Grid Computing Adoptability Model for Collaborative Research in Universities

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Abstract – Use of grid computing as a distributed computing paradigm for collaborative research in universities cannot be over emphasized. It is a technology which provides a platform on which computing resources from heterogeneous systems are brought together as needed by the users. Collaborating researchers who require huge computing resources can use this technology to do their work. A number of universities are in the process of adopting this technology however appropriate model to make the process easily achievable in developing countries' context is lacking. This study focused on developing grid computing adoption model for collaborative research in Universities in developing countries. The study had four objectives; to find out how universities that participated in UNESCO-HP brain gain and HP Catalyst initiatives engaged in collaborative research, to determine the extent of grid adoption in the selected universities, to evaluate critical success factors for adoptability of grid computing, and, to develop grid adoptability model for collaborative research. The study based on positivist philosophy adopted mixed methodology and survey design. The population targeted was the universities and research institution mainly in developing countries. The researcher used East Africa as a cluster zone and identified four Universities that participated in UNESCO-HP initiatives as a sample; University of Nairobi (UoN) and Masinde Muliro University of Science and Technology (MMUST) in Kenya, Makerere University (MU) and Mbarara University of Science and Technology (MUST) in Uganda. The instruments used were structured questionnaires and interview guides. In this paper, we present results of the first two objectives of the study.

Index Terms - Grid computing, collaborative research, UNESCO-HP BGI, HP Catalyst

1. INTRODUCTION

Grid computing is a paradigm in distributed processing where computing infrastructural resources spread in a number of virtual organizations are shared. Inspired by electricity grid, grid technology brings together computing resources using Local Area Networks (LAN) and Wide Area Networks (WAN) [1]. Just like in electricity grid where the user may not need to know the physical location of the power plant and its network, the user in the grid is just bothered with is accessing and using computing power and storage resources. According to [2], grid computing provides huge computational and storage resources needed for problem-solving in many scientific disciplines such as computational chemistry, medical diagnostics, engineering and mathematical models.

Since grid technology allows the use of disparate resources spread in many physical locations, universities can easily develop collaborative virtual communities to share resources, provide remote-access and even share their findings of their projects [3]. As noted by [4], African continent has scientific communities spread widely and Grid technology may, therefore, enable their collaborations in ways previously not feasible.

In recent times, a number of initiatives have been put in place that is meant to fast-track collaborative scientific research that utilizes grid infrastructure. A case in point is UNESCO-HP Brain Gain and HP Catalyst initiatives [5]. In these initiatives, twenty-one Universities in Africa participated with a total of twenty-four projects that used grid infrastructure and other technologies [6].

Though grid computing has been largely adopted in developed countries, there have been serious challenges of adoptability in developing countries as noted by [7]. A number of challenges mainly arise from constraints in resources such as technological infrastructure, shortage of well-trained faculty, limited research, lack of software and other equipments. With improved network connectivity, the grid activities in Africa have been re-energized [8].

A review of the recent literature on adoption and application of new technologies revealed that there are critical elements which must be put in place such as legal and regulatory frameworks, availability of the technology, technical people with right skills and consumers with right knowledge and attitude [9].

2. RELATED WORK

2.1 Collaborative Research

The term collaborative means the capability of working with others together on an intellectual undertaking mainly to achieve a goal that may not be achieved independently [10]. Collaborative research has been adopted by many researchers as a way of finding solutions to complex problems [11].

According to [6], there has been an increased emphasis by international donors and partners on collaborative research that utilizes grid computing and other advanced computing technologies. Through initiatives such as UNESCO-HP Brain Gain and HP Catalyst projects, researchers from developing countries such as Africa are able to work with their counterparts across the globe through ICT technologies.

Collaborative research is an important avenue for opening up borders and stimulating interaction among researchers. Collaborative research takes different forms such as sharing of research data, combined or joint experimentation, on-line conferences and other focused meetings, development of databases, standards setting, and equipment or resource sharing [12].

However, collaborative research has not matured in developing countries as in developed world [13]. This has been attributed to a number of factors. As [14] posit, out-of-date computing equipment, inadequate material resources, frequent power failure and lack of enough government support have hindered collaborative research especially in developing countries.

2.2 ICT Technologies for collaborative research

Many ICT technologies have been adopted by researchers in achieving collaborative research. In African Universities, most collaborating researchers are mainly employing telephone/mobile calls, e-mails and social media such as facebook, skype among others as tools for collaboration [11].

With the evolution of technology, there are new ways of collaborating with researchers across the globe. However as noted by [15], most developing countries such as those in Africa finds collaborative research difficult task due to its high-cost and complexity. According to [16], collaborative research can employ ICT technologies such as Web 2.0, blogs, emails, Wikis and Wikinomics.

Internet technology plays a crucial role in collaborative research. [13] considered the internet as collaborative research technology for integrating African scientists and their global counterparts into a research community. Studies done by [17] and [18] have also shown a positive relationship between diversified application of emails as collaborative ICT technology and collaborative research. Grid computing which utilizes local area networks and wide area networks like the internet been identified as a platform on which scientific collaborative research with immense benefits can be undertaken [11]. Due to the fact that grid is a collection of servers working together to solve a problem and is concerned with resource sharing, aggregation, hosting and provision of services to various virtual organizations (VOs), it has been considered appropriate for scientific collaboration [6].

With all these ICT technologies, it is important to note that their application on collaborative research largely depends on the way individuals use such technologies [17]. However various studies such as done by [19] have shown the power of these ICT technologies to transform collaborative research to global research communities.

2.3 UNESCO-HP Brain Gain and HP Catalyst Initiatives

UNESCO and HP came up with these initiatives in an effort to create brain gain in African and Arab Countries that had suffered brain drain due to an exodus of scientists and academicians [20]. In 2009, it was agreed that a sustainable e-infrastructures be developed that would bring together universities and other research institutions from different regions to carry out innovative projects particularly in education.

These initiatives empowered scientists, lecturers and even students at their home countries to participate in collaborative research with those in western countries [6]. Several countries in Africa took part in the initiatives. Among them were; Mekelle University in Ethiopia, Makerere University (MU) and Mbarara University of Science and Technology (MUST) in Uganda, Masinde Muliro University of Science and Technology (MMUST) and University of Nairobi (UoN) in Kenya. The initiatives were meant to utilize grid computing technology to support the cooperation between the collaborating institutions.

Some of the activities undertaken by the initiatives in Africa included: (i) Linking the grid node at the University Cheikh Anta Diop (UCAD) in Dakar, Senegal to the European Grid for E-science (EGEE), (ii) Linking the High Performance Computing (HPC) node at MMUST to the South African Grid (SAGRID) through University of Cape Town (UCT), and (iii) enhancing the capacity of South Africa and South African Grid SAGRID [5]. Therefore, these projects used grid computing technology as a basis for collaborative research. Table 1 below shows Higher Educational Institutions (HEI) that participated in the 24 projects.

Table 1: Higher Educational Institutions which participated in UNESCO-HP Projects

Country	Number of HEIs	No. of Projects	
		Brain Gain	HP Catalyst

Ghana	1	1	
Nigeria	1	1	1
Senegal	1	1	
Burkina Faso	1	2	
Cote D'Ivoire	1	1	
North Africa			
Morocco	1	1	
Tunisia	1	1	
Egypt	1		1
Algeria	1	1	
Central Africa			
Cameroon	2	2	
East Africa			
Kenya	2	2	2
Uganda	2	2	
Ethiopia	1	1	
South Africa			
Zimbabwe	1	1	
South Africa	3		3
Total	21	17	7

Source: [3]

3. METHODOLOGY

The main purpose of the research was to develop grid computing adoptability model that would aid collaborative research in universities especially in developing countries. However, in this paper the focus is on findings of the first two objectives;

i) To find out how universities that participated in UNESCO-HP brain gain and HP catalyst initiatives engaged in collaborative research;

ii) To determine the extent of grid adoption in Universities that participated in UNESCO-HP BGI and HP Catalyst initiatives.

3.1 Research Philosophy

The study used positivist paradigm and explanatory research to evaluate grid computing adoption for collaborative research in universities. It is argued that individuals and groups make sense of situations based on their individual experience, memories, and expectations [21]. This means multiple interpretations create social reality on which people act. This paradigm is therefore seen to be important in understanding the meanings and contextual matters that influence, determine and affect the interpretations reached by different individuals [22].

3.2 Research Approach

The study took the direction of inductive research approach. This approach is applicable to positivist philosophy due to its close association [23]. Inductive research, according to [21] is able to give an opportunity to have more explanations on what is going on.

The inductive technique as used in a research study tries to explore a subject when the variables and the theory base are not known [24].The approach began by exploring and collecting data using structured questionnaires and semi-structured interviews guides in an attempt to explore grid computing as a platform for collaborative research in universities.

The study also adopted a mixed (triangular) methodology which involved both quantitative and qualitative methods. In this study, therefore, both quantitative and qualitative data was collected, analyzed and integrated into a single research study. This is supported by [24] and [25] who considered mixing data types and methods in-order to cast different standpoints. Several related studies have also used mixed methodology. For example studies on determinants of collaborative behavior amongst scientists [26], identifying forms of collaboration and influencing factors [27], academic research collaborations in Kenya: structure, processes, and information technologies [13].

This approach, therefore, was used on assumption that methods used in the study would prevail over the weaknesses of either of the two methods and hence be able to comprehensively provide a solution to the research problem [28].

3.3 Research Design

Survey as a design for the inductive approach was used for this study. Surveys have been used widely for conducting social science research [29]. The survey involves the collection of data by using questionnaires to unravel the opinions of a population based on a sample of the identified population [30]. Other tools used to collect data are structured interviews guides [31]. According to [32], structured instruments which can be questionnaires or interview guides are used to collect responses from a sample. Further, the survey has been widely accepted as an accurate way of collecting quantitative data, even though some aspects of the survey might be qualitative [32].

3.4 Population and Sample

As noted by [33], the study population refers to a group of elements or respondents we would wish to study, the group about which we want to make some inferences, and the study group to which it is possible to generalize the results of the study. The target population of this study was the universities in developing countries. According to [34;35], most of the developing countries exhibit comparable situations.

3.5 Sampling Techniques

Purposive sampling and clustered sampling were used to identify the sample for the research study. According to [36], purposive sampling is applied based on the knowledge of the population and purpose of the study. The respondents identified were believed to have the necessary information on the area of study. The researcher purposely selected the Universities that participated in UNESCO-HP Brain Gain and HP initiatives. A total of twenty-one (21) Universities in Africa participated in the initiatives [6]. The Universities were believed to be rich with the required information on grid computing and collaborative research. According to [37] the decision of choosing one sampling technique over the other should be based on the richness of the relevant information from the intended sample.

Clustered sampling was employed due to the dispersed nature of the universities that participated in the initiatives. According to [38], it is sometimes impossible to develop a sampling frame of a target population which is widely distributed or dispersed. In cluster sampling, elements of the population are selected in naturally occurring groupings. The researcher identified East Africa as a cluster zone for the sample.

The four universities that participated in the initiatives are Makerere University (MU) and Mbarara University of Science and Technology (MUST) in Uganda, University of Nairobi (UoN) and Masinde Muliro University of Science and Technology (MMUST) in Kenya. Even though the focus was Kenya and Uganda, the findings could be generalized to the wider developing countries [34;35].

Cochran's sample size formula was used to get the sample of 384 respondents who were to be reached randomly from across different disciplines [39].

4. RESULTS AND DISCUSSIONS

4.1 Participation in Collaborative Research

In this section, the results of research question one are presented. The respondents were asked whether they had participated in the collaborative research, their scope of collaborations and the technologies they had used during collaborative research. The results are shown in Table 3 below.

Table 3: Participation in collaborative research

University	Yes	No
MMUST	28	19
	59.6%	40.4%
MU	88	45
	66.2%	33.8%
MUST	13	20
	39.4%	60.6%
UON	52	65
	44.4%	55.6%
Total	181	149
	54.8%	45.2%

Source: Author (2016)

In average, 54.8% of the respondents had participated in collaborative research while 45.2% had not.

4.2 Scope of collaborative research

The scope of collaborative research by the respondents is shown in Table 4 below.

Table 4: The scope of research collaborations

University	Within University	Universities within Country	Universities in Africa	Universities beyond Africa
MMUST	13	8	5	2
	46.4%	28.6%	17.9%	7.1%
MU	33	28	18	5
	39.3%	33.3%	21.4%	6.0%
MUST	11	0	2	0
	84.6%	0.0%	15.4%	0.0%
UON	29	16	10	4
	49.2%	27.1%	16.9%	6.8%
Total	86	52	35	11
	46.7%	28.3%	19.0%	6.0%

Source: Author (2016)

4.2.1 Discussions

The results show that majority of respondents had collaborations within their Universities and Universities of their Countries. About 19% had their scope within Africa while 6% went beyond Africa. The percentage of respondents

having their collaborations within their universities was at 46.7%. This is confirmed by a study done by [13], which showed that most researchers in collaboration in Kenya and indeed other developing countries were from the same universities.

Table 5: Levels of Universities' participation in collaborative research

	1 (0-25%)	2 (26-50%)	3 (51-75%)	4 (76-100%)	Total	M
MMUST	5	16	18	8	47	3
	10.6%	34.0%	38.3%	17.0%	100%	
MU	17	48	51	17	133	2
	12.8%	36.1%	38.3%	12.8%	100%	
MUST	4	8	19	2	33	3
	12.1%	24.2%	57.6%	6.1%	100%	
UON	13	42	39	23	117	2
	11.1%	35.9%	33.3%	19.7%	100%	
Total	39	114	127	50	330	3
	11.8%	34.5%	38.5%	15.2%	100%	

Source: Author (2016)

In the results, 38.5% believed that their universities participated in collaborative research in the range of 51-75%, 34.5% in the range of 26-50% and 15.2% in the range of 76-100%.

4.3 ICT Technologies used by the respondents for collaborative research.

Table 6 shows the ICT technologies the respondents had used for collaborative research

Table 6: Technologies used by respondents during collaborative research

Technology	MMUST	MU	MUST	UON	Total
Emails	47	133	33	117	330
	100%	100%	100%	100%	100%
Intranet / Extranet	20	44	20	78	162
	12%	27%	12%	48%	49%
Social media such as fb, twitter, linkln	17	29	22	85	153
	11%	19%	14%	56%	46%
Cloud Computing	8	10	10	30	58
	14%	17%	17%	52%	18%
Grid Computing	2	2	3	3	10
	20%	20%	30%	30%	3%

Source: Author (2016)

4.3.1 Discussions

The results show that all respondents had used E-Mails, 49% intranet/extranet, 46% social media, 18% cloud computing while dismal 6% of the respondents had used grid computing. Even though a number of studies such as done by [6] and [40], have shown the potential of grid computing in enhancing collaborative research a small number of respondents (6%) had used grid computing in their work. This is also despite efforts made by University of Nairobi to seek active collaboration that sets up grid infrastructure linking up African universities and other research organizations [41]. A number of respondents reached through interviews cited lack of grid infrastructure and knowledge on it as reasons for not using grid computing technology.

4.4 Participation in UNESCO/HP BGI and HP catalyst project

Table 7: Participation in UNESCO/HP BGI projects

University	Yes	No
MMUST	3	44
	6.4%	93.6%
MU	6	127
	4.5%	95.5%
MUST	5	28
	15.2%	84.8%
UON	11	106
	9.4%	90.6%
Total	25	305
	7.6%	92.4%

Source: Author (2016)

The results show that all the four universities participated in the projects. This is in agreement with the work done by [8] which showed that the four Universities were among the institutions that that participated in the UNESCO-HP BGI and HP Catalyst projects.

4.5 Familiarity with grid computing

The results of the level of respondents' familiarity with grid technology are shown in Table 8 below. The numbers in the table represented the frequency of responses on the Likert scale ranging from 1 (Very High) to 5 (Very Low); $\bar{x}$ is the mean; m is the mode (most frequently occurring response)

and σ is the standard deviation. The mean and standard deviation were only used to support the arguments regarding the acceptability of the mode not as the basis of data analysis. This is because according to [42] and [43], data on a Likert scale have intervals which cannot be presumed to be equal though they have a rank order. Since ordinal data was used, it was described using frequencies and percentages [42; 23] for each University and the overall.

Table 8: Levels of familiarity with Grid computing

University	1 VH	2 H	3 M	4 L	5 VL	$\bar{x}$	M	Σ
MMUST	1	18	15	9	4	2.53	2	0.69
	2%	38%	32%	19%	9%			
MU	2	17	31	40	43	3.79	5	1.08
	2%	13%	23%	30%	32%			
MUST	5	9	13	6	0	2.61	3	0.97
	15%	27%	39%	18%	0%			
UON	10	40	42	19	6	2.75	3	1.00
	9%	34%	36%	16%	5%			
Total	18	89	106	68	49	3.12	3	1.13
%	5%	27%	32%	21%	15%			

Source: Author (2016)

4.5.1 Discussions

From the results, it was clear that majority of the respondents had moderate familiarity with grid computing with an average mode of 3 (Moderate). MMUST had a higher familiarity of grid computing 9% (High). This could be explained by the information from the technical questionnaire filled by the System Admin at the University which showed that the University had briefly set up the grid and linked to University of Cape Town South Africa however due to challenges could not be operational. Challenges cited included lack of ported applications, lack of policy and inadequate financial support from the University.

The familiarity of respondents on other related technologies was also sought and the results shown in Table 9 below.

Table 9: Levels of familiarity with other related technologies

Technology	1 VH	2 H	3 M	4 L	5 VL	$\bar{x}$	M	Σ
High Power Computing	22	72	87	68	81	3.07	5	1.18
	7%	22%	26%	21%	25%			
Middleware	16	80	69	81	71	3.27	4	1.24
	5%	25%	22%	26%	22%			
Virtual Organization	16	78	79	95	56	3.30	4	1.16
	5%	24%	24%	29%	17%			
Porting Software	14	78	71	74	88	3.19	5	1.39
	4%	24%	22%	23%	27%			
Cloud Computing	43	71	107	51	58	2.76	3	1.28
	13%	22%	32%	15%	18%			
Total	129	468	519	437	403	3.26	3	1.24
	7%	24%	27%	22%	21%			

Source: Author (2016)

On average, the respondents had low (m=4) familiarity with most of the technologies related to grid computing.

4.6 Availability of grid infrastructure

We sought to know from the respondents if there existed grid infrastructure in their Universities. The responses are shown in Table 10 below.

Table 10: Availability of grid infrastructure

University	Yes	No	Not aware	Total
MMUST	1	38	9	47
	2.1%	78.7%	19.1%	100.0%
MU	7	26	100	133
	5.3%	19.5%	75.2%	100.0%
MUST	1	12	13	26
	3.8%	46.2%	50.0%	100.0%
UON	1	33	81	115
	0.9%	28.7%	70.4%	100.0%
Total	9	109	203	321
	2.8%	34.0%	63.2%	100.0%

Source: Author (2016)

4.6.1 Discussions

From table 10 above, in general, 2.8% of the respondents indicated that there was grid infrastructure in their Universities, 34.0% indicated that there was none while 63.0% were not aware. These results can be explained by the responses from the participants interviewed during the study. Participants from UoN interviewed gave an explanation that their grid was more often set up for training and lab experiment purposes and therefore did not have a working

grid for researchers as at the time of data collection. Participants interviewed from MU and MMUST indicated that the grid was set up but due to lack of ported software and researchers utilizing it, the resources remain underutilized. This was confirmed by results showing no research utilizing the grid at the time of data collection (Table 11).

Table 11: Availability of research utilizing grid computing

University	Yes	No	Not Sure	Total
MMUST	0	10	37	47
	0%	21.3%	78.7%	100.0%
MU	0	4	118	122
	0%	3.3%	96.7%	100.0%
MUST	0	7	20	27
	0%	25.9%	74.1%	100.0%
UON	0	10	72	82
	0%	12.2%	87.8%	100.0%
Total	0	31	247	278
	0%	11.2%	88.8%	100.0%

Source: Author (2016)

5. RECOMMENDATIONS

Even though a good percentage of researchers (54.8%) participated in the collaborative research, of concern was the scope of these collaborations and the ICT technologies used. Only 19% percent of them had collaborated with other researchers in Africa while only 6% with their counterparts outside Africa. As put by [3], grid computing as a computing paradigm can enable researchers across the globe to collaborate in a cost effective manner. Participants interviewed indicated that more training on collaborative research was necessary. A view supported by [13], who indicated that researchers needed more training on collaborative research and be inherently motivated to be actively involved in research. From the study, 53% of the respondents had not received any collaborative research training the previous year while 72.5% required training on the same.

According to the study results, the main ICT technologies employed in collaborative research were emails, intranet/extranet, social media and cloud computing. The grid computing technology which has been found to have great potential to enhance technology had been used by only 3% (Table 6). A number of respondents interviewed recommended collaboration between the National Educational and Research Networks (NRENs) and universities and other research institutions in setting up the grid computing infrastructure and subsequently training of the researchers and technical support staff. As [3] noted, collaborations based on ICT infrastructure such as grid computing have led to research networks which are crucial for enhancing the capacity of African research.

Though the Universities under the study had all participated in UNESCO-HP projects that sought to utilize grid computing for collaborative research, the grid computing technology was yet to be fully adopted. Most Universities had not made provisions for user training on the use of the grid technology while others had not ported applications for use in the grid. Infrastructural resources were limiting the adoption of the grid. It is recommended that NRENs and universities collaborate in the provision of computing resources such as server computers, networks, and bandwidth. Further, necessary policies for collaborative research and grid computing need to be put in place to accelerate grid adoption

6. CONCLUSION

Though the benefits of grid computing in enhancing collaborative research cannot be emphasized, the technology is still believed to be underutilized especially in developing countries. In this paper, the results of the first two objectives of the research study have been presented. The study endeavoured to develop grid computing adoptability model that is focused on maximizing its benefits for collaborative research in universities found in developing countries.

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