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# Unified Architecture for Integrated Health and Environmental Based Model; a Case of Cholera Epidemics

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**Abstract**

With the recent increase of infectious diseases characterized by epidemic outbreaks whose origin are from environmental factors, the use of environmental variables such as water bodies and weather variables for effective diseases analysis has dramatically increased. The situation has stirred up efforts of software engineers towards integrating the collection of environmental factors from Environmental Management Systems (EMSs) into Healthcare Information Systems (HISs). HISs and EMSs have a large diversity of stakeholders and technological application domains; as a result, they face interoperability complexities. In spite of the established knowledge of software-architecture, there is still a lack of unified architecture for integrated Healthcare and Environmental Management Information Systems (HEMISs) to support the development of HEMISs and solve the interoperability challenge in a holistic way. This work proposes conceptual design view of the unified architectural model for HEMIS that would serve as a blueprint for the development of HEMISs and also, enhancing the analysis of epidemic diseases which have a strong linkage with environmental factors. As a proof of concept, the designed unified architecture has adopted features from IEEE 42010-standard, Siemens' Four View Model, Protocol Translator and Key Attribute Value table architecture style, and used Unified Modeling Language (UML) in its design visualization.

**Index Terms:** Unified Architectural Model, Health Management Information System and Environmental Management Information System, View-Based Architecture, Architecture Description.



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## 1. Background Introduction

### *1.1. Introduction*

The use of environmental factors in disease analysis is significantly increasing in the world for achieving effective monitoring and controlling of epidemics such as Cholera [1]. Such essential environmental factors which have a high influence on the cause and transmission of communicable diseases that are prone to cause epidemics include lack of safe water, inadequate excreta disposal facilities, poor hygiene, poor living conditions, and unsafe food [2]. In addition, the climate is also among the major environmental factors which can lead to the transmission of the rapid epidemics. For example, flooding or heavy rains can result in sewage overflow and widespread water contamination from one region to another as well as from one person to another [3]. The collection and analysis of these environmental factors are very challenging since they require real-time EMSs which normally make use of advanced and emerging technologies such as sensors, satellite, and Geographical Information Systems (GIS) [4,5]. EMSs play a great role in providing essential environmental predictors and variables for disease analysis [6]. Despite the known linkage between such epidemics and environmental factors, most existing HISs lack timely integration of environmental factors from EMSs. To the extent that, HISs fail to significantly assist effectively in the analysis, eradication, and prediction of epidemics [7–9].

### *1.2. Literature Review*

According to the literature, HIS and EMS use a wide range of devices, stakeholders, technologies and application domains to facilitate the processes of data collection, data processing, information flow and control [10–12]. As a result, they face the recurring challenges that relate to interoperability. In healthcare, interoperability is the ability of different information systems and software applications to communicate, exchange data, and use information that has been exchanged [13]. Following the advent of emerging technologies and changes in the environmental factors, the HIS and EMS are expected to receive new concerns from various stakeholders on health and environmental issues, and also make use of more diverse devices (technologies) in; communication protocols, information semantics, data encoding etc. Such diversity and complexity can be very challenging even to the experienced software engineers [14]. In the context of software development, the issues of interoperability are mostly solved at the architectural design and system development phases; where most of the software engineers (developers) use the latter phase due to the nature of the user requirements and unexpected increase of stakeholders' concerns. Technically, solving interoperability challenges at system development phase can lead to more engineering costs [15]. In addition, several works of literature [16,17] have emphasized on solving interoperability challenges at software architecture design phase. This is because of software design architecture phase has been acknowledged by many developers and researchers as the foundation of any software since at this phase, stakeholders can reason and establish easily their concerns and requirements such as extensibility, scalability, interoperability etc. In spite of the established knowledge of software architecture, there is still a dire need to review the existing HISs and EMS in order to formulate a standard unified model which will support rapid and effective development of HEMISs and also, solve the interoperability challenge between HISs and EMSs [9,18,19].

There are several architectures of HIS and EMS which have integrated other subsystems such as collaborative module in order to fulfil additional stakeholders' concerns. For instance, in 2013 Gelogo and Kim [20] designed a unified ubiquitous healthcare system architecture with a collaborative model. In 2015, P. Locatelli et al [21] proposed architecture for governance and health services architecture which aimed at achieving user satisfaction and fulfilment optimization of health care goals. In 2009 I. Lazar et al [22] formulated unified communications for healthcare architecture to improve patient care, operational efficiency, better compliance, lower costs and the ability to deliver new and innovative patient care services. Furthermore, P. Jankowski [23] proposed an environmental management information system that ultimately helps to improve decision making processes in reverse logistic, E. Mugerezi [24] design and developed EMS which consists of land management, revenue management and thematic management modules in order to increase capacity for collection, management and utilization of environmental information. Also O. El-Gayar and B. Fritz [6] design a conceptual overview of EMS for sustainable development. The diversity of HISs and EMSs and their architectures are observed on the dimension of the application domain and fulfilment of a particular set of attributes or a new component. Despite their existing diversity, these systems and architecture technically possess similar subsystems and components that could be generalized into *Data Collection, Communication,* and *Information Control Centre Subsystems.* Where *Data Collection Subsystem* includes Mobile Apps, Satellites, Sensors and GIS devices which measure and collect health and environmental data such as the name of the patients, age of the patients, the geographical location of the patients, temperature, wind, humidity etc., pre-processing and submit the collected data. *Information Control Centre Subsystem* integrates, analyzes, processes, stores and visualizes the information as received from the *Data Collection Subsystem* based on the objectives of the users such as epidemiological analysts. *Communication Subsystem* which facilitates the information flow between the *Data Collection Subsystem* and *the Information Control Centre Subsystem.*

In response to the previous efforts, this work realizes that there is still a lack of a general abstraction representation namely a unified Architecture to represent such systems' common subsystems which will facilitate effective and efficient development of interoperable HEMISs. Unified architecture is the platform independent standard through which various kinds of systems and devices can communicate by sending messages between clients and servers over various types of networks [25]. The main goal of unified architecture is to provide robust support, secure communication between clients and systems and the consistent mechanism for the integration of process control and management systems [26]. Additionally, unified architecture is considered as a basic necessary foundation in system development towards facilitating a correct understanding of the stakeholders' concerns and requirements and all underlying principles for design and developing interoperable HEMISs [27]. The remainder of the paper is organized as follows; Section 2 explains the description of the unified architecture based on IEEE 42010-2007 standard. Section 3 explains the proposed conceptual view design of the unified architecture for HEMIS based on the adopted principles of Siemens' Four-View Model, Key-Attribute Value table architecture style, and Protocol Translator, and then Section 4 briefly presents the discussion, and lastly Section 5 concludes the paper.

## 2. Description of the Unified Architecture

For this Procedia the files must be in MS Word format only and should be formatted for direct printing. Figures (Fig.) and tables should be embedded and not supplied separately. Please make sure that you use as much as like description of the unified architecture for HEMIS adopts the format of IEEE 42010-2007 Recommenced Practice for Architecture Description of Software-Intensive Systems. The standard specifies the conventions, principles, and practices required for the description of architectures in a particular domain, which should be used when creating the proposed unified architecture for HEMIS. It also elaborates the main required functionalities for designing the software architecture, stakeholders, and their main concern [28].

### *2.1 Descripti*on of the Unified *Architecture for HEMIS*

According to the IEEE 42010 Standard, a unified architecture for HEMIS should include the followings;

A. Stakeholders: (i) the Governmental agencies include ministries responsible for providing health and conducive environmental support in order to prevent people for various epidemics. (ii) Developers: include system developers, architects, analysts, testers as well as the experts of GIS, satellite and sensor technologies. (iii) Maintainers and supporters include people who maintain and support HEMISs daily. (iv) Academic and research institutions: include concerns when conducting training and investigations (researches) about the cause, transmission, and seasonality of epidemics with their predictors such as environmental factors. (v) Users: include different roles such as the system administrators, environmental experts, and epidemiological analysts, patients, medical officers, and other citizens who require timely and high-quality service from the HEMISs.

B. Concerns: The main concern is the development of a standard unified model which will assist in the design and development of interoperable HEMISs. A key concern of the interoperability in HEMIS is to enable data collection from various devices and any additional devices. Then, after data collection, the data format has to be aligned accordingly in order to be effectively and timely analyzed.

C. Functional Requirements: includes the following functionalities as shown in Table 1.

Table 1. Functional Requirements of the Unified Architecture for HEMIS.

| **ID** | **REQUIREMENT** |
|---|---|
| RQ1 | Use base-station at the field of interest control and configure the HEMIS devices such as Mobile Applications, Sensors, GIS and Satellite |
| RQ2 | Provide timely operation status of HEMIS at the base station |
| RQ3 | Collect environmental and health variables such as wind speed, wind direction, temperature, rainfall, humidity, date of set, geographical location, laboratory result, etc. |
| RQ4 | Allow base-station to aggregate the observed health and environmental variables |
| | Allow the base station at the data collection point to allow seamlessly the flow of data from various devices and subsystems. |
| | Allow the communication subsystem to analyze and translate or convert all collected data from EMS and HIS to interoperate. |
| RQ5 | Allows the communication subsystem base station to transmit the combined health and environmental variables to the information control center for further processes. |
| RQ6 | Execute control actions |
| RQ7 | Execute data processing methods |
| RQ8 | Execute risk analysis models on the processed information to gain an understanding of the variables in order to effectively analyze and predict the possible occurrence correctly |
| RQ9 | Provide a simple, flexible and friendly user-interface that can be used even by users who are inexperienced in software engineering |
| RQ10 | Supply adaptive, interoperable, sustainable and optimized plan of exploitation based on the available resources to accurately confirm the epidemic outbreaks in terms of their size, time, location and etc. |

D. Non-Functional Requirements: includes the following functionalities as shown in Table 2.

Table 2. Non-Functional Requirements of the Unified Architecture for HEMIS.

| REQUIREMENT | DESCRIPTION |
|---|---|
| Security | It should outline security countermeasures such as allow only users with unique authentication login credentials, strongest level of password (greater than 75% of the password measurements) and automatically request users to change their passwords after every six months of use. It should encourage the software developers to work closely with the system stakeholders so as to seek the balance between risks and resource in order to achieve 100% security. |
| Maintainability | It should use client-server features in order to allow easily at the rate of 100% upgrade components independently when needed. |
| Interoperability | It should use interoperability supporting features such as key-attribute value table architecture style in order to unify heterogeneous data to support the effortless and seamless integration of different data sources and systems at a rate of 100%. |

## 3. Proposed Unified Architectural Design

The main goal of the unified architecture for HEMIS is to facilitate the development of HEMISs with interoperability efficiency in order to enable timely and effective analyses of epidemic diseases with appropriate linkage with environmental factors. The main functionalities of unified architecture for HEMIS are data collection, data processing, information flow and control via the use of *Data Collection*, *Communication*, and *Information Control Centre Subsystems* as explained in Section 1. To achieve interoperability efficiency of the unified architecture for HEMIS, Section 3.1 discusses the used approach and Section 3.2 presents and discusses the proposed design.

### *3.1 Approach for Interoperability Efficiency*

Interoperability, as defined by IEEE, is “the ability of two or more systems or components or web services (software modules) to exchange information and use information that has been exchanged” [29]. In HEMISs, interoperability is one of the critical resources which enable integration of additional devices, concerns and requirements. Nowadays, interoperability efficiency becomes a critical concern in HIS because the burden of diseases from environmental factors is increasing with the emergence of new environmental causes; which must be integrated into HIS for successful disease analysis [30]. This situation prompts a very high interest to software engineers and researchers towards designing and developing HISs and HEMISs with a very high degree of interoperability.

To improve the interoperability criteria in HEMIS, protocol translator, IEEE 42010 standard [28], key-attribute value table architecture style [31], and Siemens’ four-view model [32], have been adopted and customized. As they possess essential views which should be contained in the proposed unified architectural for HEMIS. The protocol translator is a converting scheme that enables the highest level of interoperability of independent systems by standardizing software interfaces and increasing implementation flexibility. The protocol translator consists of hub-spoke design, where each spoke represents Data Communication Subsystem communication protocol [33]. When a request is made between HIS and EMS protocols, the hub injects a translation. The first translation is made into an intermediary format. Once there is an intermediary protocol, the target translation can proceed. The implementation of an intermediary translation for all protocol enables them to require on translation scheme. Hence for a protocol to be able to interact through the hub, it only requires a mapping to the intermediary representation as shown in Fig.1. Whereas IEEE 42010 standard guide the process of organizing requirements such as modules of the subsystems. Key-attribute value table architecture style enables seamless integration of various data types from multiple devices and Siemens’ four-view model enables the re-use and reconfiguration of the software parts in order to fulfil additional user requirements and hence lead into a reduction of implementation complexity of the unified architecture for

HEMIS. In addition, UML [14] has been deployed in the design visualization of the proposed conceptual design view of the unified architecture for HEMIS.

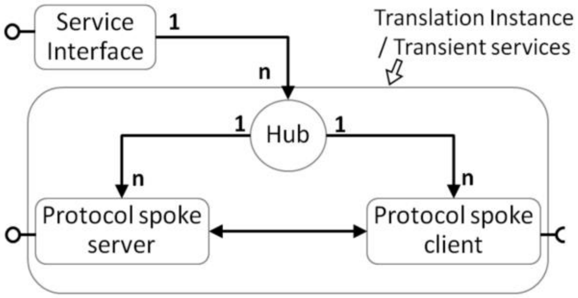


Fig.1: Block diagram of the base translator architecture by H. Derhamy [23]

### *3.2 Proposed Unified Architectural Viewpoints*

The unified architecture for HEMIS with a strong emphasis on interoperability criteria has been established based on the aforementioned stakeholders, concerns, functional requirements, and non-functional requirements. The design of the unified architecture for HEMIS in Fig.2 consists of multi-views. Fig.2 is in the Appendix section. In which the conceptual design view of unified architecture for HEMIS has been constructed to fulfil all requirements. Conceptual design view consists of *Data Collection Subsystems* to accommodate HIS and EMS devices. The *Data Collection Subsystems* has adopted the key-attribute value table architecture style in order to support and allow seamless integration of various data types. The *Communication Subsystem* has also adopted the protocol translator to allow interoperability of independent systems such as HIS and EMS. Lastly, the *Information Control Centre Subsystem* controls the information which is required by the clients or users of the system.

## **4. Discussion**

In summary, the proposed design of conceptual view of the unified architecture for HEMIS in section 3 is composed of interconnected subsystems that cater to interoperability efficiency. As noted, health-care systems require the integration of daily weather data, geographical location, and other environmental variables. The *Data Collection Subsystem* in the conceptual view design will use EMS devices to the collection and processing of the daily weather data and HIS devices to collect the cholera cases data. At this juncture, all required devices in HIS and EMS are assisted through the use of key-attribute value table architecture style to enable seamlessly dataflow. Then all this information is analyzed by the protocol translator in the *Communication subsystem* in order to enable flexible integration of information which is required by the required client or user of the system in the *Information Control Centre subsystem*. The protocol translator is designed in such as away it implements protocol spokes as half-step translator pair when moving from source protocol to target protocol in the *Communication Subsystem.* Since each spoke represents a single protocol mapping with the intermediary format, a mapping is made between any two of the supported protocols to complete the communication cycle in the unified architecture or applied system. With the recent advancements of ICTs in the healthcare sectors [10], the application of the proposed conceptual design view of a unified architecture for HEMIS will serve as a standard baseline for designing and developing concrete and interoperable HEMISs.

## 5. Conclusions

The proposed conceptual design view of the unified architectural model for HEMIS in section 3 guides the design and development of interoperable HEMISs. Interoperability has become a quality of increasing importance for information systems due to the emergent of advanced technologies and new stakeholders' concerns. In addition, software researchers emphasize interoperability as a crucial mechanism in HEMIS however; developers have focused on integrating additional requirements and subsystems at a late stage of software development. This situation led to unnecessary delays and costs, interoperability challenge and lack of concrete design as a blueprint for developing interoperable HEMIS. Despite the existing diversity of HISs and EMSs, technically they consist of similar components that could be presented in a unified architecture. Additionally, the awareness of the unified architectural domain is a promising paradigm that can provide a concrete conceptual design view for HEMIS at an early stage of software development while meeting the system demands. This paper proposes the conceptual design view of the unified architecture for HEMIS. The proposed conceptual design view, in this work, has captured all required aspects of interoperable HEMISs towards analyzing epidemic diseases whose causes and transmission have a strong linkage with the environmental factors. Future work of this research is the actual development and evaluation of the unified architecture for HEMIS.

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## Appendix A: Fig.2.

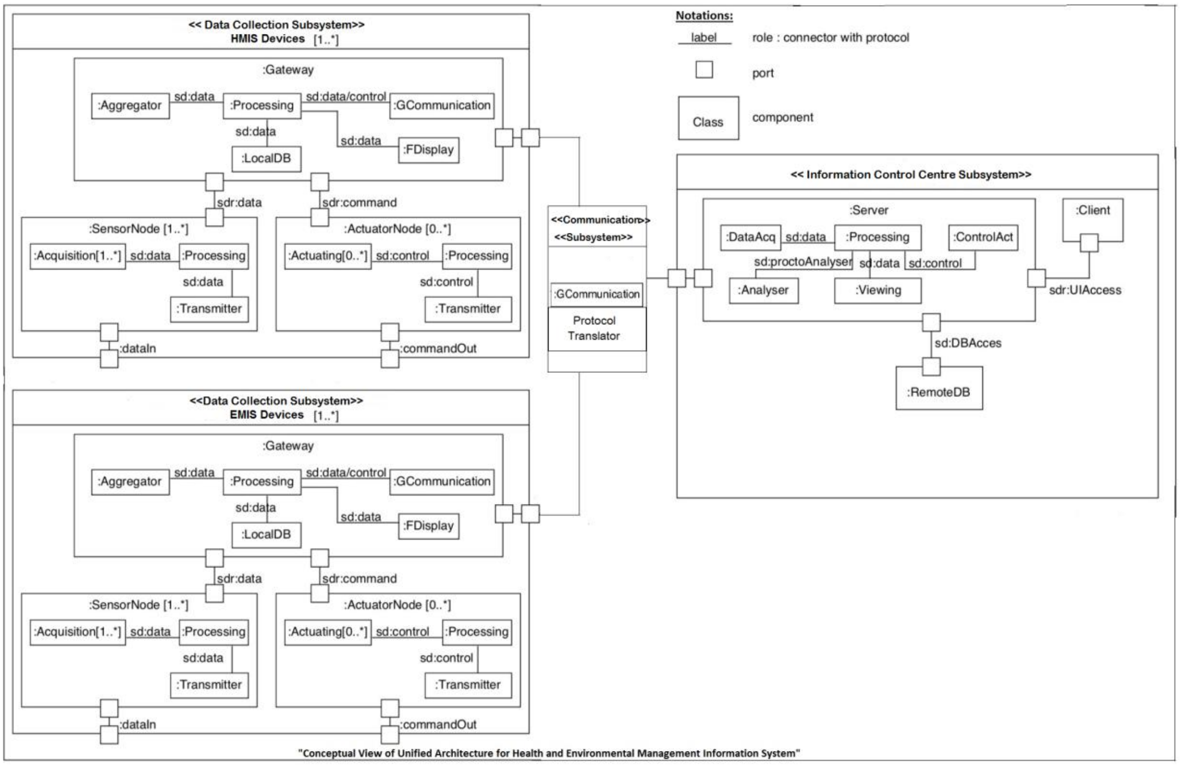


Fig.2. Conceptual View of a Unified Architectural Model for Health and Environmental Management Information System

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