

## AN INTEGRATED SOLUTION FOR AN INTEGRATED WATER RESOURCE MANAGEMENT OF LAKE VICTORIA BASIN (LVB)

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### ABSTRACT

Lake Victoria Basin is a very important resource for the five riparian countries: Uganda, Kenya, Tanzania, Rwanda and Burundi. The Lake Victoria Basin provides resources for fishing, agriculture, medicine, forestry, water transport and other economic activities. However, its surrounding is affected by population growth, urbanization, industrialization, increasing commercial activities and inadequate provision of sanitation services among others. These grossly affect the landscape and water resources around the lake basin. In this paper, a web based integrated solution prototype is presented. The system consists of web access, mobile access, web service handler, mobile service handler and a database. It can be used to address communication challenges by enhancing stakeholder's participation, information sharing and enforcement of laws by timely communication and coordination of activities of good governance. The test results confirm that the system is effective and can be used to operate in real world environment in the management of water resources by providing the key actors with relevant information to facilitate decision making.

**Keywords:** Communication, Information Sharing, Lake Victoria Basin, Integrated Water Resource Management, Integrated solution.

### 1. INTRODUCTION

Water resource is used in many ways as a multi-reference term. Many refer to it as a groundwater while others as surface water ( Mongi *et al.*, 2015). It should be noted that water resources includes all associated growth found within its environment. These are fish, trees, grasses, minerals and aquatic life. These resources also includes supply of safe and adequate water supply for drinking, sanitation, irrigation, flood management, and protection of the aquatic ecosystems.

Wang *et al.* (2015) observed that water resources face many severe challenges which include contamination, aging infrastructure, lack of data for informed decision making, weak public awareness of water challenges, and inefficient water management strategies. A lot of these challenges, according to Gebrechorkos and Fathy (2016), and Anzaldi (2014) are due to global change issues, such as population growth, economic development and climate change.

Choil, Chong, Kim and Tae (2016), noted that “water related hazards account for 90% of all natural hazards, and their frequency and intensity are generally increasing”. They projected that in the next 20 years, the gap between water demand and availability will grow significantly and is expected to reach 40% by 2030. The authors above also noted that climate change is causing increased water shortages and more frequent, more severe droughts, especially in Europe and Mediterranean countries (Anzaldi, 2014).

Projections made by Water Resource Group (Water Resources Group, 2013) shows that by 2030, the world demand for water will exceed accessible supplies significantly, threatening to impede global economic growth and result in large-scale food insecurity. Integrated system therefore allows information on topics such as water supply and replenishment, water quality,

wetland ecosystem, usage, etc. to be integrated with other relevant information about the environment, society, and economics.

Ospina and Heeks, (2012) noted that appropriate climate change information that is reliable, context-specific, targeted to local audiences, delivered in non-technical language and in user-friendly format, is lacking.

In Uganda, Lake Victoria Basin (LVB) is the major stimulus of population growth, industrial and agricultural activities which represents social, economic and political dimensions of water resource characteristics. According to Okurut (2010), it is estimated that 200 tons of untreated effluents are discharged into the Lake Victoria every day. He added that discussion among the communities had revealed there is poor fish yields/catch and that it is attributed to changes in the climate which they think has made fish go further away from their fishing ground. Okurut also indicated that because the amount of water in the lake is reducing, the quantities of fish in Lake Victoria is also declining. He added that the greatest work to be done to save water resources in Lake Victoria is to fully enforce by laws and regulations. Surprisingly, according to the research findings of Linuma and Tenge (2017), people living around the Lake Victoria Basin were not aware of the formal institutions that are involved in water resources management in LVB. This shows that there is poor communication among stakeholders and therefore calls for an integrated information system to support a reliable and effective communication.

Ospina and Heeks (2012), pointed out that issues such as geographical remoteness, difficulties in transportation and social marginalization, low literacy levels, lack of relevant and appropriate information normally constrains awareness for the local audiences. They also argued that lack of adequate skills and technologies to record and analyze data, are some of the mitigation actions that water resources management faces (Wang et al., 2015).

### **1.1 Governance Challenges**

In order to govern natural resources for example ecosystems, forests, lakes, rivers, natural resources and agricultures successfully, Ssozi, Blake and Rivett (2015) recommend that “there is need to face the increase diversity of connections between different environmental characteristics and decisions of local, regional, national, and supranational relevance, with high coordination and exchange between administrative entities and actors across the public/private and the expert/stakeholder divide”, see also (Zacharoula, 2012). It is also noted that consumers in the water sector provide a weak influence in decision (Vermesan and Friess, 2013).

Anzaldi (2014), argued that “traditional approaches to water resources management have typically been handled by technical people and developed for very specific purposes and do not include interactions with the end users or stakeholders and that, they don’t include important factors that are transparent to the public”.

To achieve sustainability, Philippe (2011) noted that all countries are required to apply an integrated and participatory water resource management approach. This again implies that technological changes can help improve services to people and help reduce the stress on water systems around the world.

## **2. METHODOLOGY**

We had gone through the procedure of analysis, design and implementation as shown below in the diagram. All three phases were performed repeatedly in a cycle until they were completed. A prototype is a smaller version of the system with a minimal amount of features. It provides a system for the users to interact with, even if it is not initially ready for use. This methodology was used to deliver the system quickly and through the iterative loops, mistakes made in the previous phases were rectified by just looping back to that particular phase. Prototyping gave users an idea of what

the final system looks like. It also encourages active participation between users and producers which enables higher output, cost effective and increase system development speed.

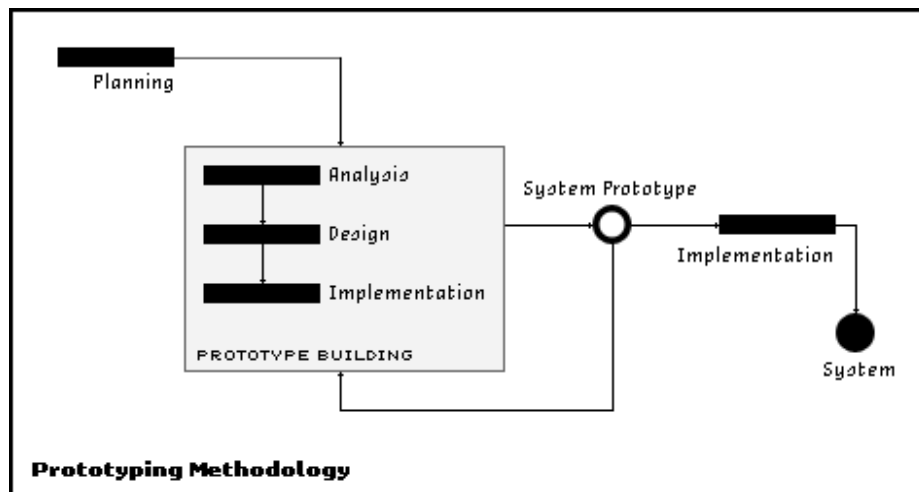


Fig 1: The illustration of prototyping methodology

The following are the phases of prototyping that was followed during the development of the system. First: There was a planning phase which essentially dealt with understanding why the system was built. Two: The analysis phase which involved investigating the current system, identifying improvement opportunities and developing a concept for the new system. Three: The design phase that specifies how the system was developed by logically designing the components of the system. Four: The implementation phase that involved rapid development into a preliminary working version and thereafter more improvement was done until fully fledged system was achieved.

### 2.1 Analysis Phase

The analysis phase involves investigating the current system, identifying improvement opportunities and developing a concept for the new system

### System Functional Requirements

The following describe the functionality or the services that developed system can provide. First: The system can collect multimedia content in the form of text, video, images and audio from multiple data sources including email, mobile phone, and computer. Second: The system can do data analysis on the reported cases e. g. water quality data. Third: The system can aggregate classified SMS and further broadcast them to classified receivers/actors such as law enforcers, decision makers, policy makers or to the radio station for wider sharing. Fourth: The system can notify stakeholders via SMS and/or email when reported data reveals problems on water resources within a dynamic timeline of the reported data. Fifth: It can support real time communication through text, audio and/or video among stakeholders and can allow policy makers and decision makers to view different kinds of reports related to water resources. The system also enable stakeholders (community, policy makers, decision makers and law enforcers) to send and receive feedback on issues regarding water resources via SMS, emails and Local Radios).

### System nonfunctional requirement

Nonfunctional requirements specify criteria that can be used to judge the operation of the system, rather than specific behaviors. The following list describes the non-functional requirements that the system can provide. First: The system is user friendly by having Graphical User Interface (GUI), different language support, and user manual assistance. Second: The system is scalable by allowing stakeholders interactions at micro, meso, and macro scales. Third: The system implements

security measures at all levels (operating systems, database management systems, application software). Fourth: The system is compatible with the following web browsers: Internet explorer, Mozilla, Opera, Google chrome and Netscape. All input functions were tested under these browsers. Moreover, the system is able to run on a different operating system environments. Fourth: The system can operate in an acceptable speed when accessing data and information from the database. It is also flexible and reliable enough to accommodate further expansion.

## 2.2 System Design

The prototype was designed using the usual phases of system design and development: conceptual, logical and physical design. The system architecture from the logical design describes the flow of information and how requests and responses are processed. The physical part presents the user interface design, database design as well as hardware and software requirements. The iterative spiral model facilitated the use of a core subset of diagrams and a framework that enabled switching from use cases to code. This gave the researchers a more structured and manageable coding cycle.

### System Architecture

The figure below shows the general community with access to mobile phones and internet. They are able to comment, share, receive and report water governance issues in their localities through the system. It also has a mechanism whereby local radios can interact with the community to share and discuss various issues related to water resource governance through mobile phone messages. Finally it has the mechanism which enables management (policy makers, decision makers and law enforcers) to view different kinds of reports and receive appropriate information and feedback on issues relating to water resources governance for appropriate actions through mobile phone, emails and web access.

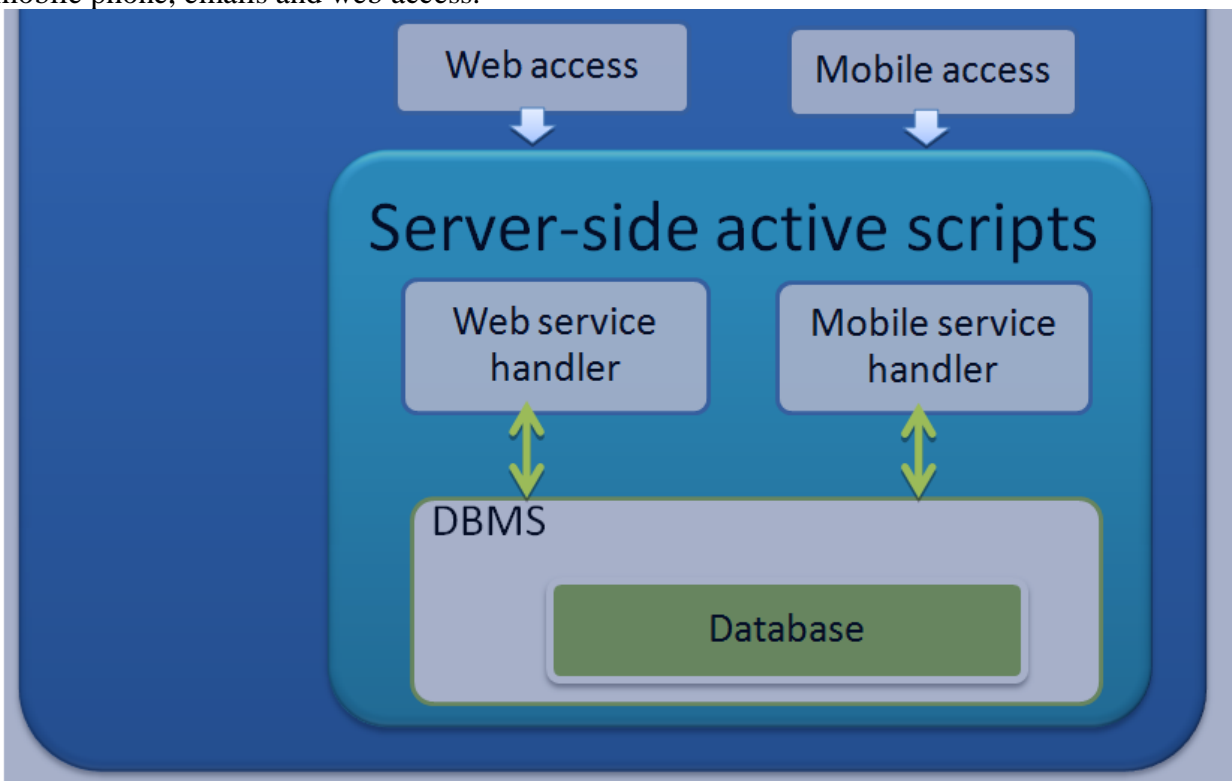


Fig 2: Abstract Architectural Design

In the above graphical representation, black components are rather open source or already built software particularly web browsers like Mozilla firefox, opera mini, IE, etc. and MySQL DMBS (open source). Grey elements are the custom developed components of the system. Mobile

app was developed using java 2 Mobile Edition (j2ME), Web services are all developed using HTML, CSS for display and php scripting for the accompanying dynamic events. Web browser such as mobile mini browsers, mobile app that runs on agents' mobile phones. Database management system is by MySQL and was developed using SQL. Below are some of the elements in the architectural design.

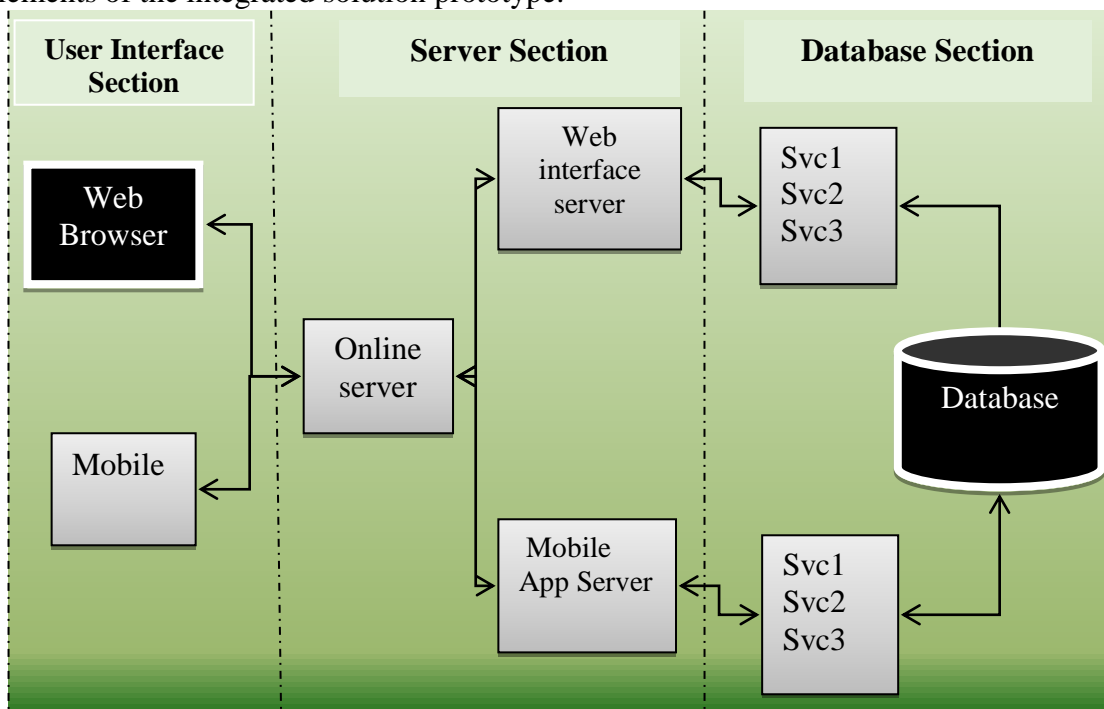
Online server: This is the online web service that receives every request. On receiving the request, it determines whether request is from web browser or from mobile app. It then routes request to the corresponding services source. Web interface server: This is a web service that handles all requests from web browser, Mobile app server: The web service that handles all requests from mobile app. Svc: These are the actual web responses that both browser and mobile app request for. They are invoked by the web interface server and the mobile app server. The web interface services are made separate from those of mobile interface to simplify the evolution in case additional modules are developed for each independently of the other. This is as observed by the functional purpose of the "online server" module.

**a) Web platform**

User arrives at home page, selects login, and enters username and password. System determines whether you are a mobile user or a web user then routes user to corresponding home page. To register new users, details are entered into the system but marked new and inactive then he/she receives email and SMS for password. To activate/ deactivate users, administrator logs into the system and lists all users, views their profile details and activates them after assigning them departments or deactivate accordingly. The system lists all messages and avail category parameter links, displays the various stakeholders who run it and pushes SMS. The system also prompts user to type messages, receives text and retrieves all contacts according to selected criteria and performs bulk SMS. When the administrator types notice, a copy of the notice is saved in a buffer with date details. Current notification area is updated with current notice.

**2.3 Database Management System**

My SQL was used to create the database for storing data relevant to water resource management around Lake Victoria Basin. SQL was used to create and connect relational tables. The design includes users' authentication. Figure 3 shows the connection between the different elements of the integrated solution prototype.



**Figure 3: Physical / Overall System Architecture**

## 2.4 Mobile App Implementation Design

The user can log into the system using the credentials such as usernames and passwords then send messages to other users or to the headquarters. The mobile users can as well read messages which have been sent by other users of the system

Figure 4 shows mobile application implementation design. It shows a physical design which describes the hardware and software that were required in the logical design and the interfaces of the implemented system. It is the actual technical implementation running design. Graphical design was by NetBeans IDE (version 8.2). The mobile app is developed using J2ME (Java) as the programming language.

Design elements includes: *Mobile devices*: Activity that launches the mobile app, *splashScreen*: An alert screen introducing the app by a short text, *loginScreen*: A prompt that demands user to enter their login credentials, *event*: to select between sending and retrieval of info online, *viewinfo*: This comes after user has selected view info, *currentnotices*: This is the text holder which displays the text content retrieved from online, *SendMessage*: Under this, one is prompted to further clarify whether information to send is a communication SMS or an observational update, *field\_of\_update*: is where one intends to send an observational update that belongs i.e. forestry, fishing and water., *text\_prompt*: one enters the text content meant to be uploaded to the online database, *closure\_screen*: this is when the screen is closed, *Recipients*: It contains the various categories describing registered users like office titles, residence, and operation station, *known\_lists*: These are the registered occurrences of each item that could be selected from the previous prompt. For example if one had selected operation station from the previous prompt, this prompt list would contain all existing operation/duty stations registered in the online system. *sms\_prompt*: prompts to enter the text message that will be pushed to recipients, *last\_screen*: message status report display.

## 3. SYSTEM IMPLEMENTATION

In order to come up with an integrated innovative solution, codes were written in Java language. This is a phase where the system is rapidly developed into a preliminary working version. Users interacted with the system and their suggestions were incorporated into the system until the final solution was achieved. The database for storing data relevant to the management of Lake Victoria resources was created using MySQL. SQL was then used to create and connect relational tables to the database.

The Mobile application was developed using Java 2 Mobile Edition (J2ME), web services were developed using HTML, CSS for display and php scripting for accompanying dynamic events.

Elements developed are presented below;

*Online server*: This is the online web service that receives every request from either a web browser or mobile app and routes to the corresponding services source.

*Web interface server*: Offers web service that handles all web browser requests.

*Mobile app server*: All requests from mobile app are handled by web service.

*Svc*: These are the actual web responses that both browser and mobile app request for.

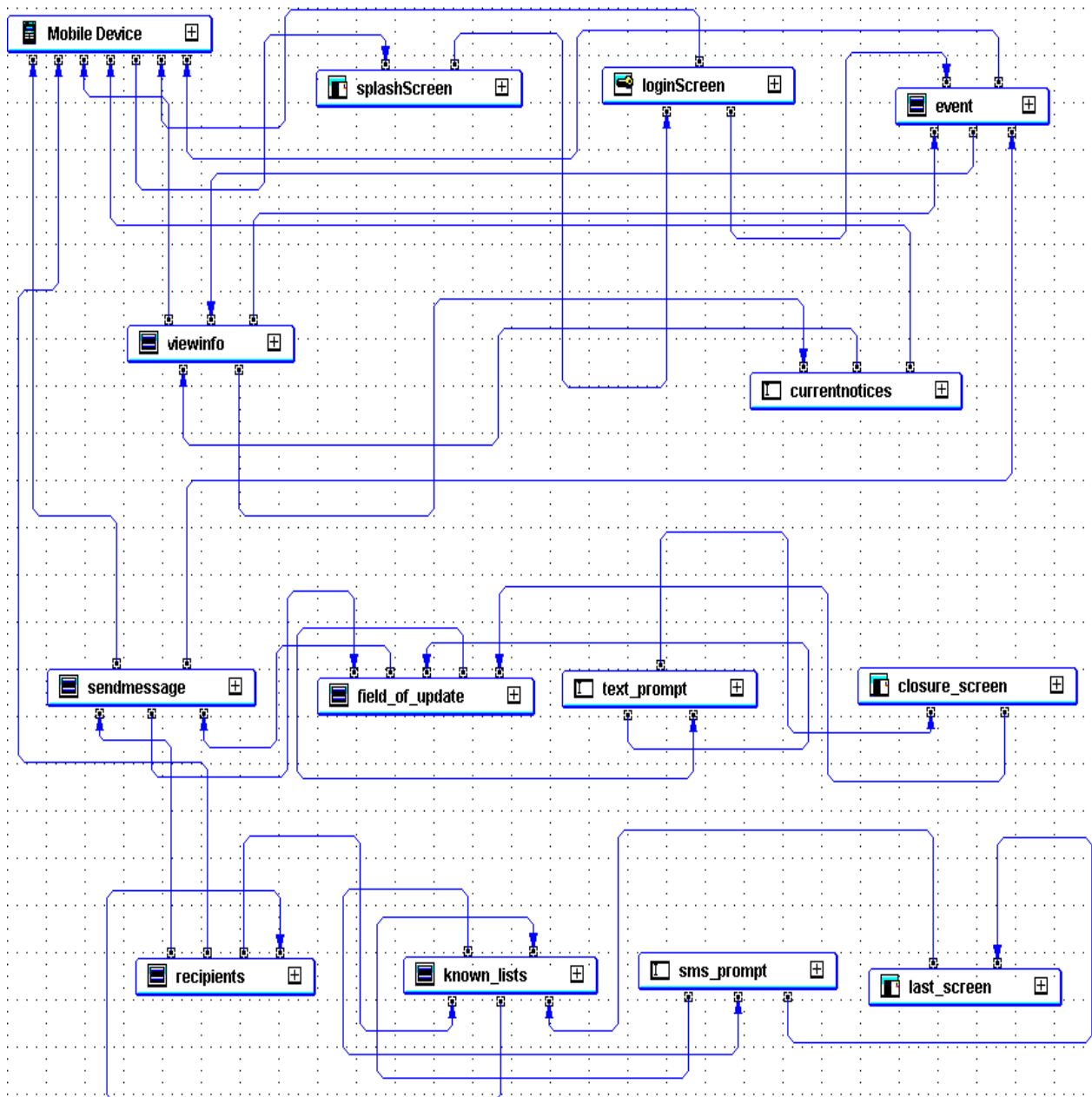


Figure 4: Mobile Application Implementation Design

## 4. SYSTEM TESTING AND EVALUATION

### 4.1 Demonstration

Prototype was accessible for demonstration and testing. The test results were fed back for fixing bugs. The process was repeated till an acceptable working state was achieved

### *System Hosting/Demonstration*

Ngrok (2018) software was used for hosting the system. It is a free online platform that gives local server presence on the web. In this case it directs all packets going to the specific subdomain down to the local machine's server. When the client program is downloaded and installed, it runs giving the particular a temporary subdomain which should be used on the web. All requests made to this subdomain are routed down through the client and unto the actual server on the local machine. For a specific customized sub domain name, one has to sign up to register this sub domain name. If you want to make your local host accessible from the internet, such that

someone types a specific url and then get the services on your local machine, follow the procedure below.

Download ngrok client, simply run it via command line specifying which port your server is running at as below.

C:>C/⟨*path to your ngrok file*⟩/ngrok 8080, In this case, the server is running at port 8080, Ngrok will then connect to the online platform and return the sub domain created for you. At this point your local server is online by virtue of that sub domain. When there is a connection to your local server, Ngrok will list it at the command line interface.

## **4.2 Testing**

The integration of the various components of an integrated innovative solution to the challenges in the management of water resources in Lake Victoria Basin was achieved using test data and obtaining the output information. In case of errors, correction measures were followed until the expected output was achieved. The System was able to send data to the central database which was visualized through the web-based portal. The web-based solutions had groups of all users and their priorities in the system. All the user groups were able to open the website, create post, view wikis and give comments on the available posts and wikis. Users were able to login into the system and communicate with other stakeholders via text, video in real time. For mobile-based solution, users were able to send SMS to the system. However, the received SMS could only be viewed by authorized users such as radio presenters, water quality experts and managers. Upon receiving data on LVB, the system was able to notify classified users (mainly those in authority and law enforcers) by SMS and email.

In-house testing was done to assess the system functionalities in a controlled environment and to provide researchers with the information on the quality of service. The system enables interaction of these stakeholders by the use of mobile phones, local radios, TVs and Internet.

- i Users were able to send data to the central database which were visualized through the web-based portal. The web-based solutions had groups of all users and their priorities in the system. All the user groups were able to open the website, create post, view and comment on the available posts.
- ii For mobile-based solution, users were able to send SMS to the system. However, the received SMS could only be viewed by authorized users for example Radio and TV presenters, System Administrators, water quality experts and managers. Upon receiving data on LVB, the system was able to notify classified users mainly those in authority and law enforcers by SMS and email.

## **5. RESULTS AND DISCUSSIONS**

### **5.1 A Uniqueness of the integrated solution**

An integrated solution integrated the best features from internet, radio and mobile phone solutions. The integration allows for the system to benefit from strengths of individual technologies. The system integrates a web-based portal which allows stakeholders with access to the Internet to communicate, create and share knowledge, report and get feedback at anytime and anywhere. Some of the existing solutions apart from missing the integration aspect did not fully solve the challenges of coordination, participation and sharing of data and information. Integration of web-based solutions with mobile technology enables community members with mobile phones to interact with the system through sending and receiving relevant multimedia information on LVB water resources.

The system empowers technicians at community level to capture and send data on LVB without a need to travel long distances with paper and pen. The current practice is not only costly but also prone and vulnerable to human error. The sent data can then be viewed by responsible LVB monitoring officers anywhere through the web-based application. The data and information can

further be relayed through other components of the integrated solution to other stakeholders depending on the need and sharing policy of the organization.

The graphical presentation can further simplify data visualization and interpretation for appropriate interventions or decision making. The information can be of great importance for enhancing law enforcement initiatives, checking on accountability, formulation of laws and regulations, awareness creations and even for improving health standards of community members. Integration of the radio/TV component allows for the interaction between the system and radio/TV presenter. The presenter has a bigger audience whereby important information for the purpose of creating awareness, educating, and sharing can be broadcasted to reach the entire community simultaneously.

### **5.2 Different Stakeholders levels supported by the System**

The developed system supports five actors: Community with web access, Community with basic mobile phone access, Law enforcers, System Manager and Radio presenter. Each actor has different roles in the system as shown below in the table

**Table 1: Showing Actors and their roles**

<b>S/N</b>	<b>ACTORS</b>	<b>ROLES</b>
1.	Community with web access	1. Upload or view videos and/or photos, 2. Send or receive messages, 3. Communicate with social Networks
2	Community with mobile phones	1.Sends 2. receive sms
3	Law enforcers	1.Receives notifications through email, web and mobile phones
4	Managers(policy makers)	1. Communicate through text, audio, video in real times.
5	Radio presenters	View message through sms, or web browsers

### **5.3 Socio-Economic Benefits**

An integrated solution will contribute towards the economic empowerments by improving the livelihood of the communities around the basin by eliminating some of the poor practices that affect water resources in LVB, minimizing monitoring costs and improving accountability in the governance of Lake Victoria Basin. It will reduce costs incurred currently in manual recording, transfer and storage of data as well as risk of unreliable data due to human errors.

### **5.4 Wealth Creation**

An integrated solution will contribute in wealth creation indirectly by improving the lives of community members in terms of ascertaining water quality before consumption, mitigating some of the poor practices in use of water resources in LVB, minimizing water quality testing and monitoring costs and improving accountability. It will reduce costs incurred currently for manual recording, transfer and storage of data. The risk of unreliable data due to human errors will also be minimized. Integrated solution is further expected to enhance environmental quality in general and therefore enhance its ability to provide intangible benefits to humankind and the ecology.

## **6. CONCLUSIONS**

This paper examined the challenges faced in water resource governance and management in most of the selected water bodies in the world including LVB. It was discovered that participation of all the stakeholders in the governance of water resource is paramount. There is no way participation of all stakeholders can be achieved unless there is a reliable communication system in place. Since stakeholders are different and complex in nature, and given the fact that they use different platforms, there is a need for an integrated system developed to bring all stakeholders on board to enhance Water Resource Governance in LVB. This innovative solution is an integration of

web based, Mobile Apps, internet, social media, Television and Radios in one platform so as to cater for many stakeholders such as community leaders, Policy makers, Government Organization, Non-Government Organizations, Community Based Organizations and law enforcers in Lake Victoria Basin.

### **Limitation**

Despite the fact that the system can perform many functions, it does not guarantee at the moment, the secure transfer of information among members. However, as the prototype matures to a full-blown Application, data and information security will be improved upon, especially during system validation. It wasn't possible to visit all the countries of the East Africa Community due to logistical constraint.

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