UNIVERSITY OF NAIROBI

COLLEGE OF BIOLOGICAL AND PHYSICAL SCIENCES

# MULTI-AGENTS BASED WIRELESS SENSOR TELEMEDICINE NETWORK FOR e-HEALTH MONITORING OF HIV AIDS PATIENTS

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A RESEARCH PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN COMPUTER SCIENCE OF THE UNIVERSITY OF NAIROBI

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## Declaration

This research project report is my original work and has not been submitted for any academic award in any other university.

Signed…… Date ……..

MUTURI MOSES KURIA

P58/76263/2012

This research project report has been submitted for examination as a partial fulfillment for the award of the Degree of Master of Science in Computer Science at the University of Nairobi with my approval as the University Supervisor.

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## Dedication

*I dedicate this project to my parents, my family and my brother Francis Mungai for their encouragement, mentorship and support, above all I thank God the Almighty for his Abundance Grace and Mercy.*

**Acknowledgement**
I would like to thank my Supervisors Dr. Elisha Opiyo for his continued support, guidance, Prof. Wagacha and Mr. Ogutu for their encouragement and critique throughout the project phases, Special thanks to my colleagues at the school of computing for their support.

**List of Abbreviations:**

HIV- Human Immunodeficiency Virus

AIDS- Acquired Immunodeficiency Syndrome

PLHIV-People Living With HIV

KNASP-Kenya National Aids Strategic Plan

NACC-National Aids Control Council

NASCOP-National Aids and STI Control Programme

ARV- Antiretroviral

BP-Blood Pressure

ECG- Electrocardiogram

JADE – Java Agent Development

MAS – Multi- agent Systems

OO – Object-Oriented

UML – Unified Modeling Language

WSN-Wireless Sensor Network

WLAN - wireless local area network

WiMAX - Worldwide Interoperability for Microwave Access

IEEE-Institute of Electrical and Electronics Engineers

UMTS -Universal Mobile Telecommunications System

WBANS-Wireless Body Area Networks

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## Abstract

This paper presents a design of a multi agent wireless sensor based network for health monitoring of HIV AIDS Patients, to address Poor monitoring program that is in the Care and monitoring of HIV infected people coupled by the few numbers of Specialists in Diseases related to HIV AIDS. Our approach is to use Multi-Agent and Wireless Sensor Technologies where the sensors collects, stores and analyze vital signs of the Patient. Signs such as body temperature, blood pressure, respiratory rate, viral load are monitored. The Multi Agent System acts as a manager to the sensors; the agent work is to collect and stores sensor information in a centralized database. The proposed Multi Agent System shall consists of four agents namely a Specialist Agent, Patient Agent, Local agent and Data agent the proposed multi agent based system shall be implemented using Java language in JADE environment. This research proposes a Prototype system in addition to use of agent technologies and Wireless Sensors as a Tool in monitoring of HIVAIDS.

# CHAPTER ONE: INTRODUCTION

## 1.1 Background

This research project focused on application of agents to manage data being transmitted by wireless sensor network in a telemedicine network, wireless sensors used for monitoring of patient vital signs in an AIDS Medical application. To ensure proper patient care real-time patient data must be managed correctly in the context of relevant Patient information and medical knowledge.

In this research we used agent technology to help in diagnosis, monitoring and administration of patient's information. An agent is defined as an object in the environment that perceives and reacts to states in the environment [Rusell and Norvig, 1995].

Agent technology encompassed use of a wireless sensor network; sensors were used to collect patient data, after collection data was sent to an agent system for analysis and tracking. According to [Yingshu Li *et al* 2008] Wireless sensor networks are currently being employed in a variety of applications ranging from medical to military.

An agent-based architecture in the management is used as a Data Management System and the objective is to provide effectiveness and security of data within a Wireless Sensor Network (WSN).

Wireless sensor networks are composed of small devices called sensor nodes with sensing, computing and radio frequencies communication capabilities. Sensor nodes are typically deployed in an ad-hoc manner and use their sensors to collect environmental [Powell, Nikoleseas 2007]

The proposed research seeks to eliminate distance barriers and improve access to medical services that would often not be consistently available in distant rural communities. It is also used to save lives in critical care and emergency situations

Telemedicine is described as the use of communication equipment to link health care practitioners and patients at different locations [(Lynn, James 2006]; telemedicine concept allows medical practitioners to carry out Tele-monitoring, Tele-consultation and Tele-diagnosis which

allows these experts to carryout diagnostics with medical instruments from a remote location [(Lynn, James 2006]

### 1.2 Statement of the Problem

Access to healthcare has been a challenge to many Kenyans, mostly those in remote areas which do not attract specialists in different diseases, in such remote areas most people travel for long distances to access specialist quality healthcare which are only accessible in urban metropolitan centers.

Kenya has seen many efforts go to the prevention of HIV/AIDS but the disease continue killing people, this is mostly attributed to the HIV/AIDS related diseases such as tuberculosis and diabetes of the already infected people, yet this deaths can be further reduced by application of better monitoring, care and e-wellness programs.

According to the KNASP there is a big Mismatch between service provision and geographical prevalence, it is approximated that 70% of PLHIV live in rural areas, but services are concentrated in urban/peri-urban areas [NACC, 2009]. Hence access to medical services/specialists Medical care in rural regions is not immediately ensured at all times.

Poor monitoring program that is in the Care and monitoring of infected peoples, the current strategies present are inadequate mostly on care and nutrition according to [NACC 2009]. Only 38 to 45% of those in need of treatment are being reached at present, 3 PLHIV are still at the risk of dying due to lack of access to treatment.

Poor administration of medicines such as ARV'S, this has seen use of SMS reminders to patients and establishment of treatment literacy initiatives. Though Additional efforts are needed to promote maintenance in care, for example one in three antiretroviral patients are no longer enrolled in care two years after starting therapy [NACC, NASCOP 2012], hence there is need to invest in information systems to manage ARV'S administration.

Few numbers of specialists in disease related to HIV AIDS. Kenya continues to struggle with a health worker shortage, with only 0.1 physicians available to serve every 1,000 people compared to 7.9 in the Euro zone. With the aim of strengthening the evidence base for health policy

making [NACC, NASCOP 2012]

## 1.3 Objectives

**Research objectives**

(i) To research the developments in the area of multi agents managed wireless sensor networks.

(ii) To explore on how multi agent system can be integrated with wireless sensors technology to eliminate distance barriers and improve access to medical services to distant rural communities.

(iii) To investigate how multi-agent wireless sensor technology can be used to reduce the spatial gap between the patient and the consultant.

**Project objectives**

(iv) To show how multi-agent systems can be used to manage information used by wireless sensor to offer diagnosis and realistic imaging of symptoms.

**Systems objectives**

(v) To develop a prototype system to demonstrate data flow from patient control agents and doctor/specialist query agent.

(vi) Evaluation of the system through actual monitoring of HIV AIDS Tests.

## 1.4 Research Question

i) What are the limitations in accessing specialist health services by people living with HIV/AIDS

ii) Are there medical facilities placed in distant areas offering the best specialist service to its HIV/AIDS patients?

iii) To what extent are telemedicine and other technologies being used to offer health related services to Kenyans?

iv) How can we integrate wireless sensor technologies and multi-agent based system to offer fast and reliable health services?

## 1.5 Justification

Wireless sensor network and agent technology allowed us to deploy medical monitoring sensors to patients who are in diverse rural regions who cannot afford specialized treatment from specialized medical practitioners.

Monitoring, diagnosis, prescription remains a great challenge faced by medical practitioners who have to rely with medical officers stationed at far rural areas in Kenya to give the specialized treatment. Hence there is need to move from traditional methods to computer based technologies such agents application to medical sensors to offer specialized treatment to patients suffering from diverse HIV AIDS related diseases.

General practitioner skills are too general to offer the best specialized care, for example a practitioner may suspect that his patient has certain symptoms of an AIDS related disease. And since they lack the knowledge and proper resources to confirm this, they resolve to refer the patient to a specialist who can make a firm diagnosis [Huang, Jennings]

Ease Management of patients records between specialist doctors shall be realized by applying agent based data management from information tracked from the medical wireless sensors.

Agent based Wireless health monitoring systems shall allow the patients to be monitored at anytime in any place.

## 1.6 Assumptions and Limitations

(i) This study assumed that there is a functional database in each and every health institution that can be queried to find symptom records on HIV Patients.

(ii) This research study also assumed that there are wireless body area sensors attached to patients.

(iii) This research did not address wearable sensor simulation instead it shall concentrate on Multiagents interaction and analysis of HIV AIDS Patient data.

(iv) Limitation in the coordination of all agents involved towards achieving desirable outcomes, since the outcome not only depends on the action it takes but also the actions taken by other agents that it interacts with.

(v) Limited in ensuring that the wireless sensor networks in use are sustainable and easier to maintain over increasingly prolonged deployments

(vi) Use of sensors for tracking presents unique limitations that range from power faults, malfunction, delay, latency.

### 1.7 Expected Contributions

1. Prototype, this research came up with a prototype to help analyze the data.
2. Agents use in health monitoring, this research contributed to the existing knowledge of agents use in the area of health more so in monitoring and coordination of diseases.
3. This research has added to the knowledge of wireless sensors and agent technologies as tools that can contribute towards reducing the gap between rural areas which have few medical personnel and urban center which boast of health specialists.

### 1.8 Definition of Important Terms

**Agent,** An agent is a Computer situated in some environment, and that is capable of autonomous action in an environment in order to meet its design objectives [Wooldridge, 2002]

**A Multi-agent system** is one that consists of a number of agents, which interact with one another. In most general scenarios, agents will be acting on behalf of users with different goals and motivations. To successfully interact, they will require the ability to cooperate, coordinate and negotiate with each other, just as people do [Wooldridge, 2002].

**Wireless sensor device,** A wireless sensor device is a battery operated device capable of wireless communication, data storage, Computation and capable of sensing physical quantities.

**Wireless Body Area Networks (WBANs),** WBANs consist of smart miniaturized devices (motes) that are able to sense, process and communicate. They are designed such that they can be worn or implanted, and monitor physiological signals and transmit these to specialized medical servers without much interference to the daily routine of the patient [Garth et al.2012]

**Sensing,** this is a technique used to gather information about a physical object or process including the occurrence of events for example a drop in temperature or pressure; Sensors communicate the collected data wirelessly to a centralized processing station [Dargie and Poellabauer, 2010]

**Telemedicine,** is described as the use of communication equipment to link health care practitioners and patients at different locations [(Lynn, James 2006]

**CD4 Cells** these are a type of white blood cell that makes up the bulk of the body's immune defense system. They are the body first defense against invaders, such as viruses (Farnan, enriquez).

**HIV Viral load** this is the amount of HIV in the blood.HIV Viral Load and CD4 counts are used by the healthcare provider to determine when someone with HIV should initiate treatment for HIV disease.

## CHAPTER TWO: LITERATURE REVIEW

### 2.0 Introduction

This section analyses and reviews finding of published works in application of Wireless Sensor Network and Multi-Agent Systems, It commences with an overview of Agent Technology, Wireless Sensor Networks applications and related work in implementation of Agent Technology in Wireless Sensor Network, The aim of this literature is to aid the present research in proposing an Agent based System that will assist in the monitoring of patients symptoms.

Agent based Wireless sensor network for monitoring patients shall allow Sensors to collect and transmit data to an Agent System using Wireless Sensor Networks, the Agents will be developed using the Java platform Simulation, tested and evaluated in its effectiveness and use in tracking the patient symptoms and response to medicine.

### 2.1 Agent Technology

An agent is a Computer situated in some environment, and that is capable of autonomous action in an environment in order to meet its design objectives. An agent system should encompass characteristics such as Autonomy; the system should be able to act without the direct intervention of humans and should have control over its own actions and internal state [Wooldridge and Jennings, 1995].

According to [Wooldridge, 2002] agents require the ability to *cooperate*, *coordinate*, and *negotiate* with each other, in much the same way that we cooperate, coordinate, and negotiate with other people in our everyday lives

Agents are software or software and hardware that is autonomous that is able to act independently and is characterized by the following:-

i. Autonomous: Agents should be able to act independently without external support to achieve goals
ii. Reactive: reactive system interacts with its environment; responds to changes that occur in it.
iii. Communication: an agent should be able to communicate and coordinate with other agents
iv. Veracity: Agents should avoid communicating false information knowingly.

v. Proactive: Agents should be able to generate and attempt to achieve goals due to own initiative.
vi. Social Ability: - they should take other agents into account when trying to achieve goals this is possible through cooperation, negotiation e.t.c.
vii. Learning: - agents should learn from previous experience and adapt with time.
viii. Mobility: - Agents should be able to move from one environment to another based on need.

**2.2 Wireless Sensor Networks**

A wireless sensor device is a battery operated device capable of wireless communication, data storage, Computation and capable of sensing physical quantities.

Wireless sensor has not only a sensing component, but also on-board processing, communication and storage capabilities. With these enhancements, a sensor node is often not only responsible for data collection, but also for in-network analysis, correlation and fusion of its own data and data from other sensor nodes [Dargie and Poellabauer, 2010]

Sensor nodes communicate not only with each other but also with a base station using wireless radios, allowing them to disseminate their sensor data to remote processing, visualization, and storage systems [Dargie and Poellabauer, 2010]

According to [Dargie and Poellabauer, 2010] Sensing is a technique used to gather information about a physical object or process including the occurrence of events for example a drop in temperature or pressure; Sensors communicate the collected data wirelessly to a centralized processing station.

Wireless Body Area Networks (WBANs). WBANs consist of smart miniaturized devices (motes) that are able to sense, process and communicate. They are designed such that they can be worn or implanted, and monitor physiological signals and transmit these to specialized medical servers without much interference to the daily routine of the patient [Garth et al.2012]

### 2.2.1 Wearable Sensors

Wearable systems include sensors for detecting physiological signs placed on-body without discomfort and possible with capability for real time and continuous recording. The system should also be equipped with wireless communication to transmit signals.

Most sensors embedded into wearable systems need to be placed at specific body locations for example motion sensors used to track body segments, physiological sensors which include pulse meters that are often in direct contact with the skin. [Annalisa Bonfiglio 2011]

#### 2.2.1.1 Commercial Wearable sensors

Small, wearable, low cost, and lightweight wireless sensors are available this include the following Vivago WristCare, which is a wrist-worn device that monitors skin temperature, skin conductivity and movement. The SenseWear Armband developed from BodyMedia which monitors ambient temperature and heat flow. Most commercial wearable devices include a wireless transmitter for communicating the collected data and possible alarms to a base station for further evaluation by a professional clinician. [Pantelopoulos and Bourbakis, 2010]

*Examples of medical sensors*

| TYPE OF SENSOR | TYPE OF BIO-SIGNAL | DESCRIPTION OF MEASURED DATA |
|---|---|---|
| **Arm cuff-based monitor** | **Blood pressure** | **Refers to the force exerted by circulating blood on the walls of blood vessels, especially arteries** |
| **Piezoelectric/piezoresistive** | **Respiration rate** | **Number of movements indicative of inspiration and expiration per unit time (breathing rate)** |
| **Heart rate** | **Pulse oximeter** | **Frequency of the cardiac cycle** |

According to [Pantelopoulos and Bourbakis, 2010] the Wearable systems for health monitoring may comprise various types of miniature sensors, wearable or even implantable. These biosensors are capable of measuring significant physiological parameters like heart rate, blood pressure, body and skin temperature, oxygen saturation, respiration rate, electrocardiogram, etc. The obtained measurements are communicated either via a wireless or a wired link to a central node, for example, a Personal Digital Assistant (PDA) or a centralized computer, which may

then in turn display the information on a user interface or transmit the aggregated vital signs to a medical center.

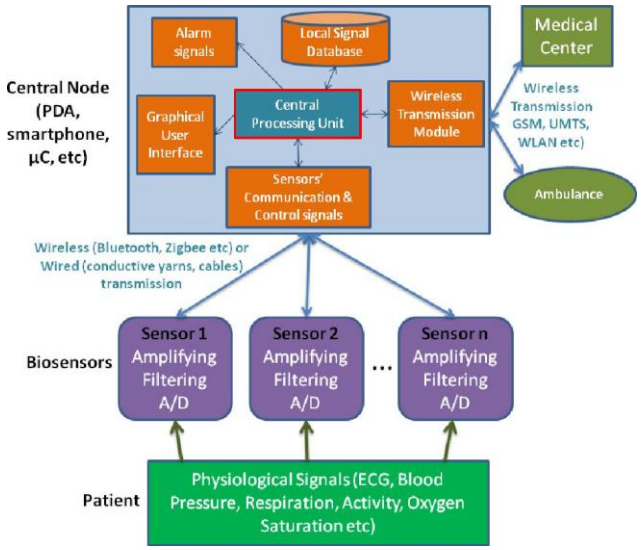



**Figure 1: Architecture of a wearable health monitoring system [Alexandros, Nikolaos, 2010]**

There are several specific requirements of vital signs. This includes how to measure and process vital signs such as blood pressure (BP), ElectroCardioGram (ECG), temperature, and oxygen saturation. Each of these requires a different type of sensor(s) at a certain part of human body [Upkar, 2009]

### 2.2.2 Wearable Sensor Data Transmission

Data transmission between the wearable health monitoring systems and a remote station or device, uses wireless technologies Such as WLAN, GSM, GPRS, UMTS, and WiMAX, this technologies offer wide coverage and ubiquitous network access. Furthermore, future advances in 4G (fourth generation) mobile communication systems are expected to guarantee worldwide seamless access to the Internet at much higher data rates. The most commonly employed wireless communication standards in BANs are IEEE 802.15.1 (Bluetooth) and 802.15.4 (widely

referred to as Zigbee, although Zigbee includes the specification of network, security, and application layers on top of the official standard [Pantelopoulos and Bourbakis, 2010]

According to [Yingshu et al 2008] a wireless sensor network has one or more base station which collects data from all sensor devices. These sinks are the interfaces through which the wireless sensor network interacts with the outside world.

### 2.2.3 Wireless Sensor Network Architecture

Network and protocols are important aspects in the design of wireless sensor networks this is due to the severe energy constraints of sensor nodes, a wireless sensor network consists of a large number of sensor nodes that are densely distributed, The sensor consists of a suite of network protocols to implement various network control and management functions for example synchronization, self configuration, medium access control, routing, data aggregation, node localization and network security [Jun et al, 2009].

A sensor network typically consists of a large number of sensor nodes densely deployed in a region of interest, and one or more data sinks or base stations that are located close to or inside the sensing region. The sink(s) sends queries or commands to the sensor nodes in the sensing region while the sensor nodes collaborate to accomplish the sensing task and send the sensed data to the sink. Meanwhile the sink also serves as a gateway to outside networks for example; the internet to the users who requested it or use the information to send data to the sink, each sensor node can use single-hop long distance transmission which leads to single-hop network architecture.

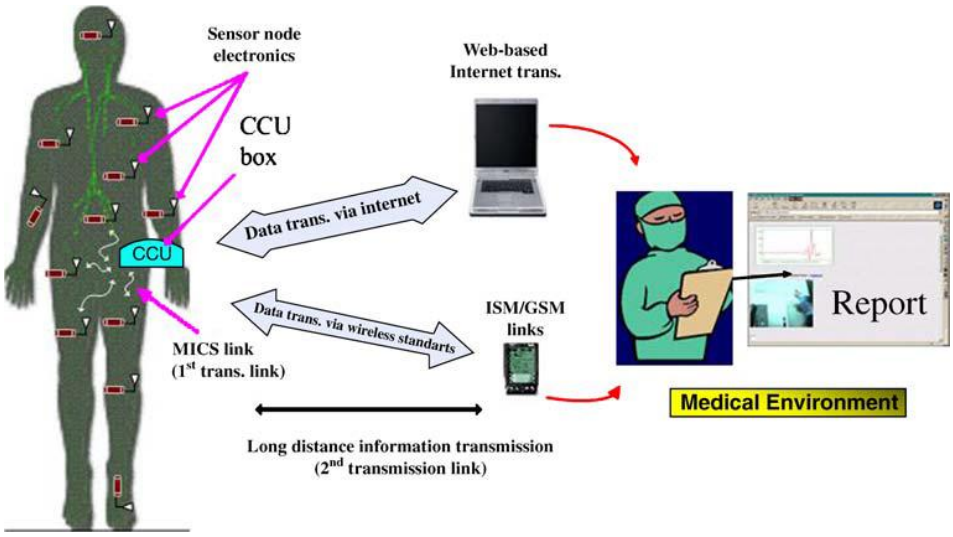



**Figure 2: A wireless system detecting and transmitting signal from sensors placed on the body for a medical sensor network application [Mehmet et al, 2007]**

The health monitoring will require comprehensive and high-speed access to wireless networks, reliable and scalable wireless infrastructure, secure and fast databases, and utilization of network intelligence and information. An increased reliability of monitoring and higher chances of transmission of alert signal can be achieved with the use of ad hoc wireless networks.

### 2.2.4 Applications of Multi-agent Wireless Sensor Network

Wireless sensor network may consist of many different types of sensors including magnetic,thermal,visual,infrared these are capable to monitor a wide variety of ambient conditions that include temperature,humidity,pressure,speed,direction as a result a wide range of applications have been deployed in areas such as health,environment,military,home and factories [Ian et al,2010].

The ReMoteCare project which is an enhancement of the Code Blue project is a software platform that uses wireless sensor network to gather medical data in pre and in hospital emergency care, disaster response and stroke patient rehabilitation, it allows automatic wireless monitoring and tracking of patients and medical staff, the multi-agent system is developed on top of the network management [Navarro 2010].

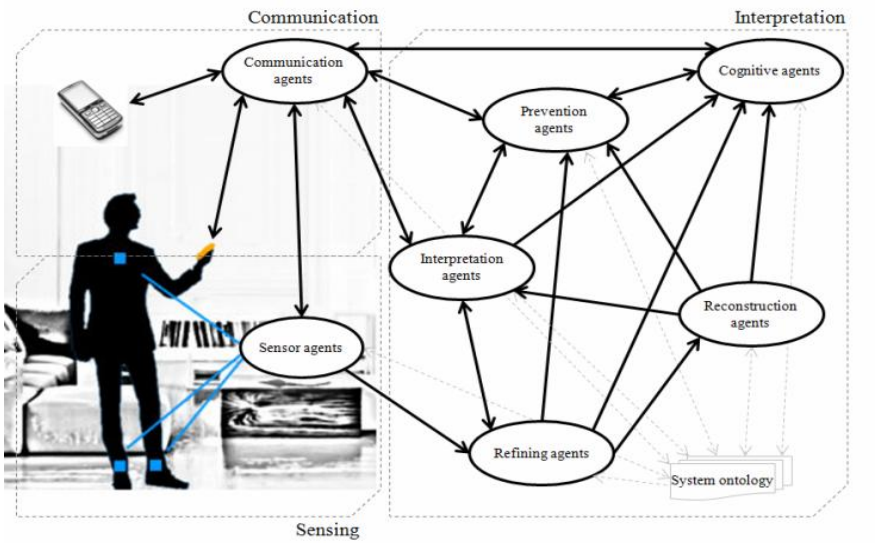



**Figure 3 :Multiagent system for remote eldercare [Bostjan et al, 2011]**

## 2.3 HIV AIDS

HIV stands for human immunodeficiency virus. It is the virus that can lead to Acquired Immunodeficiency Syndrome, or AIDS. Currently no safe and effective cure exists; Treatment for HIV is often called antiretroviral therapy. ART can prolong the lives of many people infected with HIV and lower their chance of infecting others.HIV affects specific cells of the immune system, called CD4 cells, or T cells overtime,HIV destroys so many of these cells that the body can't fight off infections and disease this leading to AIDS. [CDC, 2014]

*According to [AIDS.GOV, 2014] below are stages of HIV AIDS*

**Stages of HIVAIDS**

**Acute infection:** Within **2 to 4 weeks** after infection with HIV, someone may feel sick with flu-like symptoms. This is called acute retroviral syndrome (ARS) or primary HIV infection, and it's the body's natural response to the HIV infection during this period of infection, large amounts of HIV are being produced in the body. The virus uses important immune system cells called CD4 cells to make copies of itself and destroys these cells in the process. Because of this, the CD4 count falls quickly.

**Clinical latency:** This period is also called chronic HIV infection. During this phase, HIV is still active, but reproduces at very low levels. People who are on antiretroviral therapy (ART) may live with clinical latency for several decades. For people who are not on ART, this period can last up to a decade, but some may progress through this phase faster.

**AIDS (Acquired Immunodeficiency Syndrome):** This is the stage of infection that occurs when someone's immune system is badly damaged and has become vulnerable to infections and infection-related cancers called opportunistic illnesses. When the number of CD4 cells falls below 200 cells per cubic millimeter of blood (200 cells/mm3), someone is considered to have progressed to AIDS. (Normal CD4 counts are between 500 and 1,600 cells/mm3.) One can also be diagnosed with AIDS if they develop one or more opportunistic illnesses, regardless of their CD4 count.

According to [Farnan, Enriquez 2012] health service practitioner conduct physical exam to determine HIV symptoms which include the following.

a) Overall check for fevers,chills,night sweats,fatigue,loss of appetite, or weight loss
b) Lungs: listening to your lungs as you breathe in and out
c) Heart: listening and noting the rate and rhythm
d) Abdomen: feeling for masses or organ enlargement, measuring your liver
e) Neurology :testing the reflexes and sensations in your legs and feet
f) Skin: looking at your skin and noting any sores,rashes,abnormal bruising, or lumps
g) Feet and legs: checking to see if you have any swelling
h) Women: may also have a pelvic exam, pap smear, rectal exam and breast exam.
i) Men:penis,testicular,rectal and prostrate exams

Lab assessment and diagnostic testing include the following:

a) HIV antibody testing
b) Complete blood count
c) CD4/T Cell count
d) HIV Viral Load
e) HIV resistance testing
f) Tuberculosis tests
g) Urine testing

## 2.4 Telemedicine

Telemedicine is described as the use of communication equipment to link health care practitioners and patients at different locations [(Lynn, James 2006]; telemedicine concept allows medical practitioners to carry out Tele-monitoring, Tele-consultation and Tele-diagnosis which allows these experts to carryout diagnostics with medical instruments from a remote location [(Lynn, James 2006].

According to [Craig, Peterson 2005] the common thread for all telemedicine applications is that a client of some kind (e.g. patient or health-care worker) obtains an opinion from someone with more Expertise in the relevant field.

Telemedicine technologies include realtime, live interactive high definition video and audio communication between the specialist at a local medical center and a specialist at a regional hospital [Ryhan, 2013]

### 2.4.1 Application areas of telemedicine

The teleECG initiative in Norway is a telemedicine service used to facilitate early diagnosis and Treatment of suspected myocardial infarction in patients not in hospital This TeleECG system can either be used inside of the patient's home or in the ambulance en route to the hospital. Ambulances are fitted with equipment to capture and transmit ECG images to hospitals that have an image receiver and storage system for the images sent. Once received, the images are analyzed by a cardiologist at hospital who is able to make a diagnosis and recommend an immediate course of action [WHO Report, 2010].

The Swinfen Charitable Trust Telemedicine Network which uses a low-cost, store-and-forward telemedicine system to link health-care workers in developing countries to an international pool of consulting specialists based in the United Kingdom.

Since the first telemedicine link in 1999, the network has grown to include 193 referring hospitals and clinics from over 60 counties. At inception the network was based on a simple e-mailing system between the referring health-care professionals and the consulting physicians. The method of communication has been enhanced to a Web-based messaging system that only requires an Internet connection and no special software [WHO Report, 2010]

In Kenya and other developing countries today most of the healthcare facilities do not have enough health personnel and specialists, to offer expert diagnosis and treatment most rural patient's end up being referred to referral hospital and specialists doctor who are few in number this is both prohibitive and costly for example travel costs.

In our research telemedicine shall seek to offer teleconsultation, telediagnosis which are important concept where the patient with the local doctor consults the specialists and obtains expert advice on the treatment to offer, for effective regular monitoring and intensive care telemonitoring is further administered on the patients.

## 2.5 Related Work

*Patient monitoring system*

Patient monitoring system (the code blue project) focused on wearable sensors that monitor vital signs of patient throughout their daily lives [Malan, et al,2002] in this project sensor motes with various sensors are attached to patients for monitoring, additional motes are deployed inside the hospital to provide message delivery to/from the motes. The medical personnel can access the network through either PDAS or computers.

Agent based health monitoring of elderly people in indoor environments using wireless sensor networks [Vaidehi, Vardhini, 2013] which is a system that is capable of collecting, retrieving, storing and analyzing the vital signs of the patient. Vital signs such as body temperature, blood pressure, pulse rate and respiratory rate are monitored.

Multiagent based integrated health monitoring system for the elderly at home [Lasheng,Beiji,2012] which proposes a multi-agent based integrated health monitoring system that integrates a wireless sensor network and multi agents to provide the elderly with a mobile, ubiquitous and personalized health care and to improve the elderly people's life quality.

*Medical Path Agents* project, which is a project aimed at improving patient scheduling in hospitals. Approach of the project represented the different goals of the involved stakeholders by Intelligent agents. E.g. patient agents would try to minimize the waiting times for their patients, whereas resource agents would try to maximize the utilization of hospital resources

such as radiology units. As these goals are usually in conflict, the agents perform autonomous negotiations for producing schedules that balance the individual goals.

### 2.6 Conceptual framework

The multi-agent based system provides data in a timely manner to the users. It also updates the central database of the system. The framework has the following four main agents.

i. Patient agent
ii. GSM Agent
iii. Specialist doctor query agent
iv. Local medical agent
v. Database data agent

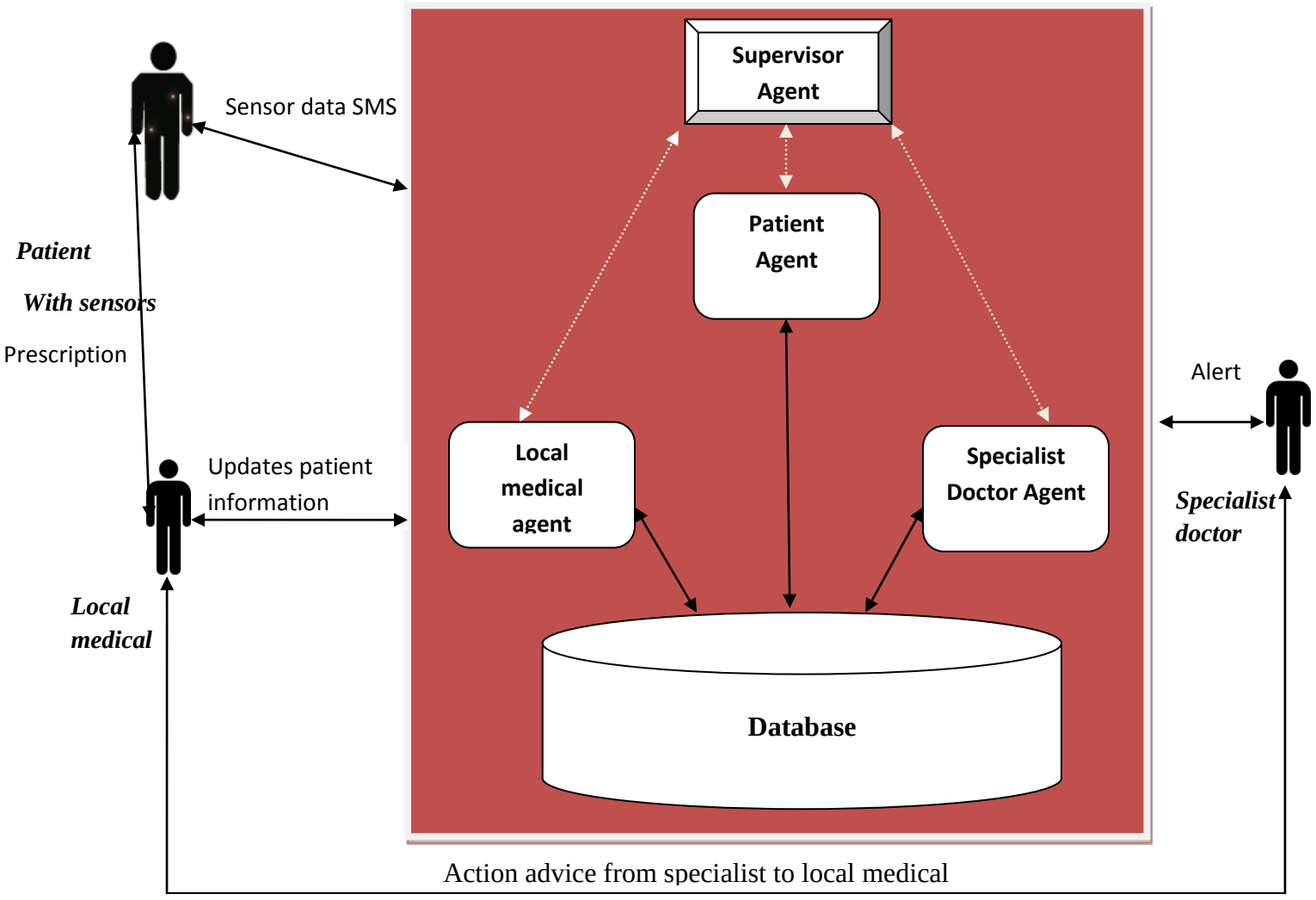



**Figure 4** Conceptual framework for the multi-agent based system

**Specialist agent**

The specialist agent comprises a query functionality that helps the specialist doctor to view the required data about any patient and the time instance for which the data was fetched, The Specialist Agent Diagnose and send prescription information to the local medical agent and patient agents.

**Patient agent**

The patient agent comprises a query agent that gets data values from a patient attached sensor and relays this information to the specialist agent that in turn validates, diagnose this information and sends information back to the patient agent in a database.

**GSM Communication Agent**

This is the agent that receives data from the wireless sensor device attached to the patient.
Its main Goal is to collect data from the Wireless sensor device.

**Local medical agent**

This is an agent that plays the assistant role it can be called by the specialist agent; this is achieved by the specialist agent sending an alert message to the local medical agent to take certain actions.

**Supervisor agent**

The Supervisor agent is responsible for the administration of the multi agent system it can invoke and terminate other agents based on the requirement of specific functionalities by the patient or doctor agent, this agent initializes the agents.

## 2.7 Summary

In the present study we worked on an architecture that uses sensors as agents, where Sensors are tagged on patients, the network encompassed a gateway with cellular connectivity to relay instant data to a centralized computer to allow medical specialists to access and monitor patient's symptoms. The method proposed in this paper is a multi-agent system that is used for health monitoring of patients living with HIV AIDS.

Agent based technology is helpful in the healthcare domain. Agents reside in one system and are invoked based upon the need of other agents. Such an approach is expected to reduce the need of specialist health experts more so in areas that are rural and distant.

## CHAPTER THREE: METHODOLOGY

In this section we explain the research Methodology, sources of data, methods and tools we used in data collection and methods to be used in data analysis.

### 3.1 Sources of data

Data was obtained mainly from primary data sources. This included interviews, observations, experiments and records from reports.

Observations of the outcomes of the prototype based on the corresponding possible sensor data inputs were critical in achieving the goal of the study.

### 3.2 Data collection

We carried out data collection using the following methods and tools:

#### 3.2.1 Records inspection

Relevant reports, documents, charts and related documents in the area of study were studied; these records included online databases and manual records. This allowed us in access of detailed information.

#### 3.2.2 Interviews

Specific individuals were interviewed to help in understanding their opinions and suggestions about the area of study; this allowed the respondent an opportunity to express their feelings relating to the area of study through verbal responses.

### 3.3 Agent methodology

A methodology aims to prescribe all the elements necessary for the development of a software system, some common types of agent methodology include MasCommonKads , Passi, Tropos among others, in our research project we propose to use the Prometheus Methodology.

### 3.4 The Prometheus methodology

Prometheus methodology shall be used in the system specification, system design and implementation. The Prometheus methodology is a detailed process for specifying, designing, and implementing intelligent agent systems.

#### 3.4.1 Why Prometheus

Supports the development of intelligent agents which use goals, beliefs, plans, and events this methodology distinguishes itself from other methodologies by supporting the development of

intelligent agents which use beliefs, goals, events, plan. Prometheus provides a start-to-end support,(from specification to detailed design and implementation),Prometheus is a detailed process, it Uses an iterative process over software engineering phases rather than a linear "waterfall" model, it Evolved out of practical industrial and pedagogical experience, and has been used by both industrial practitioners and by undergraduate students.[Padgham,Winikoff 2002]

The methodology is made up of three phases:

- System specification
- Architectural design
- Detailed design
- An overview of the methodology, including its phases, deliverables, and intermediate products, is depicted below

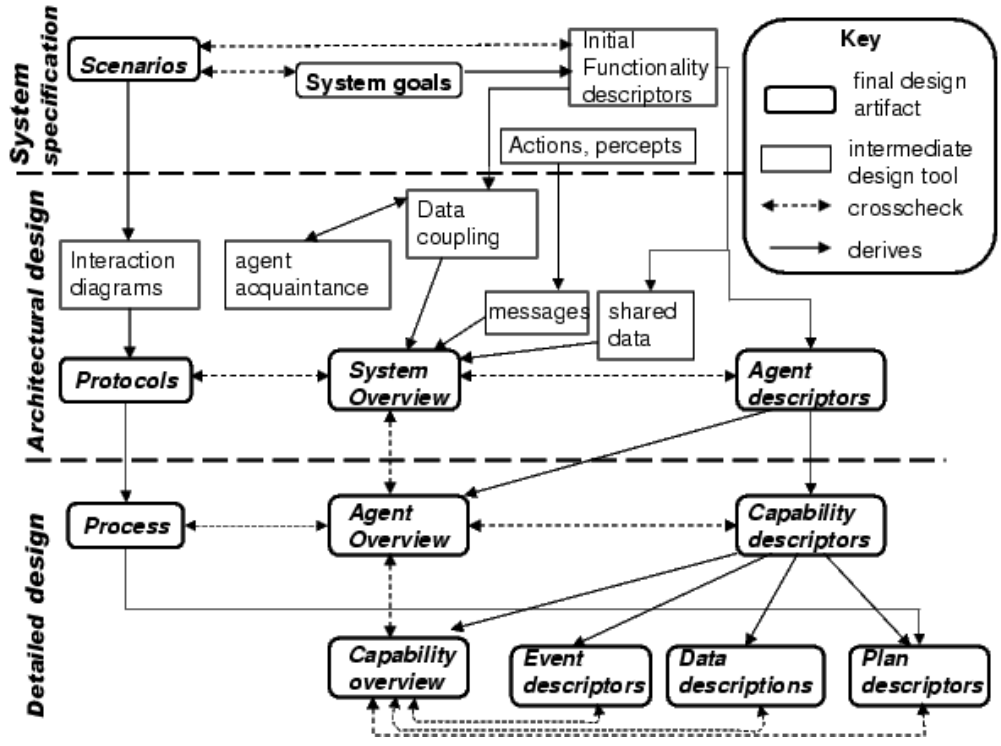



Figure 5: Overview of the methodology, including its phases, deliverables, and intermediate products [Padgham,Winikoff 2002]

### 3.4.2 System specification

Consists of the following activities:

The System Specification phase focuses on identifying the following system interface,which consists of percepts (information from the environment) and actions. basic functionalities of the system, The system goals,subgoals, use case scenarios, description of interactions with other functionalities, a list of relevant perceptions, data used and produced (inputs and outputs).

*System goals*

Systems goals, initial goals were developed into a more complete set of goals by considering each goal and showing how those goals were achieved thus identifying additional sub goals.

*Functionalities*

The functionality involves the behavior provided by the system. We defined Information required by the functionality. The functionality descriptor contains a name, a short natural language description, a list of actions, a list of relevant percepts, data used, a brief description of interactions with other functionalities and triggers.

*Use Case Scenarios.*

Use case scenarios involve detailed description of one particular sequence of events associated with achieving a particular goal or with responding to a particular event. We describe Scenarios using a name, description, and a triggering event.

*System Interface: Actions and Percepts.*

A percept is raw data available to the agent system. Percept is incoming information from the environment in our case

We included information from patient sensors that act as percepts. The Actions include responses from specialist agents and local medical agent.

### 3.4.3 Architectural Design

Uses the outputs from the previous phase to determine which agents the system will contain, how they will inter-act, and what significant events occur in the environment. The outputs of this phase are a system overview diagram, agent descriptions, agent interaction protocols and a list of significant events and messages between agents [Federico 2004].

Our Architectural design phase consisted of the following

- We identify agent types in the system and functionalities shall be assigned to it.
- The interactions between agents, this include the determination of an Interaction protocol which shows message passing and sequence of messages between agents.
- The overall system structure aimed to show different messages that are sent between agents. The system overview diagram shows the pathways of communication.

### 3.4.4 Detailed Design

During the Detailed Design phase the internal structure of each agent is explored in great detail.The designer focuses specifically on an agent's abilities to accomplish its individual tasks and the integration of these tasks with others into an overall task [Padgham, Winikoff 2002]

The outcomes of this phase are detailed diagrams showing internal functionality of each agents and its capabilities,process diagrams that show internal processing of the agent as well as descriptions of data structures used by the agent plans and subtasks and the details of plan triggers.

The focus of the detailed design phase is on defining capabilities (modules within the agent), internal events, plans and detailed data structures. A progressive refinement process is used which begins by describing agents' internals in terms of capabilities. The internal structure of each capability is then described, optionally using or introducing further capabilities. These are refined in turn until all capabilities have been defined. At the bottom level capabilities are defined in terms of plans, events, and data. [Padgham, Winikoff 2002]

The Detailed design phase consisted of the following

- Developing the internals of agents
- The agent overview shall show interactions between capabilities within an agent

- Our Capability descriptor shall contain information such as which events are generated and which events are received.

### 3.5 Implementation of the system

Implementation of Multi-agents based wireless sensor telemedicine network for E-Health monitoring of HIV Aids was done using JADE-LEAP toolkit.

Java net beans were used to build the main environment where agent resides. Jade and leap add on was used to build the agents in the system.

### 3.6 Evaluation of the system

We evaluated the system by analyzing data outputs of the prototype based on the corresponding sensor data inputs this was critical in achieving the goal of the study. Evaluation involved data collection and data analysis.

Evaluation of the system was done with help of expert from the relevant authorities; this was done once the development of the prototype was complete.

# CHAPTER 4: ANALYSIS DESIGN AND IMPLEMENTATION

## 4.0 Introduction

This system has been developed for monitoring of HIV AIDS in remote areas, the prototype system has been developed using Multi-Agent System methodology. The prototype can monitor the main symptoms of HIV AIDS and advice on the necessary action to be taken this system will allow fast monitoring and care for PLHIV patient living in remote areas.

## 4.1 User Requirements

User requirements specify what the user wants to achieve from the proposed system. These are the problems which the proposed system should solve. The following are the user requirements

a) GSM sensors attached to patient to send monitoring data
b) Interaction with the System Administrator and users using the GUI interface
c) Patients data sent to a centralized database
d) Local medical assist in sending data
e) Diagnosis database
f) Date diagnosis was drawn
g) Specialist access and prescription
h) Provision of secure access to the system

## 4.2 SYSTEM SPECIFICATION

System specifications included the following descriptions

a.) The inputs
b.) The operations the system performs for each input
c.) The output obtained for the corresponding input

Multiagent wireless sensor network for e-monitoring of HIV AIDS patients has been developed using the following Agent programs

a) Supervisor agent
b) Specialist agent
c) Patient agent
d) Local medical agent
e) GSM sensor Agent

### 4.3 Analysis and Design using Prometheus Methodology

The analysis of this system was carried out using multi-agent system methodology known as PROMETHEUS; Prometheus methodology illustrates the system specification, system design and implementation of the prototype. The Prometheus methodology is a detailed process for specifying, designing, and implementing intelligent agent systems.

#### 4.3.1 System Goals and Functionalities

**Supervisor Agent**

Functionality

The Master agent is responsible for the administration of the multi agent system it can invoke and terminate other agents based on the requirement of specific functionalities by the patient or specialist agent, this agent initializes the agents.

Main Goal

a) Initiate all the agents this includes patient, local clinician, specialist Agents
b) Validate all Agent requests

**Specialist Agent**

The specialist agent comprises a query functionality that helps the specialist doctor to view the required data about any patient and the time instance for which the data was fetched. The query Agent is created when there is a request by the specialist to view the patient details.

Main Goal

a) Perform search for requested data on the patient database.

**Patient Agent**

The patient agent comprises a query Agent that gets data values from a patient attached sensor and relays this information to the master Agent that in turn stores this information in a database.

Main Goal

a) Collect patient data and handles registration.

**Local Medical Agent**

This is an agent that plays the assistant role it can be called by the specialist agent; this is achieved by the specialist Agent sending an alert message to the local medical Agent to take certain actions.

Main Goal

a) Collect and ensure patient data is correct
b) Execute requests action from specialist agent

Collaborator

i. Patient agent
ii. Specialist agent

**GSM Communication Agent**

This is the agent that receives data from the wireless sensor device attached to the patient.

Main Goal

a.) Collect data from the Wireless sensor device

### 4.3.2 Goal overview diagram

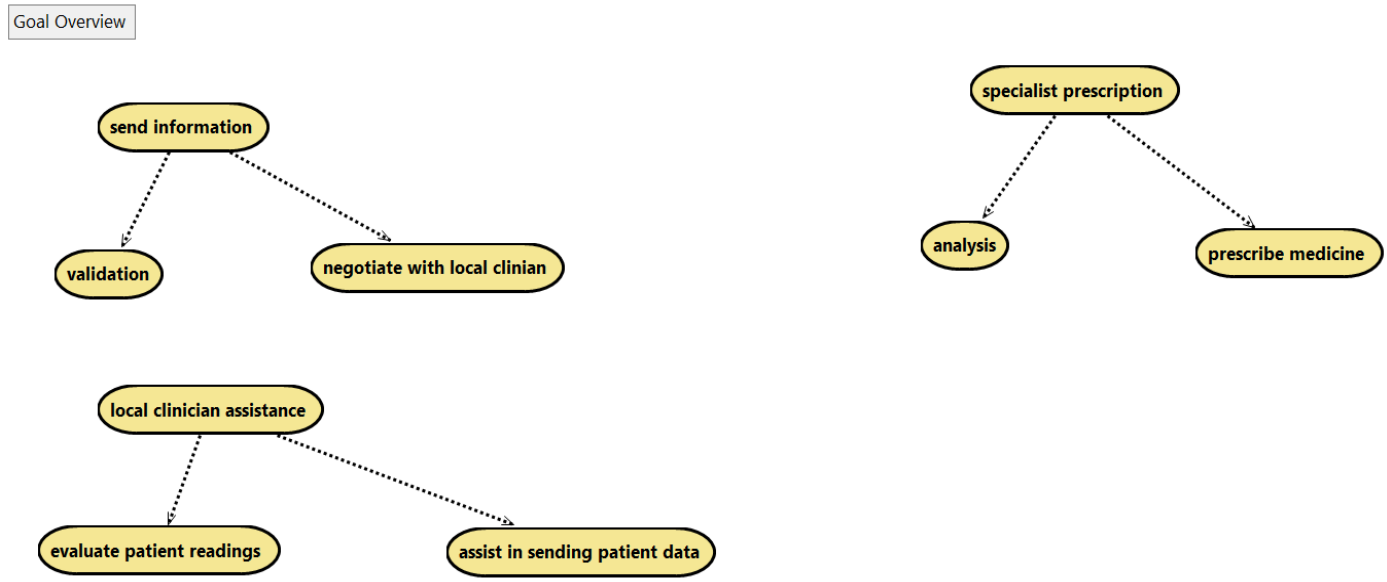
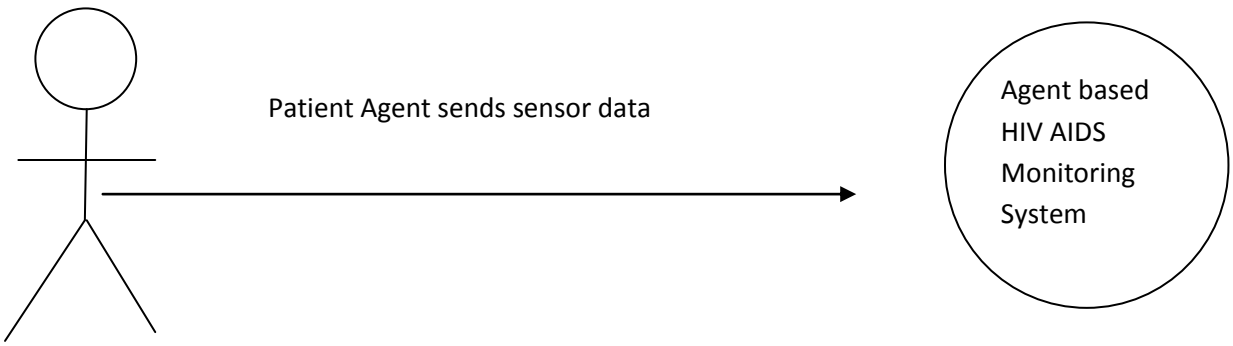



**Figure 6: Diagram showing Goal Overview Diagram**

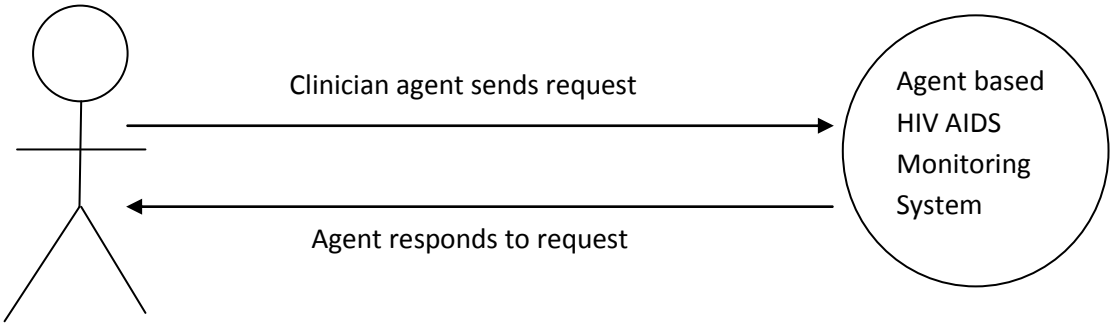
### 4.3.4 Use Case Scenarios.

Use case scenarios involve detailed description of one particular sequence of events associated with achieving a particular goal or with responding to a particular event.

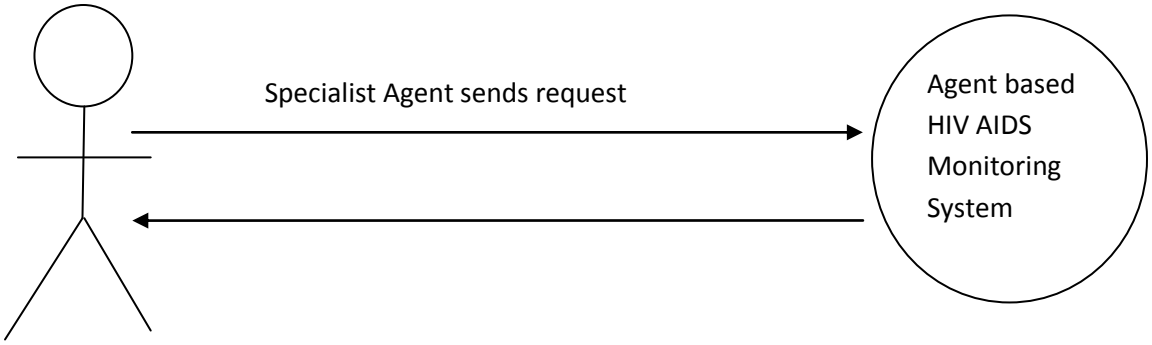
**Use case scenario (Patient agent)**



**Use case scenario (Local Medical Agent)**




**Use case scenario (Specialist agent)**




**Use case scenario (Supervisor agent)**

### 4.3.5 Actions and Percepts

A percept is raw data available to the Agent system. Percept is incoming information from the environment in our case; the system integrates information from patient sensors acts as percepts. the Actions include responses from Specialists Agents and Local Medical Agent.

Percepts -Sensor information from the patient and local clinician agent

i. CD4 Count
ii. Viral Load measurements
iii. Temperature
iv. Blood pressure

**Action example**

The Actions include responses from local medical agent and specialist agents.

This include the following

i. Specialist agent Diagnosis
ii. Local Medical assistance to sending patient data
iii. Prescription

## 4.4 ARCHITECTURAL DESIGN

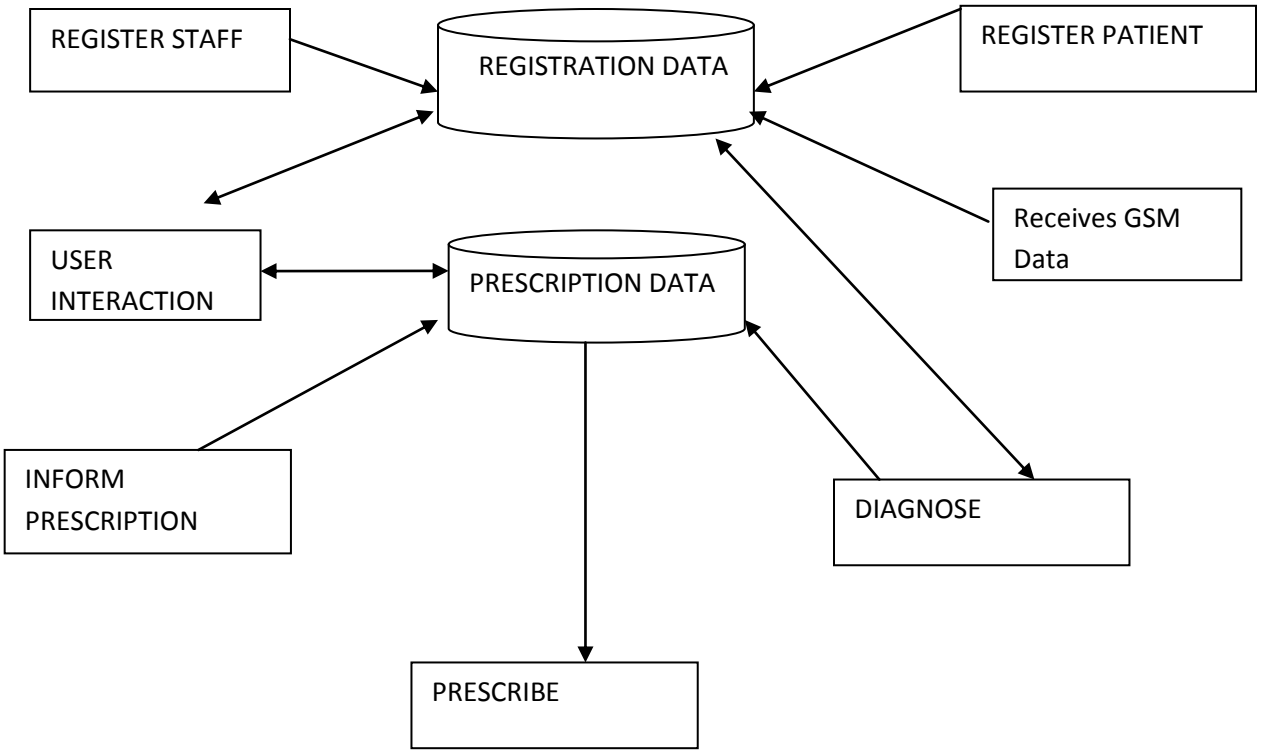
In the architectural design phase, the focus was on the following

a) Deciding on the agent types in the system, here we identified agent types, grouping functionalities based on coupling; we show this by use of coupling and an agent acquaintance diagrams.

b) An interaction diagram is part of the architectural design it aims at describing the interactions between agents using interaction diagrams and protocols, We Endeavour to shows message passing and sequence of messages between agents

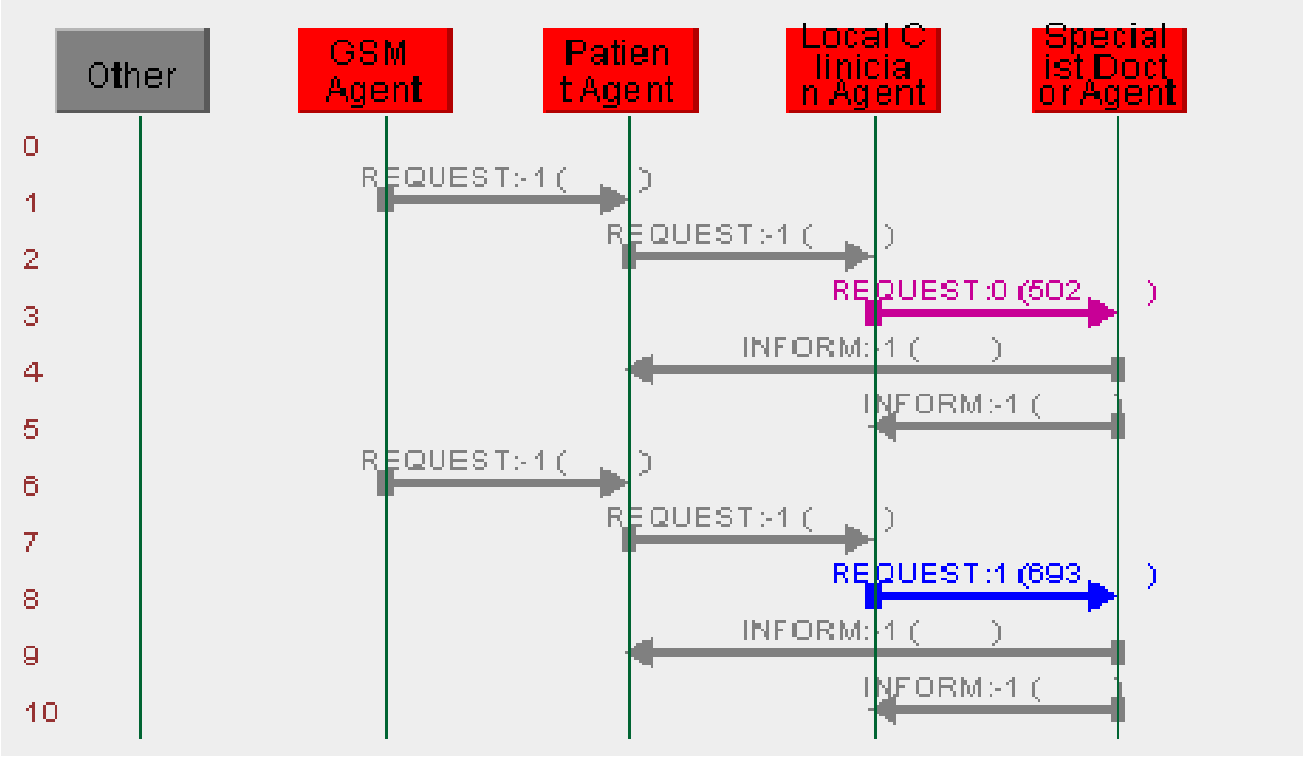
c) System Overview Diagram, The overall system structure aims to show different messages that are sent between agents, in addition the system overview diagram show the pathways of communication.

### a.) Data Coupling Diagram

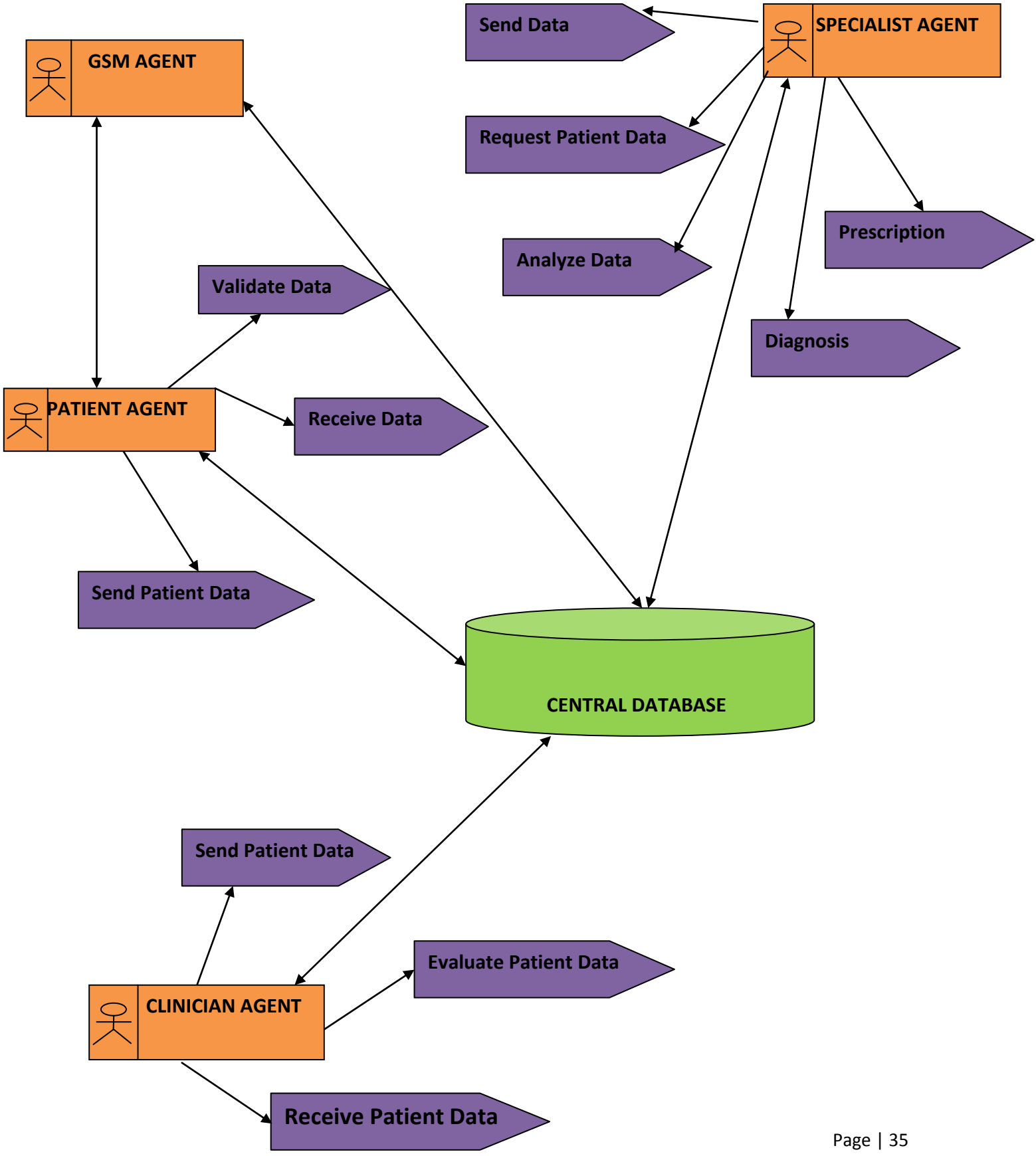


**b.) Agent Interaction Diagram**

Below is an interaction diagram that describes the interactions between agents



### c.) System Overview Diagram



## 4.5 DETAILED DESIGN

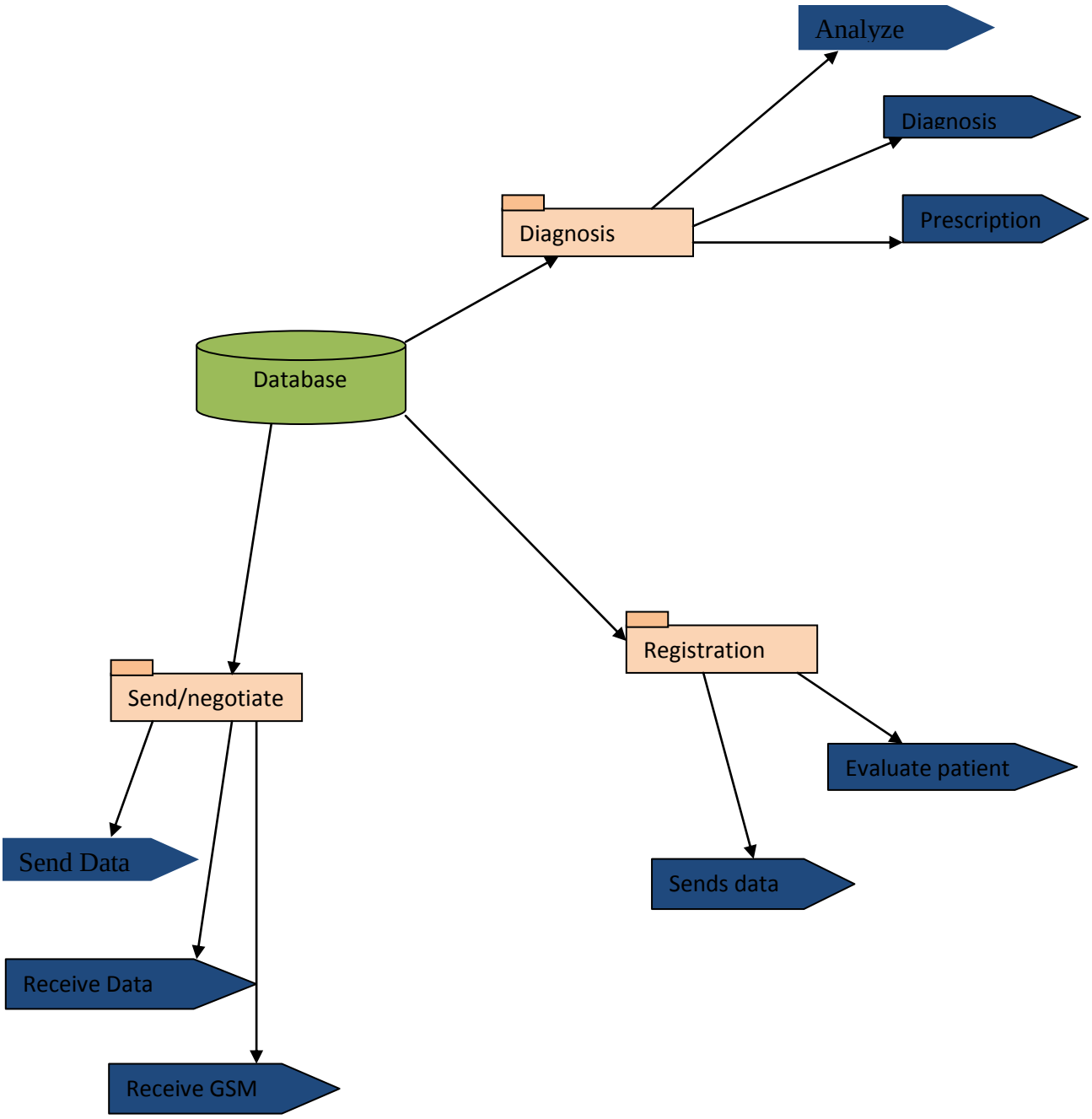
Detailed design focus on developing the internal structure of each of the agents and its behavior, we also developed the internals of agents, in terms of capabilities, in terms of events, plans and data. This is portrayed using agent overview diagrams and capability descriptors.

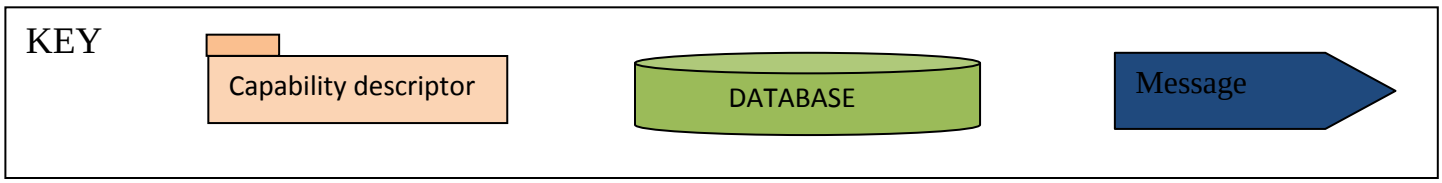
### 4.5.1 Agent Capabilities

The capabilities of each agent were identified as follows:

| **Agent** | **Capabilities** |
|---|---|
| Patient Agent | This handles patient readings registrations, negotiates with the local clinician on sending of data. |
| Local Clinician Agent | This is an agent that assist in handling registration from the patient agent, it also gets requests from the specialist agent; It also validates the registration requests |
| Persistence Agent | This handles database operations for the platform. Ensure data is persisted into the DB and initiate communication with subscribers. |
| Specialist Doctor Agent | This agent receives client requests for data. It instructs the appropriate external system agents to search for the required data and return the results. |
| RMA, DF and AMS agents | These are system agents, shipped with the JADE distribution; HostMonitor can monitor remote networks using Remote Monitoring Agents (RMA) |
| GSM Agent | These are agents that receive the sensor reading data. |

### 4.5.1 Agent Overview diagram



## 4.6 IMPLEMENTATION OF THE SYSTEM

Implementation of Multi-Agents based Wireless Sensor Telemedicine network for E-Health monitoring of HIV Aids has been done using JADE-LEAP toolkit.

Java net beans were used to build the main environment where Agent resides. Jade and leap add on were used to build the agents in the system.

**Development** Java Development Kit, this is a software development environment used for developing Java applications and applets and Net beans IDE

**Multi-agent Application** The main tool used was Java Agent development Environment which is a library in Java and was incorporated in the IDE

**Database** The database was developed using MySQL database, JDBC drivers for connecting the application to the database and Java persistence API 2 (JPA2) used object-relational mapping to bridge the gap between the object model and the relational model

# CHAPTER 5: PROTOTYPE EVALUATION AND DISCUSSION

## 5.1 Prototype

For this Agent-based Health monitoring Prototype, each agent is configured during system installation or modification. Configuration of the Agent identities will ensure that the right information is delivered and received by the right agent.

For example, new information coming from patient agent, is stored uniquely in the Database, at the same time, the specialist agent is also notified of new information coming into the system to allow it to respond to this information and offer special diagnosis and prescription.

Each agent in the system is configured to know the identity of other agents to interact with in pursuit of its goals.

### 5.1.1 User interface

The prototype user interface comprised of the following modules for different users

(i) Administrator Module
(ii) Local Clinician Module
(iii)Specialist Module

### 5.1.2 Administrator Module

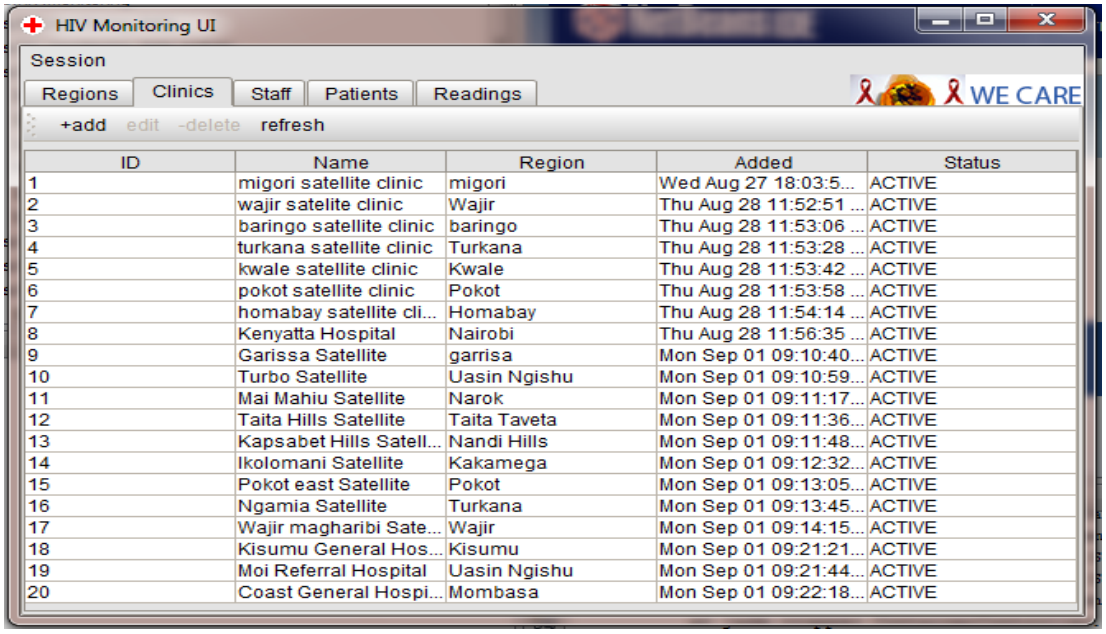
The Administrator responsible include rights to create entities and grant roles and privileges to the following

a) Regions
b) Clinics
c) Specialists
d) Local Clinicians

### 5.1.2 Administrator Module

This is a Module designed to handle registration of users of the system, the default administrator can create the entities such as regions, clinics and staff that can access the system.


**Figure 7: Diagram showing the login Window**




| ID | Name | Region | Added | Status |
|---|---|---|---|---|
| 1 | migori satellite clinic | migori | Wed Aug 27 18:03:5... | ACTIVE |
| 2 | wajir satelite clinic | Wajir | Thu Aug 28 11:52:51 ... | ACTIVE |
| 3 | baringo satellite clinic | baringo | Thu Aug 28 11:53:06 ... | ACTIVE |
| 4 | turkana satellite clinic | Turkana | Thu Aug 28 11:53:28 ... | ACTIVE |
| 5 | kwale satellite clinic | Kwale | Thu Aug 28 11:53:42 ... | ACTIVE |
| 6 | pokot satellite clinic | Pokot | Thu Aug 28 11:53:58 ... | ACTIVE |
| 7 | homabay satellite cli... | Homabay | Thu Aug 28 11:54:14 ... | ACTIVE |
| 8 | Kenyatta Hospital | Nairobi | Thu Aug 28 11:56:35 ... | ACTIVE |
| 9 | Garissa Satellite | garrisa | Mon Sep 01 09:10:40... | ACTIVE |
| 10 | Turbo Satellite | Uasin Ngishu | Mon Sep 01 09:10:59... | ACTIVE |
| 11 | Mai Mahiu Satellite | Narok | Mon Sep 01 09:11:17... | ACTIVE |
| 12 | Taita Hills Satellite | Taita Taveta | Mon Sep 01 09:11:36... | ACTIVE |
| 13 | Kapsabet Hills Satell... | Nandi Hills | Mon Sep 01 09:11:48... | ACTIVE |
| 14 | Ikolomani Satellite | Kakamega | Mon Sep 01 09:12:32... | ACTIVE |
| 15 | Pokot east Satellite | Pokot | Mon Sep 01 09:13:05... | ACTIVE |
| 16 | Ngamia Satellite | Turkana | Mon Sep 01 09:13:45... | ACTIVE |
| 17 | Wajir magharibi Sate... | Wajir | Mon Sep 01 09:14:15... | ACTIVE |
| 18 | Kisumu General Hos... | Kisumu | Mon Sep 01 09:21:21... | ACTIVE |
| 19 | Moi Referral Hospital | Uasin Ngishu | Mon Sep 01 09:21:44... | ACTIVE |
| 20 | Coast General Hospi... | Mombasa | Mon Sep 01 09:22:18... | ACTIVE |

**Figure 8: Diagram showing the Administrator Module**

### 5.1.3 Local Clinician Module

This is a Module designed to allow the local clinician to assists in input of patient's data to the system in case the local clinician the wireless sensor is not in use.

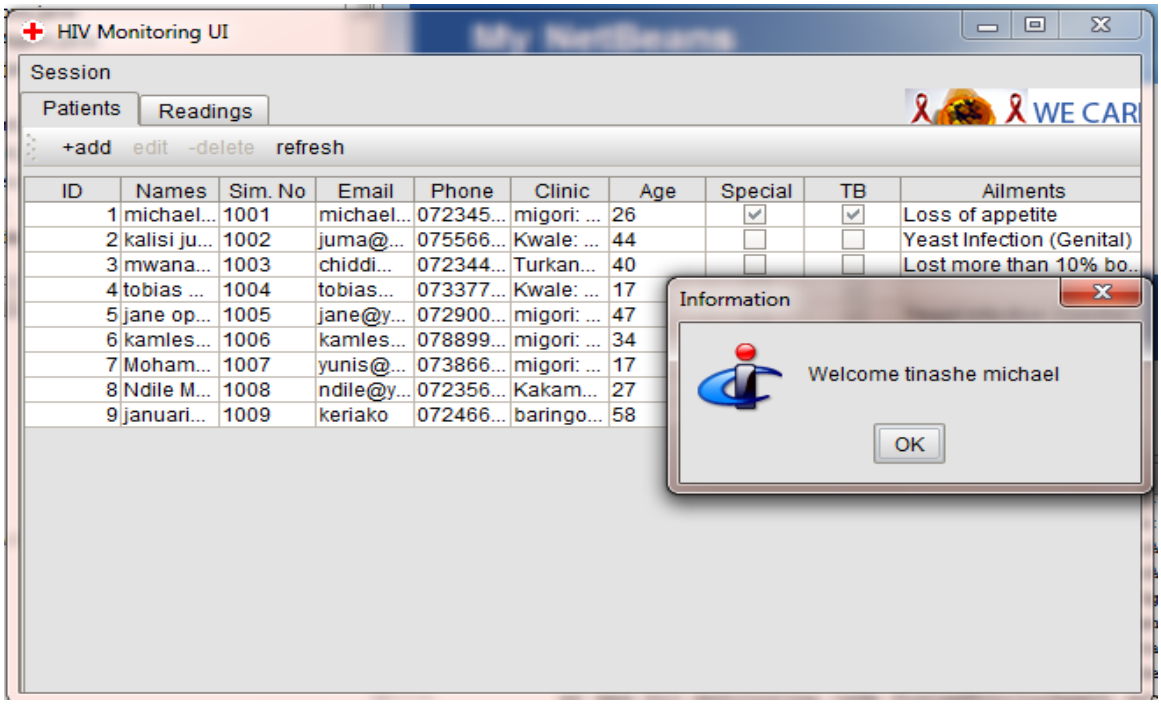



**Figure 9: A Diagram showing the Local Clinician Module**

### 5.1.4 Specialist Module

This is a Module designed for Specialist's Doctor that shows the diagnosis and treatment offered to a certain patient in consideration of the data inputs such as cd4, viral loads received.

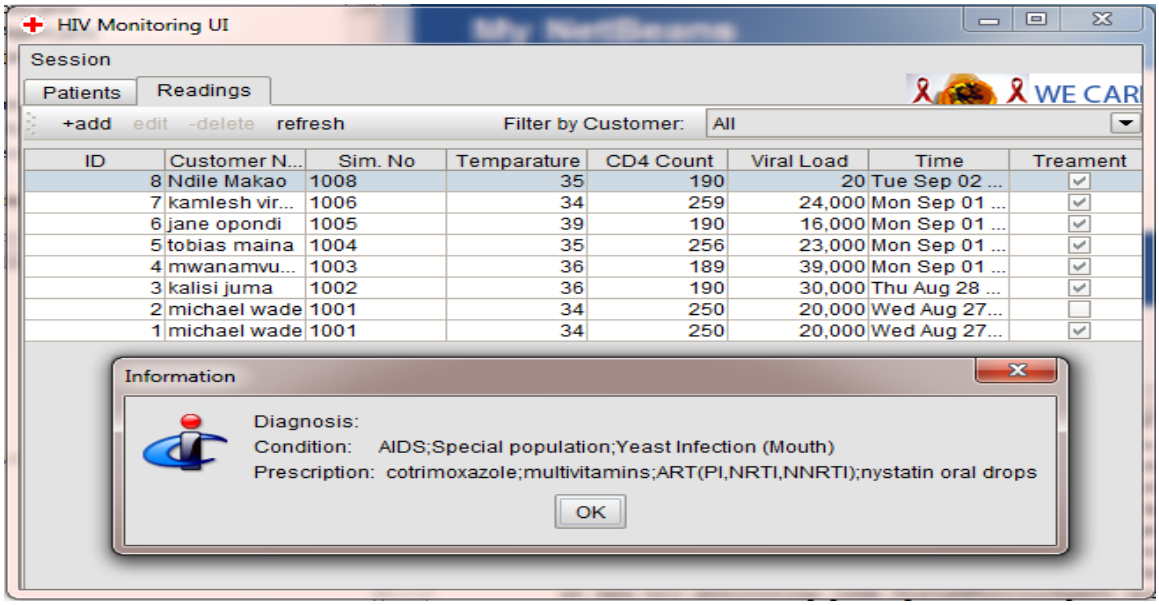


**Figure 10: A Diagram showing the Specialist Module**

### 5.1.5 Agent Interactions

Below is a diagram showing agent request and reply between the local clinician and the specialist agent where the local clinician sends data inputs of a patient and the specialist agent replies with diagnosis and prescription

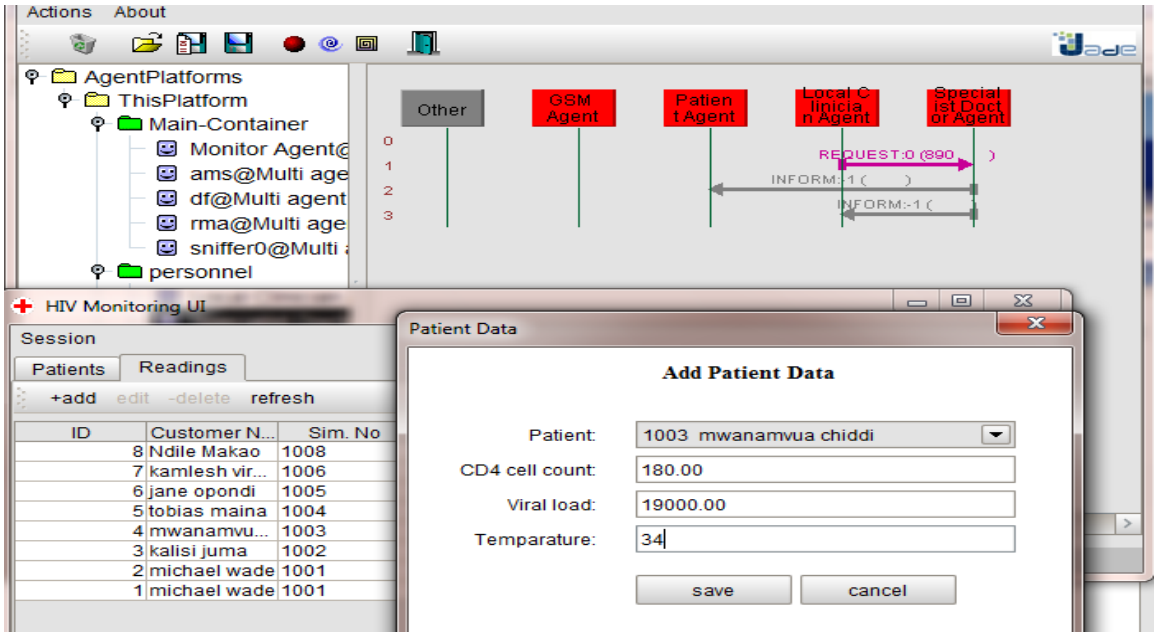
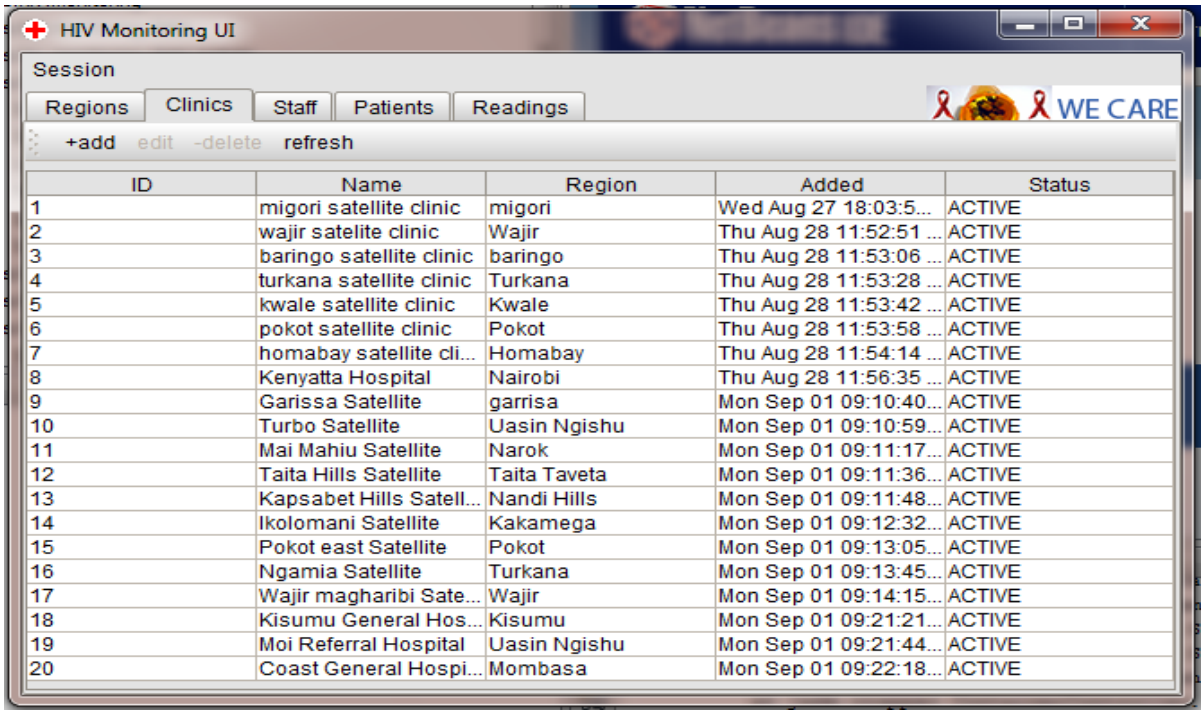



**Figure 11: A Diagram showing send and request from Local Clinician**

### 5.2 Prototype Data Inputs and Results

Types of data entities coming from the GSM Sensor attached to a patient include the following

a) Regions
b) Clinics
c) Staff
d) Patients
e) Sensor Readings




| ID | Name | Region | Added | Status |
|---|---|---|---|---|
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| 6 | pokot satellite clinic | Pokot | Thu Aug 28 11:53:58 ... | ACTIVE |
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| 8 | Kenyatta Hospital | Nairobi | Thu Aug 28 11:56:35 ... | ACTIVE |
| 9 | Garissa Satellite | garrisa | Mon Sep 01 09:10:40... | ACTIVE |
| 10 | Turbo Satellite | Uasin Ngishu | Mon Sep 01 09:10:59... | ACTIVE |
| 11 | Mai Mahiu Satellite | Narok | Mon Sep 01 09:11:17... | ACTIVE |
| 12 | Taita Hills Satellite | Taita Taveta | Mon Sep 01 09:11:36... | ACTIVE |
| 13 | Kapsabet Hills Satell... | Nandi Hills | Mon Sep 01 09:11:48... | ACTIVE |
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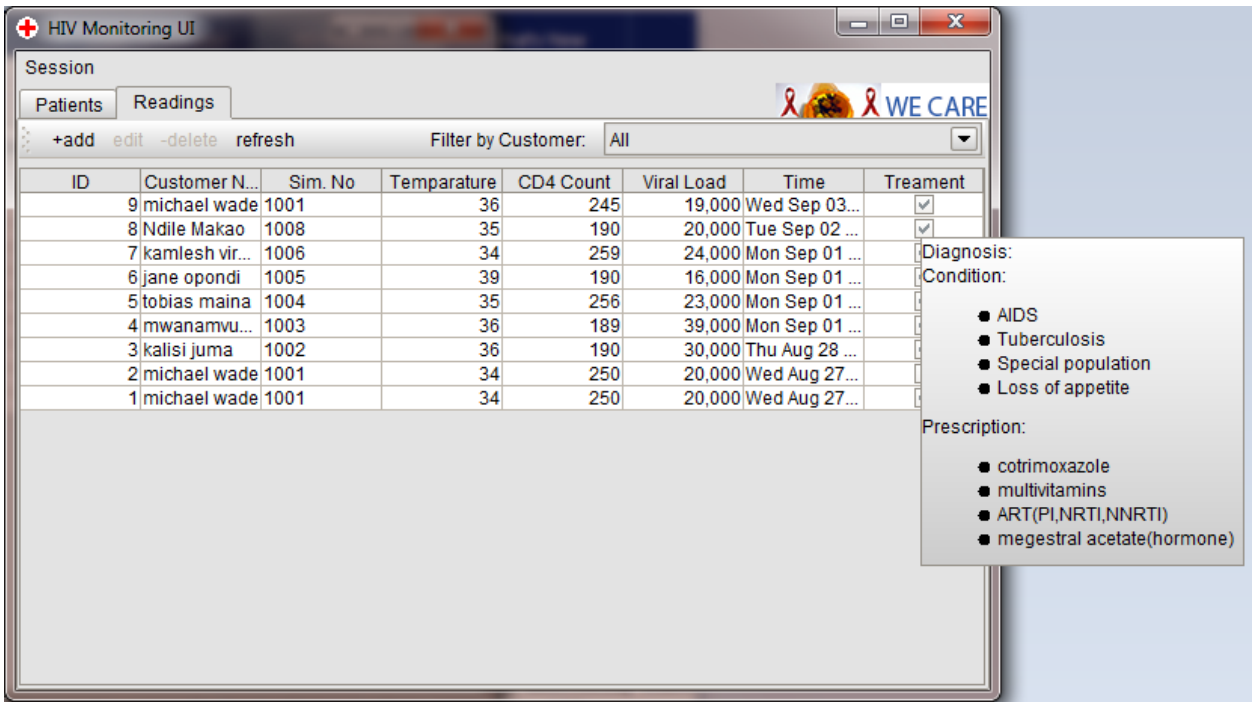
| 19 | Moi Referral Hospital | Uasin Ngishu | Mon Sep 01 09:21:44... | ACTIVE |
| 20 | Coast General Hospi... | Mombasa | Mon Sep 01 09:22:18... | ACTIVE |

**Figure 12: A Diagram showing Data Inputs of Entities for Multi-Agent Monitoring Systems**

Database showing inputs from the GSM Sensor and Action responses from the Specialist Agent.




| ID | Customer N... | Sim. No | Temparature | CD4 Count | Viral Load | Time | Treament |
|---|---|---|---|---|---|---|---|
| 9 | michael wade | 1001 | 36 | 245 | 19,000 | Wed Sep 03... | ☑ |
| 8 | Ndile Makao | 1008 | 35 | 190 | 20,000 | Tue Sep 02 ... | ☑ |
| 7 | kamlesh vir... | 1006 | 34 | 259 | 24,000 | Mon Sep 01 ... | |
| 6 | jane opondi | 1005 | 39 | 190 | 16,000 | Mon Sep 01 ... | |
| 5 | tobias maina | 1004 | 35 | 256 | 23,000 | Mon Sep 01 ... | |
| 4 | mwanamvu... | 1003 | 36 | 189 | 39,000 | Mon Sep 01 ... | |
| 3 | kalisi juma | 1002 | 36 | 190 | 30,000 | Thu Aug 28 ... | |
| 2 | michael wade | 1001 | 34 | 250 | 20,000 | Wed Aug 27... | |
| 1 | michael wade | 1001 | 34 | 250 | 20,000 | Wed Aug 27... | |

**Figure 13: A Diagram showing Action responses from the Specialist Agent**

Readings from the Sensor (inputs) include the following

a) Temperature

b) CD4 Count

c) Viral Load

The variables above are generated as a request by the patient agent and local clinician agents, Response from the specialist agent includes diagnosis and prescription for example when a specialist agent receives request of a patient with a certain reading it queries the database and gives a prescription according to the patient data received. Other condition that comes with HIVAIDS diseases has also been taken care of and subsequent prescription given.

| Patient Sim ID | CD4 Count | Viral Load | Temperature | Diagnosis | Other Conditions | PRESCRIPTION |
|---|---|---|---|---|---|---|
| 1006 | 185 | 46000 | 35 | AIDS | Yeast infection (Mouth) | Contrimoxazole<br>ART(PI,NRTI,NNRTI)<br>Multivitamins<br>Nystatin(oral drops) |
| 1001 | 250 | 29000 | 26 | HIV | None | Contrimoxazole,<br>Multivitamins |
| 1002 | 190 | 28000 | 35 | AIDS | Yeast infection (Genital) | Contrimoxazole<br>ART(PI,NRTI,NNRTI)<br>Fluconazole |
| 1001 | 260 | 25000 | 29 | HIV | Weight loss (>10%body weight )<br>Lack of appetite | Contrimoxazole,<br>Multivitamins<br>Megestral acetate (hormone) |

**Table 1: A Table showing Common Diagnosis Measures and Prescriptions**

## 5.3 Prototype Fail Safe

For the prototype to fail safe, we ensure that the data sent from the wireless sensor is encrypted to ensure there is guarantee of privacy and safety.

The wireless sensor platforms are both compact and lightweight this ensures that they can be worn without difficulty and are also acceptable by the patients.

The use of agents in this prototype will support fast processing and ensure that information sent from the patient agent received by the other agents for example the specialist agent by use of the Agent Monitors in addition to agents features such as agents social ability and proactiveness.

### 5.4 Evaluation and Discussion of Results

The prototype was evaluated by 14 users drawn from the medical field this included Doctors, Local Medical practitioners and Medical Students below are the results from the people who evaluated the system based on the following.

a) Use of System
b) Functionality of the System
c) User Preference

#### A.) Use of System

Below is a table showing ratings from the people who evaluated the system

| **Use of system** | Excellent (3 ) | Good (2) | Average (1) | Not sure |
|---|---|---|---|---|
| System ease of use | 3 | 9 | 2 | |
| User Understanding of system | 7 | 5 | 2 | |
| Ease of Diagnosis | 6 | 6 | 2 | |
| (Max total of 10) evaluated | | | | |

9/14 users rated the system as easy to use
7/14 users understood the System with ease
6/14 user found the Diagnosis of the database as ease and accurate

#### B.) Functionality of the System

Below is a table showing ratings from the people who evaluated the system in terms of its functionality.

| **Functionality of the system** | Excellent (3 ) | Good (2) | Average (1) | Not sure |
|---|---|---|---|---|
| Prescription helpful | 8 | 4 | 2 | |
| Speed of the system (speed) | 9 | 4 | 1 | |

| | | | | |
|---|---|---|---|---|
| (Max total of 12) evaluated | | | | |

7/14 users found the prescription given as helpful

9/14 users found the Speed of the System as fast

**C.) User Preference**

Below is user preference based from the people who evaluated the System

| **User Preference** | **Number of People** | **Not indicated** |
|---|---|---|
| Number of people who would wish to use the system | 12 | 2 |
| Number of people who would recommend to others | 11 | 1 |
| Suggestion on system improvement? | ✓ Increase on the tests done.<br>✓ Implement real medical sensors in the future | |

11/14 respondent said they would use such a system in their medicine practice

9/14 respondent noted they would recommend such a system to their colleague in the future

On suggestion from the users they noted that it was important to carry out more test on the prototype using real health medical sensors.

## CHAPTER SIX: CONCLUSION AND FUTURE WORK

### 6.1 Conclusion

This study has seen that multi-agent based system is a viable solution in assisting the monitoring and care of people living with HIV AIDS in remote areas with fewer Specialist Doctor this is based on the interpretation of the results.

Agent based monitoring of HIV AIDS has the potential to revolutionize healthcare by providing low-cost solutions and fast diagnosis and prescription for people living with HIVAIDS in the rural areas in comparison to the conventional methods where test samples, diagnosis measures have to be sent manually or electronically to Hospital for specialists to carry out the Diagnosis and prescription.

This research has also shown that the adoption and use of Agent based and wireless sensor technology in Monitoring HIVAIDS is a practical option that should be considered by the medical fraternity in its quest to reduce the cost that comes with the Care and Monitoring of HIVAIDS.

In addition the research outlines that the Adoption of Medical Wireless Sensors and Telemedicine can cut down Logistical, Administrative costs and time that come with offering Specialized Care to Rural Communities living in distant rural areas this is shown by the research.

However the current study highlights the fact that there are still challenges and issues that need to be resolved for wearable systems to become more acceptable by patients.

### 6.2 Recommendations and Future Work

a) Further research is required to address the issues of patient–system interaction, sensors mobilization, data extraction and adaptation.

b) There is need for more research on the implementation and testing on the different types of medical wireless sensors that can be used in the medical area.

c) Integration and securing of wireless sensor technologies in use for monitoring health services remains a challenge that can be pursued as part of future work.

### 6.3 Challenges

Challenges encountered during this study included simulation of sensor data and integration of the same with the multi-agent application. Data collection and evaluation of the system was a challenge since this is a project in the medical area and there are ethical issues to take care of.

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**Appendix A: Questionnaire**

**Health practitioner monitoring questionnaire**

## A. Health practitioner experience

1. What is your level of expertise [tick one]
   - Medical officer ☐
   - Nurse ☐
   - Specialist Doctor ☐
   - Medical Student ☐

2. How often do you handle HIV AIDS patients and related diseases?
   - Daily ☐
   - Weekly ☐
   - Monthly ☐
   - Quarterly ☐
   - Annually ☐

3. How often do you refer a HIV AIDS and related disease patient to a specialist?
   - Once ☐
   - Often ☐
   - Rarely ☐

4. Do you feed patient diagnosis, prescription, and progress data in a database?
   - Yes ☐
   - No ☐

5. If yes, how helpful is the database information?
   - Yes ☐
   - No ☐

6. Do you share medical records with other practitioners?
   - Yes ☐
   - No ☐

7. How helpful has sharing of information with other practioners in administration of patient been? (in a scale of 0 to 3,3 being very significant)
   - 0 not significant ☐
   - 1 least significant ☐
   - 2 significant ☐
   - 3 very significant ☐

**B. Health practitioner technology environment**

1. Does your institution embrace use of technology in offering health related services?
   Yes ☐
   No ☐

2. If yes, which one _____

3. Have your institution effectively incorporated technology in offering health services to patients?
   Yes ☐
   No ☐

4. Do you consider use of technology in offering health services to a patient effective?
   Yes ☐
   No ☐

5. What do you understand by the term telemedicine? _____

   _____

6. Have you used telemedicine in offering health services to a patient before?
   Yes ☐
   No ☐

7. Would you use telemedicine in offering monitoring services to a HIV AIDS and related diseases Patient?
   Yes ☐
   No ☐

8. In what type of environment would you prefer to offer specialized health services to your patient residing in a far distance from your institution?
   Face to face ☐
   Telemedicine ☐
   Referral ☐

**C. Technology performance**

1. Is your institution internet enabled?
   Yes ☐
   No ☐

2. How do you rate your institution internet speed?
   Excellent ☐
   Good ☐
   Fair ☐

Poor ☐

3. Do you use a smart device in offering health related service?
   Yes ☐
   No ☐

4. Do you have an internet enabled smart phone?
   Yes ☐
   No ☐

5. How do you rate the stability of your phone internet speed connectivity?
   Excellent ☐
   Good ☐
   Fair ☐
   Poor ☐

## Appendix B: Health practitioner Evaluation Questionnaire

### A. Use of system experience

i. How was your experience with the system in terms of ease of use? (in a scale of 0 to 3,3 being excellent)

0 not significant ☐
1 average ☐
2 good ☐
3 excellent ☐

ii. Using the proposed system what do you think is the ease of diagnosis (in a scale of 0 to 3,3 being excellent)

0 not significant ☐
1 average ☐
2 good ☐
3 excellent ☐

iii. What was the level of understanding of the system? (in a scale of 0 to 3,3 being excellent)

0 not significant ☐
1 average ☐
2 good ☐
3 excellent ☐

### B. Functionality of the system

iv. Was the prescription helpful? (in a scale of 0 to 3,3 being excellent)

0 not significant ☐
1 average ☐
2 good ☐
3 excellent ☐

v. How can you rate the Speed of the system? (in a scale of 0 to 3,3 excellent)

0 not significant ☐
1 average ☐
2 good ☐
3 excellent ☐

**C. User preference**

vi. Would you use the system? in your practice
Yes ☐
No ☐

vii. Would you recommend the system to others
Yes ☐
No ☐

viii. What Suggestion would you recommend on improving the system?

_____

_____

## Appendix C: Installation Manual

### Resource Requirements

_____

Please ensure you are running the following applications on your system before attempting to install/run this application.

1. Java runtime environment 7+
2. MySQL database 5+

### Installing

_____

Extract the contents of the zip file to your favorite directory.
Setup the mysql database.
Default credentials are:
host: localhost:3306
user: root
pass:
If the requirements above have been met, installation is complete :)

### Running

_____

Double click bat.run on windows to run.
On any other system, run the jar file using java's standar jar execution command.
i.e.
java -jar {jar-name}.jar

Enjoy