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Grid Computing For Collaborative Research Systems In Kenyan Universities

[1]Julius Murumba, [2] Elyjoy Micheni
[1]*Department of Management Science and Technology, Technical University of Kenya*
[2]*Department of Management Science and Technology, Technical University of Kenya*

ABSTRACT

Grid computing technologies have the potential of providing universities in this country with opportunities and mechanisms to utilize a wide range of heterogeneous, distributed resources for computational and data-intensive applications, and provide an avenue to heterogeneous collaborative research platforms that can be accessed by different hardware and software platforms. The objective of this paper was to find out which technologies are being used to support collaborative research and further investigate the opportunities, benefits provided by grid technologies in universities as well as the challenges faced. The study is carried out through an examination of reports and academic documents from universities in Kenya scientific research papers in journals and conference proceedings, and from online journals and. The paper concludes that there are many benefits of using grid technologies in collaborative research systems and therefore encourages researchers in universities of developing countries to consider utilizing these technologies since many universities are ready and willing to automate and integrate most of their systems that support research.

Keywords *- Grid computing, Collaborative research, Universities*

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I. INTRODUCTION

Distributed computing, the internet and cloud computing have revolutionized the university landscape, making collaborative research possible and afford universities opportunities to implement systems comprising new sets of structures that can be accessed through the internet [1]. Grid computing systems provide mechanisms to utilize a wide range of heterogeneous, distributed resources for computational and data-intensive applications such as those capable of supporting collaborative research and e-learning platforms. According to [1], The focus of the grid computing concept is on resource sharing, rather than file exchange, and as such it is concerned with direct access to computers, software, data, and other resources as is required or configured by the available range of collaborative problem-solving and resource brokering strategies. A typical grid may consist of resources owned by a number of different institutions, within which sharing arrangements are established. Users can access resources on the grid to perform various tasks related to their work, thus gaining access to additional storage, processing power and other facilities that would not otherwise be available to them. The term grid computing refers to a type of parallel and distributed system that uses middleware to coordinate disparate IT resources across networks, allowing them to function as a virtual whole. [2] define a grid to be a collection of independently owned and administered resources which are joined together by hardware and software infrastructure that interacts with the resources in a distributed computing environment, and the users of these resources to provide a coordinated and dynamic resource sharing in a dependable and consistent way accordance with policies agreed upon by all parties. Grid computing enables the dynamic sharing and aggregation of geographically distributed resources at runtime depending on factors which include cost, availability, capability and performance of the resources and users quality of service requirements [3]; [4]. Grid Technology is usually based on Web services which in turn depend on Internet. Therefore, the Internet Backbone has in recent years been the main source of Grid. Therefore, a collaborative research grid can be viewed as a collection of computational resources on demand to match computational needs of research through generic service matchmaking on the Web. [5] Highlight the emergence of trends of increased demands on information technologies for service deliveries that are acceptable; such demands include high-performance computing support and fast processing elements as well as faster communication backbones. The need for such increased computing power has in the last few years led to some universities to consider the potential of grid computing in order to address these needs, where computing resources are combined to produce enhanced performance. [6] defines scientific collaboration as interaction taking place within a social context among two or more scientists that facilitates the sharing of meaning and completion of tasks with respect to a mutually shared, super ordinate goal Majority of universities in developing countries have research systems that are constrained by limited financial resources and ICT resources such as low bandwidth and unreliable network connection [7].

II. OBJECTIVES OF THE STUDY

The study aimed at highlighting the potential grid computing technologies offer systems supporting collaborative research in universities in Kenya. Universities can take advantage of the enabling capacity of grid technologies in enhancing collaborative scientific research and help the county's drive for comprehensive development. This study was guided by the following specific objectives:

1. To find out the Information Technologies being used for collaborative research systems in universities in Kenya
2. To establish opportunities and benefits grid technologies present for collaborative research systems
3. To investigate the challenges of adopting grid technologies in collaborative research systems

III. METHODOLOGY

This study employed literature review to explore and understand grid technologies and their potential use in collaborative research systems. Scholarly journals and research materials, Books, Magazines and Thesis reports was examined. Other documents examined included online scholarly journals found on the internet and Kenya ICT policy (2006). The sources accessed and used in this paper are cited in the reference section.

IV. OVERVIEW COLLABORATIVE RESEARCH IN KENYA

Collaborative research in universities provides academic members of staff with both formal and informal professional learning opportunities, as well as opportunities for the universities to benchmark against best practices in academia. Research collaboration is defined as system of research activities by several researchers which are related in a functional way and are coordinated to attain a research goal corresponding with these researchers' research goals or interests [8]. [9] noted that such collaborations within universities provide a medium for mutual reflection on peer practices and assists professionals refine knowledge in their areas of specialization, and therefore affords the universities opportunities to be mentored and to be elevated to the level of the world's best. The motivation for collaboration among researchers and the strategies chosen to achieve collaboration are driven by personal interests and environmental constraints particularly resources [7]. A report by the Kenya Government [10] indicates that research in Kenya is constrained by limited funding allocated to research and poor coordination and harmonization between researchers and research institutions and recommended collaborative research, development of strategic linkages and partnerships between universities and with industry in order to enhance mutual knowledge exchange and innovation transfers as a way to remedy this deficit. A study on collaborations in Kenya, done by the Commission for Higher Education [11] reported that there were limited collaborative researches in Kenya, especially between Kenyan universities and industry. Figure 1 below illustrates a typical eScience scenario achievable via grid computing The International Foundation for Science-The African Academy of Sciences (2016) briefing document indicated that the benefits of collaborative research include the following: i) More scientific results and publications are achieved with less effort, while utilizing fewer resources and these results and publications have a wider geographical reach; ii) Collaboration inspires researchers to apply for and win funding; share proposal writing skills, research data, equipment and materials; and become more effective at working in teams ; iii) Scientists network and travel across Africa; learn across disciplines, regions and languages; and gain deeper and broader views of the potential as well as challenges of the African continent's; iv) Researchers are able to build expertise in various ways including planning and managing projects, logistics, team coordination, recruitment and training of field staff and field and laboratory activities. The reports further states that challenges exist including i) System challenges arising out of web-based applications and workspaces requiring reliable internet connections; ii) Intra-team, cultural and legal issues concerning the sharing of research equipment and infrastructure, materials and funds; iii) Poor communication leading to slow decision-making which in turn affect research progress and outcomes. The current trend in research in higher institutions of learning is collaborative research because many grants organizations demand collaborative research as a prerequisite for grant qualifications [7].

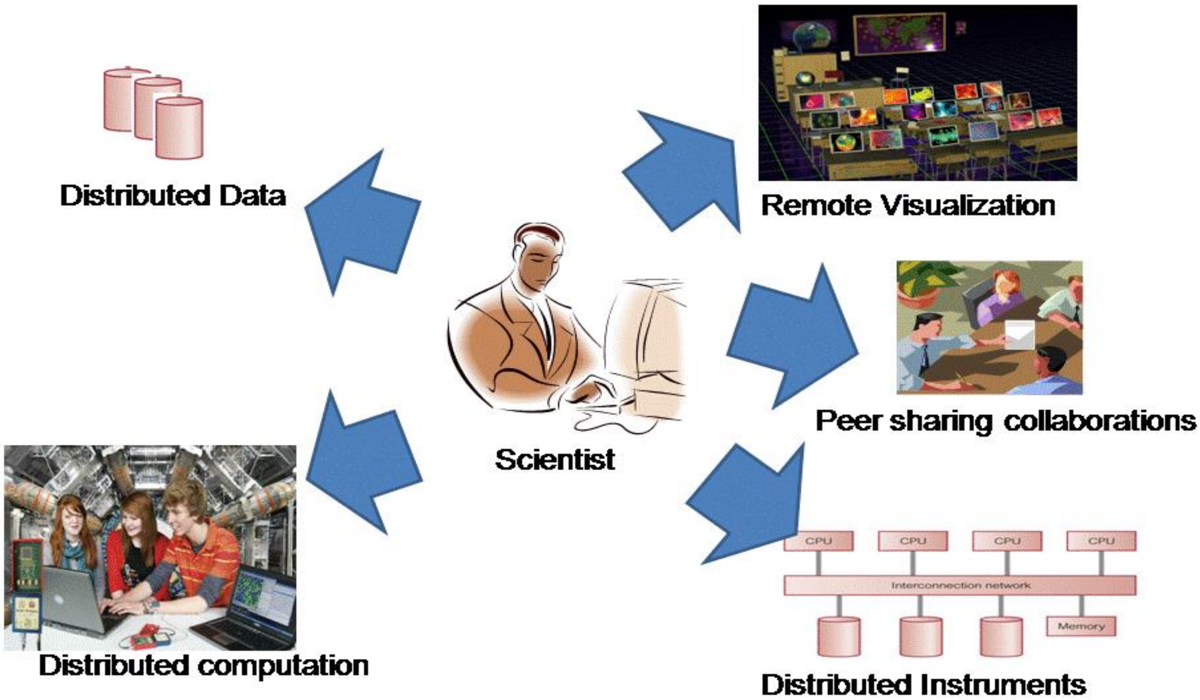

Figure 1: Illustration of collaborative research scenario: adapted from [3]

V. INFORMATION TECHNOLOGIES USED IN COLLABORATIVE RESEARCH SYSTEMS

According to [7], Information and Communication Technologies have become indispensable tools for supporting collaborative research work, and for this reason the critical role they play in supporting distributed teams can be enhanced with improvements in networking technologies and the development of tools and applications capable of supporting digital communications, access to and distribution of information. Information Technologies provide opportunities to the younger researchers and those who were not in major universities to participate in discussions with established researchers and those from prominent universities leading to an increased network of researchers and wider participation [12]. [13] states that new Information Technologies enable new communication structures that have radically reduced constraints of distance and time, and have also enabled creation of new and unique environments capable of supporting research and teaching. These new and emerging technologies afford university communities numerous opportunities to meet the challenge of the knowledge economy, offering new and novel possibilities for creating learning environments and applying knowledge in new ways in order to meet changing societal needs. The new Information Technology based infrastructures offer new possibilities for sharing of facilities and enables new forms of distributed organization. According to [13], the major components of the Information Technologies infrastructure in universities are: 1) Traditional packet switching networks and the newer point-to-point optical networks. 2). Middleware that enables integration of various technologies and makes it much easier to build university specific or inter-institutional virtual organizations in efficient, secure, and trustful ways. 3). Data and knowledge management services supported by vast networks of digital libraries, data sets, and archives providing content and sustainable knowledge management services. 4) High performance computation services capable of simulating complex phenomena such as galaxy formation or social-physical models of global warming. 5) User Interfaces and visualization services to support interaction between humans and the Information Technology environments. 6) Computer supported collaborative work to enable collaborative services to support and enable distributed teams to work together in ways similar to those in physical proximity. Various computer resources such as computer desktops, storage media, data and various input and output devices that are scattered across the university landscape can be connected via internetworking links through grid computing. Collaborative Research systems therefore can be presented as an amalgamation of grid computing technologies and research support systems in which Grid Computing functionalities are incorporated into Research systems. This way the collaborative Research Grid can be viewed as collection of computational resources on demand to match computational needs through generic service matchmaking on the Web.

VI. OPPORTUNITIES OF GRID TECHNOLOGIES FOR COLLABORATIVE RESEARCH SYSTEMS

In the context of this study, a grid may consist of resources owned by different universities, within which sharing arrangements can be established. [14] points out that the sharing in the context of grid computing is not primarily file exchange but rather direct access to computers, software, data, and other resources, as is required by a range of collaborative problemsolving and resource-brokering strategies that have emerged and are availbale in industry, science, and engineering. This sharing is highly controlled, with resource providers and consumers defining clearly and carefully just what is shared, who is allowed to share, and the conditions under which sharing occurs. A set of individuals and/or institutions defined by such sharing rules form what we call a virtual organization [14]. This continually evolving field now aims to completely disaggregate current computer platforms and distribute them across a network as resources that can be called into action by any eligible user or machine at any time [15]. A study by [16] reveals that that perceived benefits, perceived need, and facilitating conditions exert a significant influence on the adoption of grid computing by Nigerian Universities, and by extension universities on the african continent. [5] narrate their humble experiences with grid-computing experiments that culminated in presentation of a grid-computing model for Chiromo Campus of the University of Nairobi. The model involved sharing of personal computers with Linux Red Hat operating system within a distributed group and setting up the Globus Toolkit Version 3 grid-computing middleware on them. The UNESCO-HP project (2009-2012) sought to use grid computing for collaborative researchers in developing and developed nations. Several universities participated in the project among them Masinde Muliro University of Science and Technology (Kenya), University of Nairobi (Kenya), Makere University (Uganda), Mbarara University (Uganda) and Mbekele University (Ethiopia) in East Africa amongst others in other parts of Africa [17]. KENET hosted one and half day training on the use of Grid Infrastructures and Science Gateways on 30th November and the 1st December of 2016 at the KENET Training room, University of Nairobi offices. Over 25 researchers drawn from academic members of staff and PHD students in Kenya were in attendance [18]. The objective of the training was to equip participants with practical skills on how to access and use scientific applications available on Grid Infrastructures and Science Gateways for their research activities using the KENET Digital Certificates and an Identity Provider Service. KENET, whose membership includes institutions of higher learning Kenya is a licensed private networks operator recognized by ICANN and AfriNIC as a National Research and Education Network and promotes the use of ICT in institutions of higher learning whilst connecting them to the rest of the world. Grid computing provides computing infrastructural support for collaborating organizations. KENET institutions have so far been provided with affordable and efficient bandwidth [18], meaning that researchers from institutions affiliated to KENET can access resources available globally because the KENET issued digital certificates are accepted on the Africa Grid and the European Union Grid where they can have access to enormous computing and storage resources.

VII. COLLABORATIVE RESEARCH GRID ARCHITECTURE

Grid architecture defines the elements that are required for establishing and maintaining Virtual Organizations. The architecture is defined by basic components along with their purposes and functions, and the interactions between them [19]. Grid infrastructures support the sharing and coordinated use of resources in dynamic global heterogeneous distributed environments. These include resources that can manage computers, data, telecommunication, network facilities, and software applications provided by different organizations [20]. Grid computing is a service-oriented architectural approach that uses open standards to enable distributed computing over the Internet, a private network or both, providing high performance computing and large storage capacity. In order to address the requirements of grid computing in an open and standard way a framework consisting of core set of interfaces, expected behaviors, resource models, and bindings for distributed systems is necessary. The architectures for grid infrastructures include the Globus toolkits and Legion and programming systems for Grid applications such as Triana, composition systems for web services, distributed file systems and peer to peer network file sharing systems [21]. The open source Globus Toolkit has emerged as a de facto standard. [14] observes that the Global Grid Forum has made major efforts to define the Open Grid Services Architecture (OGSA), which modernizes and extends Globus Toolkit protocols to address emerging new requirements, while also embracing Web services. The open source Globus Toolkit 4 (GTK4) contains services, programming libraries, and development tools designed for building Grid-based applications. It was developed by the Globus Alliance and other contributors from around the world [19]. The Open Grid Services Architecture (OGSA) defines requirements core grid capabilities, therefore providing general reference architecture for grid computing environments. Though it does not go to the level of detail such as defining programmatic interfaces or other aspects that would guarantee interoperability between implementations, it can be used to identify the functions that should be included based on the requirements of the specific target environment [22].

Grids are typically implemented as a form of middleware which provides all grid related services and can also use the Internet as a communication infrastructure. The basic grid computer architecture may be viewed as a layered architecture consisting of: Application layer; collective services layer; resource and Connectivity protocols layer, and fabric layer [14]. An example is the Open Grid Services Architecture which is a common framework for building grids across the enterprise and beyond. Open Grid Services Architecture (OGSA) is a set of standards that extends Web services and service-oriented architecture to the grid computing environment. OGSA definitions and criteria describe how information is shared and distributed among the components of large, heterogeneous grid systems; they apply to hardware, platforms and software [23]. The Open Grid Services Architecture enables the integration of services and resources across distributed, heterogeneous, dynamic virtual organizations—whether within a single enterprise or extending to external resource-sharing and service-provider relationships [20]. [22], in their work have indicated that a Grid service is presented in the form of a web service which conforms to a set of interfaces, and behaviors that define how a client interacts with a grid service. Such web services are presented via web interfaces together with other Open Grid Services Infrastructure (OGSI) mechanisms associated with Grid service creation provide a robust grid environment. The Open Grid Services Infrastructure provides the Web Service Definition Language (WSDL) definitions for these key interfaces. The Globus Toolkit 4 s a good example, since it includes several of its core functions as Grid services conforming to OGSI. The Open Grid Services Architecture (OGSA) was developed to provide an extensible framework of services that support Grid functionalities by combining the realms of Web services and Grid technologies [24]. The architecture of the grid system consists of a series of key protocols and application programming interfaces implemented at five different layers as identified in the Grid protocol architecture shown in figure 2 below.

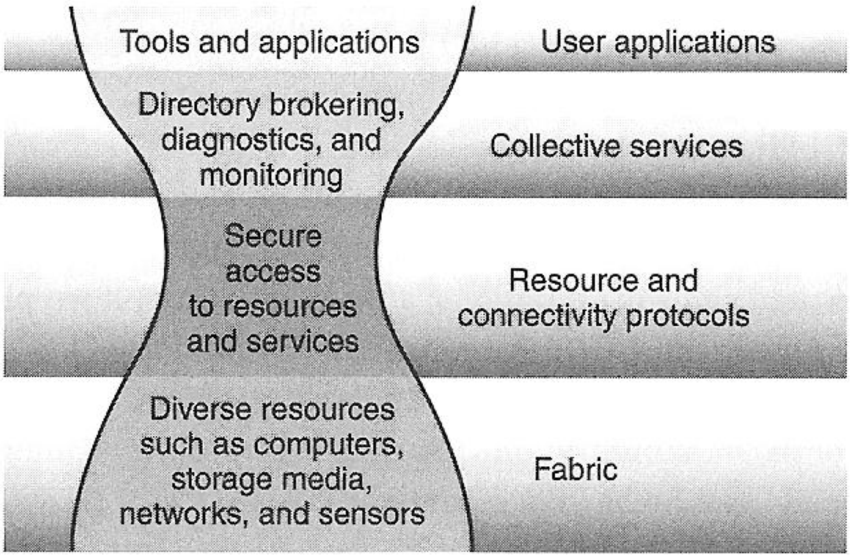

Fig 2: Model of the grid architecture: Adapted from [14]

The Grid Fabric layer consists of all the globally distributed resources that are accessible from anywhere on the Internet and to which shared access is mediated by the Grid protocols: the physical devices or resources that Grid users want to share and access, including computers, storage systems, catalogs, and networks [25]. The Globus Toolkit has been designed to use existing fabric components which include vendor-supplied protocols and interfaces. The Connectivity layer contains core communication and authentication protocols that are required for Grid-specific network transactions. Examples of such protocols are TCP/IP, HTTP, HTTPS, and DNS. The Grid Security Infrastructure (GSI) protocol provides a standardized mechanism for proxy credential creation and mapping to local access authentication scheme [19]. Authentication protocols at this layer provide cryptographically secure mechanisms for verifying the identity of users and resources [20]; [14]. The Resource layer contains services, Application Programming Interfaces (APIs), software development kits (SDKs), and protocols for managing resources individually [19]. The Grid Resource Access and Management (GRAM) protocol performs functions of a job manager and reporter and is used for allocation of computational resources and for monitoring and control of computation on those resources [14], while the GridFTP is used for data access and high-speed data transfer [20]. The Collective layer contains protocols, services, and APIs that implement interactions across collections of resources. Because Collective components build on the narrow Resource and Connectivity layer 'neck' in the protocol hourglass, they can implement a variety of sharing behaviors without placing new requirements on resources. Examples of Collective services include directory and brokering services, for resource discovery and allocation; monitoring and diagnostic services; data replication services; and membership and policy services for keeping track of who in a community is allowed to access resources [14].The Collective layer consists of protocols, services, and Application Programming Interfaces (APIs) that implement interactions across collections of resources, and coordinates sharing of resources. Examples of components in this layer are directory services that allow participants in the Virtual Organization to access resources and data replication services capable of supporting storage access and management [19]. The Application layer comprises the actual user applications that run and operate within a Grid system. Such user applications are built on top of the protocols stated above and Application Programming Interfaces (APIs) and operate in Virtual Organization environments [26].

VIII. BENEFITS GRID TECHNOLOGIES PRESENTS TO THE COLLABORATIVE RESEARCH SYSTEMS

Grids have the ability to make possible research projects that would otherwise be impractical or unfeasible due to dispersed physical location of vital resources [4]. For example using a grid, researchers in Kenya can conduct research that relies on databases situated in Europe and computational power in the United States. Grids make resources available and therefore facilitate new possibilities for collaborative research in institutions of higher learning. According to [27], Grid technologies have the potential to help researchers worldwide collaborate, analyze data and carry out research, by allowing grids users to create virtual research communities and organizations, providing a platform to share resources, information and ideas. Grid technology is well suited for collaborative research because of the distributed nature of the Grid and its users, providers and operators [28]. Such a widely distributed computing system and equally distributed user groups means that it makes sense to design systems which can be accessed from many and widely dispersed locations rather than to require users to travel to a central location. [22] stated that the benefits of grid technologies for collaborative research systems include: 1) Exploiting underutilized resources, whereby jobs can be run on any available idle machines on the grid .2) Parallel CPU capacities consisting of CPU-intensive grid applications which can be thought of as many smaller sub jobs, each executing on a different machine in the grid. 3) Virtual resources and virtual organizations for collaboration-grid computing which provide an environment for collaboration among wider audiences. Sharing on the virtual organizations can include files and other resources such as specialized devices, software and services.

IX. CHALLENGES OF ADOPTING GRID TECHNOLOGIES IN COLLABORATIVE RESEARCH SYSTEMS

There is existence of non technical or cultural barriers which are likely to impede implementation of e-learning grids [29]. [30] observed that while Grid computing is about resource sharing, institutional cultures of some of these institutions may not be supportive of this, and therefore successful implementation and use of grid technologies may require redefinition of ownership, copyrights, and licensing, since these present cultural and legal issues which have to be resolved before adjusting the institutional cultures and policies to integrate with what grid technologies provide. This is because grid computing is about resource sharing while institutional cultures of some institutions of higher learning may be opposed to this. In addition grid computing may require redefinition of ownership, copyrights, and licensing all of which present cultural and legal issues which have to be resolved before adjusting policies and expectations of these institutions to integrate with what technology provides. In order to use grid technologies, researchers may need an enabling knowledge of using grids and how to make choices between alternative application components, files, or locations [31]. [3] observed that the heterogeneity resulting from the vast range of technologies, both hardware and software, encompassed by the grid is one of the main challenges that face implementation of grid systems. [32] states that challenges of Grid Service include the following 1) Poor Information Technology infrastructure to support Grid Technology especially in developing countries where it is needed most. 2). Lack of awareness about the advantages of Grid technologies 3). Lack of Information Technology professionals have the skills to instal and maintain grid technologies such as the Globus toolkit 4). Grid Technology does not feature in the curriculum as a course in undergraduate and at post graduate studies. 5). World class IT training providers like Microsoft, Cisco, Comptia have not yet started any professional certification course on Grid Technology. 6). Grid services are susceptible to attackers who can get into any resources of the Grid making Grid Security may be a big challenge

X. CONCLUSION

There are numerous benefits of using grid technologies in collaborative research systems for Kenya and other developing countries, and therefore collaborative research systems will be enhanced if universities in these regions are willing to integrate their research systems with grid technologies. This means if all academic institutions go this way, it will be possible in the future to increase the quality of research, and academic institutions in Kenya can compete with and will be at par with other world class institutions. By using grid technologies researchers will be able to get access to computing resources that would otherwise not be possible. This will encourage even the upcoming institutions to see the need to invest in grid technologies. It is also possible in the author's opinion that universities can collaborate in implementing grid infrastructure. This will help in saving the initial investment costs that may be incurred during implementation grid enabled systems.

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Julius Murumba is a Doctoral student of Information Technology at Kibabii University, Kenya. He holds a Bsc and MSc (Information System), and is currently a Sessional Lecturer at the Technical University of Kenya. His research interests include Technology enhanced Learning, Cloud computing and Grid computing

Dr. Elyjoy M. Micheni is a Senior Lecturer in Information Systems and the Chairperson, Department of Management Science and Technology at The Technical University of Kenya. She holds a PhD (Information Technology) from Masinde Muliro University of Science and Technology, Master of Science (Computer Based Information Systems) from Sunderland University, (UK); Bachelor of Education from Kenyatta University; Post Graduate Diploma in Project Management from Kenya Institute of Management. .She has taught Management Information System courses for many years at University level. She has presented papers in scientific conferences and has many publications in referred journals. She has also co-authored a book for Middle level colleges entitled: "Computerized Document Processing"
Her career objective is to tap computer based knowledge as a tool to advance business activities, promote research in ICT and enhance quality service.