International Journal of Trend in Research and Development, Volume 3(6), ISSN: 2394-9333
www.ijtrd.com

# Multi-agent Based Surveillance System for Diseases

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***Abstract***—In this paper the authors make a case for medical care practitioners and governments to harness the power of technology to improve surveillance of diseases. Thus, using the multi-agent technology based surveillance system for diseases as a solution to the surveillance problems facing the healthcare sector in Kenya and the entire continent of Africa. The current surveillance problem is as a result of disease cases being carried out in a manual, inefficient and ineffective manner. An agent oriented methodology –Prometheus was used in the analysis, design, implementation and evaluation of a program designed to assist medical care practitioners..

***Keywords—****Surveillance; Muti- agent ; System; Diseases*

## I. INTRODUCTION

Surveillance is particularly important for the early detection of outbreaks of diseases. In the absence of surveillance, disease may spread unrecognized by the responsible health care or public health agency, because sick people would be seen in small numbers by many individual health care workers. By the time the outbreak is recognized, the time to take intervention measures might have been over. Surveillance is essential for the early detection of emerging (new) or re-emerging (resurgent) infectious diseases. In the absence of surveillance, individual health care workers may not recognize the new disease.

The challenge facing most Governments especially Kenyan Government is to get information on patients suffering from the various health institutions ,visitors entering the country , voluntary testing centre‟s (VCT‟s) centre’s within the country and be able to analyze the same information in a timely manner so that decisions can be made immediately. A critical challenge in the health sector in developing countries is to ensure quality and effectiveness of surveillance and public health response in an environment of decentralization. In September 1998, the 48th meeting of the Regional Committee for Africa was held in Harare, Zimbabwe. Through resolution AFRO/RC48/R2, member states adopted IDSR as a regional strategy.

### *Approaches to Surveillance case studies*

CASIS [1] is an event-driven service-oriented and multi-agent system framework whose goal is to provide context-aware healthcare services to the elderly resident in the intelligent space. CASIS framework allows remote caretakers, such as concerned family members and healthcare providers, to closely monitor and attend to the elders physical and mental well-beings anytime, anywhere. The smart environment interacts with the elder through a wide variety of appliances for data gathering and information presentation. The environment traces the location and specific activities of the elder through sensors, such as pressure-sensitive floors, cameras, bio-sensors, and smart furniture. Meanwhile, the elder receives multimedia messages or content through speakers, TV, as well as personal mobile devices. The caregivers may access the elder’s health and dietary information through any Web enabled device like a PC or PDA. Context-aware computing enables the environment to respond at the right time and the right place, to the elders needs based on the sensor data collected. However, this does not address the analysis and evaluation of health cases.

United States of America (U.S) providers have been experimenting with adopt health information technology (HIT) since at least the 1960s. Though high-quality data about HIT adoption is fairly thin, the best studies indicate that about 17–24% of physicians in outpatient settings use electronic health records (EHRs). The outlook in the hospital sector is considerably brighter. According to a 2007 American Hospital Association survey of its members, 68% reported fully or partially implemented electronic health records in 2006. However, only about 11% reported fully implemented electronic health records. Hospitals in the second category are likely to be large, urban, or teaching hospitals.

The technological challenges experienced are:-EHRs do not integrate with other provider software, are difficult to use, do not passively report quality metrics, and suffer from a variety of other issues and also that providers have been trained to conduct medicine based on decades-old workflow, which is not conducive to new technologies.

One of the key areas identified is its present failure to capture the necessary data, with particular emphasis placed on chronic disease cases including HIV/AIDS as the largest and most costly challenge in a country with a generalized epidemic. Another area of major concern are availability of data to effectively manage complex acute conditions such as medical, psychosocial and forensic care for survivors of gender based violence. Despite the acknowledged importance of monitoring and evaluation in the health sector, the system has not been adequately targeted for development and expansion to date and remains highly fragmented and uncoordinated.

The following are some of the syndromic surveillance systems used for global public health status monitoring systems:-

1. BioSense system is an initiative to support early outbreak detection by providing technologies for timely data acquisition, near real-time reporting, automated outbreak identification, and related analytics[2]. BioSense collects ambulatory care data, emergency room diagnostic and procedural information from military and veteran medical facilities, and clinical laboratory test orders[2]. BioSense also monitors over-the-counter (OTC) drug sales, and laboratory test results. BioSense aims to monitor 11 syndrome categories including fever, respiratory, gastrointestinal illness (GI), hemorrhagic illness, localized cutaneous lesion, lymphadenitis, neurologic, rash, severe illness and death, specific infection, and botulismlike/botulism.

BioSense receives data from its sources using XML into either an oracle or SQL server database. Tagging and parsing is then done on the data before using ETL tools to finally load the data to another SQL server and a GIS server. The web application server reads data from the two servers after analysis has been done. Still, this does not address surveillance of HIV /Aids & tuberculosis cases.

2. Biological Spatio-Temporal Outbreak Reasoning Module (BioStorm) aims to integrate disparate data sources and deploys various analytic problem solvers which consists of a data broker, a data mapper, a control structure and a library of statistical and spatial problem

Biostorm is developed using a JADE-based architecture for deploying a network of agents that focus on collaboratively analyzing one or more streams of data. The architecture has three layers: (1) a knowledge layer, containing all models that describe the problem decomposition, (2) an agent platform, which contains the deployed agents in a system, and a (3) data source layer, which represents a semantically characterized view of the external environment of the agents. However, this does not address the collection and evaluation of all diseases cases in the health sector.

Multi-agent systems therefore can be considered a suitable technology for the development of healthcare applications where the use of loosely coupled and heterogeneous components, the dynamic and distributed management of data and the remote collaboration among users are often considered the most relevant requirements. Multi-agent systems are one of the most interesting areas in software research and they have been importantly contributing to the development of the theory and the practice of complex distributed systems. In particular, they have shown their potential to meet critical needs in high-speed, mission-critical, content-rich, distributed information systems where mutual interdependencies, dynamic environments, uncertainty, and sophisticated control play a notable role [5]. However, on top of the challenges of establishing unified information system in the public sector there can also be substantial barriers to persuading non-state health providers to adopt the same information system as the one being used in the public sector. In many countries non-state provision can account for the large majority of health care provided so that data from non-state clinics and hospitals is critical for having a holistic picture of population health. Non-state providers may be reluctant to integrate into national information systems because of using their own established systems already (e.g. in faith based health networks) or because they are nervous of giving too much detail about their resource flows.

The vision of integrating information from a variety of sources, into the way people work, to improve decisions and process is one of the cornerstones of biomedical informatics. Thoughts on how this vision might be realized have evolved as improvements in information and communication technologies, together with discoveries in biomedical informatics, and have changed the art of the possible. There is little improvement because to integrate information, we must also integrate data mining and filtering [6]

Other researchers (Ana Ferreira et al., 2004) have focused on Virtual Electronic Patient Record (VEPR) which uses agent technologies for the retrieval and integration of clinical records in a VEPR, thus making patient information available at any point of care. An agent-based platform Multi-Agent System for Integration of Data (MAID) ensures the communication among various hospital information systems. Clinical reports are retrieved from clinical department information systems (DIS) and stored into a central repository in a browser friendly format. Documents are retrieved in HTML and PDF format and are digitally signed at storage [4]. However this does not give the required information for decision making.

Information technology and informatics can help in attaining the surveillance vision [7]. Specifically, technology can facilitate the collection, analysis, and use of surveillance data, if data standards are developed and compatible systems are established. Analysis of surveillance data can also be transformed by using available technology. Sophisticated algorithms can be applied to data as it is collected to determine when (and how) an alert should be sent to local, national, or even international health officials to indicate a need for immediate investigation [7]. It is therefore apparent that this realization is still far from being realized. While the technology exists to manage most of the direct causes of ill health and death, we are not yet able to adequately mobilize, and utilize this. Some of it is rather costly. However, some, though low cost, is not prioritized as required investment, or worse still is invested in but not adequately utilized. Harnessing the existing efforts and support towards efficient response to addressing our health challenges is still not yet ideal. The integrated disease surveillance and response (IDSR) guidelines developed by the World Health Organization (WHO) [8] seeks to:

1. Strengthen the capacity of health systems to conduct effective surveillance activities
2. Integrate multiple surveillance systems so that forms, personnel and resources can be used more efficiently and effectively
3. Improve the use of information for decision-making
4. Improve the flow of surveillance information between and within levels of the health system
5. Improve laboratory capacity and involvement in confirmation of pathogens and monitoring of drug sensitivity
6. Strengthen the involvement of laboratory personnel in epidemiological surveillance
7. Increase the involvement of clinicians in the surveillance system
8. Emphasize community participation in detection and response to public health problems

## II. MULTI AGENTS SYSTEMS (MAS)

A multi-agent system is a new paradigm for understanding and building distributed systems, where it is assumed that the computational components are autonomous: able to control their own behavior in the furtherance of their own goals.

Agent-based systems technology has been hailed as a new paradigm for conceptualizing, designing, and implementing software systems which are distributed in nature. Agents are sophisticated computer programs that act autonomously on behalf of their users, across open and distributed environments, to solve a growing number of complex problems. Increasingly, however, applications require multiple agents that can work together. In particular, multi-agents have shown their potential to meet critical needs in high speed, mission-critical, content-rich, distributed information systems where mutual interdependencies, dynamic environments, uncertainty, and sophisticated control play a notable role [5]. Multi-agent systems approach has offered the following advantages over a single agent or centralized approach:

1. Multi-agent system (MAS) distributes computational resources and capabilities across a network of interconnected agents.

2. MAS models problems in terms of autonomous interacting component-agents, which is proving to be a more natural way of representing task allocation, team planning, user preferences, open environments, and so on. 3. MAS efficiently

retrieve, filters, and globally coordinate information from sources that are spatially distributed.

4. MAS provide solutions in situations where expertise is spatially and temporally distributed.

5. MAS enhance overall system performance, specifically along the dimensions of computational efficiency, reliability, extensibility, robustness, maintainability, responsiveness, flexibility, and reuse.

MAS clearly contain many agents within the contextual environment. In addition to inter-agent communication, we need to recognize that, within MAS, agents need to both compete and cooperate. Although essentially selfish in their autonomy, agents act like humans: sometimes aiming to fulfil their own goals at the expense of all other agents/humans but mostly in a more social structure in which it is recognized that collaboration and sharing of work is mutually beneficial as well as individualistically profitable [9].

## III. PROMETHEUS METHODOLOGY

Agent-Oriented Methodologies presents, analyses and compares the most significant methodological approaches currently available for the creation of agent-oriented software systems [9]. There are different agent-oriented methodologies developed so far for example Gaia[12], Prometheus [12], MaSE[11], CommonKADS[13]. Prometheus is an iterative methodology covering the complete software engineering process i.e. Analysis, Design, Detailed Design, and Implementation. It has a complete lifecycle methodology for analyzing, designing and developing heterogeneous MAS [12]. It uses a goal-driven development and is independent of a particular multi-agent system architecture, programming language, or message passing system [10].

The following activities were carried out in multi-agent based surveillance system for diseases: (a) the system specification phase focused on identifying the basic functionalities of the system, along with inputs (percepts), outputs (actions) and any important shared data sources. (b) the architectural design phase used the outputs from the previous phase to determine which agents the system will contain and how they will interact and (c) the detailed design phase will look at the internals of each agent and how it will accomplish its tasks within the overall Multi-agent Based Surveillance System for diseases.

## IV. SYSTEM SPECIFICATION

The system specification activities are as follows: identifying the basic functionalities of the system, along with inputs (percepts), outputs (actions) and any important shared data sources. System Specification phase of Prometheus methodology entails defining the goal diagram, user case scenarios and functionality descriptors.

***Initial System Description***

The health personnel dealing with disease surveillance require information of diseases falling under the three categories i.e epidemic, diseases targeted for eradication and those for general information as they occur in the field. Use cases aid in separating the system into actors and use cases. Use cases form a set of possible sequences of interactions between system and users within the environment relating to a particular goal.

***Goal Diagram***

The overall system goal is to do surveillance on all diseases.

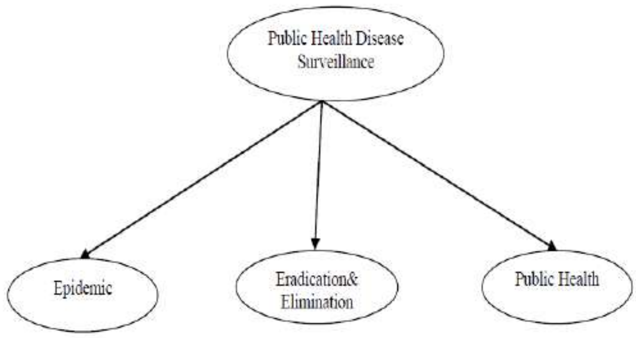


Figure 1: Goal diagram.

***Actors***

The main actors in the public health surveillance are as follows:-

a) Patient

An ill person presents himself/herself for medical attention. Information about the patient is recorded in the system. The system is to include information for both inpatients and outpatients. At a minimum, the following data are collected: the patient‟s Name, date of presentation at the, date of discharge (inpatient), village (location), age, diagnosis, treatment and outcome (inpatient only).

b) Doctor

If the clinician suspects a disease or condition that is targeted for elimination or eradication, or if the disease has high epidemic potential, the disease is reported immediately to the designated health staff. One action that is taken if an outbreak is suspected is to obtain laboratory confirmation. Laboratory specimens are obtained and the following data are documented: type of specimen, date obtained, date sent to the lab, condition of specimen when received in the lab and lab results. The investigation results are used to plan a response action with the health facility.

c) Surveillance Officers at Headquarters

The surveillance team at the headquarters waits for data to be sent from various health facilities across the country before analysis on the data is carried out.

Table I indicates the seven agents need in the Multi-agent based Surveillance System for diseases. Each agent has a role as indicated by its description.

Table 1: Agent Descriptors

| No | Agent type | Description |
|---|---|---|
| 1 | Communication Agent | Application interface to the outside work |
| 2 | Database(DB) Agent | Performs Database modifications checks |
| 3 | Surveillance Agent | Monitors incoming agents |
| 4 | Message Agent | Parses Incoming messages, and formats outgoing messages |
| 5 | Eradication Agent | Handles cases of diseases targeted for eradication |
| 6 | Epidemic Agent | Handles cases of epidemic |
| 7 | Health Information Agents | Handles cases of diseases that are meant for general information only |

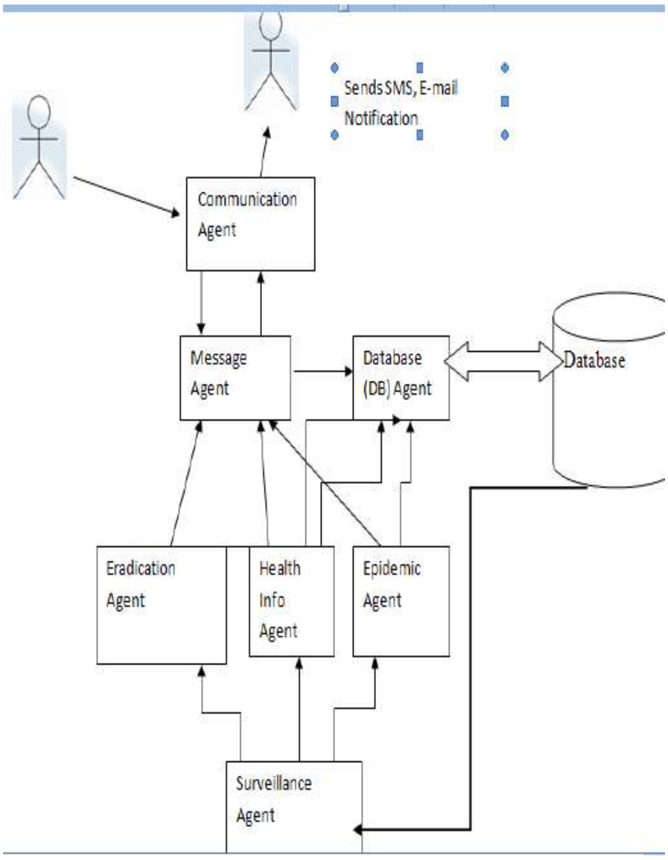


Figure 2: Technological infrastructure: system overview diagram

## V. DETAILED DESIGN

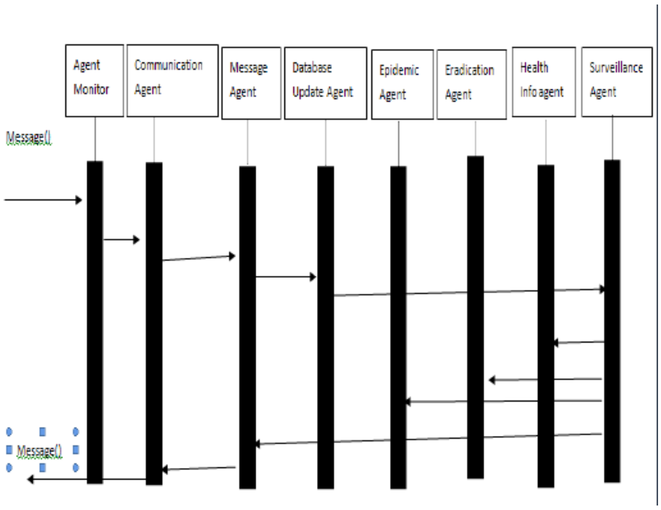


Figure 3: Interaction diagram

Fig. 3 indicates with clarity how the seven agents interact when they receive messages. Multi-agent based surveillance system for diseases is inherently modular and can handle a lot of data from distributed point.

## CONCLUSION

Multi-agent based surveillance system for diseases enables the faster analysis of data and continuous surveillance of cases as they happen.

Improved public health surveillance can lead to earlier implementation of prevention and control measures. More timely and accurate data facilitate earlier epidemic detection and control. With better surveillance data, the impact of intervention activities and other public health programs can be evaluated more accurately. An enterprise can thus accrue the benefits of continuous surveillance by deploying the Multi-agent based Multi-agent based surveillance system for diseases surveillance system for diseases.

Since Multi-agent based surveillance system for diseases is inherently modular, it is easier to add new agents to the multi-agent architecture to address future needs.

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