance monitor configured to provide comprehensive performance monitoring of all devices on the network. It is done through a customizable web interface in a unified view to provide real-time views of their performance and availability statistics. Each service's data on the ODeL environment using a script interfaced with an automated network discovery and mapping feature that scans the network for changes and monitors new devices.

The installation file was obtained from (SolarWinds, 2018). The setup completion is by setting device information, selecting simple network management protocol (SNMP), connecting to Sustainable HMM application for data gathering, setting up warnings, setting limits to read data by time. Finally, launched the monitor to commence the experiment, of which a week was used to monitor the results' accuracy and consistency. Obtaining the bandwidth consumption of the various services follows Algorithm 1.6.

Algorithm 1.6: SolarWinds monitoring

```
    INPUT: Services bandwidth utilization (peak and off-peak)
    OUTPUT: Table of recorded services bandwidth utilization (peak and off-peak)

Step 1: SET i = 1;
    2: GET peakStatus
    3: GET bandwidthLevel
    4: IF (peakStatus == off_peak) THEN
    WHILE (bandwidthLevel == l)
        WHILE( i <= 7)
          Record si(l)
          i ++
        END WHILE
    END WHILE
    WHILE (bandwidthLevel == m)
        WHILE( i <= 7)
          Record si(m)
          i ++
        END WHILE
    END WHILE
    WHILE (bandwidthLevel == h)
    WHILE (bandwidthLevel == l)
        WHILE( i <= 7)
          Record si(l)
          i ++
        END WHILE
    END WHILE
    WHILE (bandwidthLevel == m)
        WHILE( i <= 7)
          Record si(m)
          i ++
        END WHILE
    END WHILE
    WHILE (bandwidthLevel == h)
    WHILE( i <= 7)
          Record si(h)
          i ++
        END WHILE
```

WHILE(i <= 7)	END WHILE
Record $s_{i(h)}$	END IF
i ++	5: STOP
END WHILE	
END WHILE	
ELSE IF (peakStatus == peak) THEN	

3.7.4 HMM Interfacing with Network Performance Technology

a. *Formal sustainable HMM description*

Formally, the sustainable HMM is modeled as temporal records over time 1 to t, such that:

$S_t = \{s_1, s_2, s_3, \dots s_t\}$, implies observed states sequences,

$B_t = \{\text{L}, \text{M}, \text{H}\}$, implies hidden states.

Figure 3.6 depicts the relationships between the observed and hidden states on the sustainable HMM.

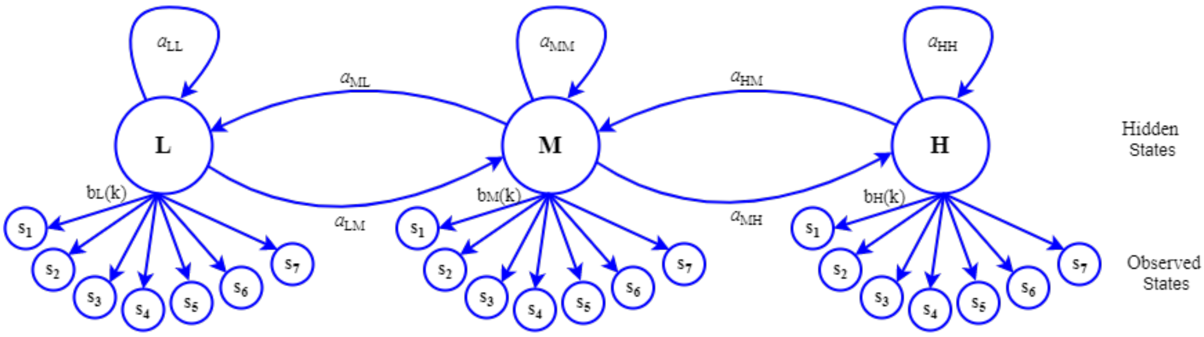


Figure 3.6: Sustainable HMM structure

The structure requires computing the probability of hidden bandwidth states in equation (3.5).

$$P(Bandwidth) = P_{ij} = P(B_t\,|B_{t-1}),\ \ t = 1, 2, 3, \dots T \tag{3.5}$$

It also requires computing the probability of observed/extracted states in equation (3.6).

$$P(service) = b_j(k) = P(S_t\,|B_t),\ \ t = 1, 2, 3, \dots T \tag{3.6}$$

S_t represents the observed bandwidth demand obtained by the SolarWinds network monitoring tool for the six services $(S_1, S_2, S_3, \ldots, S_6)$

b. *Emergence of Candidate HMM*

This section of the research aims to assess whether a higher weight to a bandwidth demand for service presents better accurate HMM. Prioritizing the initial state probability π of bandwidth demand as weighted states of a high, medium, or low bandwidth demand for services leads to the emergence of three variants of HMM configured as follows:

HMMα with π: {w = 0.5* H, w = 0.3* M, w = 0.2* L};

HMMβ with π: {w = 0.3* H, w = 0.2* M, w = 0.5* L};

HMMγ with π: {w = 0.2* H, w = 0.5* M, w = 0.3* L};

This can be hypothesized as follows:

H_0: (HMM - HMMα - HMMβ – HMMγ) = 0

H_1: (HMM - HMMα - HMMβ – HMMγ) ≠ 0

(where H_0 = null hypothesis and H_1= alternative hypothesis)

3.7.5 Learning Process of the Sustainable HMM

This research then derives the joint probability using the forward algorithm. Algorithm 1.7 presents the learning process of Sustainable HMM.

Algorithm 1.7: Learning process of the sustainable HMM

INPUT: Services bandwidth utilization (peaks and off-peak) OUTPUT: Approximate HMM's parameters
s = state, *N* = number of hidden states, Ω = observation sequence, *t* = number of observations, *A* = state transition matrix, *B* = observation probability matrix, a_{ij}= probability of a transition from state *i* to state *j*, $b_j(\Omega_t)$ = observed probability Ω_t at state *j*, π = initial state probability, $\lambda = (A, B, \pi)$ = HMM compact notation, $\delta_t(i)$ = an auxiliary variable of a projection of the maximum probability for a partial

observation series and state sequence up to t, $\Pi_t(i)$ = posteriori probability, $\xi_t(i,j)$ = forward and backward variables of auxiliary variable.
Step 1: Accept monitored bandwidth data, s_i 2: Derive joint probability For t = 1, 2, 3, to n, also i = 1, 2, 3, to N Compute: $B_t(i) = P(\Omega_1, \Omega_2, \Omega_3, \ldots \Omega_t, q_t = s_i \mid \lambda)$ 3: Set $P(\Omega\mid\lambda) = 1$ and $B_t(i) = \pi_i b_i(\Omega_1)$ 4: For t = 1, 2, 3, to n, also i = 1, 2, 3, to N Compute: $B_t(i) = \left[\sum_{j=1}^{N} B_{t-1}(j)\, a_{ij}\right] b_i(\Omega_t)$ Then, $P(\Omega\mid\lambda) = \left[\sum_{i=1}^{N} B_n(i)\right]$ And $\delta_t(i) = P(\Omega_{t+1}, \Omega_{t+2}, \Omega_{t+3}, \ldots \Omega_n \mid q_t = s_i, \lambda)$ 5: Applying a recursive function Set $\delta_t(i) = 1$ for i = 1, 2, 3, to N For t = n – 1, n – 2, n – 3, … and i = 1, 2, 3, … N Compute: $\delta_t(i) = \sum_{j=1}^{N} a_{ij} b_j\,(S_{t+1})\delta_{t+1}(j)$ At state s_i at the time t, compute: $\Pi_t(i) = P(q_t = s_i \mid \Omega, \lambda)$ Compute: $\Pi_t(i) = \frac{B_t(i)\delta_t(i)}{P(\Omega,\lambda)}$ 6: Re-estimate A, B, π For i = 1, 2, 3, to N, set $\pi_i = \Pi_t(i)$ For i = 1, 2, 3, to N also j = 1, 2, 3, to N Compute: $a_{ij} = \frac{\sum_{t=1}^{n-1} \xi_t(i,j)}{\sum_{t=1}^{n-1} \Pi_t(i)}$ For j = 1, 2, 3, to N also k = 1, 2, 3, to N, Compute: $a_{ij} = \frac{\sum_{t=1,\ \Omega_i=k}^{n} \Pi_t(i)}{\sum_{t=1}^{n} \Pi_t(i)}$

3.7.6 Predicting Future Services Bandwidth with HMM Viterbi Algorithm

This research employs the Viterbi algorithm to predict future services bandwidth, which computes the best-hidden bandwidth sequence.

The future bandwidth for the services prediction process is in Algorithm 1.8.

Algorithm 1.8: Predicting future service bandwidth

INPUT: Services bandwidth utilization (peaks and off-peak) OUTPUT: Predicted bandwidth utilization (peaks and off-peak)
s = state, q = hidden state, N = number of hidden states, Ω = observation sequence, t = number of observations, A = state transition matrix, B = observation probability matrix, a_{ij}= probability of transition from state i to state j, $b_j(\Omega_t)$ = observed probability Ω_t at state

j, π = initial state probability, $\lambda = (A, B, \pi)$ = HMM compact notation, $\delta_t(i)$ = a supplemental variable created to forecast the maximum likelihood for the partial sequence of observation and sequence of state up to *t*. $\Pi_t(i)$ = posteriori probability, $\xi_t(i, j)$ = auxiliary variable to the forward and backward variables.
Step 1: Define $\Pi_t(i) = \max P(q_1, q_2, q_3, \dots, q_t = s_i, \Omega_1, \Omega_2, \Omega_3, \dots, \Omega_t \mid \lambda)$ 2: Set $\Pi_t(i) = \pi_i b_i(\Omega_1)$, *i* = 1, 2, 3, to *N* 3: For t = 1, 2, 3, to n and i = 1, 2, 3, to *N* $\Pi_t(i) = \max_j [\Pi_{t-1}(j) a_{ij}]\, b_i(\Omega_t)$ For *j* = 1, 2, 3, …, *N* 4: Then compute the best hidden bandwidth sequence $q_n = argmax_j [\Pi_n(j)]$ 5: Predicted bandwidth $\xi_t(i, j) = \frac{B_t(i) a_{ij} b_j(\Omega_{t+1}) \delta_{t+1}(j)}{P(\Omega \mid \lambda)}$

3.7.7 Planning: Sustainable HMM Handshakes with Normalization-Policy

The bandwidth planning is achieved based on the HMM's prediction (HMM_{pred}) with an optional handshake with Normalizer. If the total predicted bandwidth for all services exceeds the available bandwidth capacity, each service prediction is forwarded to the Normalizer to plan appropriately within the maximum capacity, otherwise allocating the predicted values without change. Normalization policy is formulated as:

$$B_i = \frac{HMM_{pred}(i)}{\sum_{i=1}^{N} HMM_{pred}(i)} * L_{cap}$$

(3.7)

Further, this research presents the deduction of the planning as:

$$B_i = \begin{cases} HMM_{pred} \;, \; if\; B_{tot} \leq L_{cap} \\ \frac{HMM_{pred}(i)}{\sum_{i=1}^{N} HMM_{pred}(i)} * L_{cap} \;, \; if\; B_{tot} \geq L_{cap} \end{cases}$$

(3.8)

Where, B_i indicates allocated bandwidth for each service, HMM_{pred} denotes the predicted value from HMM, B_{tot} represents total bandwidth demand for services, and L_{cap} represents the available bandwidth capacity.

3.7.8 Analytical Scenario

In an ODeL environment, thousands of users may send requests to the single system remotely at the same time. This research achieves optimal bandwidth demand allocation in our Sustainable HMM model by analyzing results under two scenarios in Table 3.2.

Table 3.2: Analyses of off-peak and peak scenarios

Scenario 1: At the off-peak time	Scenario 2: At the peak time
GIVEN: Network capacity (L_{cap}) is 250MB HMM PREDICTED: Course resource download = 109.5MB Registration demand = 33.0MB Submitting Assignments = 63.0MB Online Exam = 42.0MB E-tutoring = 40.0MB Video Conferencing = 0.0MB REQUIRED TO SCHEDULE: Total bandwidth demand (B_{tot}) = 109.5 + 33.0 + 63.0 + 42.0 + 40.0 = 287.5MB OUTPUT: Extra demand $= B_{tot} - L_{cap}$ = 287.5MB – 250MB = 37.5MB	GIVEN: Network capacity (L_{cap}) is 250MB HMM PREDICTED: Course resource download = 60.7MB Registration demand = 16.3MB Submitting Assignments = 100.6MB Online Exam = 48.9MB E-tutoring = 63.0MB Video Conferencing = 65.1MB REQUIRED TO SCHEDULE: Total bandwidth demand (B_{tot}) = 60.7 +16.3 +100.6 +48.9 +63.0 +65.1 +115.4 = 354.6MB OUTPUT: Extra demand $= B_{tot} - L_{cap}$ = 354.6MB – 250MB = 104.6MB

From scenario 1, if the network capacity (NC) is 250MB, it will happen that some of the services may not accomplish because of an extra 37.5MB required to satisfy all services at the off-peak period. Augmenting the bandwidth capacity with 100MB (to 350MB) will still have a deficiency of some services unaccomplished during peak time in scenario 2.

Considerably, if HMM predicts, the Normalizer planner will apportion only the available bandwidth capacity to all required demands.

3.7.9 Scoring and Evaluation Mechanisms

Error metrics and accuracy

This research computed the model's error margins to determine accuracy and precision. The discrepancy between a model's anticipated and actual values is frequently measured using the mean square error (MSE) as well as the root mean square error (RMSE). This research also computed the mean absolute error (MAE) obtained by taking the absolute value for each error. The formulas of these standard evaluators are as follows (Hyndman & Athanasopoulos, 2018):

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{t=1}^{n}(x_t - \overline{x_t})^2} \quad (3.9)$$

$$\text{MSE} = \frac{1}{N}\sum_{t=1}^{n}(x_t - \overline{x_t})^2 \quad (3.10)$$

$$\text{MAE} = \frac{1}{N}\sum_{t=1}^{n}(|\, x_t - \overline{x_t}\, |) \quad (3.11)$$

where N = n-1, n is the sample size, x_t denotes the forecast values, and $\overline{x_t}$ represents the mean sample size.

3.8 Conceptual Framework on Proactive Conflict Management in ODeL

This section considers a review that aims to identify, evaluate and interpret all relevant available publications suitable under specified criteria to address the research question on how to manage conflict in ODeL to promote smart education. The work of Kitchenham et al. (2010) presents a detailed plan to specify the quality measurement for literature selection to ensure the review quality. This research employs such a plan to ensure the review quality. The likelihood of bias is reduced significantly in the review process to advance research efforts with a balanced analysis and interpretation of findings

This research follows a three-step strategy; the first step is to identify the review requirements, establish the research questions, deduce, and evaluate a review procedure. The second step is to conduct the search policy, choose the criteria and articles' quality, and perform extraction processes to obtain the relevant models. Finally, the relevant models are discussed and reconstructed to incorporate conflict management.

3.8.1 Model for Automatic Smart Conflict Management in Smart Education

Coping with conflict proactively in Smart Education, automatic conflict resolution principles are employed to propose a model. Since real-time responses are management operations needs for real-time systems, integrating all conflict classifications with the execution of their resolution mechanisms is necessary for automatic conflict detection and resolution.

To find and resolve conflicts, all conflict detection and resolution procedures are run simultaneously in real time. So that they can execute concurrently, this can be done by multithreading. The model for proactively resolving conflict in smart education is shown in Figure 3.7. The themes deduced under the literature survey for addressing conflict in ODeL for smart education underscoring the model are as follows:

i) *Smart education models:* under this theme is to analyze the established models for smart education to ascertain the possibility of fusing in them conflict management to provide QoS in ODeL.

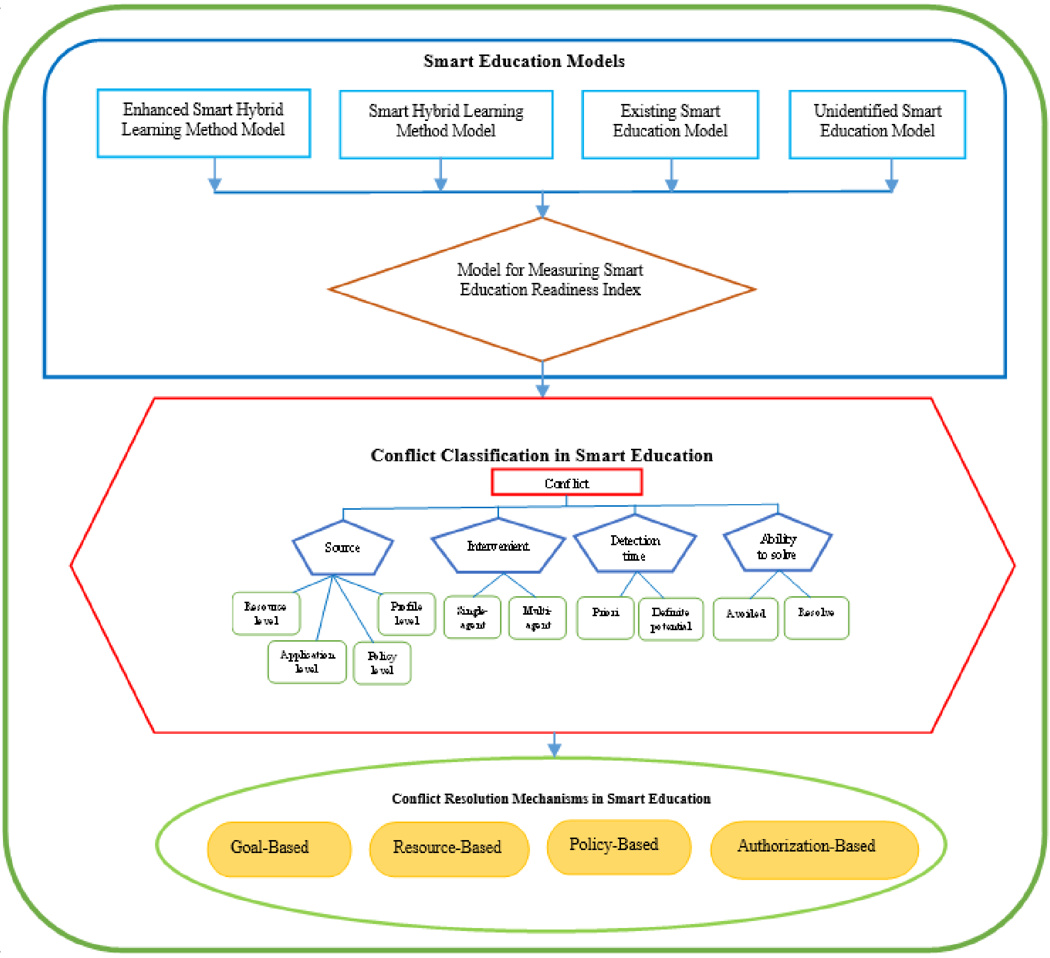


Figure 3.7: Automatic conflict resolution model for smart education

ii) *Analysis of measuring smart education readiness:* a model for establishing criteria for the readiness of institutions that are into smart education.

iii) *Conflict classification in Smart education:* a consideration of identifying the various conflicts and classify them under four themes to aid in managing the conflicts.

iv) *Conflict management approached:* following the classified conflicts this theme analyzes the mechanisms suitable for addressing conflicts in smart education for QoS in ODeL.

When a conflict is automatically identified, the next step is to categorize it based on its source, intervenors, detection time, and resolvability. It is regarded as non-classified if it is unrelated to any of these classes. These conflicts can be ones that arise from vague behaviors in the context of smart education.

Every conflict that can be categorized to fit a certain resolution mechanism that will help the situation is entered into the resolution phase. Goal-based, resource-based, policy-based, and authorization-based resolution procedures are some of these. A single disagreement can be resolved through a variety of techniques. As a result, the adoption of parallel processing will result in significant increases in the system's capacity and traffic, which will ultimately result in system inefficiencies.

Conflict in smart education is not limited to the conceptual framework for the implementation and at the start but can evolve at any point in the teaching and learning processes. These depend on several factors, as indicated by Hasan et al. (2006). The framework proposed in this research evaluates the various environmental factors and classifies them as conflict patterns in smart education. Classification as source conflict may be from a resource of smart education system not satisfying all agents. Applications running on the smart education systems may not be the best source of requirements, some smart education policies may hinder the system’s smooth running, and some profile specifications or limitations such as the agent’s sticking to his preference to win. Intervenient conflict could be single-agent having personal conflicting issues such as possible adverse health effects of long-period technology usage or multi-agent between teacher and student, staff and students, student and learning system, teacher and learning system and other conflict involving two or more agents. Another classification is the conflict detection time prior to its occurrence or at a definite potential period in the process of teaching and learning. Conflict classification an as well be based on its ability to provide a solution. Avoidance results in not pursuing the conflicting issue, and the second is resolving, which is a conflict that suggests the ability to dig beneath the pressing issue and propose an appropriate solution. The other ways of classification under the ability to solve could be yielding by neglecting or sacrificing some benefits to keep the system moving or compromising by playing safe with identified middle ground amid the conflicting issues.

Identifying and categorizing the various conflicts in smart education provides a springboard spanning into a resolution mechanism. The automatic smart education conflict resolution framework identifies four resolution approaches. Single or multiple approaches may help in resolving the conflict. Every stage in a smart education's teaching and learning process has specific goals; hence, conflicting goals may arise from each stage. A goal-based conflict resolution mechanism is applied to resolve any conflict related to conflicting goals in the smart education environment. Conflicts that occur due to resource limitations, such as bandwidth constraints, are resolved through resource-based conflict resolution mechanisms in smart education. There is a need for an appropriate response to resource distribution to all agents in a smart education environment. Policy issues such as smart course scheduling requirements present some smart education conflict and are resolved through policy-based conflict resolution techniques. Last but not least, authorization is a crucial component of a smart learning environment, particularly in smart assessment. Authentication, privacy, and other security-related conflicts are considered under authorization and addressed by authorization-based conflict resolution mechanisms.

3.8.2 Databases and Search String

The study concentrated on the journals and conference proceedings from January 2012 to June 2022. The selected academic databases as primary sources were Scopus, Science Direct, IEEE Xplore, SpringerLink and ACM Digital Library. These relevant academic repositories were selected based on the advancement in smart education concepts and ODeL.

The chosen search string for limiting the number of articles obtained and ensuring their relevance by applying keywords of Boolean operators like OR and AND representing synonyms and associative words, respectively. Keywords related to the research topic, synonyms, and alternative words were identified manually. The keyword criteria employed to search in the database indexes include; "smart education", "smart model", "smart learning", and "e-learning conflict", "virtual conflict". Diverse combinations of these keywords applying "AND" and "OR" commands are used as the search string.

3.8.3 Criteria for Inclusion and Exclusion

This stage was carried out to determine which article is relevant for further review. We defined the criteria for inclusion and exclusion in Table 3.3.

Table 3.3: Criteria inclusion and exclusion

Inclusion criteria	Exclusion criteria
Published between 2012 and 2022	book chapters, abstract publications, technical reports, and dissertations
Written in English	Do not mention keywords in the research area.
Discussed smart education or e-learning models, e-learning conflict, or virtual conflict.	Discussed general education and conflict issues.
Included in scientific conferences and journals	Do not include smart education models, and strategies for conflict management.

3.8.4 Search and Selection

A quality assessment filter was used to ascertain the articles that passed the inclusion and exclusion criteria for smart education models, conflict identification, and resolution. The results of the search and selection process are displayed in Table 3.4.

Table 3.4: Search and Selection Process

Selection process	Number of articles
Identification with the search string	754
Exclusion & inclusion criteria	62
Remove duplicated studies	58
Screened titles, abstracts, and keywords	27
Eligibility assessment	7

3.9 Development of IQSODeL Model and Validation

The overall intelligent quality of service model for open distance electronic learning follows the integration of all the QoS elements. This integration is presented in Figure 3.8.

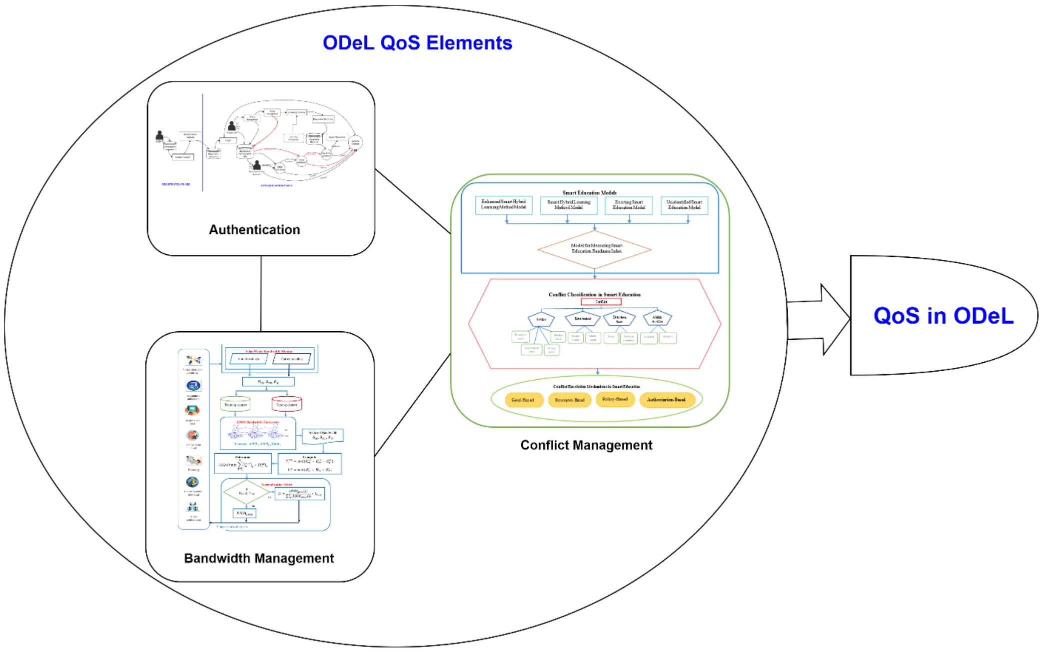


Figure 3.8: An intelligent model for quality of service in ODeL (IQSODeL)

The model constituents are the critical elements for QoS in ODeL, which are evaluated in the research.

3.9.1 Validation of IQSODeL

With respect to the validation of IQSODeL model the data collection tool was a self-administered questionnaire through the application of Microsoft Office forms. The first part of the questionnaire constituted the data on profile; gender, age, designation, and study level of student of respondents. The second part employs the SERVQUAL model to obtain the data on the QoS in ODeL, which each quality elements identified through the five dimensions (assurance, reliability, tangible, empathy, and responsiveness).

The updated SERVQUAL model that was suggested by Parasuraman et al. (1985) was employed in this research to evaluate the QoS based on the security, network bandwidth management, and conflict management in the ODeL environment.

A significant number of works in the literature show the use of the SERVQUAL framework to assess service quality in many institutions (Wang et al., 2015). SERVQUAL was used in a cross-sectional research to gauge students' quality of experience (Aboubakr & Bayoumy, 2022). Considering the implementation in academic institutions (Gilavand & Maraghi, 2019; Misaii et al., 2019; Yousapronpaiboon, 2014), the summary of the questions for performance assessment of QoS dimensions is presented as:

- Assurance: Knowledge of systems, civility, and their capacity to inspire confidence. For example, standardized system requirements implementation to ensure security and cheating free examination.
- Reliability: the capacity to carry out the essential service accurately and dependably. This is to ensure the consistent availability of functional system resources such as appropriate bandwidth allocation.
- Tangible: This includes the physical surroundings, tools, and personnel appearance. This is to ensure consistent availability of learning resources, suitable study, and service timetables in order to prevent conflict.
- Empathy: Considerate and individualized attention that the institution provides to learners. For instance, instructors and staff are empathetic, enough advisors and staff to address learners' problems.
- Responsiveness: willingness to assist students and deliver quick service. This includes clear communication from the teachers and a system for receiving feedback, simple access to the system and materials, courteous instructors and staff who give learners excellent service, and rapid turnaround times for services.

The questionnaire consisted of 25 items of which the first parts with four items seeks to identify significant profile of the respondents. On a 5-point Likert scale, the other 21 items collect the QoS determined by SERVQUAL: "strongly agree" (5), "agree" (4), "unsure" (3), "disagree" (2), and "strongly disagree" (1).

3.9.2 Data Analysis

The key elements for constructing intelligent model for QoS in ODeL were accomplished through approaches for both quantitative and qualitative data analysis. The experimental process for user authentication used the cross-validation based on leave-p-out method, which 40 space difference intervals are taken into account for both testing and training for facial and voice recognition whereas interval of 20 was used for keystroke dynamics authentication. To help assess the sensitivity and specificity of the data set, the research used a receiver operating characteristics curve. A confusion matrix was used to evaluate how well the data were categorized. The study of the developed bandwidth management model's accuracy and precision is done by calculating the mean square error, mean absolute error, and root mean square error. On the analysis of conflict management for QoS in ODeL for smart education, thematic analysis was used. The selected models for smart education in ODeL were examined to identify the thematic concepts to reconstruct the models to incorporate conflict management. Thematic analysis has been found to be useful for qualitative research (Sharifi, 2022; Castleberry & Nolen, 2018) and for developing theoretical frameworks (Vaismoradi et al., 2013)

The overall intelligent QoS model, IQSODeL was analyzed by uploading the collected data from the respondents on the questionnaire administered on Office Form into Statistical Package for the Social Sciences (SPSS). With the aid of exploratory and confirmatory factor analyses and the construction of a structural equation model (SEM), the demographic features of the participants were examined. In factor analysis it is stated that when a scale's Cronbach Alpha (α) value is .60 or higher, it is regarded as dependable; if it is .80 or higher, it is regarded as highly reliable (Kalayci, 2010). Field (2017) opines that scale with a value above .70 can be deemed to have an adequate reliability coefficient.

Particularly in the social sciences, the boundary value of factor loads can be decreased below 0.30 when the items quantity in a scale is constrained in confirmatory factor analysis (CFA) and exploratory factor analysis (EFA). Additionally, even though a factor loads below 0.30 affects the content validity, studies can be done without removing the linked item from the scale (Osborne, 2014). Researchers utilized the AMOS 24.0 tool to conduct scale-level CFA and SEM analyses of the correlations (Shek & Yu, 2014). CFA typically is used after EFA to produce more precise statistical results (Kline, 2015). A SEM was also developed, and it is now a highly favored model because it is superior to other models for experimental or survey research that adheres to the concept of discovery and confirmation (Bagozzi & Yi, 2012; Hurley, 2022). This research therefore, employed these to confirm the QoS elements suitable for constructing intelligent model for ODeL.

3.10 Chapter Summary

This chapter went into great detail on the methodology used to create the IQSODeL framework. The research participants involved in the authentication of users for secured cheating-free examination in ODeL, bandwidth management, and validation of quality elements were presented. The qualitative techniques for establishing conflict management model in ODeL were presented. The instruments employed for data collection were discussed.

The tools and techniques for the development of the QoS are presented and further discussion on the development of the QoS elements framework with the mathematical and algorithmic processes is detailed in this chapter. The next chapter present the experimental evaluation of the models proposed in this chapter to ascertain their performance in achieving QoS in ODeL.

CHAPTER 4

EXPERIMENTAL EVALUATIONS OF ODEL FRAMEWORKS

4.1 Introduction

In-depth experimental evaluations of the models created for user authentication and bandwidth control in an ODeL for QoS are presented in this chapter. The experimental setup of the tools and techniques employed for bimodal authentication, fused multimodal authentication, and bandwidth management are discussed. The experimental results are analyzed and discussed. The analysis of the conceptual framework for automatic conflict management for smart education in ODeL for QoS is presented. In addition, the quantitative analysis and discussion of the overall QoS model (IQSODeL) is presented.

4.2 Experimental Evaluation of Authentication Model

This section presents the experimental evaluations of the bimodal and the fused multimodal authentication method for cheating-free ODeL examination.

4.2.1 Experimental Setup for Bimodal Authentication

One hundred fourth-year undergraduate students in the fields of computer science, information technology, and education who were majoring in information technology at a university volunteered to participate in this study. The ODeL environment for the experiment was the Moodle learning management system. This was chosen since it is well-known to the students and because the institution has accepted it as its e-learning platform. The client-server implementation setup's network topology, shown in Figure 4.1, shows the many places where agents (students) were linked to the system for training and authentication. The computer lab, a resident hall (where a connection was built through the intranet), and one's home were determined to be the three primary places (connected through the internet).

It is supposed that the non-venue-based test necessitates the examinee to be in a closed space wherever the student can access the testing system.

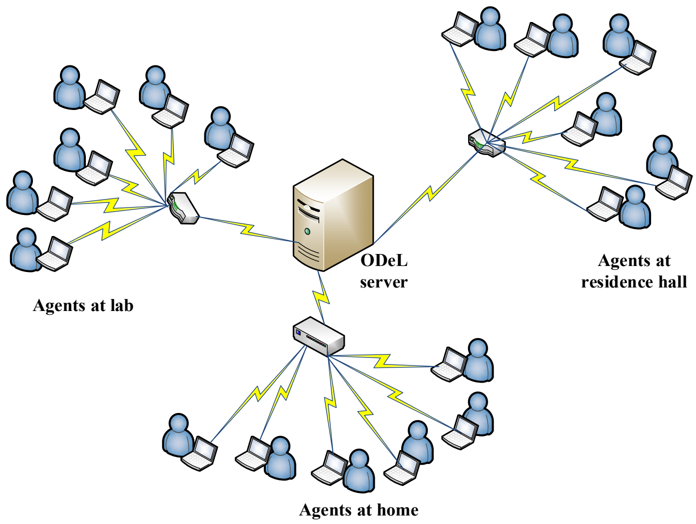


Figure 4.1: Client-server implementation network diagram

4.2.2 Authentication of Facial Biometrics

The Gabor filter was used to pre-process the photographs after taking pictures of the students' faces. Additionally, a 30-second movie was recorded, filtered, and all of these pictures were stored in a database. The pupils' computers' webcams were turned on to do this. The student data set was then utilized to train the machine learning algorithm created using OpenCV, the Haar feature-based cascade classifier.

Both a detector and a trainer are included with OpenCV. OpenCV was used to develop a classifier utilizing cascade classifier training in an effort to train one for any picture or movie. This has to do with figuring out where in the database each image or video had been stored. Since OpenCV already has a large number of classifiers that have been pre-trained for face, eyes, grin, and other features, it was further used for face authentication based on the chosen technique.

4.2.3 Authentication of Keystroke Dynamics

Since all students' laptops have QWERTY keyboards, one was made available for everyone. Keyboard examples are displayed in Figure 4.2. It has been demonstrated that the type of keyboard has no bearing on keystroke dynamics or performance (Giot et al., 2011). When agents' keystrokes were logged, the initial entries were removed for operational efficiency.

In terms of authentication, GREYC keystroke software created at the GREYC Laboratory is used to capture the keyboard biometrics data (GREYC Laboratory, no date). In a single month, the students who used the system twice daily and five times a week provided over 6000 samples of data.

(a)

(b)

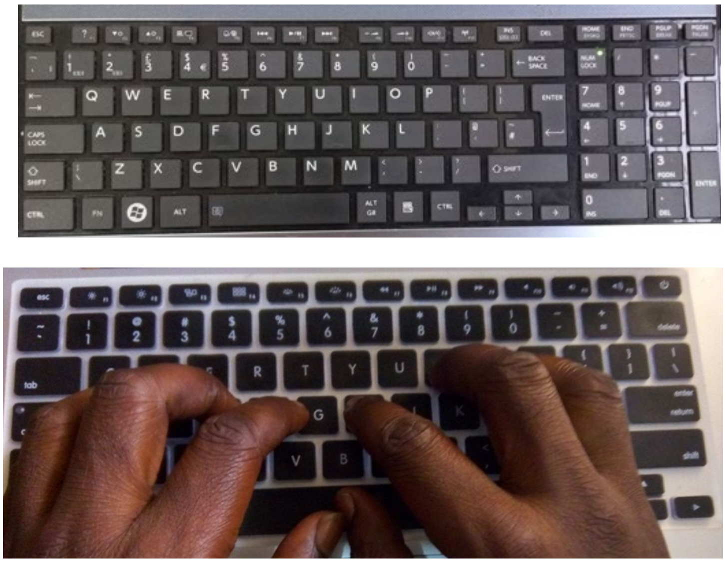


Figure 4. 2: Samples of user's keyboards

4.2.4 Face Data Samples Description

The sample comprises of 75% males and 25% females, with 20% majoring in computer science and 70% majoring in information technology (IT). Students majoring in information technology who are studying in education make up the remaining 10%. We used 20 third-year IT students as the imposter data set during the authentication step to evaluate the system's FAR.

In the first database, 520 data samples were recorded, of which 200 were movie images of the agents when they were in different locations around campus and 320 were still pictures of the agents: 315 still photos and 195 video images totaling 510 samples were recorded for the second database. These were gathered from students both on campus and off campus, at various points in their residence halls. These served as the algorithm's training data. When the pupils were out of the classroom, 480 samples—290 still photographs and 190 motion images—made up the data set for a third database.

In all three instances of the database population, the students were instructed to connect to the main ODeL server from their laptops equipped with webcams located on the university campus. Figure 4.3 shows a cross-section of faces for each instance of the database of the three agents due to the secrecy rule. It displays the lips and eyes that were taken out of the face for classification.

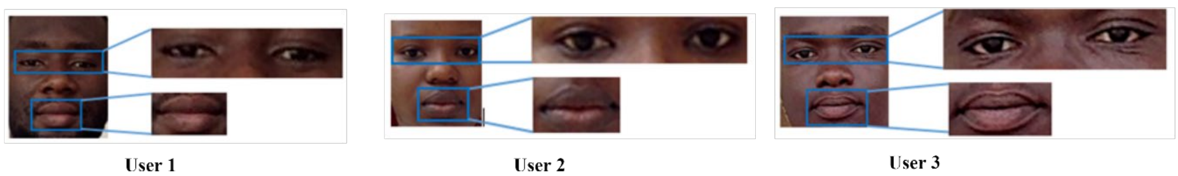


Figure 4.3: Three agents; facial cross-sectional features for classification

4.2.5 Experiment 1: Faces at a Distance Physiological Authentication

Table 4.1 displays the results of the experiment on different genders (three students' scores from six separate tests from each database instance) for facial feature authentication. The implementation results screen for students for six exams is also shown in Figure 4.4, along with the students' FAR, FRR, and recognition rate (RR).

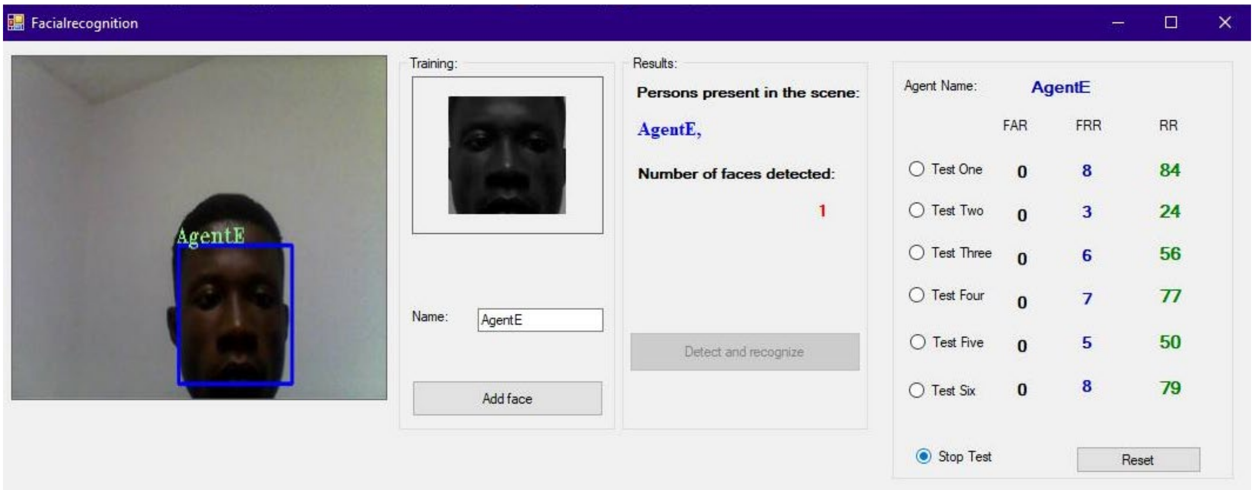


Figure 4.4: Screenshot of implementation results of a student

Table 4.1: Outcomes on authentication of three agents' facial features

Users	Test	Recognition rates (%)	FRR (%)
USER 1	1	96	0.04
	2	89	0.11
	3	90	0.10
	4	83	0.17
	5	75	0.25
	6	71	0.29
	Average	**84.0**	**0.16**
USER 2	1	97	0.03
	2	94	0.06
	3	87	0.13
	4	85	0.15
	5	79	0.21
	6	74	0.26
	Average	**86.0**	**0.15**
USER 3	1	93	0.07
	2	95	0.05
	3	91	0.09
	4	88	0.12
	5	76	0.24
	6	71	0.29
	Average	**85.7**	**0.143**

The following computations were used to arrive at the results for the recognition rate in Table 4.1:

= (Number of images accurately identified / Sum of all images) *100

For USER 1, the second recognition rate is calculated as follows: (8/9)*100 = 89%.

When the initial trial with three users for six tests is taken into account, the findings are shown in Table 4.1. As the agents advance through the testing process, a decline in the recognition rate can be seen. The erroneous rejection rates rise as a result of the earlier test recognition rates being higher than the later ones. This could be a result of the processing of the faces' lighting, position, and emotion.

The results of the first test on facial feature authentication at the three database instances are shown in Table 4.2 (DB1, DB2, and DB3). (The trials were carried out at three separate sites for the agents: the university computer lab, several residence halls, and during their free time at home.)

Table 4.2: Outcomes of all users' facial features authentication

Databases	Training	Testing	Recognition rates	FAR
DB1– Students in lab (520 records)	200	320	58%	0.012
	240	280	71%	0.019
	280	240	65%	0.015
	320	200	82%	0.028
	360	160	86%	0.014
	400	120	89%	0.011
	Average		**75%**	**0.017**
DB2 – Students at residence hall (510 records)	205	305	64%	0.016
	245	265	61%	0.019
	285	225	79%	0.021
	325	185	84%	0.006
	365	145	91%	0.011
	405	105	93%	0.010
	Average		**79%**	**0.014**
DB3 – Students at home (480 records)	210	270	71%	0.019
	250	230	77%	0.013
	290	190	84%	0.016
	330	150	77%	0.023
	370	110	90%	0.012
	410	70	95%	0.011
	Average		**82%**	**0.016**

The results show a great recognition rate percentage for each database. The recognition rates for the three databases are shown in Figure 4.5 along wit valuees from training and testing.

Table 4.2 shows that the recognition rate increases and the false acceptance rate decreases as the amount of testing data decreases. This might be due to processing effectiveness, which is reliant on the amount of processed data. The results' pattern is shown in Figure 4.5. According to the pattern, agent identification rates during training increase with an increase in trials, however during testing, recognition rates decline with an increase in tries. This is because the agents are more aware during training than during evaluation, when they might not be gazing into the camera as frequently.

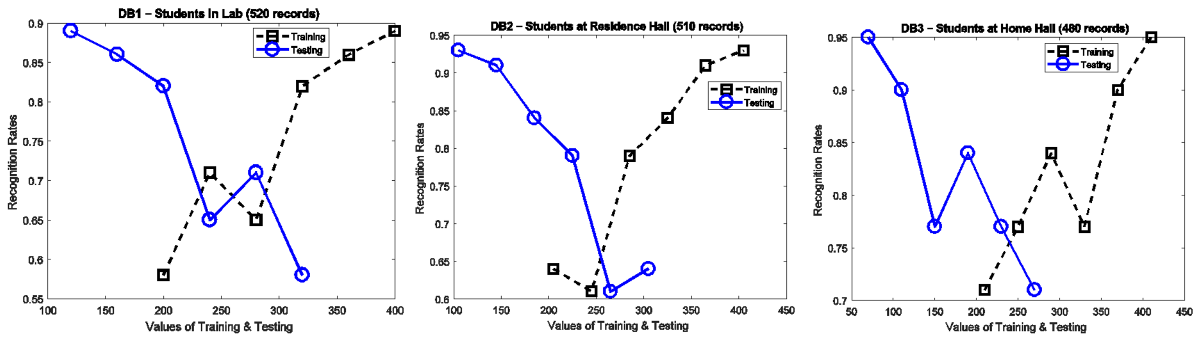


Figure 4.5: The three databases' recognition rates at training and testing

Additionally, Figure 4.6 displays the facial rate of recognition (ROC) in proportion to the false acceptance rate for the three datasets with various sizes. According to the ROC, mistake rates decrease as recognition rates rise.

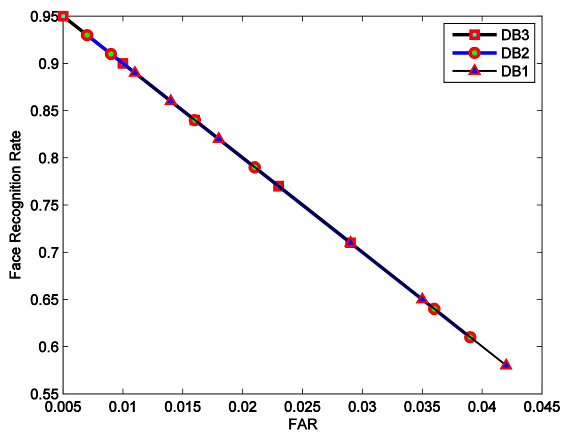


Figure 4.6: ROC: Facial rate of recognition and rate of false acceptance per database

4.2.6 Experiment 2: Students Behavioral Authentication at a Distance

Table 4.3 shows the keystroke patterns of three users—two men and one woman—for various character counts, including space (3, 6, 9, 12, 15, and 18). Table 4.3 also shows the results of the users' time intervals for various characters in chosen sentences. In order to show the trend, line graphs are enhanced. The recognition rates were calculated by counting the instances in which an agent successfully input a certain word based on the calculated delay between key release and key push. According to six experiments with roughly five success variables, the word "intelligent" (used as a password by user 1) yielded an 89% recognition rate.

The screenshot of an agent authentication process result in Figure 4.7, which displays the GREYC software (in the left pane) and displays identification and rejections (error), as well as timings of user key press and key release length, is shown.

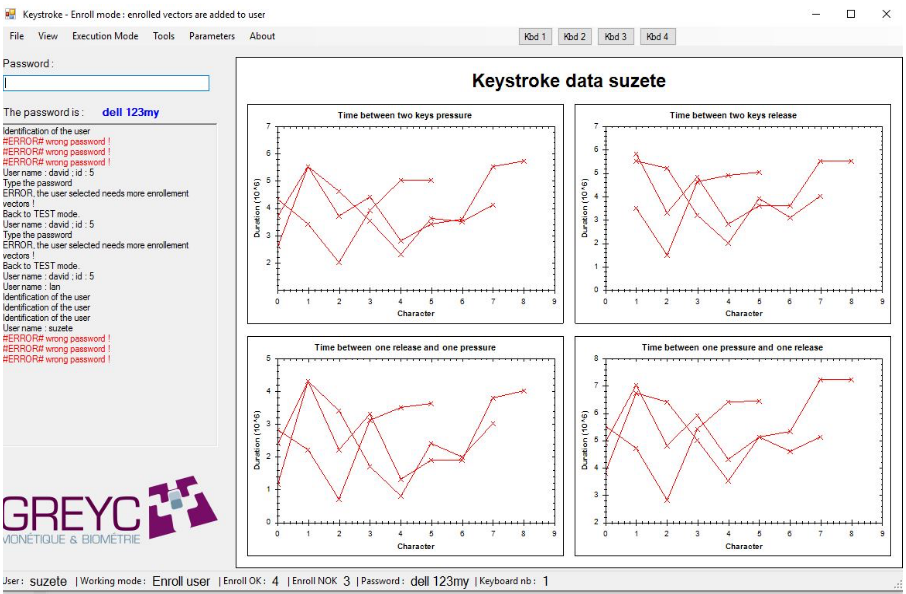


Figure 4.7: Agent keystroke process screen

Table 4.3: Keystroke patterns of three users examined on various characters

Users	Characters	Recognition rates (%)	FRR (%)
	Yes (3)	94	0.12
	System (6)	94	0.12
	Different (9)	90	0.2
	Intelligence (12)	89	0.22

	Characteristics (15)	71	0.58
	Distance education (18)	63	0.74
	Average	**83.5**	**0.33**
	Yes (3)	88	0.24
	System (6)	95	0.3
	Different (9)	91	0.38
	Intelligence (12)	84	0.52
	Characteristics (15)	75	0.5
	Distance education (18)	72	0.56
	Average	**84.2**	**0.42**
	Yes (3)	95	0.3
	System (6)	90	0.22
	Different (9)	77	0.46
	Intelligence (12)	81	0.38
	Characteristics (15)	74	0.52
	Distance education (18)	65	0.7
	Average	**80.3**	**0.43**

According to Table 4.3, as seen in Figure 4.8, the recognition rate is often greater for fewer characters typed in by agents. It is also evident that fewer characters have a lower erroneous rejection rate. This suggests that while fewer characters are being typed, agents' keystroke dynamics are more stable.

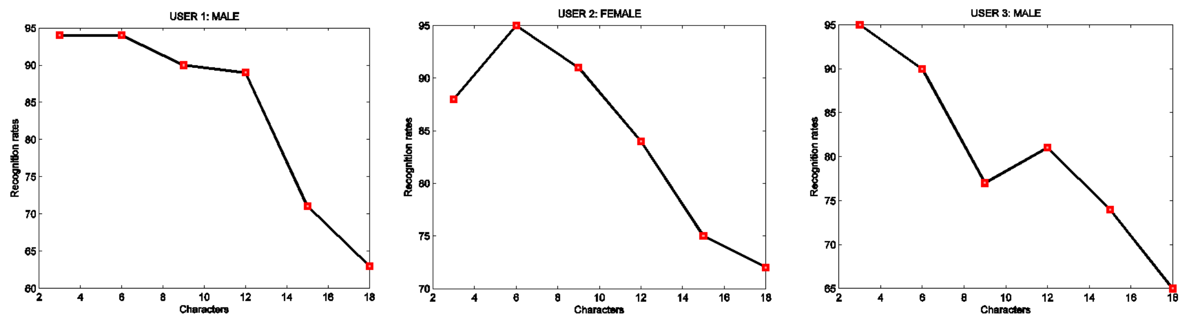


Figure 4.8: Keystroke patterns of three users on various characters

The average duration between pressing a key and releasing it for particular characters (E, O, I, C, V, D, A) in certain phrases of female and male users is shown in Table 4.4.

Table 4.4: Keystroke patterns of character in time interval

Users	Phrase	Character	Average Time
	Expert System user	E	0.325
	No option	O	0.174

	Artificial Intelligence	I	0.193
	Face recognition	C	0.121
	Valley View University	V	0.322
	Distance education	D	0.369
	False acceptance	A	0.241
	Expert System user	E	0.361
	No option	O	0.101
	Artificial Intelligence	I	0.236
	Face recognition	C	0.142
	Valley View University	V	0.326
	Distance education	D	0.382
	False acceptance	A	0.258
	Expert System user	E	0.317
	No option	O	0.157
	Artificial Intelligence	I	0.191
	Face recognition	C	0.144
	Valley View University	V	0.331
	Distance education	D	0.301
	False acceptance	A	0.227

With reference to Table 4.4, it can be inferred that some characters, including O, I, and C, reveal more time than ones like E, D, and V. This could be attributed to how these letters are arranged. The later characters are typed with the left hand, in contrast to the previously listed characters, which are mostly entered with the right hand, which will have a substantial impact on the typing time. Additionally, compared to women, men took less time between pressing and releasing a key. Figure 4.9 displays the pattern of the amount of time that has passed between three users' key presses and key releases on various characters. It is abundantly evident that a character's placement on the keyboard has a substantial impact on the dynamics of key press and key release; as a result, changes to each character's key press and key release will have an impact on the pattern.

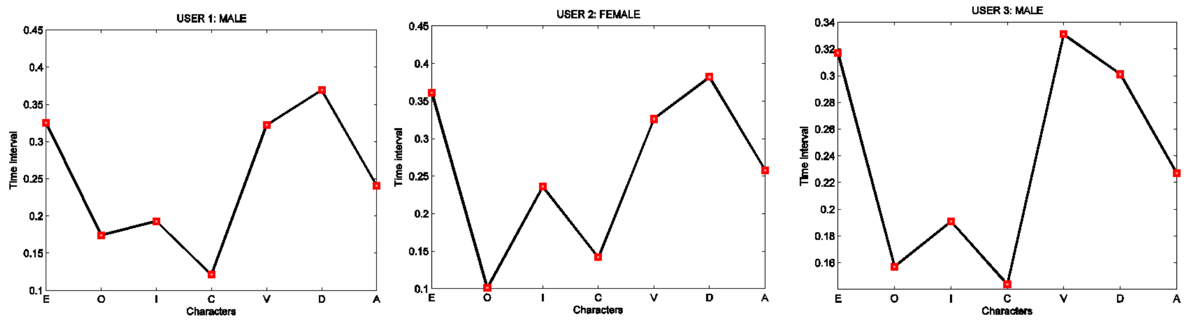


Figure 4.9: Keystroke patterns and the interval between key presses and key releases of characters

Figure 4.10 also displays comparison patterns between two users, user B and user C, as well as test data for a variety of characters used for training and authentication of some exam answers. The graphs show that as the number of characters increases, the recognition rate marginally declines, but there is no discernible difference between the training pattern's outcome and the authentication pattern. This is so that the recognition rate of typing long words compared to typing short words will be affected because differences in typing rhythm are brought on by outside causes like injury, exhaustion, or attention.

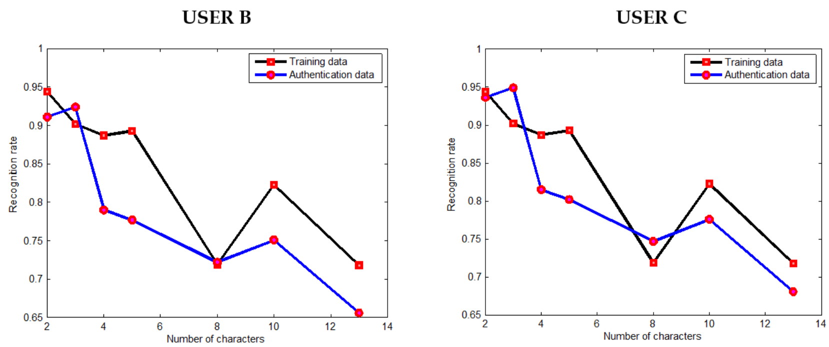


Figure 4.10: Training and authentication test set comparison of the user B and user C patterns

4.2.7 Experiment 3: Non-venue-based Assessment Bimodal Authentication

This section describes how to apply the suggested bimodal framework to the authentication of agents in non-venue-based assessment.

The suggested bimodal authentication is efficient and trustworthy for identifying agents during the evaluation. The combined results of the two authentication techniques for three users, with high and low recognition rates, are shown in Table

4.5. As a result, it has been found that agents' earlier findings had higher recognition rates than those from their later outcomes. This assumes the model will be effective throughout the assessment period, which will persist for that time frame.

Table 4.5: Recognition rates of fusing faces and keystrokes

Users	**Recognition rates of faces (%)**	**Recognition rates of keystroke (%)**	**Average fusion (f)**
	94	83.5	88.8
	86	84.2	85.1
	85.7	80.3	82.7
	65	50	57.5
	63	48	55.5
	55	51	53
Average	**74.7**	**66.2**	**70.4**
	97	88	92.5
	87	75.1	81.1
	77	72.4	74.7
	68	60	64
	61	64	62.5
	52	65	58.5
Average	**73.7**	**70.8**	**72.2**
	93	95	94
	88	77	82.5
	76	74	75
	71	63	67
	63	60,5	63
	59	56	57.5
Average	**75**	**73**	**74**

The bimodal authentication of User 1 in six separate trials of high (A-C) recognition rates that were approved and low (D-F) recognition rates that were rejected is combined in Figure 4.11. Both keystroke dynamics authentication (KD) and facial feature authentication (FR) are confirmed for each user. Based on the combination of FR and KD, which yields the average percentage values shown in Table 4.5, access to assessment resources is allowed. Denial of access will occur if either of them has an authentication failure.

Additionally, using equation (20) to calculate the variance of the average fusion result, a threshold is calculated.

$$T = \frac{\sum(x - u)^2}{n} \tag{20}$$

given T is the threshold, n is the total number of average fusion values, x is the average fusion value, and is the average fusion mean. A threshold of 67.95% was obtained by applying equation (20) to the average values of the facial recognition rate in Table 4.2 and the keystroke recognition rate in Table 4.3.

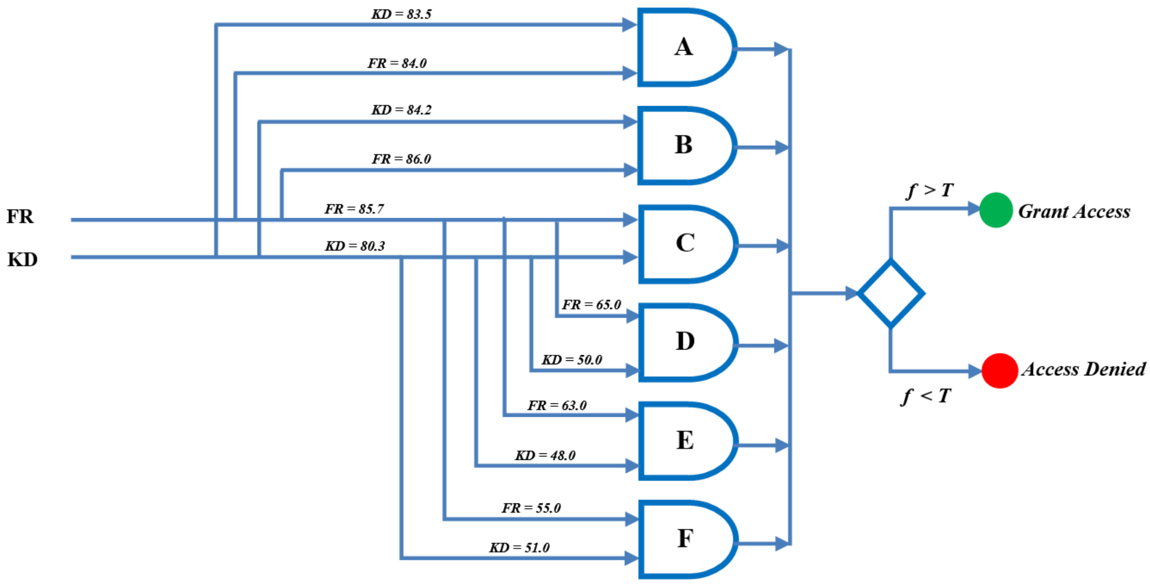


Figure 4.11: Keystroke dynamics fused with face authentication in six trials of an agent

Therefore, it is suggested that T = 67.95% of the fusion result be the minimal requirement before a user is given access. Any threshold selected should always, up to a proportional rate, be corresponding to the value of x since x is a ratio of the percentage of face and keystroke recognition. Therefore, a cutoff point for the related average fusion values needs to be established. In this instance, agents with average fusion values greater than 67.95% are allowed access to the system, whereas agents with lower values are not.

As shown in Table 4.5, the three users' fusion recognition rates show three approvals and three denials, chosen from various agent trials.

To ascertain whether or not the classification model generated an appropriate prediction, a two-class confusion matrix of recognition and rejection is shown in Table 4.6.

Table 4.6: Confusion matrix

N = 120	Recognition	Rejection	Total
Positive data set	84	16	100
Imposter data set	2	18	20
Total	86	34	120

Based on the 20 imposters added to the experiment and the 100 positive data sets, the following conclusions are drawn from Table 4.6:

- There were 84 true positives (TP), which represent the number of acknowledged agents who were eligible.
- There were 18 genuine negatives (TN), or imposters who were actually rejected.
- There were two false positives (FP), which represent the number of imposters who were acknowledged as being eligible.
- There were 16 false negatives (FN), or eligible agents who were rejected despite being eligible.

As a result, the classifier's accuracy may be calculated as (TP + TN) / Total = (84 + 18) / 120 = 0.85. This suggests that using these authentication techniques in ODeL will help achieve quality of service in the area of reducing exam fraud.

4.2.8 Experimental Setup for Multimodal Authentication

The experiment participants consisted of 245 undergraduate students of bachelor of Education in Information Technology on the Moodle learning management system in an online course. These participants were from three different campuses of the affiliated institution of the researcher. Out of the 245 students, 220 were registered into the system and 25 non-registered represented as imposters. The system was set up at the main campus, and the participants in the other two campuses connected remotely. The client-server architecture of implementing the non-venue-based examination system is presented in Figure 4.12.

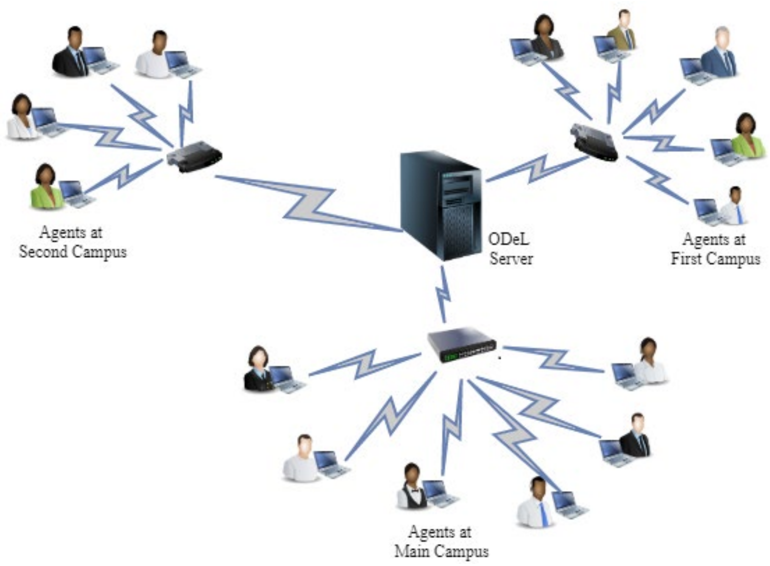
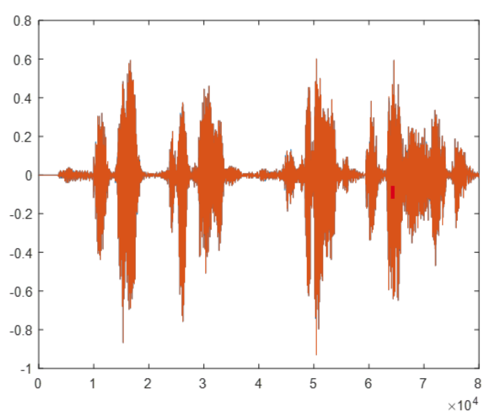


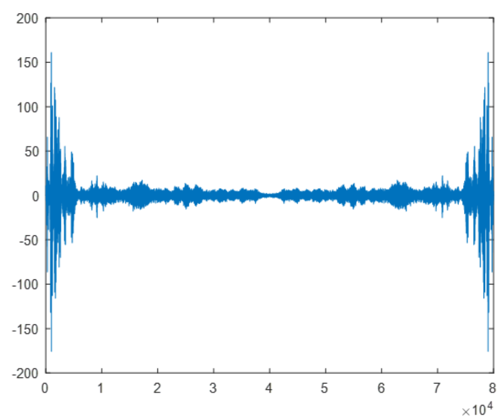
Figure 4.12: Client-server architecture agents at three campuses

4.2.9 Experimental Results on Voice Biometric Authentication

The augmented component of the authentication model is voice biometric authentication, and as such, this section presents findings of voice authentication. An agent's voice pitch with the corresponding frequency from the main campus is presented in Figure 4.13.



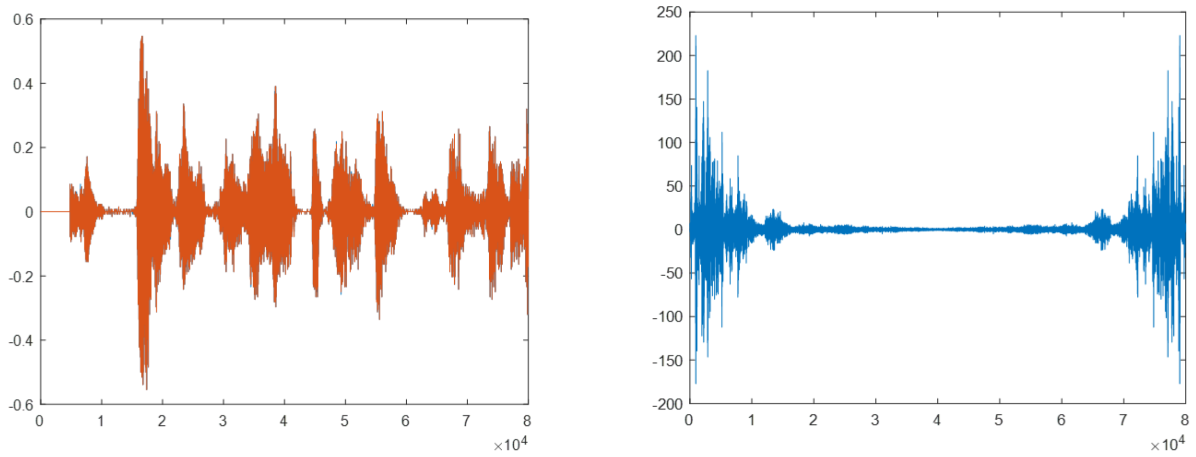
(a) voice pitch



(b) Corresponding frequency

Figure 4.13: An agent's voice record from the main campus

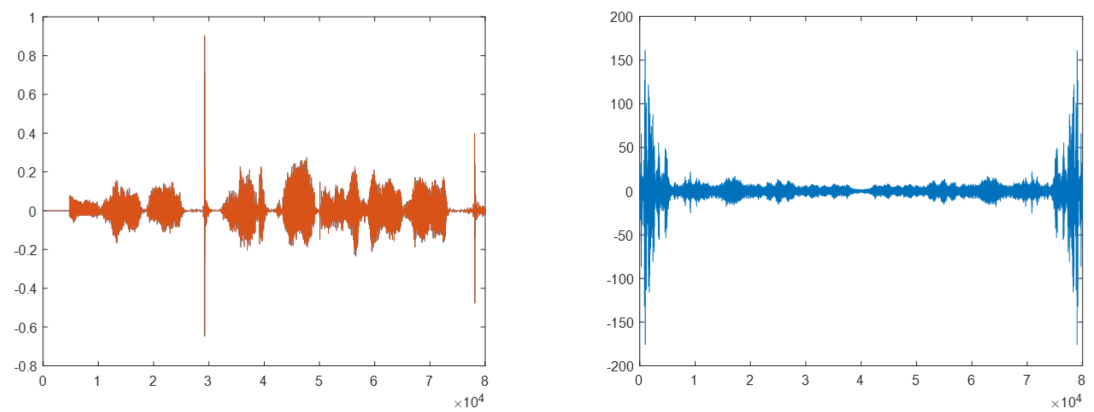
Figure 4.14 shows the sample of an agent's voice pitch with the corresponding frequency from the first campus.



(a) voice pitch (b) Corresponding frequency

Figure 4.14: An agent's voice record from the first campus

Also, Figure 4.15 presents the sample of an agent's voice pitch with the corresponding frequency from the second campus.



(a) voice pitch (b) Corresponding frequency

Figure 4.15: An agent's voice record from the second campus

According to the concept of a percept, the fundamental frequency is the pitch, which is one of the most important acoustic cues for auditory perception. The vocal folds' vibration, which produces pitch in speech, naturally varies over time. Speech identification is made easier by the prosodic information that pitch dynamism carries (Brown et al., 2011). Table 4.7 shows the experimental outcomes of the three campuses on recognition rates.

Table 4.7: Recognition rates of agents' voice

Campus	Learning	Authentication	Recognition rates	FAR	FRR
Main	50	20	95%	0.005	0.05
	30	40	90%	0.005	0.1
	10	60	89%	0.003	0.11
	Average		**91.00%**	**0.003**	**0.09**
First	60	20	96%	0.003	0.04
	40	40	91%	0.002	0.09
	20	60	89%	0.002	0.11
	Average		**92%**	**0.002**	**0.08**
Second	50	20	94%	0.001	0.06
	30	40	91%	0.002	0.09
	10	60	87%	0.002	0.13
	Average		**91%**	**0.002**	**0.09**

It can be inferred from the results above that agents' recognition rates are quite better for voice and, therefore, will improve the authentication process in the online exam. This model will specifically disallow cheating based on a dictator calling the answers for the candidate taking the exam.

4.2.10 Experimental Result of Non-venue-based assessment on Fused Multimodal Authentication

The experiment results on fusing the three authentication mechanisms conducted on the agents from the three campuses are presented in Table 4.8. It has been determined that using the suggested model to authenticate agents in non-venue-based assessments results in better performance than using a previous experiment that just used facial recognition and keyboard dynamics. However, the pattern of recognition still favors earlier results produced by agents over later ones. Therefore, it suggests that it will be important during the assessment time.

Table 4.8: Recognition rates of fusing faces, voices, and keystrokes

Campus	Learning	Authentication	Recognition rates	FAR	FRR
Main	50	20	95%	0.005	0.05

	30	40	90%	0.005	0.1
	10	60	89%	0.003	0.11
	Average		**91.00%**	**0.003**	**0.09**
First	60	20	96%	0.003	0.04
	40	40	91%	0.002	0.09
	20	60	89%	0.002	0.11
	Average		**92%**	**0.002**	**0.08**
Second	50	20	94%	0.001	0.06
	30	40	91%	0.002	0.09
	10	60	87%	0.002	0.13
	Average		**91%**	**0.002**	**0.09**

Figure 4.16 shows a fusion of the multimodal authentication of three agents, one from each campus depicting successes and failure based on recognition rate of facial (FR), voice (VR), and keystroke dynamics (KD). The verification of the agent to allow access to the examination resources is to pass FR, VR, and KD. Failure in any of them causes denial to the examination resources. The caveat is an average percentage value that should exceed the threshold (x) of 69.4%, which is the average fusion result obtained by applying equation (4.1).

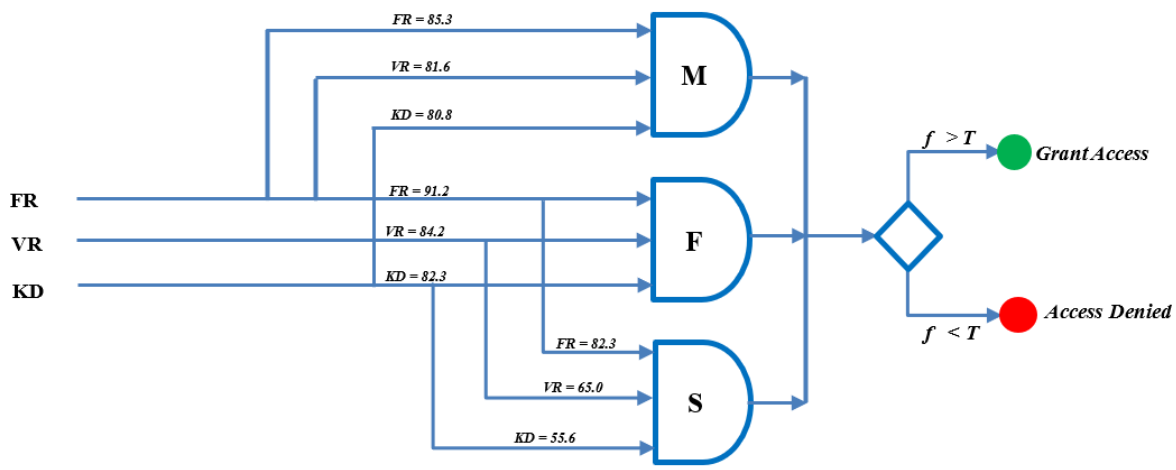


Figure 4.16: Fusion of FR, VR, and KD of three agents

The percentage of facial, voice, and keyboard recognition still makes up the value of x, and any chosen threshold should always, up to a proportional rate, correspond to the value of x. The associated average fusion values, of which this experiment achieved 69.4%, must also be a defined threshold. Agents are allowed access to the system if their average fusion value is greater than 69.4%, while agents with lower values are prohibited.

Figure 4.16 shows that agents from the main campus and first campus are granted access while agent from the second campus is denied access.

For the classification model's accuracy, Table 4.9 displays a two-class acceptance and rejection confusion matrix.

Table 4.9: Confusion matrix

N = 245	Recognition	Rejection	Total
Positive data set	198	22	220
Imposter data set	2	23	25
Total	202	45	245

Based on the 25 imposters added to the experiment and the 245 data set of 220 positive data sets, deductions are made from Table 4.9 as follows:

- ❖ Number of recognized valid agents = true positives (TP) = 198.
- ❖ Number of rejected imposters = true negative (TN) = 21
- ❖ Number of accepted imposters = false negative (FN) = 4
- ❖ Number of rejected valid agents = false positive (FP) = 22

The accuracy of the classifier obtained as:

$$Accuracy = \frac{TP + TN}{N} = \frac{198 + 23}{245} = \frac{221}{245} = 0.90$$

When a dictator assists the agent, the system recognizing the alien voice ceases to continue access grant.

4.3 Experimental evaluations of Sustainable HMM Model for Managing ODeL Platform Bandwidth

This section discusses the analysis of the experiments conducted on bandwidth management as a key element of quality of service in ODeL.

4.3.1 Experimental Setup

On evaluating the model, the e-tutor electronic learning platform was set up and hosted on a server at a university for lecturers (or Professors), students, and some administrators to access the experiment. The University has three campuses in three regions of the country and three learning centers in the other three regions. The student population is over 4,000 from five different schools and faculties, of which two-thirds of them are distance and sandwich students who do most of their learning activities online: over 600 faculty members and staff working at the University. About 250 constitute the University's teaching staff, of which the remaining are the non-teaching staff.

The administrators were required to create courses, assign them to professors, and add students to the various courses as part of the class. Students of the various classes were from different parts of the country and some international students. A bandwidth capacity of 200Mbps is available for the institution's network system, of which users obtain 250Kbps dedicated up speed and 250Kbps down speed.

The client-server implementation setup is provided in Figure 4.17 to demonstrate distance connections of students, professors, and staff to the ODeL server. It also indicates the various services undertaken on the platform, in which the model allocates the appropriate bandwidth.

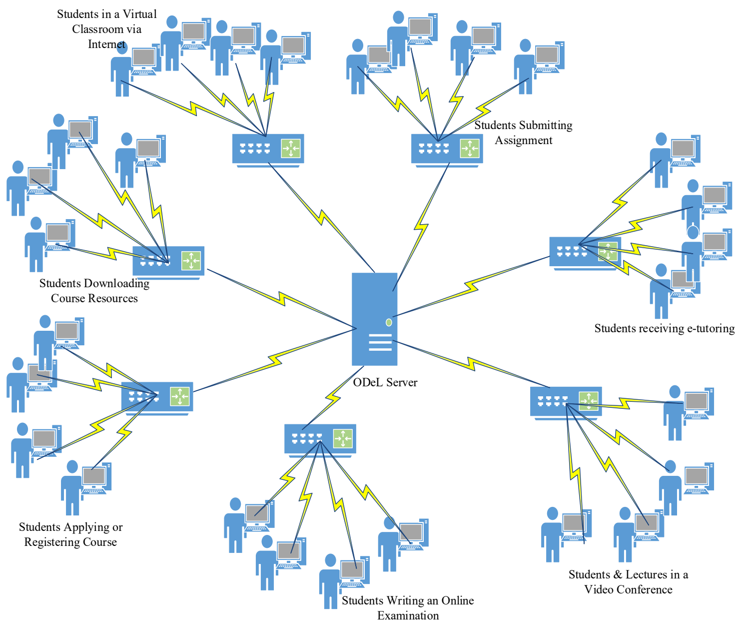


Figure 4.17: Client-server implementations for n-services

SolarWinds bandwidth monitoring tool interfaced with the sustainable HMM-based application used to monitor the network bandwidth. The e-tutor learning management system was hosted on a single server that provides access to services. This research uses such tools due to real-time tracking and network performance monitoring. Alerts are easily configured for correlated events, sustained situations, and complicated blends of device states. Monitoring network device and interface availability as well as performance metrics of bandwidth usage is the key to its acceptance. Figure 4.18 indicates the setting up of device information

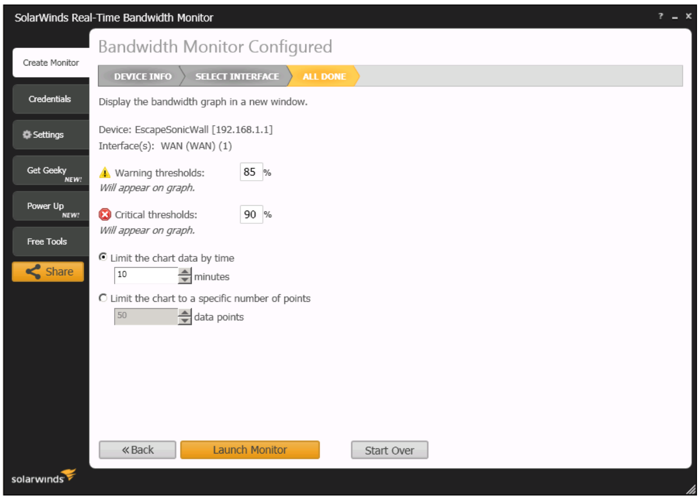


Figure 4.18: Setting up the device information on SolarWinds

The model's dataset for predicting bandwidth demand was obtained over four months using the SolarWinds NPM tool. Figure 4.19 provides a sample of bandwidth utilization at peak time, and Figure 4.20 also indicates off-peak time bandwidth utilization for e-tutoring.

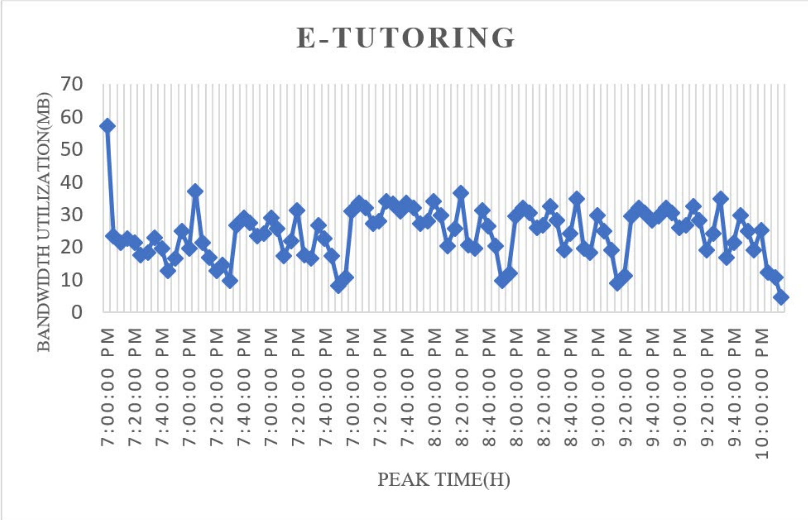


Figure 4.19: Bandwidth utilization at peak period

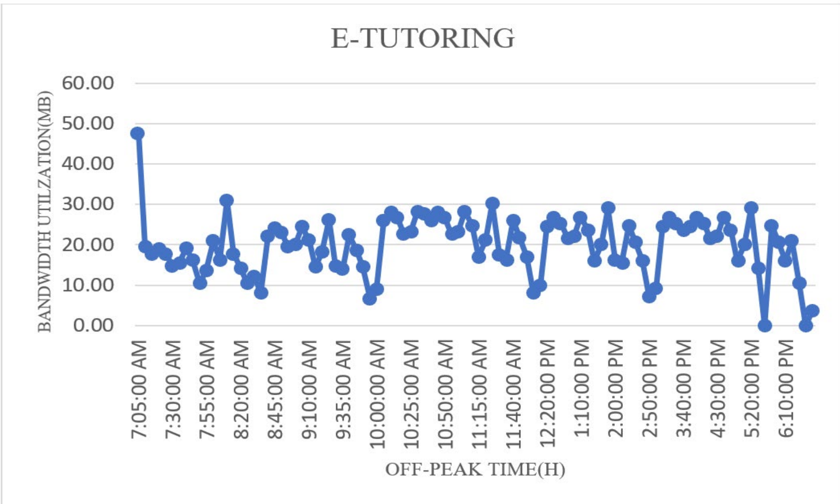


Figure 4.20: Bandwidth utilization at an off-peak time

Analyzing the periods of bandwidth consumption, a peak time in this research has focused on 7 pm to 10 pm, which realizes that many students access the system and perform most of the services. Python was used to implement the sustainable HMM models.

4.3.2 Experiment 0: Performance of the Emerged HMMs on Bandwidth Demand

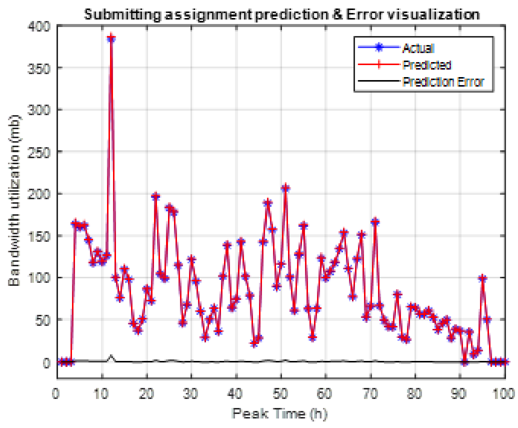
In this experiment, submitting assignments bandwidth demand at peak time was used to evaluate the HMM variations, determining their RMSE, MSE, and MAE from equations (3.9), (3.10), and (3.11). Submitting assignment bandwidth demand was used because it recorded the most data during the peak and off-peak periods with high bandwidth utilization: 20% of the dataset was used for testing, while the remaining 80% was used for training the model. The average error results are displayed in Table 4.12.

Table 4.10: Evaluation of emerged HMMs

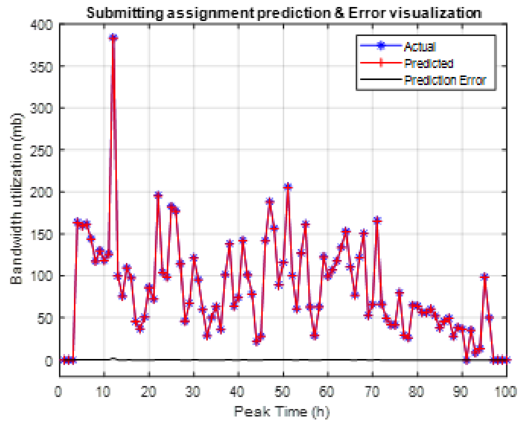
Models	MSE	RMSE	MAE
HMM (non-weighted)	0.56	0.75	0.61
HMMα	0.17	0.41	0.34
HMMβ	0.32	0.56	0.41
HMMγ	0.92	0.96	0.68

Since there is variability in the error results impacting the predicted bandwidths, the null hypothesis H_0 is rejected, as indicated in section 3.7.4.

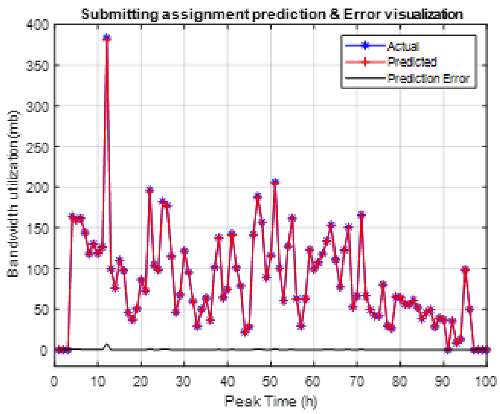
The observation from Table 4.10 is that HMMα produced the best fit result with the least minimal error with MSE of 0.17 while others produced MSE above 0.20. Figure 4.21 (A-D) show the HMM model variants' visualizations presenting the actual, predicted, and MSE prediction errors.



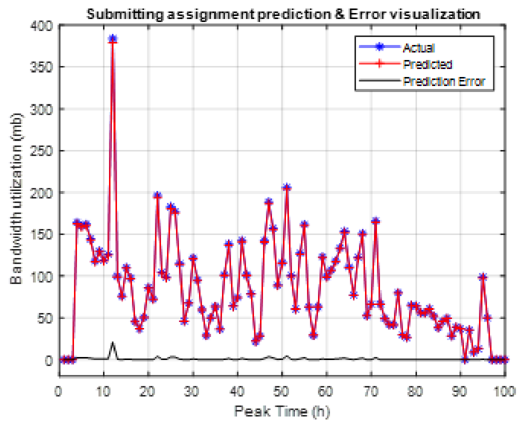
(A) HMM(non-weighted)



(B) HMMα



(C) HMMβ



(D) HMMγ

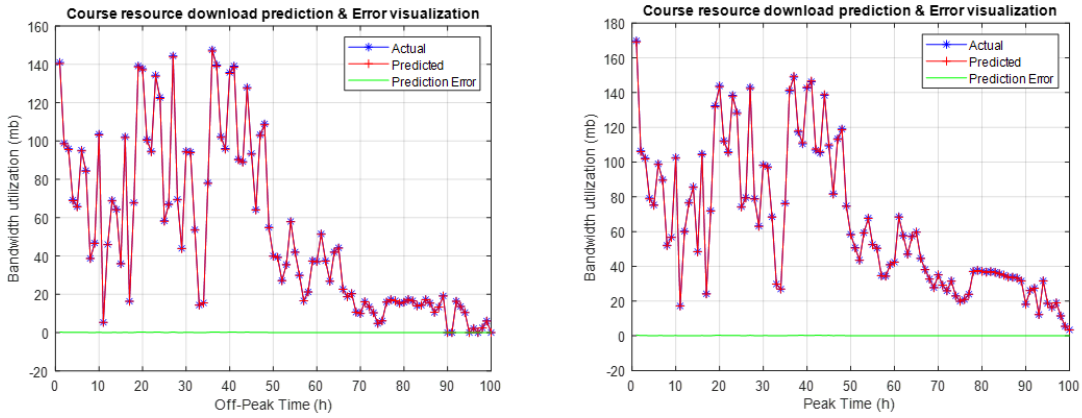
Figure 4.21: HMM model variants' visualizations

This research then progresses with HMMα as the proposed model for the further experiment on all the services to forecast the bandwidth demands.

4.3.3 Experiment 1: Predictive Analytics of the Emerged HMMα on n-services at Off-peak and Peak Periods

This section presents the predictions on the various services by HMMα at off-peak and peak periods. It indicates that not all the services continuously demand bandwidth during off-peak periods. On the other hand, the peak period is when almost all the services demand bandwidth at all times. A general observation is that the HMMα model produces accurate predictions, which is evident in the actual and forecast data's closeness with near-zero prediction error.

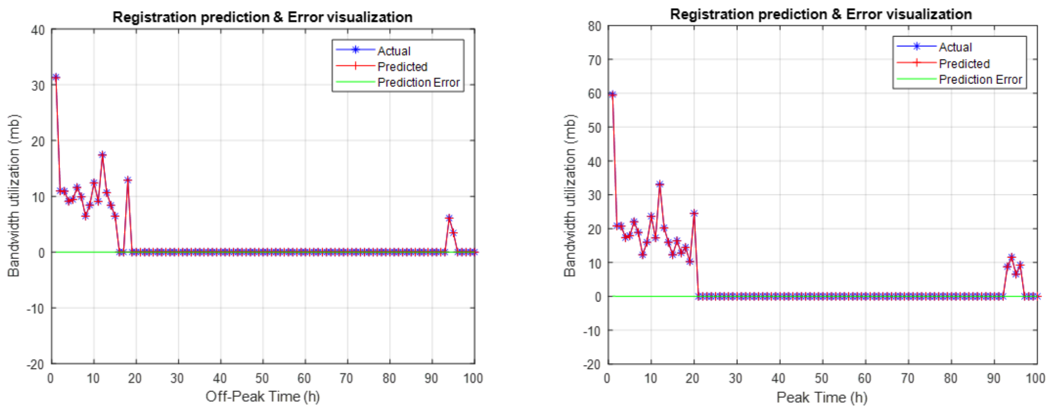
The results produced on bandwidth utilization of course resource download indicate that the HMMα model functions well since the actual and predicted values are very close, as shown by the marginal error below 0.5 presented in Figure 4.22 (a) off-peak and (b) for peak period. The bandwidth demand is high from 0 to 50 hour periods and declines at the later hour periods.



(a) (b)

Figure 4.22: HMMα prediction for bandwidth demand on course resource download

The prediction pattern for registration demand is very close to the actual presented in Figure 4.23 (a) for off-peak and (b) for the peak period. The bandwidth utilization is high at the early hour period and mainly no demand during the later hour periods.

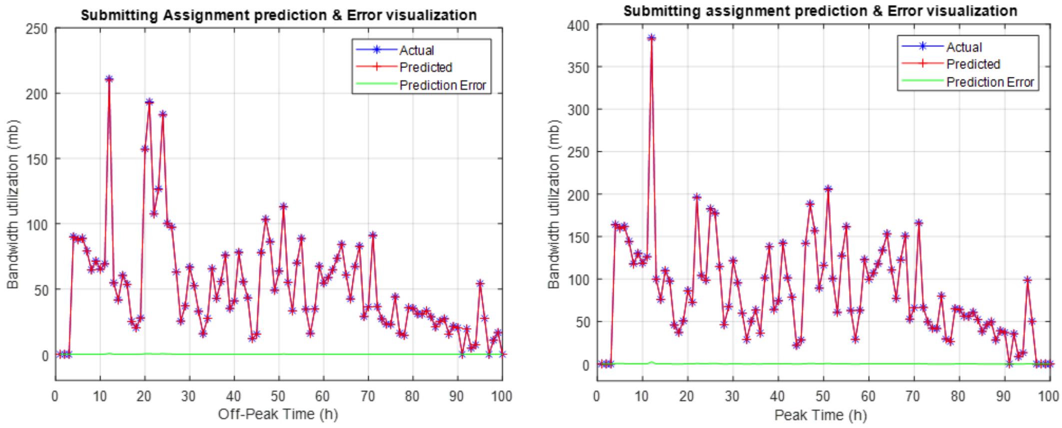


(a) (b)

Figure 4.23: HMMα for registration bandwidth demand

Bandwidth utilization is predominant with submitting assignments concerning other services. Figure 4.24 (a) and (b) show bandwidth demand forecast on submitting assignments with forecast error. It reveals that the actual and predicted utilizations are very close, producing a minimal error.

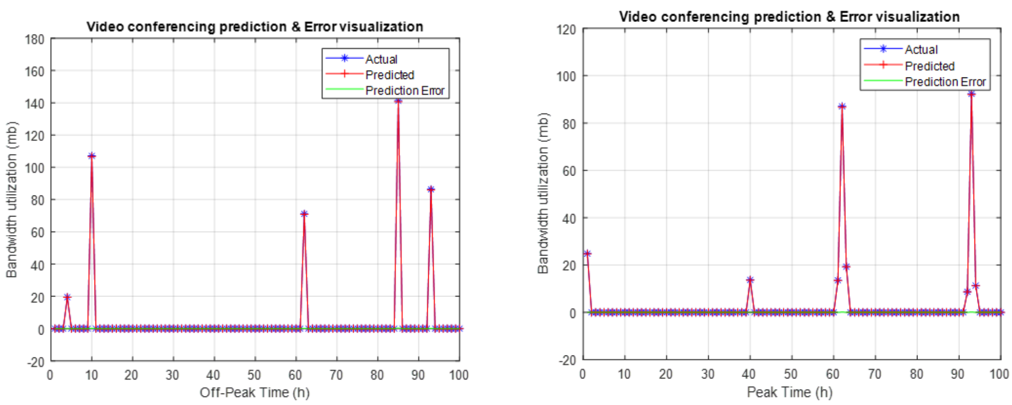
The demand is high between the 10 hours and 30 hour periods and low in the later hours for an off-peak period while realized high at the 13 hours, and relatively low demand is obtained between 80 hours and 95 hour periods at peak time.



(a) (b)

Figure 4.24: HMMα for submitting assignment bandwidth demand

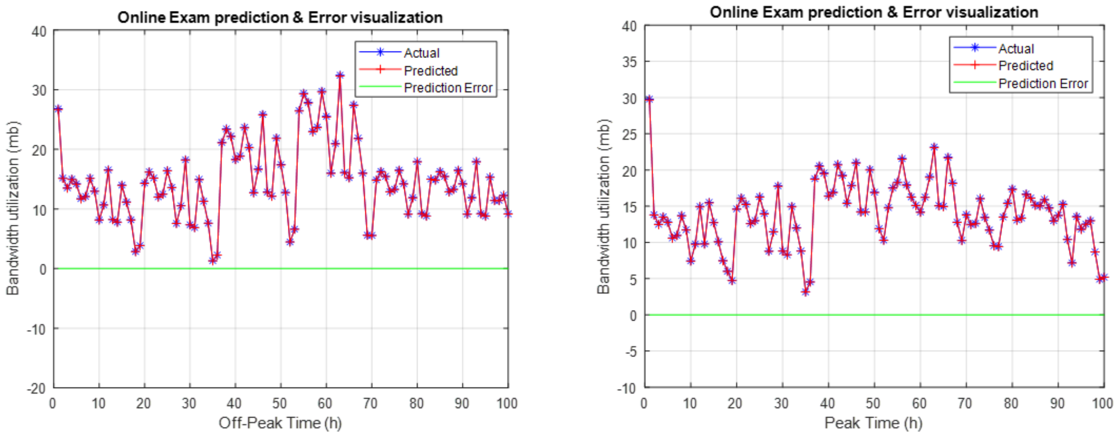
For video conferencing, the observation is that there is no bandwidth demand in most hours; for example, between the hours of 10 and 60 no utilization was recorded, which is evident in both actual and predicted shown in Figure 4.25 (a). Near zero error is visualized between actual and predicted. Figure 4.25 (b) shows that high consumption is 62 hour and 93 hour peak periods and other hour periods recording almost zero utilization.



(a) (b)

Figure 4.25: HMMα for video conferencing bandwidth demand

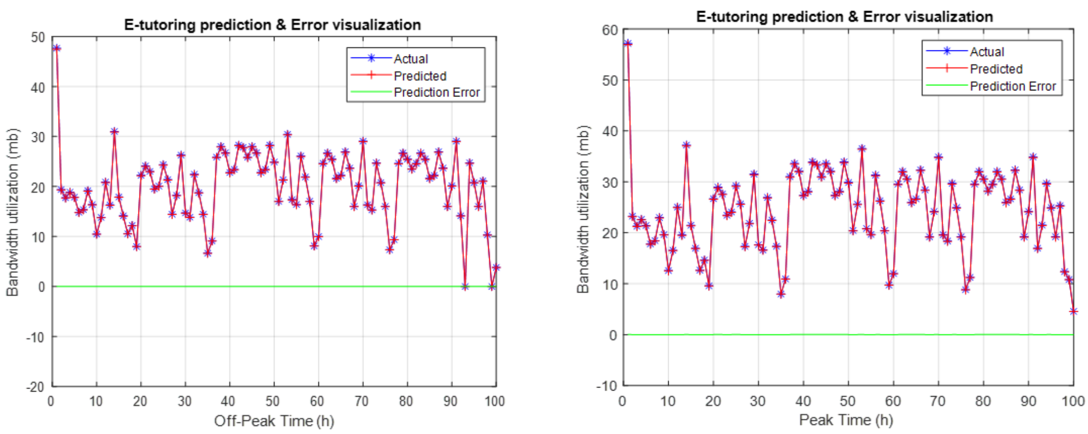
Online exam bandwidth demand presents high at 60 hour period and low at 35 hours for off-peak, and the trend is not much different from the results at peak time. The actual and predicted utilization is very close with minimal error, as indicated in Figure 4.26 (a) and (b).



(a) (b)

Figure 4.26: HMMα for online exam bandwidth demand

E-tutoring records high bandwidth utilization in both actual and predicted results in the early hours off-peak period as they show up and down patterns in all hours, as can be deduced from Figure 4.27 (a) and (b) also shows a similar pattern for the peak period, and the prediction error margin is near zero.



(a) (b)

Figure 4.27: HMMα for e-tutoring bandwidth demand

It establishes at the off-peak period that based on the results, the bandwidth demand for various services is close to the actual values obtained from the bandwidth monitoring tool. The indication is that the HMMα performs well in forecasting the bandwidth demand during the off-peak period since the error margin is between 0 and 1.5. The HMMα model performs better in predicting the bandwidth demand for the various services at the peak period. The prediction error in all the services output indicates that the mean square error (MSE) margin is less than 0.2. These promising results are due to the quality data fed into the proposed HMM model from the bandwidth monitoring tool and the emergence of HMMα from appropriate parameters.

4.3.4 Planning: Normalization-Policy (NP) Leveraging on Bandwidth Budget Constraints

After predicting bandwidth demand for the next day beyond the dataset last day, NP (from equation 3.8) optionally plans the services based on suggested limited budget constraints of available bandwidth for the institution. Table 4.11 provides predicted bandwidth demand and percentage plan for each service on the next time step considering the peak period.

Table 4.11: Normalizer plan for services on bandwidth budget constraints

Bandwidth budget constraint	Schedule	Course resource download	Registration	Submitting Assignments	Video Conferencing	Online Exam	E-tutoring	Total
200	Predicted	51.87	12.24	117.43	0.00	13.67	22.89	218.1
	%Planned	47.57	11.22	107.68	0.00	12.54	20.99	200
250	Predicted	102.19	23.57	118.32	0.00	7.43	12.53	264.04
	%Planned	96.76	22.32	112.03	0.00	7.03	11.86	250
300	Predicted	98.6	21.99	161.35	0.00	10.58	17.73	310.25
	%Planned	95.34	21.26	156.02	0.00	10.23	17.14	300
350	Predicted	169.11	59.38	103.1	24.71	29.66	56.95	442.91
	%Planned	133.64	46.92	81.47	19.53	23.44	45.00	350
400	Predicted	123.42	57.53	117.56	86.67	18.99	31.91	436.08
	%Planned	113.21	52.77	107.83	79.50	17.42	29.27	400
450	Predicted	132.62	46.27	175.22	87.35	12.76	19.13	473.35

	%Planned	126.08	43.99	166.58	83.04	12.13	18.19	450
500	Predicted	59.96	33.01	382.22	68.74	14.91	24.94	583.78
	%Planned	51.35	28.27	327.37	58.87	12.77	21.36	500

The observation is that each service is allocated the maximum bandwidth within the limited available bandwidth by percentage ratio.

4.3.5 Experiment 2: Predictive Analytics of the Proposed Method on Publicly Available Data

The performance of the newly developed HMMs on three publicly accessible datasets is evaluated in this section. In all, 80% of each dataset was employed in training and 20% for testing throughout implementation.

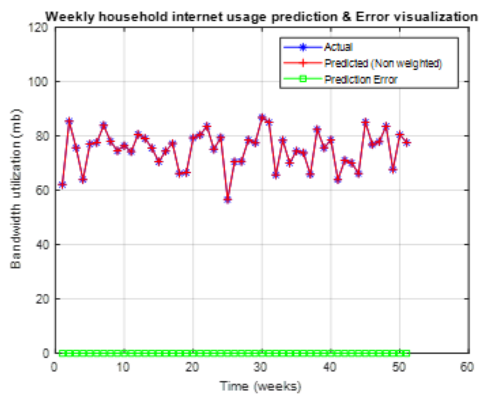
v) 2010 Household internet usage of 51 States in the United States

Table 4.12 presents the forecast errors of the HMMs on 2010 weekly United States of America household internet usage of 51 states. The data was obtained from Data world (2010) and then pre-processed by putting all the 52 weeks data into one XML file. The forecast is made for the fifty-third week and compared with the fifty-second-week data as the actual.

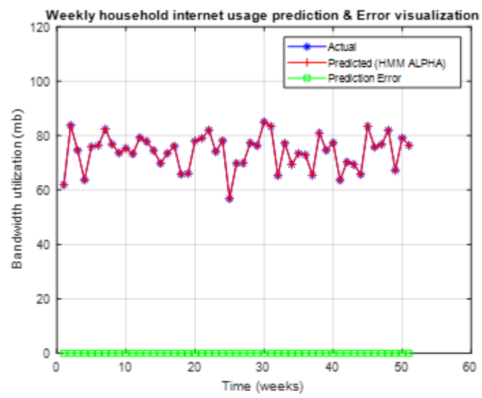
Table 4.12: HMMs performance on household internet usage

Models	MSE	RMSE	MAE
HMM (non-weighted)	0.68	0.82	0.72
HMMα	0.09	0.30	0.30
HMMβ	0.08	0.28	0.28
HMMγ	0.09	0.30	0.29

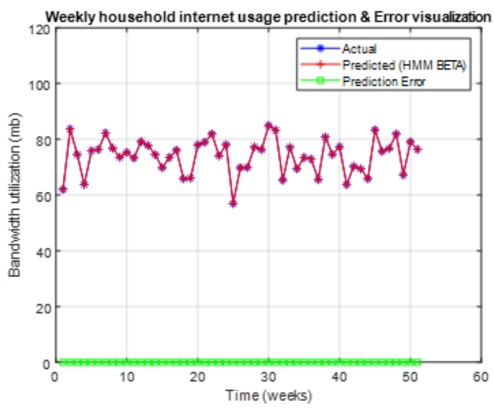
The realization is that prediction error is high on non-weighted HMM, indicating error values above 0.5 while the other models produce the error below 0.5. Figure 4.28 (a) to (d) present the various models' actual, predicted, and error visualization.



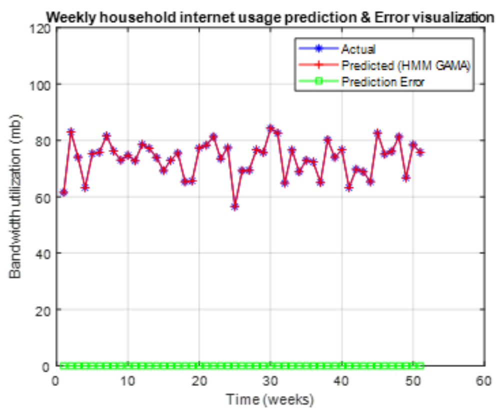
(a) HMM (non-weighted) model



(b) HMMα model



(c) HMMβ model



(d) HMMγ model

Figure 4.28: Predicted household internet usage

Since the hidden pattern in a dataset is a significant driver on prediction results, the HMMβ model emerged as the most fitted on this data sample instead of the HMMα in the former sample. Hence, it is incorrect for one size fits all.

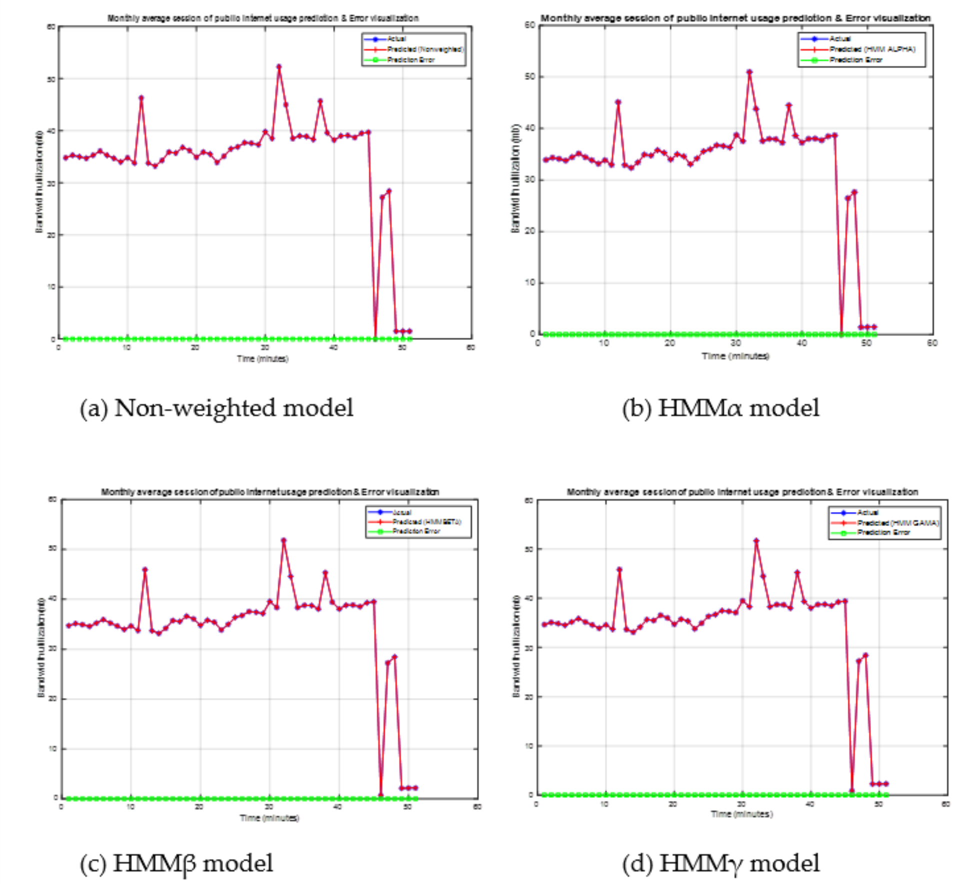
vi) Australian monthly average session of public internet usage

The HMM variant models also tested Australian monthly average public internet usage sessions (Australian Government, 2020). The monthly data obtained from July 2016 to September 2020 was organized correctly in a single XML file. The prediction made for October 2020 compared with the September 2020 actual data. Generally, the performance of the models shows a minimal error margin for all the models. Compared with the 2010 American household internet usage, it is better on this dataset for the non-weighted model but a bit high error margin on the other methods as depicted in Table 4.13.

Table 4.13: HMMs performance on monthly average session public internet usage

Models	**MSE**	**RMSE**	**MAE**
HMM (non-weighted)	0.26	0.51	0.49
HMMα	0.18	0.42	0.40
HMMβ	0.18	0.42	0.41
HMMγ	0.15	0.39	0.37

Figure 4.29 (a) to (d) displays the models' actual, forecast, and error visualization. The results indicate that models perform well and can attribute to the proposed modeling approach.



(a) Non-weighted model (b) HMMα model

(c) HMMβ model (d) HMMγ model

Figure 4.29: Predicted monthly average session public internet usage

In this case, one can see that the HMMγ model emerged as the most fitted on this Australian data sample.

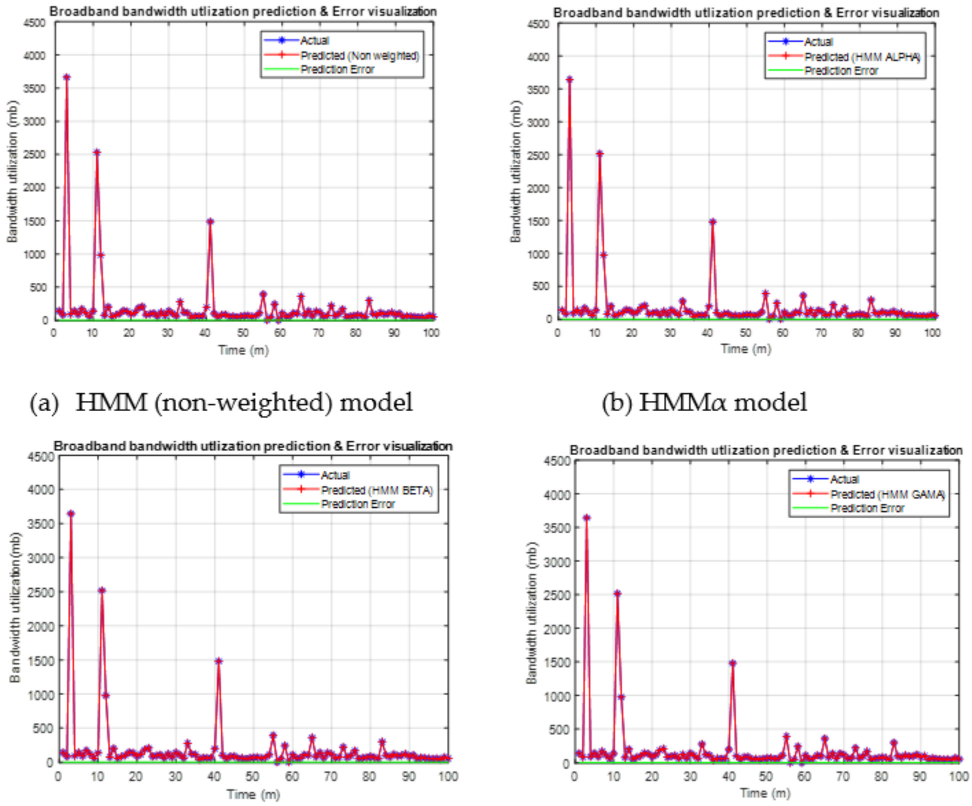
vii) Broadband bandwidth usage on cellular and Wifi from August 2016 to December 2020

Further assessment of the performance of our candidate models was on another dataset obtained from Netbravo (2020). It is considered the most voluminous dataset among the three datasets used. It constitutes many measures from crowdsourcing measures collected by NetBravo as a monthly series of aggregated datasets and published on the European Union Open Data Portal. A selection of the broadband bandwidth usage for speed test (100m) measurements on cellular and Wifi from August 2016 to December 2020 was preprocessed into a single XML file. The forecast is made for January 2021, considering actual data for December 2020. Table 4.14 shows that the models' performance produced a slightly higher error margin than the previous samples. Therefore, data quality needs improvement for possible minimization of the errors.

Table 4.14: HMMs performance on broadband bandwidth utilization

Models	**MSE**	**RMSE**	**MAE**
HMM (non-weighted)	1.99	1.41	0.53
HMMα	1.64	1.28	0.40
HMMβ	1.98	1.41	0.72
HMMγ	2.10	1.45	0.56

Figure 4.30 (a) to (d) show the performance of the models that indicate that at periods where bandwidth consumption is very high, the prediction error is relatively high. However, the forecast accuracy (considering MSE results) is still better for HMM models than other prediction models considered in this research.



(a) HMM (non-weighted) model (b) HMMα model

(c) HMMβ model (d) HMMγ model

Figure 4.30: Predicted broadband bandwidth usage on cellular and Wifi

HMMα model appears in this case as the most fitted on this NetBravo data sample. It can be concluded that the model is generally suitable for managing bandwidth specifically in ODeL to achieve QoS.

4.4 Chapter Summary

The detailed experimental evaluations of the models constructed for QoS in ODeL is discussed in this chapter. The results of the bimodal biometric authentication model were discussed and then benchmarked with prevailing state-of-the-art methods. Further on the authentication is the discussion of the multimodal biometric model, which indicated an improvement on the authentication as a QoS element in ODeL. The analysis followed with discussion on bandwidth management model pointing out the results obtained from the experiments. The outcomes were related with other existing methods and bandwidth management practices in institutions to validate the effectiveness of the proposed technique.

The theoretical conflict management model's analysis was presented, demonstrating the value of ODeL environments as intelligent learning environments for QoS. The identified smart education models in the survey were compared with the proposed proactive conflict management framework to ascertain its significance.

To determine the significant improvement on existing state-of-the-art techniques contributing to the QoS in ODeL, the following chapter benchmarks the outcome of the proposed models in this research and further validates the intelligent quality of service model (IQSODeL).

CHAPTER 5

COMPARATIVE ANALYSIS AND VALIDATION OF IQSODEL MODEL

5.1 Introduction

In order to determine whether the models are better than current models and practices in institutions, this chapter compares the models reviewed in the previous chapter. The comparison is to reveal how the QoS elements outperform the existing techniques in achieving quality service in ODeL and the validation of IQSODeL is discussed.

5.2 Comparative Analysis of Authentication Models with Existing Techniques

The work of Gupta et al. (2015) incorporated a Hidden Markov Model implementation of Keystroke Dynamics (HMM). In contrast, bimodal facial and keystroke dynamics (FACKD) produced an average FRR of 4.3% and an average FAR of 1.7%, which can be found in Table 5.1. Their Face Recognition yielded FAR of 5.4% and FRR of 9.2%. The effectiveness of the Haar feature-based classifier and GREYC over HMM is responsible for this FACKD outcome. Although this is a sizable improvement, it has been found that the trials' exam-like setting affected the agents' typing habits, which in turn affected the accuracy of authentication.

The FACKD bimodal biometric authentication is a much better solution for reducing malpractices; nonetheless, it can support the technique of turning off all other programs on assessment platforms (Sabbah, 2012). Table 5.1 displays FAR and FRR findings for FACKD-like algorithms using various types of data.

Table 5.1: Methods comparison

Paper	Participant	Method	FAR %	FRR %
(Nayak & Narayan, 2012)	200	Neural Networks (face)	0.001	66.27
(Draffin et al., 2014)	13	Neural network (keystroke)	14	2.2
Average			**7.00**	**34.24**
(Madhu & Amutha, 2012)	70	Statistical (face)	2	19
(Singh & Arya, 2011)	20	Statistical (keystroke)	2	4
Average			**2**	**11.50**
(Maria De et al., 2016)	-	Machine Learning (face)	2.74	3.15
(Messerman & Mustafi, 2011)	55	Machine Learning (keystroke)	2.02	1.84
Average			**2.38**	**2.50**
(David & Hons, 2005)	-	Heuristics (face)	0.34	17.17
(Buchoux & Clarke, 2006)	20	Heuristics (keystroke)	0	2.5
Average			**0.17**	**9.84**
(Gupta et al., 2015)	500	HMM (face and keystroke)	**5.4**	**9.2**
FACKD	120	Gabor filtering and Haar feature-based cascade classifiers from OpenCV and GREYC	**1.7**	**4.3**

Figure 4.18 shows how combining keyboard and face authentication of comparable methods might result in higher FAR and FRR than FACKD. These values are determined by averaging the facial and keystroke values. This suggests that using the OpenCV and GREYC software's Gabor filtering and Haar feature-based cascade classifiers will be the best option for authenticating and assuring cheating-free evaluation in an open distance electronic learning environment.

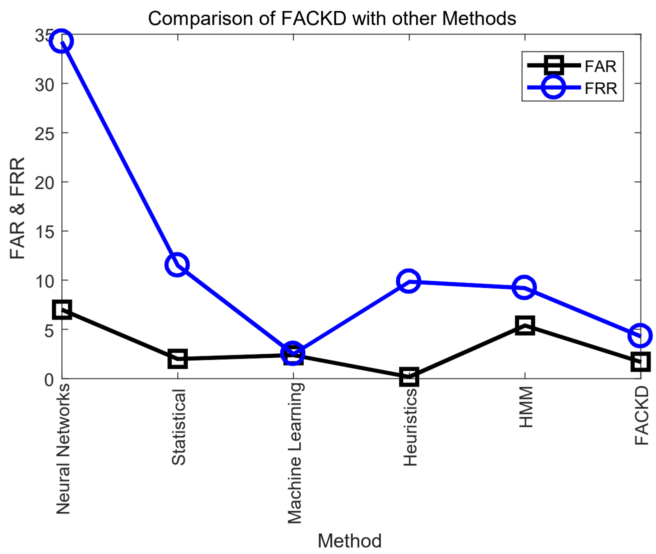


Figure 5.1: Comparison of other methods with FACKD based on FAR and FRR

Compared with the earlier work, which relied on bimodal authentication of face and keystroke benchmarked with other existing methods, the results show significant improvement in the fused multimodal biometric framework for ODeL. It is realized that the prediction accuracy of 0.90 (90%) against 0.85 (85%) in the earlier work on bimodal authentication scheme is significant. Also, in the bimodal authentication experiment achieved 1.7% and 4.3% FAR and FRR, respectively, compared to FAR of 1.11% and FRR of 3.8% obtained in this research. This result is attributed to the increased authentication feature and the number of datasets used in this research. It indicates that an increased number of security features for authentication, as in multiple factor authentication, enhance a system's security.

Table 5.2 presents comparison of existing study on multimodal biometric authentication techniques with the propose method based on the biometric features.

Table 5.2: Comparison of multimodal authentication methods

Paper	**Authentication Features**	**Pros**	**Cons**
(Galbally et al., 2014)	Iris, Fingerprint, and Face Recognition	• High authentication accuracy	• Delays in real-time fingerprint feature authentication • Not appropriate in ODeL

(Bigun et al., 2005)	Voice, face and signature	• High authentication accuracy	• Delays in real-time authentication on signature features • Not appropriate in ODeL
(Sae-Bae et al., 2012)	Palm position, fingertip movement and dynamic.	• Relatively high authentication accuracy	• Feature extraction in real-time is very complex • Not appropriate in ODeL
(Kim et al., 2010)	Face, teeth and voice	• Moderately high authentication accuracy	• Teeth feature extraction in real-time is very complex • Not appropriate in ODeL
(Jagadiswary & Saraswady, 2016)	fingerprint, retina and fingervein	• Moderately high authentication accuracy	• Fingervein feature extraction in real-time is very complex • Not appropriate in ODeL
(Monwar & Gavrilova, 2009)	Face, Ear, Signature	• Relatively high authentication accuracy	• Ear and signature feature extraction in real-time is very complex • Not appropriate in ODeL
Propose method	Face, Voice, Keystroke	• High authentication accuracy	• Feature extraction in real-time is very simple • Very appropriate in ODeL

5.3 Comparing the Proactive HMM Model with Common Bandwidth Management Practices

Table 5.3 presents a qualitative comparison of HMMα-Planner and other current bandwidth management schemes used in institutions.

Table 5.3: Comparing with other current practices in institutions

HMMα-Planner surpasses all the schemes concerning management since it provides proactive bandwidth requirements under all types of loads being high, moderate, or low, and no administrative support is required for such efficient distribution of bandwidth demand.

The University referenced by Philip Smith (2005) provides a utility that aids in checking an agent's connection speed to their web server but does not provide a mechanism to manage bandwidth consumption.
As stated in the work of Akpah and Aryeh (2017), a university's firewall server runs squidGuard. By giving legal users access priority and limiting access to low-priority users, it specifies access protocols and policies to efficiently monitor and control the network traffic. However, it does not apportion bandwidth to users based on a forecast of users' consumption and the available bandwidth, hence not planning.
Most universities in Africa, according to Lockias (2012), do not have a formal accepted use policy that would help manage bandwidth.
Research conducted on bandwidth management in a university by Osman (2017) used a volume-based control strategy. However, it fails to provide appropriate bandwidth allocation based on a forecast of users' consumption.
Bandwidth throttling, identified as the method widely used in many universities to manage network congestion, has several limitations: service denial, slow loading, skipping, and shuttering experiences (Yahya-Imam et al., 2014).

The above bandwidth management techniques may be efficient in smaller network environments because they do not optimize bandwidth on predictive demand, but are therefore, not suitable for ODeL bandwidth management for QoS.

5.4 Comparative Analysis of Existing Smart Education Models

To make ODeL smarter for QoS require structuring all the components and activities to manage conflict proactively. Table 5.4 provides analysis of the existing smart education models in view of conflict management.

Table 5.4: Comparative analysis of smart education models

Smart education model	Specific model	Strength	Weakness	Conflict management
(Meng et al., 2020)	Smart pedagogy framework	Promotes learning outcomes	Fails to address the conflict between teaching and learning agents and their environment	Absent of conflict management method

(Hartono et al., 2018)	Model of smart hybrid learning	• Combines case-based learning and challenge-based learning with the flipped classroom approach. • Provides an all-inclusive learning platform	Does not address conflict issues	No conflict management techniques incorporated
(Indrawati et al., 2018)	Smart education readiness index	Provides a summarized smart education and model for measuring its readiness	Does not present conflict issues	No conflict management process included
(Zhu et al., 2016)	Conceptual framework for smart education	Describes three vital components in smart education	Components does not provide effective conflict management method	Model fail to provide conflict management principles
Proposed model	Automatic Conflict Resolution Model smart education	Integrate the key features of smart education to provide QoS.	Not yet identified	Incorporate conflict management principles.

5.5 Analysis of IQSODeL Model for Quality of Service in ODeL

Based on the defined QoS factors, this section analyzes the overall quality of services in ODeL. The results of the quantitative survey to validate the QoS elements in ODeL are analyzed.

5.5.1 Evaluation of Demographic Data

In Table 5.5, the status of the participants' distribution is presented indicating over 88% being students. This is very useful because the students are the most beneficial stakeholders in the QoS of ODeL. Table 5.6 displays the participants' gender breakdown.

Table 5.5: Status distribution

Status	Frequency	Percentage
Administrator	14	2.5
Lecturer	49	8.9
Student	488	88.6
Total	551	100.0

Table 5.6: Gender distribution

Gender	Frequency	Percentage
Male	471	85.5
Female	78	14.5
Total	551	100

The results show a majority of male respondents, i.e., about four times more males than females in the institution. Table 5.7 represents the age ranges of the respondents.

Table 5.7: Age range distribution

Age range	Frequency	Percentage
Less than 20	5	0.9
20 –25	43	7.8
26 - 30	173	31.4
31 –35	162	29.4
36 - 40	80	14.5
41 and above	88	16.0
Total	551	100

The results show that over 60% of the respondents are of the ages from 26 to 35. This indicates that most of the respondents in the age range who are familiar with technology and are able to provide reliable responses. Considering the students, the distribution of their levels was obtained as presented in Table 5.8.

Table 5.8: Student level

Student level	Frequency	Percentage
Level 100	5	1.0
Level 200	64	13.1
Level 300	145	29.7
Level 400	238	48.8
Postgraduate	36	7.4
Total	488	100

Table 5.8 shows that most of the students who took part in the survey are in the level 300 and 400. This is quite significant for the determination of the QoS in the ODeL platform since they have had enough experience in the university than the lower levels. They have also participated in both online and face-to-face classroom instruction at the university.

5.5.2 Validation of IQSODeL Model

This research used the Analysis of Moment Structure - AMOS version 23 program, as mentioned in the methodology, for the CFA of scales and SEM to identify the correlations. Figure 5.2 displays the SEM in detail.

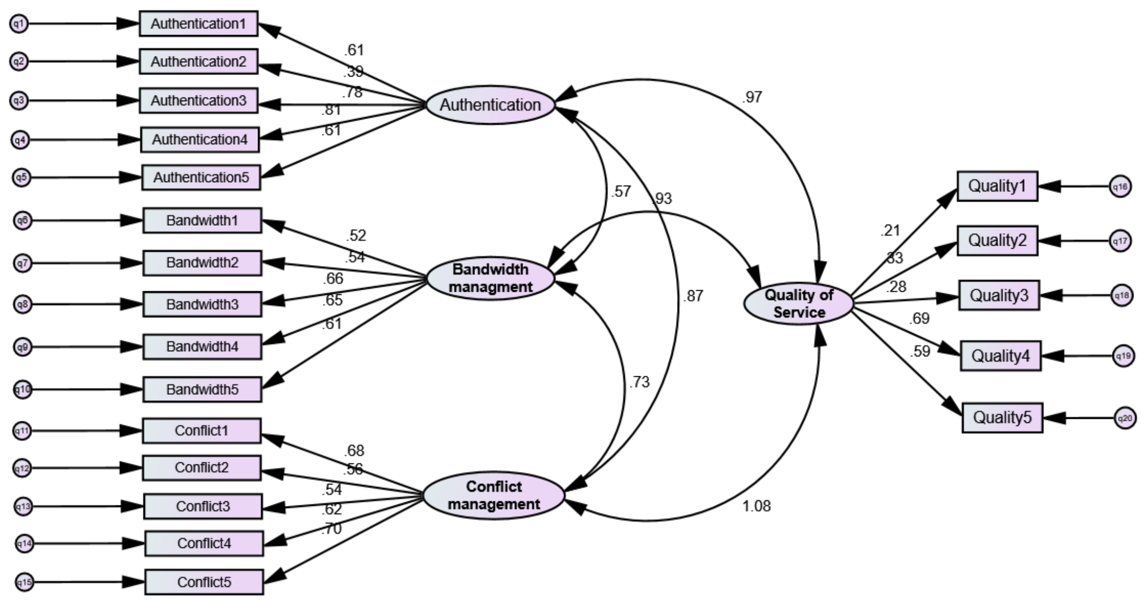


Figure 5.2: Confirmatory factor analysis model of the scale of IQSODeL

The Intelligent Quality of Service Model for ODeL involving three factors and 25 items established based on SERVQUAL model. Internal consistency analysis performed by Cronbach Alpha revealed that the total scale's internal consistency was α=.924. Five-point Likert-type items on the scale were assessed as "strongly agree" (strongly agree), "agree", "unsure", "disagree", or "strongly disagree" (1). Furthermore, the scale's CFA was performed, and it was found that the fit indices were within acceptable boundaries.

First, all items under the overall quality of service aspect in the data collected for this study were changed to positive. For factor analysis, the data were suitable since the values of Chi-square (CMIN) =1521.762, degrees of freedom (DF) = 1064, and likelihood ratio (p) =.000.

Table 5.9 shows the indexes and parameters that make up the model fit results in AMOS. The results are compared with the acceptable fit values referenced by (Uedufy, 2022)

Table 5.9: Model fit results

Fit Index	**Meaning**	**Model fit results**	**Recommended values**	Source
Likelihood Ratio	P-value	**0.000**	**≥ 0.05**	(Joreskog & Sorbom, 1996)
CMIN/DF	Chi-square divided by Degree of Freedom	**1.430**	**≤ 3** = acceptable fit **≤ 5** = reasonable fit	(Kline, 1998) (Marsh & Hocevar, 1985)
GFI	Goodness of Fit Index	**0.921**	**1** = perfect fit **≥ 0.95** = excellent fit **≥ 0.9** = acceptable fit	(Kline, 2005) (Hu & Bentler, 1998)
AGFI	Adjusted Goodness of Fit Index	**0.911**	**≥ 0.90** = acceptable fit	(Tabachnick & Fidell, 2007)
CFI	Comparative Fit Index	**0.920**	**1** = perfect fit **≥ 0.95** = excellent fit **≥ .90** = acceptable fit	(West et al., 2012) (Fan et al., 1999)
RMSEA	Root Mean Square Error of Approximation	**0.044**	**≤ 0.05** = reasonable fit	(MacCallum et al., 1996)
RMR	Root Mean Squared Residual	**0.054**	**≤ 0.05** = acceptable fit **≤ 0.07** = acceptable fit	(Diamantopoulos & Siguaw, 2000) (Steiger, 2007)
SRMR	Standardized Root Mean Squared Residual	**0.045**	**≤ 0.05** = acceptable fit	(Diamantopoulos & Siguaw, 2000)
CN	Critical N	**230**	**≥ 200** = acceptable fit	(Joreskog & Sorbom, 1996)

The results show that the model matched the gathered data. The objects' factor loads ranged from 0.21 to 1.08. The internal consistency coefficient scale had the following

Cronbach Alpha values: user authentication is a key factor in ODeL QoS = 0.94, bandwidth management is a key factor in ODeL QoS = 0.88, proactive conflict management is a key factor in ODeL QoS = 0.96 and overall scale = 0.94. 57.183% of this three-factor scale explains the total variance.

CFA was used to test the structure created by EFA. The modification indices (M.I.) were considered to determine the scale's proper (fit) values in terms of fit indices. In accordance with the modification indexes and suggestions, four items were removed from the scale, and four error covariances were generated (q2, q16, q17, and q18).

It is therefore evident that achieving quality of service in ODeL requires the consideration of secure cheating-free examination based on suitable authentication techniques with appropriate network bandwidth allocation schemes and proactive conflict management model.

5.6 Chapter Summary

This chapter analyzes the IQSODeL model with the considered state-of-the-art techniques for establishing QoS in ODeL institutions. The results of the bimodal and the multimodal biometric authentication model were benchmarked with existing models. The analysis followed with bandwidth management model pointing out the compared with bandwidth management practices in institutions to validate the proposed model's efficiency.

The identified smart education frameworks in the survey were compared with the proposed proactive conflict management framework to ascertain its significance.

To validate the QoS elements employed in constructing the overall intelligent model for ODel QoS, this chapter provided an explanation of the confirmatory factor analysis performed on the gathered data from the quantitative survey. The results proved that the IQSODeL framework is acceptable for ensuring QoS in ODeL in reference to the existing acceptable standards.

The next chapter presents the conclusions of this research. Recommendation and future works are also presented.

CHAPTER 6

CONCLUSIONS AND FUTURE DIRECTIONS

6.1 Introduction

This chapter presents the conclusions of the research by examining how the original research goals were met. On the basis of the study's research findings, the chapter also offers recommendations. Since ODeL places a high priority on service quality, its practical constraints as well as potential future possibilities are discussed. The key issue addressed by this study's aims was the lack of an intelligent quality of service model capable of reorganizing and reacting to changes in open-distance electronic learning in order to provide smart education for quality service.

6.2 Research Conclusions

The core objective of the study was **to use methods and techniques to develop an intelligent quality of service model capable of reorganization and adapting to changes within open distance electronic learning (ODeL) for smart education.** This research employed three main techniques that include a fused multimodal biometric authentication model to provide cheating-free assessment in ODeL for QoS in the area of examination and assessment. The second technique was a hidden Markov-based sustainable bandwidth management for such a massive bandwidth-consuming environment as ODeL for quality bandwidth allocation on limited network bandwidth. The third technique was a proactive conflict management framework for smart education in ODeL for QoS. The proposed techniques were validated with a survey of the participants who were involved in the experimental evaluation and the data was confirmed using confirmatory factor analysis. In achieving the global objective of this research, the specific objectives were fulfilled and the following conclusions are made.

Concluding on the objective 1 - To develop a model for authentication in ODeL on a real-time execution in non-venue-based assessment for QoS for smart education.

The main challenge in an open distance electronic learning environment is authenticating examinees during examination since existing technologies cannot provide accurate authentication. This is substantiated by the decision of Australian leading universities to return to pen and paper exam due to cheating in online exam (Caitlin Cassidy, 2023). The results of this study have highlighted a few difficulties that arise in a setting of open-distance electronic learning. It is acknowledged that the biggest challenge is securing and preventing cheating in non-venue based assessments, for which the most recent state-of-the-art practices have not yet offered an ideal method of user authentication, or prevented a third party from taking the exam in place of the examinee. Based on behavioral keystroke dynamics and physiological facial recognition, a bimodal biometric authentication paradigm was developed. Application using OpenCV's Gabor filtering and Haar feature-based cascade classifiers, as well as GRYEC's keystroke dynamics software.

Combining the dynamic face and keystroke authentication systems from Table 4.5 resulted in an average recognition rate of 85% in the trial conducted in the MOODLE virtual learning environment. According to Table 4.8, it also generated an average FAR of 1.7% and an average FRR of 4.3%. This result illustrates that employing the FACKD biometric model for non-venue based evaluation displays reliable security and minimizes impersonation more than state of the art techniques like the portfolio based distance assessment without supervision when benchmarked with similar solutions such as (Gupta et al., 2015b) with FAR of 5.4% and FRR of 9.2%. It is certain from the FAR and FRR results of this study that ODel institutions and examination organizations will benefit from this improved solution.

The research further suggested an authentication technique based on speech recognition analysis to detect an intruder's voice to prevent an agent from obtaining responses from someone standing at an unnoticeable position. An authentication method that combines physiological facial recognition, behavioral keystroke dynamics, and another physiological speech recognition was further investigated in this study. The Mel-Frequency Cepstral Coefficient for feature extraction and the Gaussian Mixture Model in the Sci-kit Learn package in Python form the basis of the augmented voice authentication technique.

The results for the fused multimodal biometric authentication model from the Moodle virtual learning platform's experiment indicated an improved recognition rate of 90%, FAR of 1.11%, and FRR of 3.8% on the union of face authentication, voice authentication, and keystroke patterns authentication technique. As stated by (Srivastava & Sudhish, 2016), compared to a single-factor authentication system, a multi-factor authentication system provides greater accuracy. The comparison of the multimodal authentication method proposed in this study in table 5.2 indicates that ODeL institutions' challenge of examination malpractice can be controlled. Some institutions such as (Godfrey Okoye University, 2020) prevent open distant examination malpractice using facial recognition but cannot prevent cheating through the dictation of answers to the examinee which the voice authentication feature of this research does.

The voice recognition implementation aids in disallowing the agent from obtaining answers from a dictator from an unnoticeable location during the examination. Of course, it's crucial to remember that such authentication implementation in open distance electronic learning environment will require considerable amount of high bandwidth with optimal speed.

Concluding on the objective 2 - To develop a sustainable bandwidth planning strategy to reduce bandwidth requirements for massive users with competing services in a constrained network capacity of an ODeL environment for QoS for smart education. Users need the right management approaches to make ODeL smarter for high-quality teaching and learning, taking into account the degree to which ODeL can regulate bandwidth based on capacity efficiency for enormous virtual environments.

This study proposed a Hidden Markov model to forecast bandwidth and normalization policy for bandwidth planner in an ODeL environment. The prediction results showed MSE of 0.17, RMSE of 0.41, and MAE of 0.34. The normalization policy plan for three days ahead for each service based on the constraint bandwidth available for uniform allocation. The prediction error in existing methods such as (Rana et al., 2017) reduced mean absolute percentage error (MAPE) by 15.42%, MSE of 2.22 obtained by (Namel et al., 2019).

Learning institutions consider network bandwidth as a key element for QoS in ODeL, (University of Northern Lowa, 2023) indicates that bandwidth is key to remote learning, (University of Bristol, 2023) admits proper allocation of bandwidth as the potential for students to successfully participate in online and blended learning. Students are left behind in the online learning atmosphere due to network bandwidth issues (Ryan Matte, 2020). Therefore, appropriate network bandwidth allocation in ODeL is a key element to providing QoS.

This research proposed a sustainable Hidden Markov Model bandwidth planner as a pandemic response for distance learning institutions to provide appropriate bandwidth allocation for the ODeL environment for QoS. The design of this technique is to provide optimized bandwidth utilization in resource-constrained platforms with many services performed by several users in the network contending for bandwidth. First, this research employs an HMM to predict future traffic for off-peak and peak times. A Normalization Policy (NP) then allocates bandwidths based on constraints. The goal of HMM-NP is an optimization of the bandwidth allocation to many services based on interaction with the SolarWinds network performance monitoring tool and performance databases.

The HMM-NP method produced bandwidth allocations for various loads at both peaks and off-peak periods under constraints. The model was also evaluated on three publicly available datasets to demonstrate its effectiveness in addressing the bandwidth challenges discussed herein. It was also realized that the proposed method outperformed the baseline approaches in the experiments. According to the findings of this research, it is reckoned that the HMM-NP is proficient in providing a sustainable bandwidth plan as a pandemic response for distance learning institutions learning technologies and collaborates with the authentication model to achieve QoS in ODeL for smart education.

Concluding on the objective 3 - To propose a framework for proactively managing conflict for QoS to make open distance electronic learning smarter. A proactive automatic smart education conflict management framework is proposed to provide a comprehensive concept of resolving conflict in smart education. The framework was developed based on a comparative analysis of smart education models in view of conflict management presented in Table 5.4.

Mathew, (2015) argues that conflict is not a by-product of quality design, it is an important ingredient in design for QoS; therefore, it must be appropriately planned for, emphasized, and not be downplayed. T. H. Ozturk & Hodgson, (2017) suggest that it's critical to understand not just how to manage or resolve conflict, but also how it is caused and can be prevented, in order to fully comprehend the complexity of conflict in democratic pedagogies in online and blended learning settings. They further indicate that developing a framework for conflict management in an online education system cannot be undermined. A literature review conducted by Onwe & Nwogbaga, (2014) showed that status (such as identity authentication), power, and resource (such as bandwidth management) issues are the root causes of conflict and crises in learning management systems.

Smart education is the new paradigm of virtual education, but appropriate management of elements that are catalysts of conflict remains unattended. A framework to serve as a guide to managing conflict in smart education is required to enhance open distance electronic learning quality.

This research presents the concept of smart education conflicts and resolution mechanisms, and a discussion on smart education points out the basic requirements. The general and specific research perspectives on conflicts in smart education relate to the characteristics of an institution that provides smart education. The various conflicts identified are classified based on the source, intervenient, detection time, and ability to solve. Smart education or smart learning models are enhanced to incorporate conflict management.

In conclusion, the proposed framework for proactively managing conflict in open distance electronic learning has the potential to enhance the quality of service offered in this mode of education. Conflict is an inevitable part of any educational environment, and when it is well-managed, it can promote constructive discussions, better understanding, and improved learning outcomes. By implementing a framework that promotes proactive conflict management, educators and learners can address conflicts before they escalate, maintain positive relationships, and ensure that the learning environment remains conducive for all parties involved.

Concluding on the objective 4 - To propose a framework incorporating methods and schemes to implement QoS adaptation in an ODeL. The proposed model, IQSODeL for implementing quality of service adaptation in open distant electronic learning can play a significant role in enhancing the overall quality of education delivery. The model draws on various methods and schemes, including authentication, dynamic bandwidth allocation, and conflict management, to ensure that learners have access to a reliable, efficient, and high-quality learning experience. By prioritizing critical cheating-free examination in educational applications, allocating network resources according to their needs, and managing conflict, educators can ensure that the learning environment remains conducive and engaging for all learners.

The proposed framework draws on existing literature on QoS adaptation and electronic learning. The literature suggests that QoS adaptation is essential in ensuring that the quality of the learning experience is not compromised, even in bandwidth-constrained environments (Ossiannilsson et al., 2015; Shang, 2021). Moreover, the literature highlights the importance of dynamic bandwidth allocation and traffic management in ensuring that the network resources are efficiently utilized and allocated according to the needs of the application (Balkaya & Akkucuk, 2021; S. et al., 2023).

Overall, the proposed framework for implementing quality of service adaptation in open distant electronic learning can help promote a reliable and efficient learning environment that meets the needs of all learners. By drawing on the existing literature on QoS adaptation and electronic learning, this framework offers a practical and comprehensive approach to managing network resources in distance learning environments.

Quality of service is a key component of making the current educational system smarter. Still, methods and schemes are not organized appropriately to achieve it in an open distance electronic learning environment. The research achieved this objective with the construction of the intelligent model for quality service in ODeL (IQSODeL) based on the integration of the QoS elements evaluated. The IQSODeL model is then validated with a survey on the participants in the experimental processes using the SERVQUAL model. The analysis was accomplished with a confirmatory factor analysis using AMOS. It was evident from the analysis results as benchmarked with the recommended standard model fit values such as P-value, Comparative Fit Index, Goodness of Fit Index, and the others were within range presented in table 5.9. It is therefore concluded that QoS in ODeL is dependent key elements such as secure cheating free examination, appropriate network bandwidth distribution, and proactive conflict management.

6.3 Research Contributions

6.3.1 Contributions to the Scientific Body of Knowledge

This study provides considerable contributions to the open distance electronic learning body of knowledge through the following:

- Development of a bimodal biometric authentication framework using facial recognition and keystroke dynamics technology for non-venue-based examination at ODeL institutions.
- Using real-world male and female data sets on a client-server ODeL platform, thorough experimental evaluations of the model produced fantastic results that outperformed cutting-edge methods on metrics like the receiver operating curve (ROC), false acceptance rate (FAR), false rejection rate (FRR), and other measures.
- Further advancement on the authentication by augmenting with voice recognition to provide multimodal authentication in the e-learning environment. This increased the validation accuracy.
- Development of a sustainable bandwidth planning strategy based on the emergence of a new HMMα and Normalization policy (HMM-NP) to allocate bandwidth for massive users with competing services in a constraint network capacity of an ODeL environment.
- Detailed experimental evaluations on the emerged HMM using real-life data gathered through the bandwidth monitoring tool on a client-server network of virtual learning platforms predicting time window bandwidth planned for users with various load conditions.

- Development of conflict management framework to resolve conflicts in ODeL for smart education.
- A comprehensive framework for quality service in open distance electronic learning environments serving as a prototype for virtual organizations. This reveals the researcher's view of QoS in ODeL opening up new areas of research on security, bandwidth management, and conflict resolution as key quality elements in ODeL.

6.3.2 Declaration of Publications Emerging from this Research

The publications that resulted from this research are listed below:

Published:

- P. Y. O. Amoako and E. Mnkandla, "Fused Multimodal Biometric Authentication for an Open Distance Learning Environment Online Examination", *International Journal of Smart Technology and Learning (IJSMARTTL)*, vol. 3, no. 3, 2023, ISSN: 2056-4058, doi: 10.1504/IJSMARTTL.2023.10059328.
- P. Y. O. Amoako and I. O. Osunmakinde, "Emerging bimodal biometrics authentication for non-venue-based assessments in open distance e-learning (OdeL) environments", *International Journal of Technology Enhanced Learning*, vol. 12, no. 2, 2020, doi: 10.1504/IJTEL.2020.106287.

Conference Proceedings

- P. Y. O. Amoako, Conceptual Framework on Proactive Conflict Management in Smart Education, 11th Sustainable Education and Development Research Conference - Sustainable Industrialization and Innovation: Proceedings of the Applied Research Conference in Africa (ARCA), August 24-27, 2022, Springer Nature

- P. Y. O. Amoako and I. O. Osunmakinde, "Sustainable Markov Model Bandwidth Planner Enhancing Learning Technologies in Constrained Distance Learning Environments – a Pandemic Response, IEEE 20th International Conferences on Information Technology Based Higher Education and Training 7-9 November 2022, Side, Antalya, Turkey

6.4 Recommendations

From the outcome of this research, it is clear that many institutions and organizations operating open distance electronic learning to a very large extent stand to benefit from the use of IQSODeL. It is therefore recommended that:

a) IQSODeL implementation in the online or e-assessment system will guarantee students' trust in such systems. This is because the sole assurance of the identity of student and their authorship attached to assignments, tests, or any alternative online activity is a trustworthy and user-friendly authentication system.

b) Implementation of IQSODeL aid an institution that provides distance or correspondence education to satisfy the quality assurance requirement by the accrediting agency or association to have procedures in place that prove the student enrolled in the program or course is also the one who took part in it, progress to completion and is awarded academic credit for it.

c) Institutions with limited network bandwidth can rely on IQSODeL to manage the bandwidth allocation to massive users with varying services to promote quality service.

d) A number of conflicts in ODeL on functional and non-functional requirements of the learning management systems hinder the QoS. IQSODeL provides a framework for conflict management that is useful for resolving ODeL conflicts.

Considering the stated benefits of IQSODeL, the researcher recommends its implementation by all institutions and organizations that employ e-assessment having network bandwidth limitations and conflict issues in their systems to ensure quality service.

6.5 Limitations and Future Directions

It is realized that the authentication schemes employed for ensuring secured cheating-free examination on ODeL will require considerably high resources for processing, storage, and network bandwidth that may limit the QoS. The preliminary investigation of the ODeL crisis uncovered various difficulties, including the changing nature of technology and problems with hardware and software capability. The research does not consider all the factors that compromise the QoS, which this research considered all under conflict management.

Considering such limitations, it is necessary to point out the following future directions:

a) Research into techniques and processes for reducing the resource capacity of authentication schemes cannot be overemphasized.
b) Further studies on bandwidth management in ODeL for QoS would consider optimization of bandwidth allocation space by conducting long-period planning for services. Another direction would be to consider the categorization of users and their needs in bandwidth management to ensure fair sharing and service availability guarantee.

The future direction of research will focus on developing a smart conflict management system based on the various frameworks by employing deep learning techniques. Additionally, to analyze conflict classifications in open distance electronic learning using machine learning techniques. This broadens the range of conflicts that ODeL may address.

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APPENDIX A: Questionnaire

Evaluating Open distance electronic learning service quality elements through SERVQUAL model

Demographic information

1. **Gender**
   a. Male
   b. Female

2. **Age**
   a. Less than 20
   b. 20 –25
   c. 26 - 30
   d. 31 –35
   e. 36 - 40
   f. 41 and above

3. **Designation**
   a. Administrator
   b. Lecturer
   c. Student

4. **If student indicate your level**
   a. Level 100
   b. Level 200
   c. Level 300
   d. Level 400

5. **Identification of the Quality Elements**

a. Secured and cheating free examination in open distance electronic learning environment is a significant element to ensure quality of service
b. Optimal network bandwidth allocation is a significant element for quality of service in ODeL environment
c. Conflict management is significant in promoting quality of service in ODeL environment

6. **User authentication as ODeL QoS element**

Scale: "strongly agree" (5), "agree" (4), "unsure" (3), "disagree" (2), and "strongly disagree" (1)

a. Assurance: Cheating free examination through trusted authentication systems assures quality of service in ODeL.
b. Reliability: Accurate and reliable authentication mechanisms promote quality of service in ODeL
c. Tangible: Appropriate tools and equipment implementation for authentication ensures quality of service in ODeL.
d. Empathy: Authentication in ODeL inspire lecturers to provide quality content and motivates students' acceptance of fair assessment.
e. Responsiveness: Prompt feedback from authentication systems enhance the quality of service in ODeL

7. **Bandwidth Management**

Scale: "strongly agree" (5), "agree" (4), "unsure" (3), "disagree" (2), and "strongly disagree" (1)

a. Assurance: Appropriate allocation of limited bandwidth to prevent network drain in such a high-demand bandwidth environment assures quality of service in ODeL.
b. Reliability: Continuous access to ODeL system for maximum user uploads and downloads ensure quality of service in ODeL
c. Tangible: Techniques well suited to allocate bandwidth relatively or specifically to each user and service for ODeL platform efficiency promote quality of service in ODeL
d. Empathy: Continuous communication between students, lecturers and staff enhance quality of service in ODeL.
e. Responsiveness: Prompt and uninterrupted retrieval of feedback ensure quality of service in ODeL

8. **Conflict Management**

Scale: "strongly agree" (5), "agree" (4), "unsure" (3), "disagree" (2), and "strongly disagree" (1)

a. Assurance: Proactive automatic conflict resolution to provide smart education assures quality of service in ODeL.
b. Reliability: Continuous functional and availability of system resources to all agents ensure quality of service in ODeL
c. Tangible: Open system architecture requirements are to excellently support the integration of emerging interfaces, smart devices, and diverse learning data in a conflict-free operating learning environment to promote quality of service in ODeL
d. Empathy: Fair distribution of resources, care for students, lecturers and staff ensures quality of service in ODeL.
e. Responsiveness: Avoidance, prompt identification and resolution of conflict among agents (students, lecturers, and administrators) enhance quality of service in ODeL

9. **Quality of Service**

Scale: "strongly agree" (5), "agree" (4), "unsure" (3), "disagree" (2), and "strongly disagree" (1)

a. Quality of service in ODeL cannot be realized without ensuring cheating free examination.
b. Quality of service in ODeL depends greatly on the appropriate implementation of bandwidth management techniques
c. Conflict resolution is a key factor and overall determinant of quality of service in ODeL platform

APPENDIX B: Ethics Clearance Certificate

UNISA university of south africa

UNISA COLLEGE OF SCIENCE, ENGINEERING AND TECHNOLOGY'S (CSET) ETHICS REVIEW COMMITTEE

5 August 2021

Dear Prince Yaw Owusu Amoako

ERC Reference #: 2021/CSET/SOC/050
Name: Prince Yaw Owusu Amoako
Student #: 57640777
Staff #:

Decision: Ethics Approval from 2021 to 2025
No humans involved

Researcher(s): Prince Yaw Owusu Amoako
57640777@mylife.unisa.ac.za

Supervisor (s): Prof IO Osunmakinde
osunmakindeio@yahoo.com

Working title of research:

Multi-Agent Systems in Virtual Organizations

Qualification: PhD in Computer Science

Thank you for the application for research ethics clearance by the Unisa College of Science, Engineering and Technology's (CSET) Ethics Review Committee for the above mentioned research. Ethics approval is granted for 5 years (PhD studies).

*The **negligible risk application** was expedited by the College of Science, Engineering and Technology's (CSET) Ethics Review Committee on *decision date* in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment. The decision will be tabled at the next Committee meeting for ratification.*

The proposed research may now commence with the provisions that:

1. The researcher will ensure that the research project adheres to the relevant guidelines set out in the Unisa COVID-19 position statement on research ethics attached.

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2. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
3. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the College of Science, Engineering and Technology's (CSET) Ethics Review Committee.
4. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
5. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
6. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
7. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data require additional ethics clearance.
8. No field work activities may continue after the expiry date *expiry date*. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.
9. *Permission to conduct research involving UNISA employees, students and data should be obtained from the Research Permissions Subcommittee (RPSC) prior to commencing field work.*
10. *Permission to conduct this research should be obtained from the [company, CE organisation, DoE, etc name] prior to commencing field work.*

Note

The reference number 2020/CSET/SOC/050 should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.

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Yours sincerely,

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URERC 25.04.17 - Decision template (V2) - Approve

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APPENDIX C: Certificate of Language Editing

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Dear Sir/Madam,

Re: PhD Thesis Proofreading & Editorial Cleaning

This is to certify that Amoako Prince Yaw Owusu's PhD thesis titled "An Intelligent Model for Quality Service in Open Distance Electronic Learning" has been proofread by Ms Bib Hughes of Ella Carver Hughes Ltd Editorial Services and has undergone editorial cleaning.

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APPENDIX D: Screen Shots of Turnitin Similarities Summary

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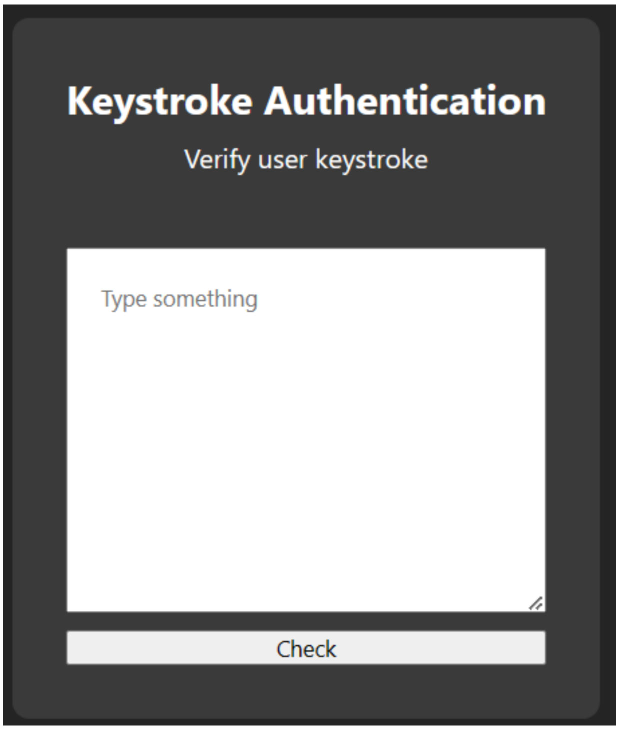
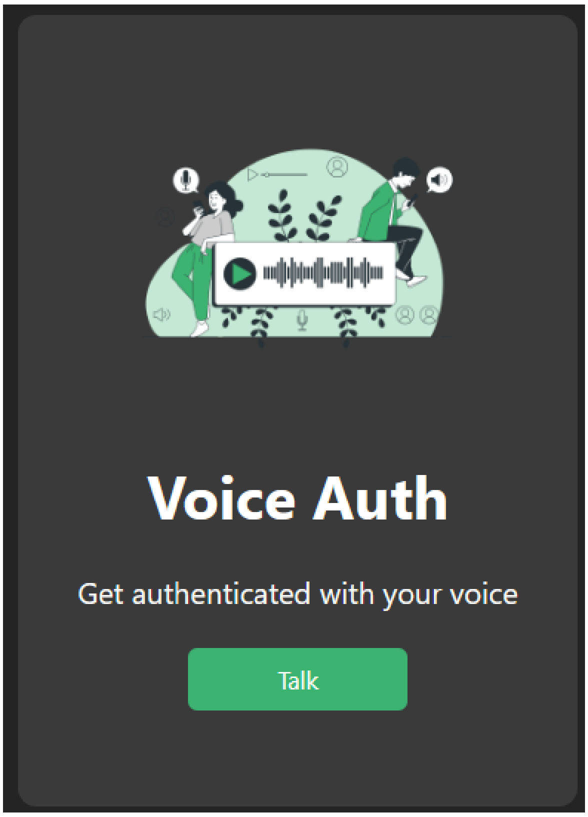
2	Submitted to University of South Africa Student Paper	1%
3	searchcio.techtarget.com Internet Source	1%
4	coek.info Internet Source	1%
5	Submitted to Roehampton University Student Paper	<1%
6	edtechbooks.org Internet Source	<1%
7	uedufy.com Internet Source	<1%

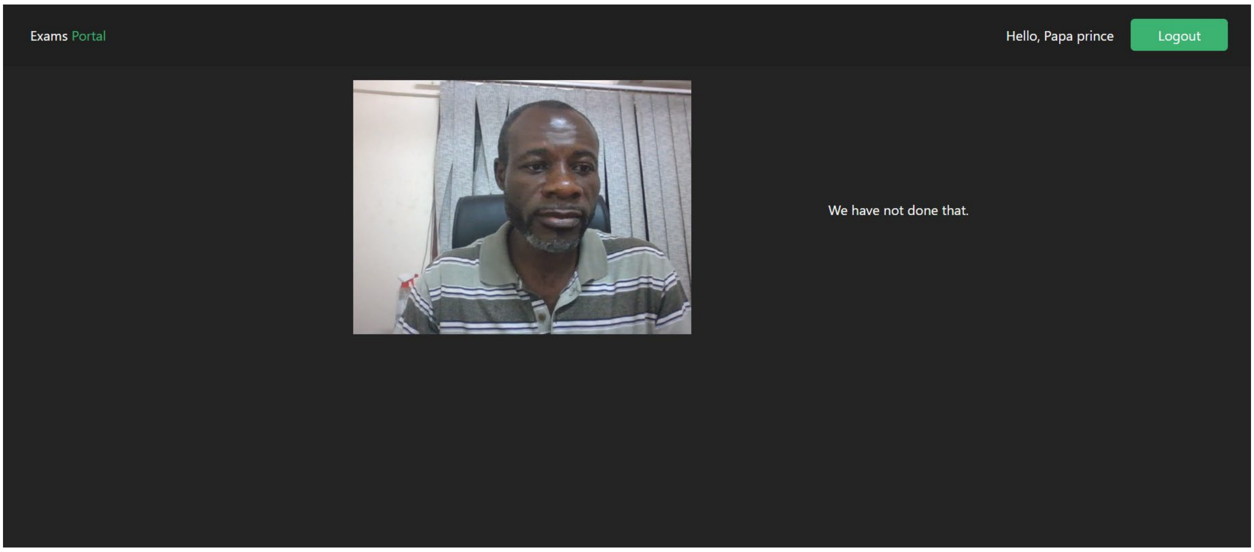
APPENDIX E: Screen Shots of Developed Tools



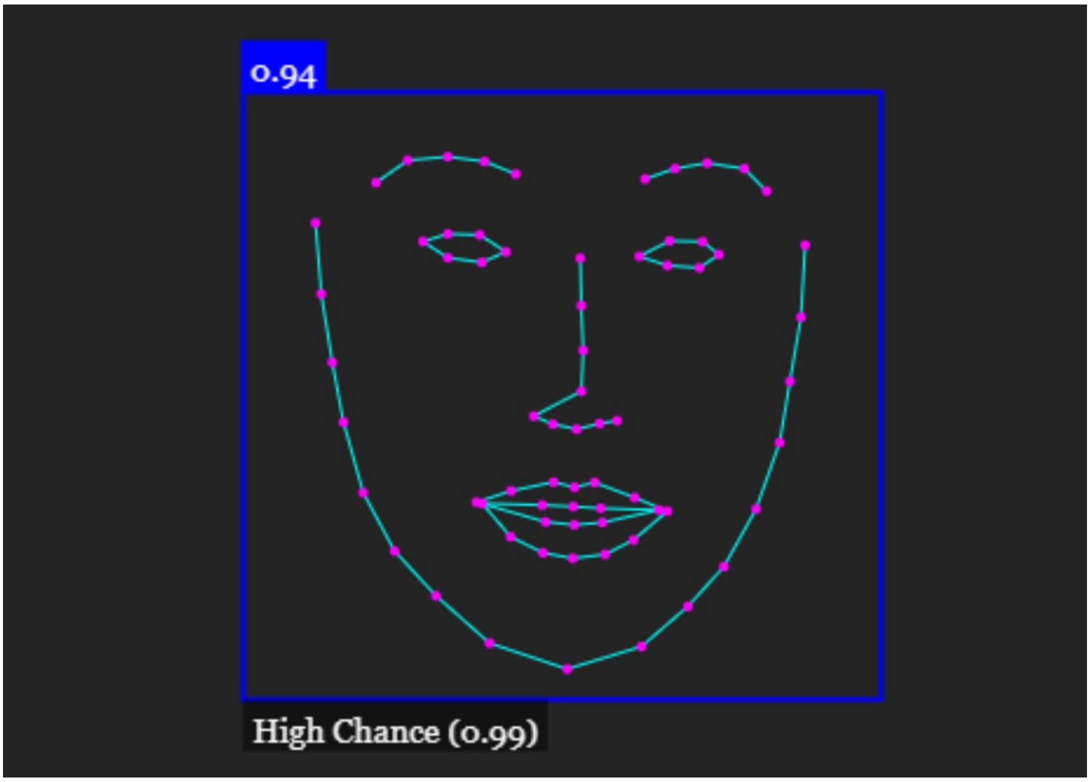
Keystroke Dynamic Authentication



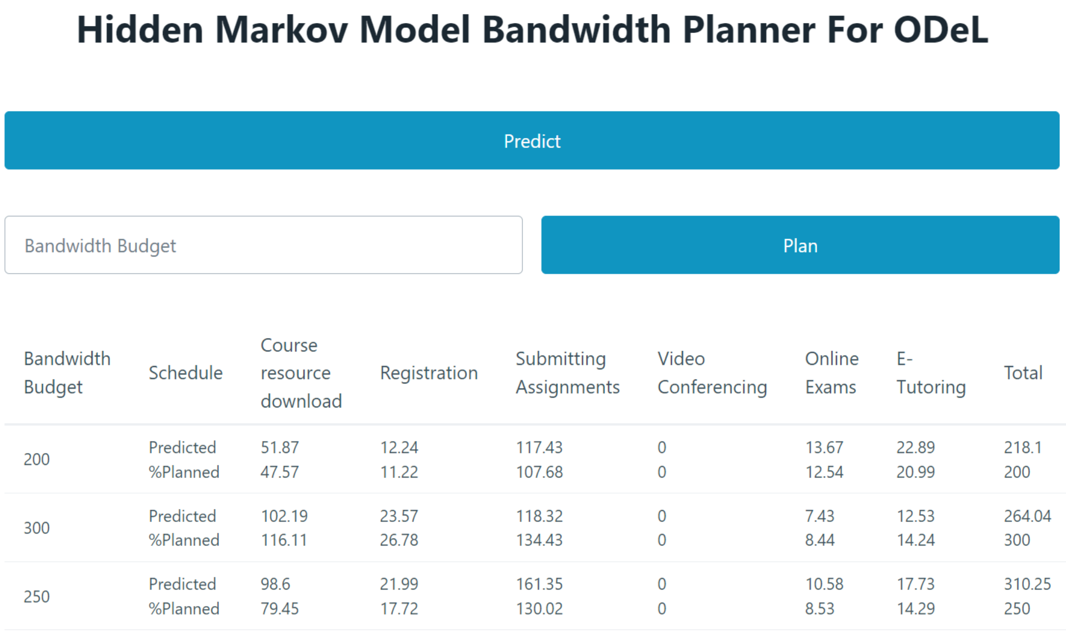
Voice Authentication



Facial Recognition



Facial Authentication Mapping



Bandwidth Budget	Schedule	Course resource download	Registration	Submitting Assignments	Video Conferencing	Online Exams	E-Tutoring	Total
200	Predicted %Planned	51.87 47.57	12.24 11.22	117.43 107.68	0 0	13.67 12.54	22.89 20.99	218.1 200
300	Predicted %Planned	102.19 116.11	23.57 26.78	118.32 134.43	0 0	7.43 8.44	12.53 14.24	264.04 300
250	Predicted %Planned	98.6 79.45	21.99 17.72	161.35 130.02	0 0	10.58 8.53	17.73 14.29	310.25 250

Bandwidth Planner

APPENDIX F: Links to Access Implementations and Dataset

- Link for Multimodal Authentication Implementation in ODeL
  https://papaprinceproject.000webhostapp.com/index.html

- Link for Bandwidth Management Implementation in ODeL
  https://plan.scuppal.com

- Link for Bandwidth Utilization Dataset
  https://www.kaggle.com/datasets/princeyawowusuamoako/bandwidth-utilization

- **Link for the data collected for Evaluating Open distance electronic learning-ODeL (or online learning) service quality**
  https://forms.office.com/Pages/DesignPageV2.aspx?origin=NeoPortalPage&subpage=design&id=jIuayqM-mUekPlUQOY56O8EATPbY9w1CkczZ9sXXznBUMTNCQVVOV1RDTUcxWFBRMFc2TUQ2Q0tJOS4u