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Development of a Health Information Exchange (HIE) system using the Unstructured Supplementary Service Data (USSD) Technology

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ABSTRACT

Most advanced nations have existing software systems that enforce a significant level of Health Information Exchange interoperability. A straightforward implementation or integration of the technique of such an application into the healthcare system in regions that have infrastructure challenges may not achieve the maximum result. Existing EHR interoperability solutions are primarily Web-based and are explicitly compatible to particular health standards. Resulting from this, such current technologies also need, at the very least, secure access to internet connectivity. On the other hand, several regions around the world (especially in developing countries) are characterized with bad internet accessibility, imbalanced spread of computer technology and literacy, and acute information breach. Therefore, this work aims to develop a system that allows patient records to be exchanged between health facilities given the challenge of lack of ubiquitous internet connectivity, unreliable internet access and also bridging the digital divide gap. This research will have positive impacts on different stakeholders in the health sector. Health institutions can access patients' information evading the issue of poor or no internet connectivity. As a result of this, healthcare professionals will be able to give better and prompt treatments in cases of emergencies and avoid medical errors. Medical practitioners will also not have to deal with the communication gap or barrier when seeing a patient with low literacy level. This research would not only be of relevance to the health sector, it can also be adapted by other sectors using the USSD technology as a means of storage and retrieval of information.

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INTRODUCTION:

The institution of Electronic Medical Records (EMRs) alleviated some of the troubles of wrong information. EMRs and Electronic Health Records (EHRs) are a crucial part of the structure through which medical health professionals can convey vital patient information to other members of the health care group and also to the patients. Electronic Health Records are electronic formats of patients' healthcare records. An electronic health record collects, generates, and stores the health record electronically. The electronic health record has been slow to be adopted by healthcare providers. The federal government in some developing nations passed legislation compelling the adaptation of electronic records or face heavy monetary penalties. The EHRs will enhance clinical documentation, quality, healthcare utilization tracking and make health records portable without stress (Seymour, Frantsvog&Graeber, 2014).

EMRs are designed to be mostly peculiar to a particular practice, making it tough to relay information to external providers, to different health care systems, and even to the patients. Due of such boundaries, over time, EHRs were unfolded and became widely accepted. EHRs have the ability to house all of the roles of the EMR and have vital added essentials. EHRs are particularly intended for information dissemination, not only among a variety of healthcare providers who may be situated in a number of environs (in-patient, primary care, abroad, emergency department), but between healthcare providers and patients. EHRs not only have an effect on providers and health care organizations, but they improve the patients' capability to follow up on their own medical schedules and assure that the information is made obtainable only to those chosen by the patient, whether it is a "significant-other" or a health care provider (Mcmullen, Howie, Philipsen, Bryant, Setlow, Calhoun & Green, 2014).

To reduce these errors to the barest minimum and bridge the gap of patients' health record exchange errors, the Unstructured Supplementary Service Data (USSD) can be introduced. The USSD also called Quick Codes has always been in use since the introduction of the Global System for Mobile (GSM) phones to access quick and short mobile functions which include cellphone Airtime Recharge and Airtime Balance Check which are the most basic and primary use of the USSD (Sanganagouda, 2011). As against the Short Message Service (SMS) which is an added primary characteristic of the GSM Phones, USSD messages are between 1 to 182 alphanumeric characters lengthy. When a session is ongoing, USSD messages are in instant connection; they have interational capabilities and attributes that make them effective on several menu-based utilities if well taken advantage of (Sanganagouda, 2011).

The USSD Network design is made up of the Mobile Station Controller (MSC), Home Location Register (HLR), Visitor Location Register (VLR), Complex logic to aid collective implementations within a solitary USSD platform, Simple Messaging Peer-Peer (SMPP) interface for applications to authorize services, USSD Gateway and every precise USSD application servers (Baraka, Anael, &Loserian, 2013). The USSD design is shown in Figure 2.1.

In 2016, Akinde focused on developing a model for Health Information Exchange using SMS as an alternative medium. The aim was to achieve interoperability in the healthcare system in developing countries, especially while bridging the gap of lack of ubiquitous access to the internet. The model leveraged on SMPP to transfer and receive HL7 version 2x encoded messages to known recipients via SMS. The HAPI (HL7 Application Programming Interface) was used at the application layer.

In 2017, Hong, Morris & Seo proposed a system to interconnect Personal Health Record (PHR) ecosystem using Internet of Things (IoT) cloud platform and Fast Healthcare Interoperability

Resources (FHIR). The aim was to provide a PHR based on an IoT module which communicates with hospitals and public clouds. The system intended to store and share raw EMR and life log data based on the IoT module. The Health Information System (HIS) prototype ran on the JBoss web server to meet the requirements of security and seamless data sharing through a public cloud and the PHR system was implemented on Samsung's ARTIK 10 IoT module. A mobile application was developed to manage the PHR, HIS and cloud account information. The Samsung Health (S-Health) application was used. The work showed how the PHR ecosystem was suitable for the

real-world scenario and majorly focused on developing a gene-based obesity management system. A home gateway PHR system on an IoT module that provides full control of individuals' PHRs was implemented. APIs were also added to a public cloud that provide for anonymous data sharing with 3rd parties. In addition, a mobile application which is connected with existing healthcare service providers for better compatibility and usability was developed. Figure 1.3 shows the model designed, the HIS consists of several open-source projects: FHIR server, 'SMART on Genomics', and an email module.

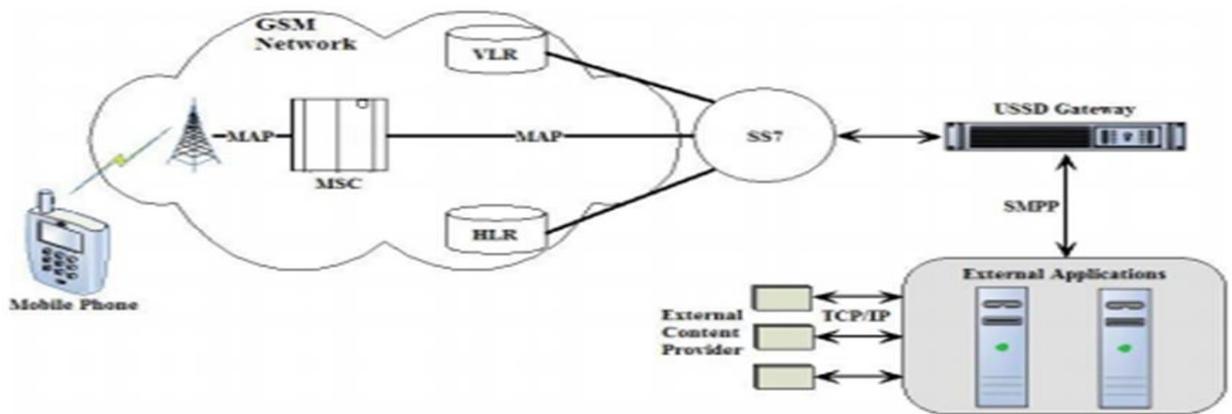


Figure 1.1: USSD Architecture (Baraka, Anael, & Loserian, 2013)

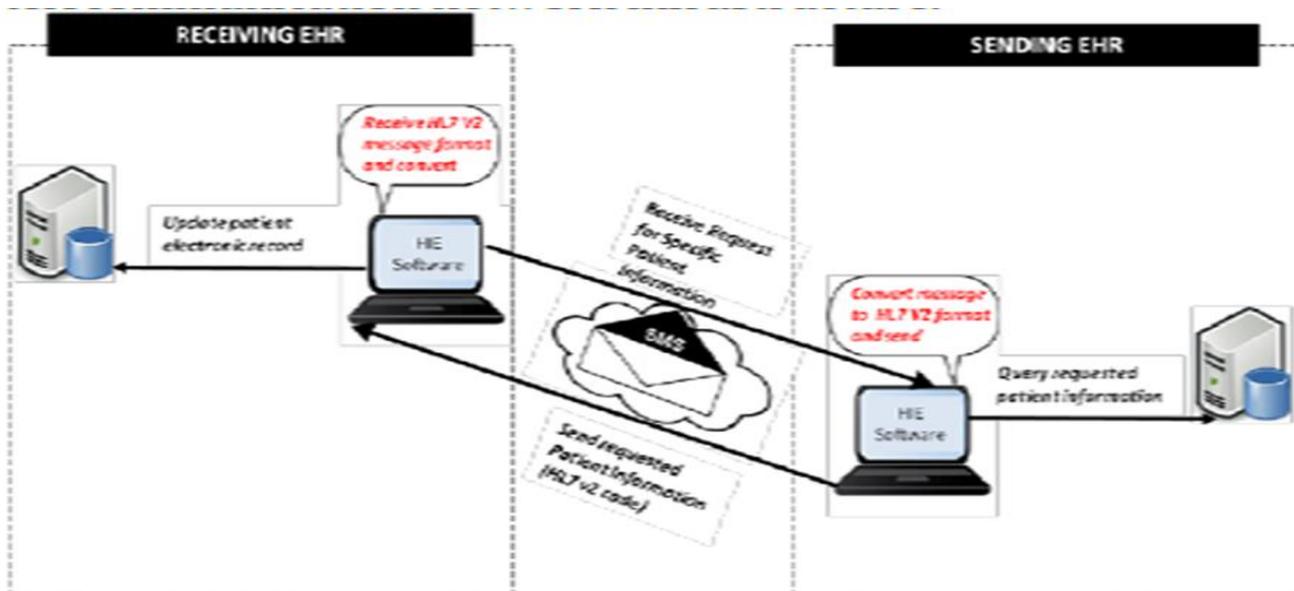


Figure 1.2: The proposed Health Information Exchange model for EHRs (Akinde, 2016).

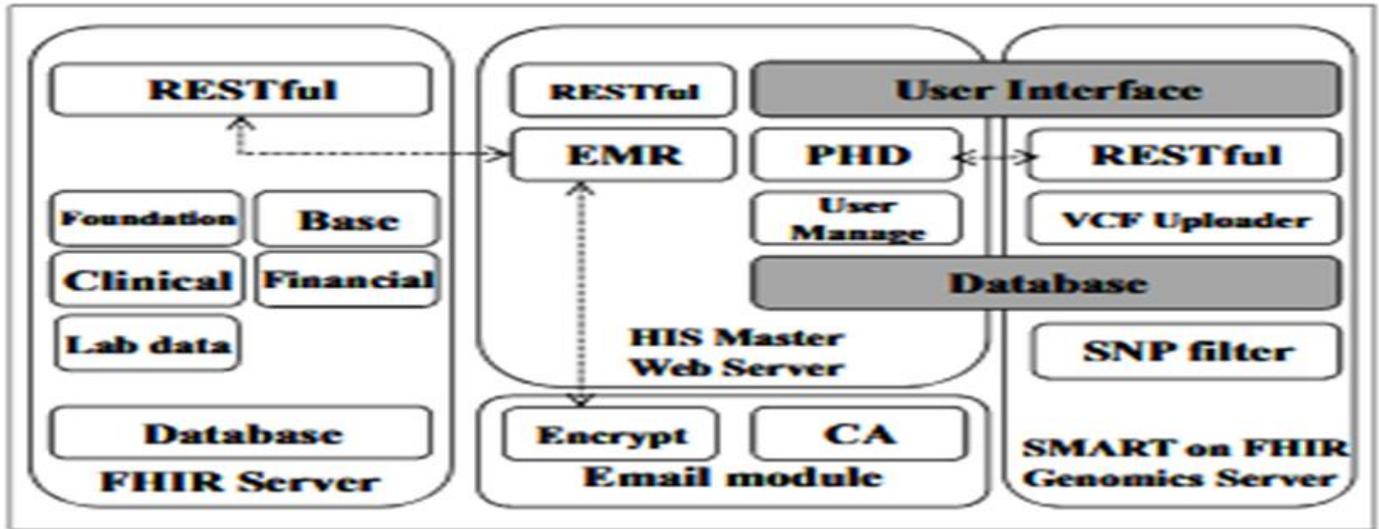


Figure 1.3: A prototype of Hospital Information System. (Hong, Morris & Seo, 2017)

A variety of the literature examined used the web services distributed middleware software to provide a remedy to the eHealth interoperability issue and a significant benefit of adopting the web services technology is that, as against CORBA / DCOM middleware technology, specific skill is not a necessity to run the program. Though, while the web service technique has clearly demonstrated efficacy in addressing the problem of address system and language interoperability, the implementation of web services involves complicated coding operations as thousands of programming Lines of Code (LoC) might be required even for the easiest web services. Therefore, in the process of launching these web services for the provision of eHealth Interoperability, a great deal of system resources such as memory and processor is being used up.

The OWL Ontology approach has also been used in a few of the literature studied, and the principal benefit of this method is that it allows a recipient HIS to translate information received from another HIS on the spot, despite the fact that there was no previous peer-to-peer consensus on the semantics and syntax of the data sent. The semantic-based model also enables interoperability with non-EHR standards-developed health information systems. A major benefit of the OWL Ontology approach is that there is a small need for human

involvement. A major flaw of this approach is that it may be time- and resource consuming to check for all member path mappings among two broad ontologies. Another key problem with the OWL ontology approach is Scalability as the method does not permit the volume of data in the HIS that the approach can be used on to be scaled up or down easily.

The Information System Design Analysis (ISAD) was used by another literature reviewed. It also signifies the Internet as the media that communicates with medical professionals through the system. A benefit of the ISAD is that it makes the system easy to use as it uses the USSD as the communication media. This system's downside is that the system must send an ad to the user's cell phone before the user can start sending requests. Some of the literature reviewed also adopted Service Oriented Architecture (SOA), while others embedded the approach to Web service. A vital input to this technology is the effortless integration within and between institutional enterprises. EHRs designed with different programming languages can effectively communicate easily with this method. Nevertheless, instead of using SCP-ECG files, the use of SOA and XML involves an increase in overhead, thus lowering performance.

METHODOLOGY:

In order to achieve the objectives of this paper which is to develop of a Health Information Exchange (HIE) system using the Unstructured Supplementary Service Data (USSD) Technology, the following procedures were adopted

- A system for the exchange of information among health institutions in developing countries was developed.
- The system was designed to meet the goal of the Electronic Health Records technological and semantic interoperability.
- The system transmitted and received HL7 version 2.X encoded messages to known receivers via a telecoms operator's USSD channel.
- The system was designed using Java J2EE (J2EE was the choice because the system was designed as an enterprise system) and ideamatt/remsoft.
- These tools were used for the simulation of USSD technology.
- MySQL was used to create and manage the database and the Java Persistence Architecture (JPA) was used as the database connector. The Netbeans IDE 8.2 was the adopted Integrated Development Environment

Framework Design: Here the researcher explained step by step how the framework will be designed and what the users should expect also.

System Creation: The system was designed with a repository where all records are kept to check and disallow all anomalies and to ensure there is no duplication of health records.

Health Facilities Registration: Health facilities were enrolled on the platform and their identification numbers were generated automatically.

Health Professionals' Registration: Health professionals were also enrolled on the platform.

Patients' Registration: After running the necessary tests, the users were enrolled on the

platform and this was done using the user's cell phone number. After this, a unique ID was generated for the user.

Model Design for Health Information Access using USSD Technology: A conceptual model will be created to illustrate a communication master plan that achieves a health care professional's access to health information for patients without relying on internet connection accessibility. The model evolves from a model that utilized the established telecommunications infrastructure that still needs internet connection. In the proposed model, every member has a distinct identity which can be used to access the patient's basic information once registered on the USSD platform and will require a healthcare professional's access code to get through to the second level. The participating institutions also must be ready to conform to the guidelines and laws set by the Health Standard body which in the case of this research work is the Health Level Seven (HL7) v2.6 standards.

Functional Design of USSD-HIE: The practical blueprint of the Unstructured Supplementary Service Data for Health Information Access (USSD-HIA) identifies the various entities included in this model.

User Enrollment: This is where the first step the user has to take to enable accessibility to the platform and the entities in this section are identified below;

User

Health Care Facility (HCF)

HCF Database

Patient Registration

Licensed HCF Registered Name: Babcock University Teaching Hospital

- **Acronym Given:** BU
- **Patient's Generated Reg No:** A1
- **UNID:** BUA1

Enrolling on the USSD Platform: For an HCF to be enrolled on the USSD platform, it has to have fulfilled two major criteria; full registration and license approval by the NMA so as to curb

illegal enrolment. Steps to be taken before an HCF is enrolled are as follows;

- Step 1: The HCF sends a request to the NMA
- Step 2: The NMA looks into the sent request to ensure the HCF is fully approved and licensed

Step 3: Once it is settled that the HCF has met the set requirements, a positive response is sent back, and is issued is a Registration ID and the HCF is enrolled on the USSD platform.

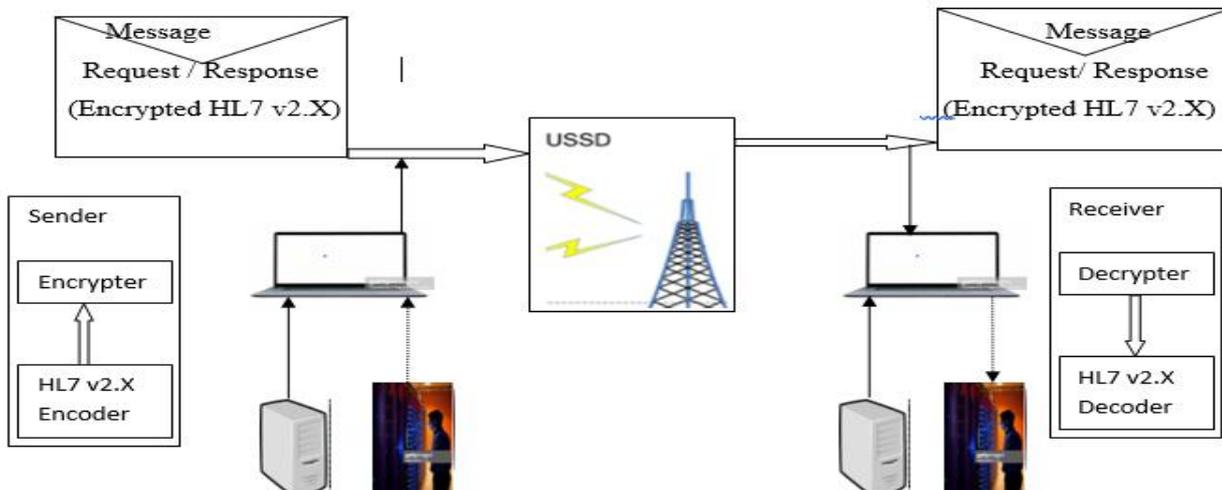


Figure 1.4: Proposed Model (Researcher’s Model, 2019)

Enrolling on the USSD Platform: For an HCF to be enrolled on the USSD platform, it has to have fulfilled two major criteria; full registration and license approval by the NMA so as to curb illegal enrolment. Steps to be taken before an HCF is enrolled are as follows;

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- Step 3: Once it is settled that the HCF has met the set requirements, a positive response is sent back, and is issued is a Registration ID and the HCF is enrolled on the USSD platform.

Data Repository: This is where all data is stored to when enrollment is carried out and accessed from when the need arises either in the case of emergency or in the case where illiteracy stands as a barrier to treatment, the entities in this section are identified below;

- National Medical Association (NMA)**
- National Data Warehouse for HCF**
- National Data Warehouse for HCP**

HCP’s Cell in HCF: This section shows the instance where the USSD call is initiated from the Health Care Professional’s cell phone in the absence of the patient’s cell phone.

Health Care Professionals (HCP)

Patient’s Cell in HCF: This section depicts the instance of the USSD call being initiated from the patient’s cell phone and as can be seen in the arrow labeled E there is a connection from the Patient’s phone to the HCF’s database. This will occur should in case a classified information of the patient is needed which this can only be accessed by a licensed HCP and this action will need the passkey of the HCF which will be duly verified by the NMA system before access is granted. Others include;

Labeled Arrows

Multidirectional Arrows: This shows the interconnections in the model. To abstract the layout in which the USSD messages are exchanged, for a standard USSD message request and message response, a message abstraction is sketched out correspondingly.

This is shown according to the USSD HIA model in Figure 1.5

- a. The HLR delivers a MAP Process Unstructured Request to the USSD Gateway once the user initiates a USSD Call.
- b. Once the MAP Process Unstructured Request of the begin-type is received, the USSD Gateway triggers a third-party application by means of an HTTP Post Request bearing an XML Payload with relevant USSD data.
- c. The third-party application should then receive a brand-new bout and keep it until the final answer. The application then sends an HTTP reply to the USSD Gateway, bearing an XML payload.
- d. The USSD Gateway must give the HLR a form Continue MAP Process Unstructured Request.
- e. The User receives a list for selecting and answering. The HLR must transmit a MAP Unstructured Response form Continue to the USSD Gateway once the user responds.
- f. The USSD Gateway will then submit a request for HTTP Post to the third-party client in that very same session, bearing an XML payload.
- g. The third-party client must submit a last reply (HTTP Response, bearing an XML payload) depending on the user's feedback and nullify the session.
- h. The USSD Gateway must transmit to the HLR a MAP system of type End unstructured response. The user will therefore obtain a last reply.

HTTP Payload XML Design

The HTTP Request / Response bears XML Payload with particular USSD details as described below:

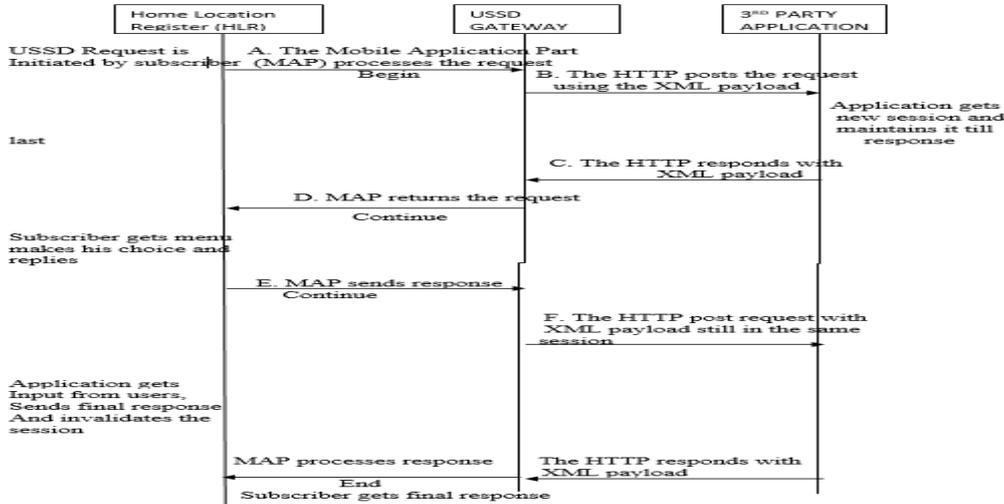


Figure 1.5: The UHealth Health Information Access Abstraction

```

<dialog type="Begin" appCntx="networkUnstructuredSsContext_version2"
  networkId="0" localId="1" remoteId="1" mapMessagesSize="1"
  returnMessageOnError="false">
  ....
  ....
  ....
</dialog>
    
```

Figure 1.6 Source: Restcomm.com

The 3rd party application can be any of the technologies highlighted on any licensed Operating System: Apache Tomcat or Oracle Application Server on Java platform PHP or ASP Microsoft IIS.

Requirements: the requirements are broken down into two parts namely: The User requirements and The System requirements

The User Requirements: For smooth running on this part, there are majorly four participants:

1. The National Medical Association: This is the regulatory body that ensures only approved and licensed bodies utilize this platform. They are also in charge on the central data warehouse and this participant major roles include
 - Licensing Healthcare Facilities
 - Giving licensed healthcare facilities the approval to join the platform
 - Approve and Verify User IDs
 - Initiate sessions on the platform
 - Access to patient information on both levels
 - Medical professionals' registration
2. The Healthcare Facilities: This is the first point of call for patients to be registered on the platform. They are licensed and authorized bodies. These participants should be able to
 - Register Patients
 - Initiate USSD sessions
 - Upload and Update patients' health records
 - Have access to information on health
3. The Clients: These are the ones whose health information is populated in the database. This participant should be able to:
 - Enroll on the platform
 - Access their Healthcare records

4. The Medical Professionals: They are the ones who query for patients' information when the need arises. These participants should be able to:

- Initiate USSD sessions
- Query for patients' health records
- Access the second level of detailed patient information.

Analysis of the capacity and HL& v2.X encoding of the UHealth Model: A detailed examination of the size of the information content to be accessed via USSD was carried out based on the 184-character content limit of a standard USSD message. This examination takes the segment and concerned field needed by an implementation of the UHealth model shown in Figure 3.1 into consideration. The HL7 ORU_R01 message was adopted for this examination because that is the message type which is commonly used for requesting and for responding to laboratory observations which often exchanged.

REPORT:

The modules that made up the prototype UHealth software implementation include:

- I. The Patients Health Information Module
- II. The USSD Service Module with a simulator

The Patients Health Information Module: The implementation of the Patient Health Information Module involved the creation of a Relational Database using My SQL. The application was developed using Java J2EE and this choice was informed by the existing Java API by HL7. The application was designed to create a knowledge-base for both Patient Observation and Diagnosis. The program is a multithreaded application where the major thread is used for user interaction on the application's interface and all the information is being uploaded via an excel prototype.

USSD Service Module: Unstructured Supplementary Service Data, USSD was used as a medium for information exchange. The USSD service relies on a telecommunications

service provider to deliver message to the receiving application.

The USSD Service was implemented as a Web service developed to run continuously for as long as the application is working. Its objective was to communicate messages from the Application to

the USSD device using MySQL Server database as the staging area. Messages queued up on SQL server were sent and decongested by the USSD service. The JBoss was used in hosting the application. Messages read from the device were also stored in the SQL server database. USSD service loops at intervals.

Table 1.1 Analysis of the USSD capacity and the HL7 v2.X encoding

Required Segments	Segment Components	Required Character Constituents	Estimated No. of Characters
MSH	Required Fields:	MSH-1 (Delimiter Characters)	5
		MSH-8 (Message Type)	13
		MSH-9 (Message Type)	4
		MSH-11 (Version)	3
	Delimiters	Field Separator	11
		Component Separator	2
PID	Required Fields:	PID-5 (Patient Name)	35
		PID-7 (Date of Birth)	8
		PID-8 (Sex)	1
	Delimiters	Field Separator	8
		Component Separator	2
OBR	Required Fields:	OBR-1	1
		OBR-3	15
		OBR-4	2
		OBR-25	3
	Delimiters	Field Separator	25
		Component Separator	3
OBX	Required Fields:	OBX-2	2
		OBR-5	15
	Delimiters	Field Separator	5
Total number of Characters			158

An iteration of the USSD service involved the execution of the following:

1. Accepting incoming messages
2. Accessing them and updating the Service Event log

3. Reading message from the device by executing the AT commands
4. Storing all newly read messages in the database using dedicated stored procedure

5. Clearing the device of any message so as to accommodate incoming message
6. Reading queued messages in the right chronological order. Note that one message was sent per service iteration. This was to ensure the device was in ready state before sending and to avoid timing issues. This measure ensured reliable message delivery without error.
7. Halting the current service thread.
8. Starting another loop (or iteration)

CONCLUSION

As more hospitals in the implementation strategy and frameworks used for software solutions get on the "train of diversity," the challenge of integrating such diverse structures becomes more obvious and complicated. There is a need for cooperation between all hospitals to allow a national interoperability of information systems for health care. This partnership will require a significant participation of stakeholders in the health sector of each nation.

Given the performance of the prototype HIE Software, the UHealth HIE model has proved effective and reliable. While considering implementing a software solution for information between developing countries, the quality of Internet connection is often a matter of concern.

The UHealth HIE model is an alternative that can be explored to provide remote access to specific patient information at a lower cost and with high reliability to allow technology transfer in

diversified regions. The model was developed with the salability versatility in mind and as such it can be easily adapted to cover more facets of eHealth and other sectors in resource-challenged nations. It cannot be ruled out that this research provides for relevant patient information to be made available to hospitals. The average time needed for accessing messages is competitive this would be better than spending time and money conducting laboratory tests and diagnostic procedures.

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