DESIGNING A DISEASE OUTBREAK NOTIFICATION SYSTEM IN SAUDI ARABIA

Farag Azzedin, Salahadin Mohammed, Jaweed Yazdani and Mustafa Ghaleb

King Fahd University of Petroleum and Minerals
Dhahran 31261, Saudi Arabia
Email: {fazzedin,adam,jaweed,g200905270}@kfupm.edu.sa

ABSTRACT

This paper describes the design and development of a Disease Outbreak Notification System (DONS) in Saudi Arabia. The main function of DONS is to warn for potential outbreaks. A prototype of the DONS was implemented in a hybrid cloud environment as an online/real-time disease outbreak notification system. The system notifies experts of potential disease outbreaks of both pre-listed diseases and totally unknown diseases. The system only accepts cases from pre-registered sources. It is designed to also share information about disease outbreaks with international systems. As soon as the system detects a potential disease outbreak it notifies stakeholders and experts. The system takes feedback from experts to improve the disease detection capabilities and to adapt to new situations.

KEYWORDS

Disease Outbreak Notification System, Saudi Arabia, Prototype, Outbreak

1. INTRODUCTION

Outbreaks such as MERS, SARS [1, 2], the threat of bio-terrorism (e.g. anthrax) [3] and Mad Cow diseases (BSE) [4] as well as the recent different strains of "bird flu" or Influenza (i.e., H1N1 and H5N1) [5] are the most intriguing and complex phenomena that confront scientists in the field of microbiology, virology and epidemiology [6, 7, 8]. The ability of these viruses to mutate and evolve is one of the acute mysteries that puzzle health officials, who are trying to find out the root cause of worldwide pandemics since the late 1880s. Pandemics occur when small changes in the virus over a long period of time eventually “shift” the virus into a whole new subtype, leaving the human population with no time to develop a new immunity.

Unlike bacteria, viruses are sub-microscopic and do not have a cellular structure [9]. Their essential component is genetic material—either DNA (Deoxyribonucleic Acid) or RNA (Ribonucleic Acid)—that allows them to take control of a host cell. Viruses reproduce by invading a host cell and directing it to produce more viruses that eventually burst out of the cell, killing it in the process.

Therefore, a tremendous and an unforeseen threat could mark the start of a global outbreak given the above mentioned scenarios, namely (a) the ability of the virus to shift into a whole new subtype, (b) the time shortage of the human population to develop a new immunity, (c) the

Natarajan Meghanathan et al. (Eds) : ACSIT, FCST, ITCA, SE, ICITE, SIPM, CMIT - 2014
pp. 01–14, 2014. © CS & IT-CSCP 2014 DOI : 10.5121/csit.2014.4601

limitation in terms of the effect of immunization, and (d) the viruses' ability to change to a form that is highly infectious for humans and spreads easily from person to person. Furthermore, as outlined by World Health Organization (WHO) and the World Organization for Animal Health (OIE) [10, 11], the international standards, guidelines and recommendations in an event of an outbreak state that member countries are obliged to notify within 24 hours epidemiological information with regards to occurrence/reoccurrence of listed notifiable diseases, the occurrence of a new strain of a listed disease, a significant change in the epidemiology of a listed disease, or the detection of an emerging disease.

The disease outbreak reports within specific time limits are required to be sent on the presence or the evolution of the listed diseases and their strains. It is apparent that the increasing threat of disease outbreak highlights the need to provide timely and accurate information to public health professionals across many jurisdictional and organizational boundaries. Also, the increasing frequency of biological crises, both accidental and intentional, further illustrates that Disease Outbreak Notification System (DONS) needs to be in place to meet the challenges facing today's society. Such DONS should prevent, prepare, and respond to an outbreak having the potential to affect humans and/or animals. The surveillance and management roles and responsibilities should be identified for a unified approach that considers humans, domestic animals, and wildlife.

The importance of such a system to Kingdom of Saudi Arabia (KSA) is tremendous. It is well known that the KSA is a vital hub for two major events: (a) around 2.5 million pilgrims from more than 160 countries take part in the Hajj in the holy city of Makkah every year during a very short time spanning only four weeks, and (b) around six million Muslims perform Umrah every year. These two events make KSA a fertile place for outbreaks as people fly into KSA from overseas every year. As such, a contagious disease outbreak overseas such as MERS, H1N1 or H5N1, whether natural or due to bioterrorism can spread long before an epidemic is recognized. This will not only jeopardize people's health but also impact worldwide because pilgrims and those performing religious duties will eventually return to their countries and can spread the disease worldwide.

This paper, as stated previously, focuses on the design and prototype implementation of a DONS for KSA. The rest of the paper is organized as follows. Section 2 discusses the existing methodology of disease outbreak monitoring in Saudi Arabia. Section 3 describes the proposed architecture of the system. Section 4 provides implementation detail and results from the prototype system implemented. Finally, Section 5 outlines the conclusions reached from our work.

2. THE CURRENT SYSTEM IN KINGDOM OF SAUDI ARABIA (KSA)

The Saudi Ministry of Health (MoH), by way of its objectives, policies and projects seeks to deliver the best-quality integrated and comprehensive healthcare services throughout the Kingdom. According to the MoH website (http://www.moh.gov.sa/), the MoH is committed to the provision of healthcare at all levels, promotion of general health and prevention of diseases. MoH is also accountable for performance monitoring in health institutions, along with research activity and academic training in the field of health investment. In this section, we analyze and present the processes and data flow of the current health systems for infectious diseases.

The process of analysis of the current system started in this project two years back in March 2012. The MoH is presently in the process of implementing a cloud-based health system with IBM which was initiated in May 2013 [55]. The MoH plans to fully integrate to the new cloud-based system for reporting diseases in three to five years. This cloud-based implementation at

MoH aligns with our vision as proposed in our work and outlined in the design and architecture of KSA DONS in this paper.

2.1 PROCESS AND DATA FLOW OF THE CURRENT SYSTEM

The current system is a manual system that consists of four main entities, namely, the Local Healthcare Unit (LHU), the Primary Healthcare Center (PHC), the Directorate of Health Affairs (DHA), and the Ministry of Health (MoH) [12]. A LHU can be a hospital belonging to MoH or other government sectors, private hospitals, private dispensaries, and private clinics. The main tasks of a LHU include: {a} discover new cases and notify PHC about its discovery; {b} isolate the cases of infectious diseases; {c}confirm the diagnosis; {d} conduct treatment; {e} conduct epidemiological survey; and {f}record disease status [12].

The main tasks of a PHC include: {a} epidemiological surveillance of infectious diseases in the affiliated areas of health care centers and work to limit and contain epidemics; {b} review forms survey epidemiological and procedures; {c} follow-up cases that are subject to treatment and provide feedback; {d} take the necessary preventive measures;{e} data collection, conducting statistics, and reporting the cases and mortality rates of infectious disease; and {f} notify the regional directorate of health affairs [12].

The DHA functions at the regional level and its main tasks include: {a} compile the forms of communicable diseases received from PHCs; {b} monitor, analyze and extrapolate epidemiological data received from LHUs and PHCs to identify trends in disease and detect epidemics; {c} take preventive measures; {d} identify people and places most vulnerable to disease; and {e} report to MoH and send feedback to LHUs and PHCs [12]. The main tasks of the MoH include: {a} development and implementation follow-up of policies and plans for the prevention and control of communicable diseases; {b} monitor and control epidemic infectious diseases in the Kingdom; {c} receive regular and monthly reports of infectious diseases with analysis and extrapolation of data; {d} identify and provide vaccinations to the areas most vulnerable to infectious diseases; {e} monitor epidemiological diseases regionally and globally and develop the necessary policies to prevent its arrival and spread in the Kingdom; and {f} report the diseases that are subject to international health regulations to the World Health Organization (WHO) [12].

The flow of reporting among these entities is shown in Figure 1.

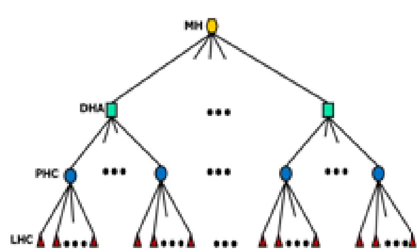


Figure 1 : Information flow among entities of the current KSA System

When a new case is discovered, the Infection Control department collects the data from the LHU where the disease occurred. Then, the data is accumulated at the district level by the PHC followed by the DHA at the province level. Finally, the accumulated data is analyzed and monitored by the preventative sector for communicable diseases at the MoH. This notification process is shown in Figure 2.

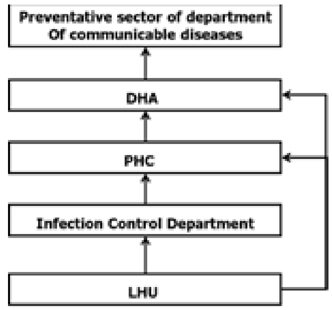


Figure 2 : The notification channel between the 4 entities of the current system

The current system presently handles 35 notifiable diseases [12]. These diseases are classified into 2 classes. The first class consists of quarantinable diseases, such as, Avian influenza, H1N1 (Swine Flu), SARS. Cases of this class of diseases are reported immediately by the LHU or PHU to the corresponding DHA by fax, or telephone. Table 1 lists the diseases of this class.

Table 1 : Quarantinable diseases which are reported immediately

Cholera	Diphtheria	Acute F. Paralysis	Dengue Fever
Yellow fever	Measles	guillain-barré syndrome	Rift V Fever
Plague	Tetanus	myelitis Transverse	Hemmorhagic Fevers Other
Mumps Neonatorum	German measles	Enceph/Mening	

The second class consists of communicable diseases, such as Chicken Pox, Echinococus, Hemolytic Uremic Syndrome, as listed in Table 2. Each case of this class of diseases is reported weekly, by the LHU or the PHU where the disease occurred, to the corresponding DHA. The DHA then reports these cases monthly to the MoH. Each disease is reported with its degree of specificity which is either a suspect (low specificity), or probable, or confirmed (high specificity) [12].

Table 2 : Notifiable diseases which are reported monthly

Tetanus	Hepatitis A	Salmonellosis	Hemolytic Uremic Syndrome
whooping cough	Hepatitis B	Malta Fever	Pneumococcal Meningitis
German Measles in new born	Hepatitis C	Shigellosis	Hemophylus Influenza Meningitis
Typhoid & Para typhoid	Hepatitis Other	Echinococus	Meningitis Other
Amebic dysentery	chicken Pox	Rabies	

The process flow of both classes of diseases is shown in Figure 3. As indicated in the figure, the process flow spans across various entities including the Saudi National Health Authority (NHA) and WHO. The two process flow differ in the frequency of reporting which is immediate in quarantinable while weekly/monthly in communicable diseases.

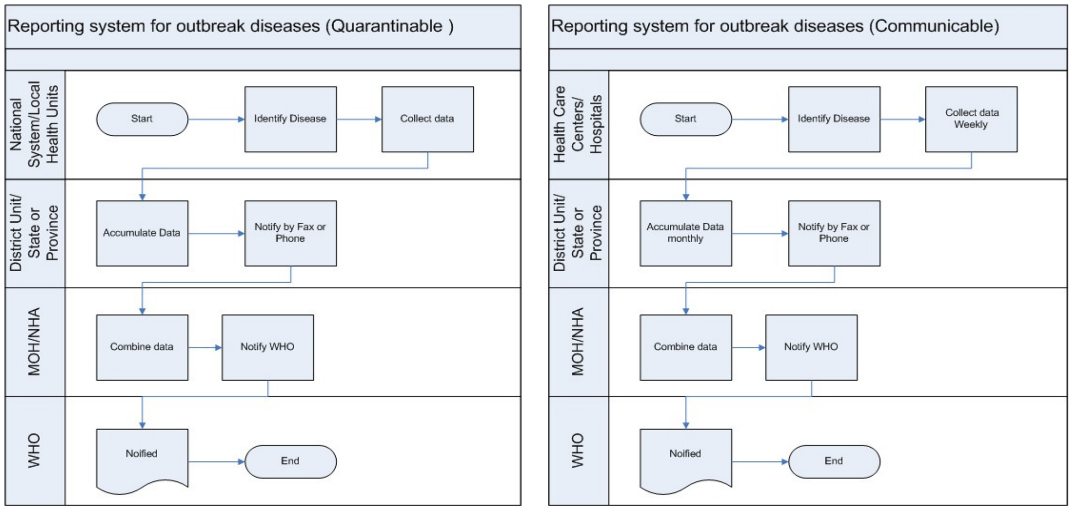


Figure 3 : Process flow for both quarantinable and communicable diseases

2.2 SAUDI HEALTH ELECTRONIC SURVEILLANCE NETWORK (HESN)

The Saudi HESN is a comprehensive, integrated public health information system that helps public health professional work together to efficiently manage individual cases, outbreaks, immunizations, and vaccine inventories. The new cloud-based system will provide public health professionals with tools to better protect the health of the Kingdom's citizens with a secure, easy-to-use application to collect, share and analyze health information critical in managing public health outbreaks such as SARS, influenza and any other communicable diseases [13]. IBM and Saudi Ministry of Health have announced the successful implementation for the first stage in Jeddah, Makkah, Taif and Qunfudah on May 2013 [14]. The program will be in place throughout the entire Kingdom within three to five years.

The goal of the system is to improve public health, as it cuts down the need for paperwork, consolidation of operations and health forms and reports in the entire Kingdom in electronic form, which in turn will increase the accuracy of the data and reduce the difference in monitoring between areas and facilities of the Ministry of Health, and increases the personal and professional skills of the staff.

The HESN system has unique characteristics such as protects public health through the prevention, detection and management of communicable disease occurrences, enables collaboration (interoperability), and follows industry standards (HL7 messaging, SNOMED).
The HESN system is flexible to suit the requirements of health care [15], which vary according to geographical area. The system provides predefined forms and installed on the system and ready to be filled by the users. HESN allows the users to configure a new report form to enter new information about health conditions that are not monitored by the system, and to collect data commensurate with the needs of the region or the program or the situation. The HESN system allows the owners of the powers of the user access to the reports, notification forms and extracts data (Business Object Universes).

The HESN system will not guarantee all units in the public health system to monitor and manage diseases. The major components in the first stage are [15] include communicable disease case management, outbreak management, immunization management, family health materials, vaccine inventory management, notifications and work management.

3. THE PROPOSED KSA SYSTEM

In this section, we present our effort as the proposed Disease Outbreak Notification System (DONS) for the Kingdom of Saudi Arabia (KSA), which we will refer to as KSA DONS. This system is designed to detect potential disease outbreaks within KSA and notifies preregistered experts about the outbreak. In order to come up with a sound design for KSA DONS, our effort was concentrated on the functionalities and features of a typical and generic DONS. Using the taxonomy and critical features generated in that effort, we mapped those features and functionalities to the KSA DONS design.

3.1 CRITICAL FEATURES IN KSA DONS

Based on the taxonomy of various DONS implementation world-wide that we studied, we have identified the critical features that our KSA DONS should have. These features are shown in Tables 3 and 4.

Table 3 : Core features of the proposed KSA DONS

	Collection & Analysis						**Core Functions**							
	Collection				Analysis		Case-Level		Group-Level			Notifications		
System Name	Stakeholders	Data Sources	Collection Strategy	Data Formats	Computation Detection Algorithms	Statistical Analysis	Detection	Confirm & Register	Signal Extraction	Interpretation	Reporting	Communication Procedures	Target Entities	Output/Message Formats
Existing KSA DONS	✓	✓	✓	✓								✓	✓	
Proposed KSA DONS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 4 : Additional features of the existing KSA DONS

	System Features														**Support Functions & System Interfaces**							
	Attributes														Support Functions					Networking& Partnerships		
System Name	Completeness	Timeliness	Usefulness	Real-time	Coverage	Portability	Sensitivity	Availability	Accessibility	Usability	Interface Design	Mobility	Flexibility	Specificity	Standards	Training	Communication	Monitoring & Evaluation	System Administration	Experts & Institutions	Coordination	Feedback
Existing KSA DONS			✓		✓					✓										✓		
Proposed KSA DONS	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓

4. KSA DONS PROTOTYPE IMPLEMENTATION

A prototype was implemented as a proof-of-concept (PoC). The prototype was a hybrid implementation using a multi-tier architecture spread across physical hosts and the private research cloud infrastructure at KFUPM. The prototype implementation was thoroughly tested for functional and technical performance with a considerably large dataset of diseases and cases. Integration testing between the various modules of KSA DONS was done as well. The prototype KSA DONS is deployed on the KFUPM Cloud Infrastructure service called KLOUD. KFUPM cloud service offers servers and storage as per required specifications from a wide range of available infrastructure templates.

The detection algorithms used in the KSA DONS were selected and adapted after a thorough study of all algorithms from selected DONS systems. We have used five efficient algorithms that are used in CASE system [16]. These five algorithms can detect isolated cases of known diseases and their potential outbreaks. Our preference for these algorithms was based on the fact that the coverage of the list of known diseases included in KSA DONS is handled by these detection algorithms. We have also implemented an outbreak detection algorithm for unknown diseases using data mining techniques. Our implementation uses expert epidemiologists for consultation purposes to confirm outbreaks.

We have adopted a three-tier system architecture which supports features such as scalability, availability, manageability, and resource utilization. Three-tier architecture - consisting of the presentation tier, application or business logic tier and data tier - is an architectural deployment style that describes the separation of functionality into layers with each segment being a tier that can be located on a physically separate entity. They evolved through the component-oriented approach, generally using platform specific methods for communication instead of a message-based approach. This architecture has different usages with different applications. It can be used in web applications and distributed applications. The strength of this approach in particular is when using this architecture for geographically distributed systems. Since our platform is cloud-based and geographically spread across the Kingdom, we were motivated to use this three tier architecture for our prototype implementation.

In our implementation, the methodology used is as follows:

- The presentation tier is through the network using wired and wireless devices.
- The application or business logic tier is entirely hosted on virtual hardware on the cloud platform
- The data tier is hosted on physical servers

The application development tools in implementation of the KSA DONS are JCreator, PHP, and Java. The database development tools used in the implementation of the KSA DONS are MySQL, Oracle SQLPLUS, and Oracle SQL Developer.

The presentation tier is the topmost level of the application. The presentation layer provides the application's user interface. Typically, this involves the use of Graphical User Interface for smart client interaction, and Web based technologies for browser-based interaction. As shown in the Figure 4, the terminals for primary health centres and experts use the DONS browser-based application for data entry and decision making.

The application tier controls an application's functionality by performing detailed processing. The application or the business logic tier is where mission-critical business problems are solved. The components that make up this layer can exist on a server machine, to assist in resource sharing.

These components can be used to enforce business rules, such as business algorithms and data rules, which are designed to keep the data structures consistent within either specific or multiple databases.

Because these middle-tier components are not tied to a specific client, they can be used by all applications and can be moved to different locations, as response time and other rules require. In Figure 4, the web servers and application server constitutes the logic tier. A cluster of web servers and applications servers can be used for load balancing and failover among the cluster nodes.

The data tier consisting of database servers is the actual DBMS access layer. It can be accessed through the business services layer and on occasion by the user services layer. Here information is stored and retrieved. This tier keeps data neutral and independent from application servers or business logic. Giving data its own tier also improves scalability and performance. In Fig. 2, the database servers and the shared storage constitute this tier.

The flow of data in the three tiered architecture is described next. In the presentation layer, the users access the DONS applications over the network through the web browser. The request is securely sent over the network to a firewall. Then the trusted requests from the firewall are forwarded to load balancers. The firewall ensures that trust relationships between the presentation and application tiers are complied with. The trusted requests are sent to a DNS server for name resolution and to load balancers which are capable of distributing the load across the web servers and manage the network traffic.

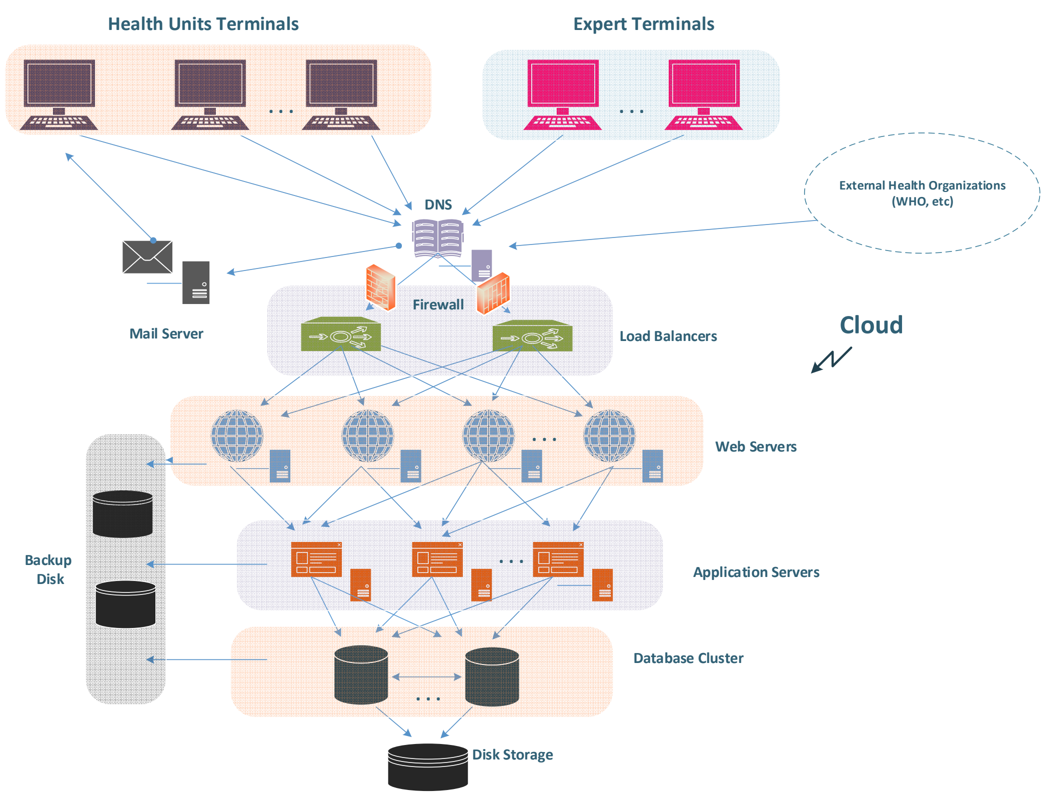


Figure 4 : KSA DONS Prototype System Architecture

In the logic tier of the KSA DONS, web and application servers are deployed to handle all user requests. While the user requests (http or https) are served by the Apache web servers, the application servers handle all the business logic processing and data processing. The data tier provides all the data needed for the logic tier through SQL queries using database specific protocol over TCP/IP. The database tables are maintained by insertion, updating and deleting of data. To avoid loss of data due to data corruption or system failure, the data backup of all the critical servers and databases is performed periodically in a separate storage location. The data retention policy is applied for timely recovery of data in case of any disaster.

4.1 PROTOTYPE APPLICATION TIER

The prototype implementation of the generic KSA DONS architecture, described in the previous section, utilizes the KFUPM research cloud KLOUD and associated hardware and software tools. In this section we describe all the entities, software and tools used in this tier. A prototype is shown in the Figure 5 and contains the following entities: Health Unit 1, Health Unit 2, Eastern Province Health Department and MoH (Ministry of Heath), Database System, Experts and Users. Health Unit 1 and Health Unit 2 are physical units with Windows 2008 Server operating system (DELL OptiPlex 9010 server). Eastern Province Health Department client is a KLOUD virtual machine with Red Hat Linux 6.4 as its operating system. Ministry of Health (MOH) is also a KLOUD virtual machine with Windows Server 2008 server on it. The database server is again a physical server with Red Hat Linux 6.3 operating system. The Oracle client software was configured on all the servers and clients mentioned in the above figure in order to communicate with each other and to connect to the database server. The web services offered to the clients are configured on an Apache web server on MoH KLOUD virtual server for accessing the application tier of KSA DONS.

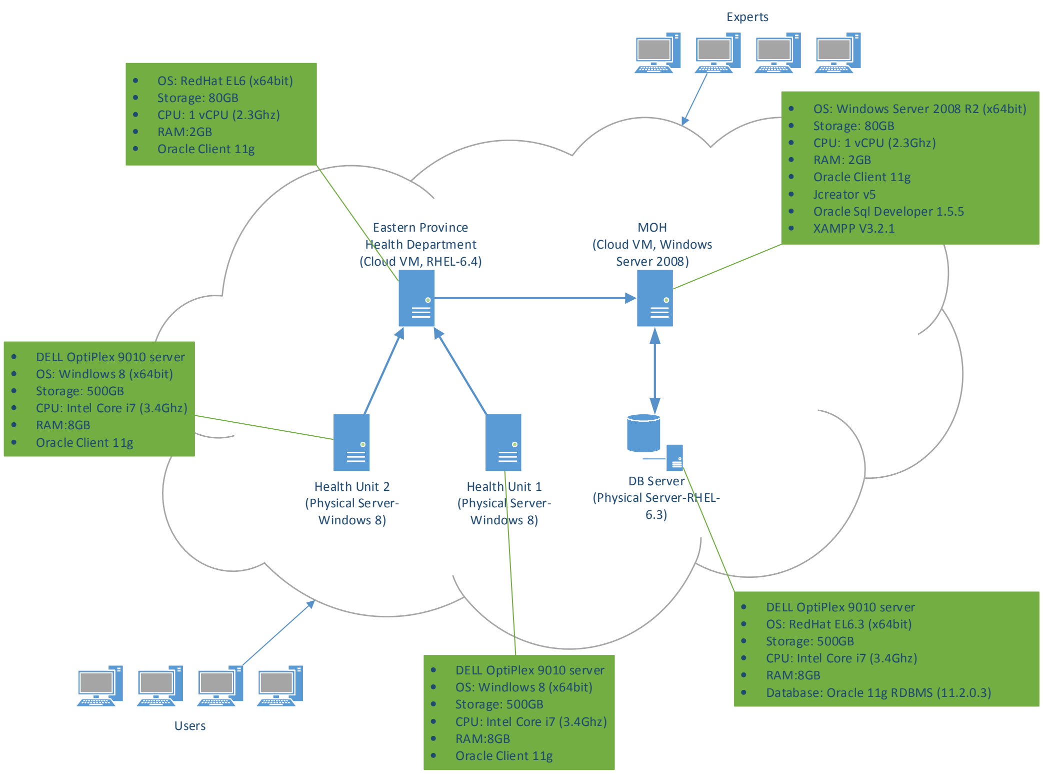


Figure 5 : Prototype System Architecture for the Application Tier

In many disease notification systems, the users had to be manually notified of any new outbreak. In the KSA DONS prototype system, we have developed an application to automate this notification procedure.

Figure 6 shows the data flow of notification delivery system in KSA DONS.

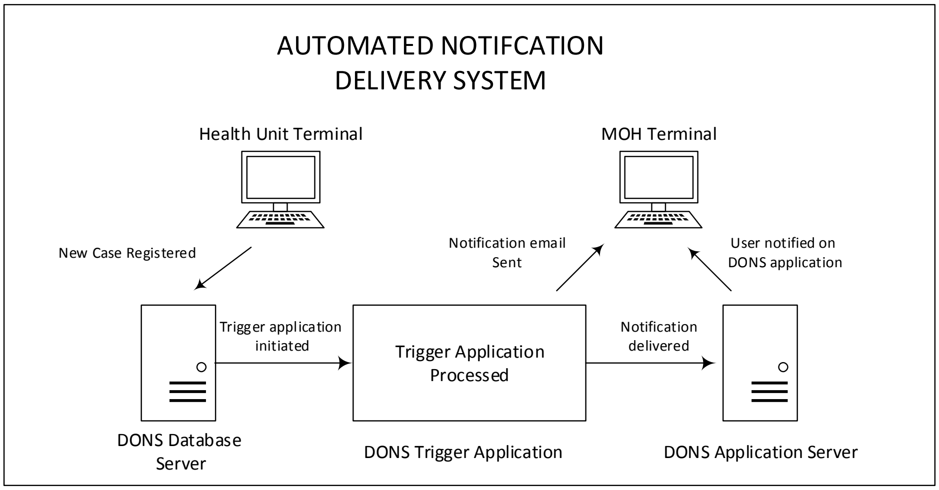


Figure 6 : Data flow in the Notification Delivery System in KSA DONS

Whenever a new disease is registered by the Health Units in the DONS database, a trigger defined in the database runs the trigger application. This application is responsible for delivering the disease notification to the DONS application server over the network, which in turn notifies the appropriate/responsible user in MOH. The trigger application also sends the notification to the email box of the users. The technical details of this implementation of the data flow of notification delivery system in KSA DONS are shown in
Figure 7 .

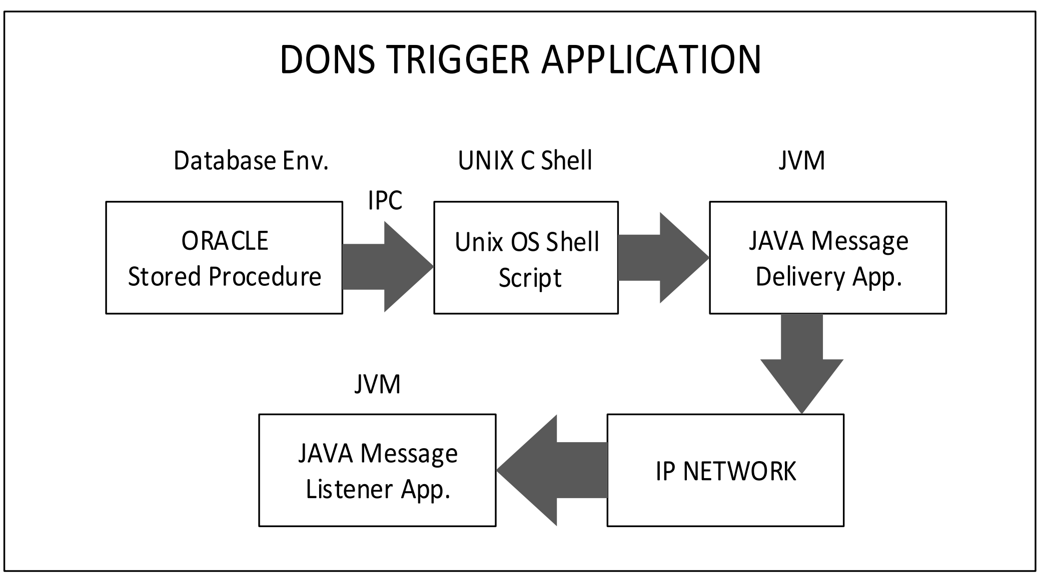


Figure 7 : Technical Implementation of the Notification Delivery System in KSA DONS

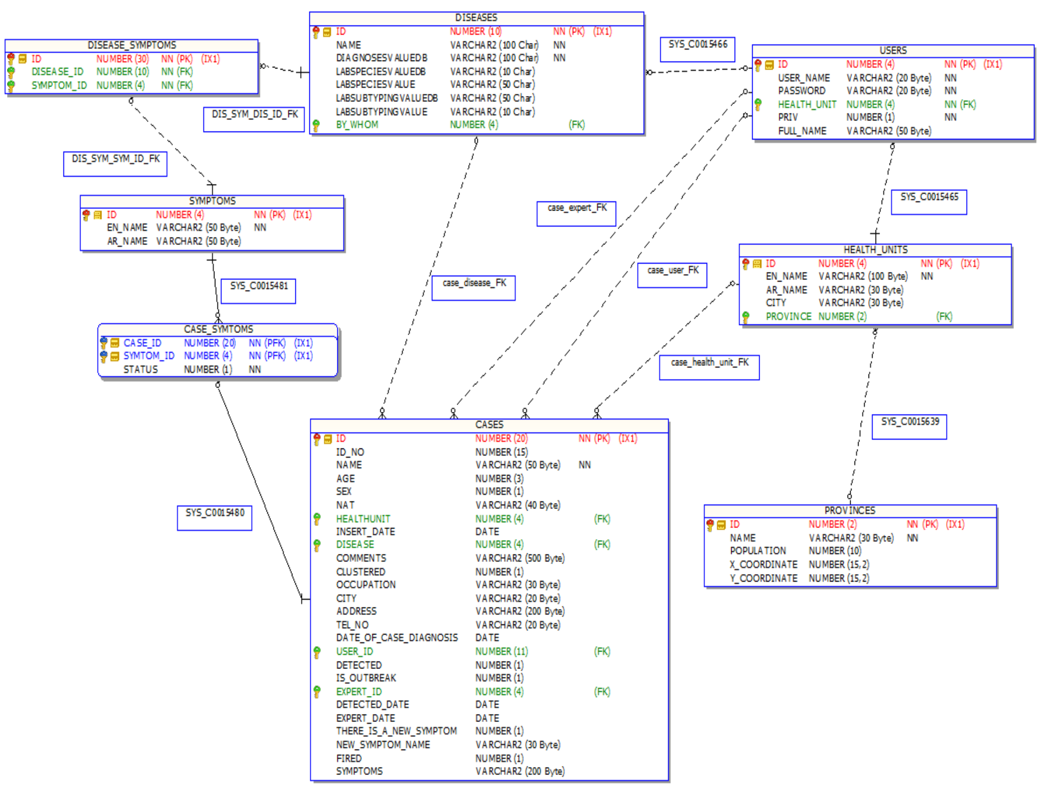
The entire process implemented in the trigger application shown in
Figure 7 is described here. A new disease case is registered in the database by inserting a row of data in a CASE table. A trigger is defined in the DONS database which executes a stored

procedure whenever a row of data is inserted in the CASE table. The stored procedure from the database environment calls a shell script present in the operating system (OS) environment through an Inter Process Communication (IPC).

This shell script is a batch program which can perform multiple tasks sequentially. The shell script runs a Java-based message delivery application within a JVM and also sends the notification e-mail to the end users. The message delivery application sends the notification message over the network to DONS application residing on the application server. At the application server, a message listener application continuously monitors an application port for notification message reception.

4.2 PROTOTYPE DATA TIER

The data tier implemented in the KSA DONS prototype implementation went through two phases of development. Initially, the open database development platform MySQL was used in the prototype development. At a later stage, the entire database with all the associated objects such as the database schema, stored procedures, triggers etc., were migrated to the Oracle database platform. The database server is configured with Oracle Version 11gR2 relational DBMS and was created database using DBCA utility. The data from MySQL database was migrated to the Oracle database using SQL Developer utility offered by Oracle. The complete KSA DONS database schema on the Oracle platform is shown in Figure 8.



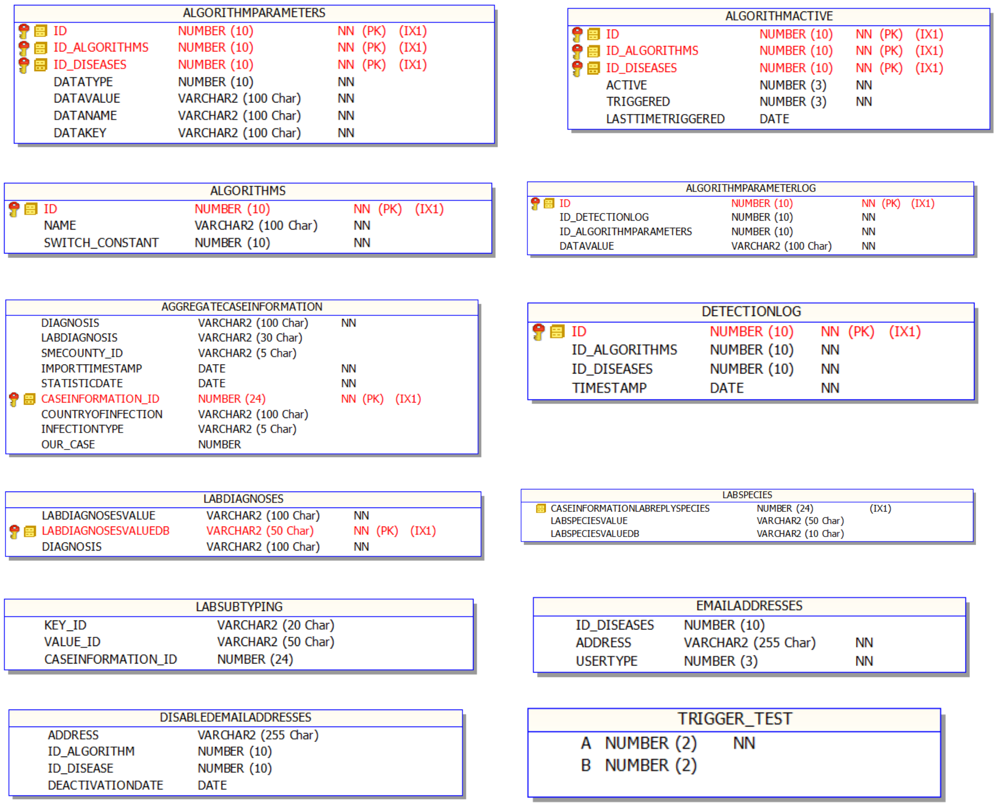


Figure 8 : Complete KSA DONS Database schema on the Oracle platform

5. CONCLUSIONS

This paper describes the design and development of Disease Outbreak Notification System (DONS) in Saudi Arabia. The main function of DONS is to warn for potential outbreaks. The KSA DONS is an online/real-time disease outbreak notification system built for Saudi Arabia. The system notifies experts of potential disease outbreaks of both pre-listed diseases and totally unknown diseases. The system only accepts cases from pre-registered sources. It also shares information about disease outbreaks with international systems. As soon as the system detects a potential disease outbreak it notifies stakeholders and experts. The system takes feedback from experts to improve its disease detection capabilities and to adapt to new situations. A prototype implementation in a hybrid cloud environment was completed to validate the design of the system.

ACKNOWLEDGMENT

The authors would like to acknowledge the support provided by the Deanship of Scientific Research at King Fahd University of Petroleum & Minerals (KFUPM). This project is funded by King Abdulaziz City for Science and Technology (KACST) under the National Science, Technology, and Innovation Plan (project number 11-INF1657-04).

REFERENCES

[1] C. Leung, M. Ho, and A. Kiss, "Homelessness and the response to emerging infectious disease outbreaks: lessons from SARS," J. Urban Heal., vol. 85, no. 3, pp. 402–410, 2008.
[2] M. Muller and S. Richardson, "Early diagnosis of SARS: lessons from the Toronto SARS outbreak," Eur. J. Clin. Microbiol. Infect. Dis., vol. 25, no. 4, pp. 230–237, 2006.
[3] M. Donohoe, "Internists, epidemics, outbreaks, and bioterrorist attacks," J. Gen. Intern. Med., vol. 22, no. 9, p. 1380, 2007.
[4] W. Slenczka, "Mad cow disease.," Emerg. Infect. Dis., vol. 7, no. 3 Suppl, p. 605, 2001.
[5] N. Cohen, J. Morita, D. Plate, and R. Jones, "Control of an outbreak due to an adamantane-resistant strain of influenza A (H3N2) in a chronic care facility," Infection, 2008.
[6] Guidelines for Outbreak Prevention , Control and Management in Acute Care and Facility Living Sites. Alberta Health Services, 2013, pp. 1–54.
[7] G. Cruz-Pacheco, L. Esteva, and C. Vargas, "Seasonality and outbreaks in West Nile virus infection.," Bull. Math. Biol., vol. 71, no. 6, pp. 1378–93, Aug. 2009.
[8] D. Tam, S. Lee, and S. Lee, "Impact of SARS on avian influenza preparedness in healthcare workers," Infection, vol. 3, no. 5, pp. 320–325, 2007.
[9] R. M. Roop II, J. M. Gaines, E. S. Anderson, C. C. Caswell, and D. W. Martin, "Survival of the fittest: how Brucella strains adapt to their intracellular niche in the host," Med. Microbiol. Immunol., vol. 198, no. 4, pp. 221–238, 2009.
[10] "WHO | Influenza at the Human-Animal Interface (HAI)." [Online]. Available: http://www.who.int/influenza/human_animal_interface/en/. [Accessed: 11-Feb-2014].
[11] "Prevention and control of animal diseases worldwide. Economic analysis- Prevention versus outbreak costs. Final Report. Part 1, September 2007." [Online]. Available: http://www.oie.int/fileadmin/Home/eng/Support_to_OIE_Members/docs/pdf/OIE_-_Cost-Benefit_Analysis__Part_I_.pdf.
[12] "Guidelines for epidemiological surveillance and preventive measures for infectious diseases." [Online]. Available: http://qh.gov.sa/uploads/files/.
[13] "Health Electronic Surveillance Network." [Online]. Available: http://www.moh.gov.sa/Hesn/Pages/default.aspx.
[14] "IBM, Saudi Health Ministry rolls out cloud-based system.," May-2013. [Online]. Available: http://www.arabnews.com/news/450055.
[15] "HESN FAQ LEAFLET.," Mar-2013. [Online]. Available: http://www.moh.gov.sa/Hesn/Versions/Documents/HESN\ FAQ\ LEAFLET\ -\ ARABIC.pdf.
[16] B. Cakici, K. Hebing, M. Grünewald, P. Saretok, and A. Hulth, "CASE: a framework for computer supported outbreak detection," BMC Med. Inform. Decis. Mak., vol. 10, no. 1, p. 14, 2010.

AUTHORS

Farag Azzedin is an associate professor at the Department of Information and Computer Science, King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia. He received his BSc degree in Computer Science from the University of Victoria, Canada. He received an MSc degree as well as a PhD degree in Computer Science from the Computer Science Department at the University of Manitoba, Canada.

Salahadin Mohammed is an assistant professor at the Department of Information and Computer Science, King Fahd University of Petroleum and Minerals (KFUPM). He received his BS and MS degrees in Computer Science from KFUPM. He received a PhD degree in Computer Science from the Computer Science Department at the Monash University, Melbourne, Australia.

Jaweed Yazdani is a faculty member at the Department of Information and Computer Science and the manager of Administrative Information Systems (ADIS) at King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia. He received his MS degree and BS degrees in Computer Science from KFUPM.

Mustafa Ghaleb earned his BS in computer science at King Khalid University (KKU), Abha, KSA in 2007. At the moment, he is pursuing his MS degree in Information & Computer Sciences at King Fahd University of Petroleum & Minerals (KFUPM).