E-Management Framework for Teaching Hospital Complexes in Developing Countries

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***Abstract*—Accurate and timely information is crucial to good health delivery system. This is necessary for medical personnel to effectively perform their life saving assignments. Nevertheless, accurate and timely information are far from many developing nations' health care delivery systems due to various shortcomings in their medical record departments. For easy access to necessary information in hospital complex, this paper presents a framework for developing nations due to the heavy cost of wireless communication equipments. In addition, the architecture for the implementation of the software is discussed and performance comparison between the present record keeping (manual record keeping) in hospital complexes, and the proposed scheme were carried out using response time and cost implication of the systems as performance metrics. Mathematical models were developed for the two schemes. The algorithms for agent authentication on mobile devices and agent verification at the sever side before update and retrieval of information is presented. The simulation result shows that automating this sector of economy has a lot of tremendous benefits to the developing nations' health care delivery system.**

***Index Terms*—Mobile agents, Information Retrieval, PDA, Communication Networks, Medical personnel.**

I. Introduction

Timely information is essential for business issues, education [1], and more importantly to life [2].The medical personnel in many developing countries (DCs) have little or no information about their patients as at when due. For these medical doctors to excel and discharge their duties of life saving efficiently and productively, accuracy and timely information is necessary. Any technology that will help facilitate this accurate and timely information in developing nations will worth its price. However, in the developing countries of sub-Saharan desert, where the economy is growing at a snail speed, if not totally stagnant or rather degenerating, there may be political will on the part of the government to provide infrastructures in the hospitals to enhance health workers' productivity; but the economy is rather too narrow to accommodate the heavy cost of communication equipments. The cost of telecommunication equipments especially, wireless telecommunication equipment has forced the hospitals in DCs to use the traditional manual of record keeping. This is time wasting and error prone. This has equally reduced the desirable productivity expected in this sector of economy in most of these nations when compared with advanced ones. Patients' information mutilation, wrong records or lost due to manual record keeping and many other factors have led to the increase in death rate in many of the DCs hospitals [10]. There are cases where patients return to the same hospital after been discharged for further treatment because the sickness relapses, to discover that the case file is no longer in the shelve. The doctor now depends on oral information offered by the illiterate patient to discharge his/her duty. Such cases are aggravated, when the consultant that handled the case is no longer in the service of the hospital.

Therefore, to address the aforementioned problems, this paper proposes the use of mobile agent framework for information storage and retrieval system in developing nations' hospital complexes for efficient hospital management.

Rationale for Lightweight Mobile Agent

Lightweight mobile agent technology is an efficient tool for implementing mobile computing and distributed applications. It is attractive and relevant in situations where network bandwidth is very narrow and unreliable. This is because it does not take all the required intelligence with it when migrating on computer networks. It should be sounded clear here that many developing nations' computer networks exhibit low-bandwidth connectivity [22][23], and they therefore require a scheme such as the one being proposed in this study. Also, partially connected devices such as Laptops, PDAs, mobile phones etc. can be connected to a network and then get disconnected for a long period of time and resumes connectivity when the mobile device reappeared in the network. It is easy for lightweight mobile agent to migrate from mobile devices (which are characterized with small memory) such as PDAs or mobile phones through the computer network to the Internet to do some computational tasks and return to the mobile device. When the agent has left the mobile device, it is possible for the agent to autonomously continue its computational tasks and return to the mobile device with the result of its task when the mobile device gets connected to the network. It is cheaper in terms of bandwidth usage either the available bandwidth is reliable or not, since the agent is not continuously connected to the mobile device, bandwidth is left for other purpose once it departs from the mobile device. It is highly reliable especially

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when connections are not stable, the agent does not require network connection during its computational task on the network.

Therefore, in this work, we propose a mobile agent scheme to implement network-eccentric applications on DCs computer networks. Also, infrastructural development is in a low state in many of the DCs. Therefore electricity supply is often epileptic. This situation will not support a network application that takes a long time on computer network before computational work are completed.

The rest of this paper is arranged as follows: section two discusses the relevance of mobile agent for this type of software, section three shows the proposed architecture of the system, section four summaries the advantages that are attached to this system for developing nations while section five is the conclusion.

II. Mobile Agent Technology

In this paper, we present a mobile agent based system to support distributed applications on computer networks of developing nations' hospitals. It is worthwhile to say that the terms mobile agent and lightweight agents are used interchangeably in this paper. An agent is a computer program that can autonomously act independently on behalf of another entity either another application program or person. A mobile agent is a code that can move through a heterogeneous network independently without human control, migrating from one computer system to another either carrying out computational tasks or interacting with other agents and resources on each system. The agent returns to the home node where it was lunched with the result of its computation. The migration advantage of mobile agent helps to reduce network traffic, network latencies, and enhances robustness and fault-tolerant abilities of distributed systems [3] [7]. These indicate the major difference between the traditional software and mobile agent software [11]. The agent can suspend it execution, migrate to another machine and resume execution on the new machine from the point where it was suspended [3] [4]. When dispatched, the agent can migrate from system to system on the network performing information processing on its own [18].When an application requires low bandwidth, overcome network latency, reduce network load, and provide robust and fault-tolerant performance, mobile agent is very useful [12][13]. There are several applications that have benefited from mobile agent implementation, though there are arguments in research circles on security implication of the software. Nevertheless, information storage and retrieval systems have benefited tremendously from mobile agent implementation [14][15][16][17]. Agents are sent to remote locations on heterogeneous network to retrieve information from databases and to return results to the user. Specific examples of mobile agents application in information storage and retrieval in different domains are; mobile agents are used as personal office assistant [21][19], electronic trading [18]. In telecommunication, mobile agents have been used to realize network responsiveness [19]. Several researchers have proposed mobile agent for different applications, but it is noteworthy that all software applications cannot be agent based. And we argue that what agent can do some other software can equally achieved pleasantly. The following features define an agent: it is autonomous, has the ability to operate as a standalone process, perform actions without human intervention, communicative, the agent can perceive and respond to changes in its environment and can learn and adapt appropriately to the environment.

Mobility infrastructure [9], classified agent into two types: static agent and mobile agent. The mobility infrastructure makes mobile agent to find more attractive applications in distributed information processing, particularly in mobile computing scenarios where users have portable computing devices which require intermittent, low-bandwidth connections to the main network [5][6]. Hospital management normally adopt distributed information paradigm for their operations. In distributed platform, heterogeneous data often exist due to partial automation of each section of the hospital. Many of the programs for the partial automation were developed by different programmers for different sections over some period of time. The data are heterogeneous too and often incompatible. A flexible technology that can interface with multiple heterogeneous information sources is thus required. Therefore, any technology that will be used should have the following characteristics to meet the information exchange requirements:

1) Security support: data encryption before transmission and user authentication before accessing information
2) Optimization of bandwidth usage: the bandwidth required is very low, so that the DCs will be able to provide facilities for such a low cost bandwidth
3) Robust and fault-tolerant communication over unreliable environment and portable personal communication devices: the communication networks in DCs are highly unreliable due to power supply problem.
4) The system should be empowered to integrate heterogeneous data from different sources
5) Easily scalable system: It should be easy to add more PDAs as the medical personnel in the hospital increases with little or no modification to the application.

The mobile agent technology readily finds application in the above scenario. The agent can move from the portable device to the network location of a needed information resource, and perform computation locally [3][7]. The results of computation are integrated if the sources of data are heterogeneous before such data are transmitted back to the portable device through an interface to the user. Figure 1 illustrates a medical practitioner retrieving a patient's record from the central server within the local area network of the hospital.

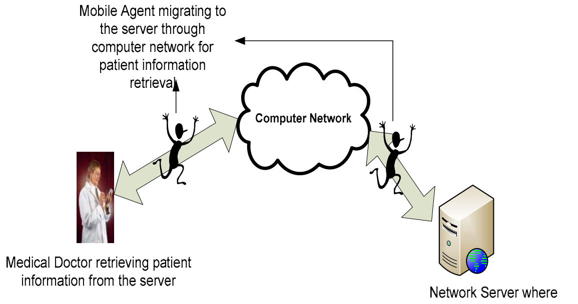

Figure 1: Medical personnel retrieving patient information

III. System Architecturural Design

The architectural design is divided into two phases: network architecture and software development architecture.

A. Network Infrastructure

The architectural design assumes that any hospital that will implement this framework should have a local area network (LAN) setup and every ward in the hospital is connected to the central server or relevant server where multiple servers are used. This work assumes minimum of eight ports switch connection in every ward. This will allow a minimum of four teams of medical doctors to operate in the same ward at a time. A port for uplink and the extra three ports are left free to reduce the load on the switch. Each consultant, who is the head of the team is entitled to a Personal Device Assistant (PDA) which is empowered to do some mobile computational work especially information storage and retrieval [8]. Otherwise, laptop computer system may be the next option. When connectivity infrastructures are available, the medical doctor with his/her PDA, and out-patients equipped with mobile devices can connect to the network at a remote site or make use of the Outpatient department computer room for connectivity. The account officers in the hospital are connected to the central server to view financial status of patients prior to their discharge from the hospital, and for other information storage and retrieval activities. There is a security check on all users, and immediately when a patient is discharged, his or her particulars are sent to the outpatient table. When doctors have finished with patients, the access to such patients' information is deactivated. Such information is reactivated when there is a reoccurrence of the ailment.

B. Software development architecture

We adopted lightweight mobile agents for our system development. Lightweight mobile agents are agents with minimal source codes. The agent's intelligence is separated from the migrating source code. Thus, the agent is very small and it is easier and faster to be transmitted on a low-bandwidth network which characterized wireless network. The lightweight mobile agent as opposed to the "heavy weight" mobile agent who encapsulates all intelligence required for its computational task on any targeted node on the network. Thus, lightweight agent is very small; it is dynamically updatable and upgradeable because dynamic aggregation allows runtime addition of new functionalities into the agent [24]. It is much more flexible and easier to program than the agent with large intelligence. The agent gets to the node where computational work is expected to be done and upgrade itself with the required intelligence which is previously stored at the node. Actually, storage facilities is no longer a big issue in the modern computer technology, storage facilities ranges in hundreds of gigabyte. Therefore, storage of the required intelligence on every node on the network has little or no overhead. The acquired knowledge is deleted when the agent has finished its computational task at that node, and it is about to return to the home node.

The mobile agent is a Java-based mobile agent, which is platform independent. It provides a simple but structured way for a mobile agent to migrate from one computing node to another (server) for information retrieval purposes. The PDA or laptop hosts the mobile agent therefore; it must be equipped with sufficient storage capacity and memory facility to store and run the mobile agent. Within the architecture lies an interface called *DOKKY* which provides an execution environment for the migration of the mobile agent to the network. It also receives an incoming agent from the network and provides an interface for communication between the agent and the user. At the database end of the architecture is a server with a static agent called MAAnI which registers and verifies the agent authenticity before permission is granted to the agent for information storage or retrieval purpose. If the MAAnI finds a strange *agent* that it cannot register, alert is immediately sent to the network administrator of the possibility of malicious agent on the network. The system software architecture is presented in Figure 2 while Figure 4 presents the algorithms for *DOKKY* and MAAnI.

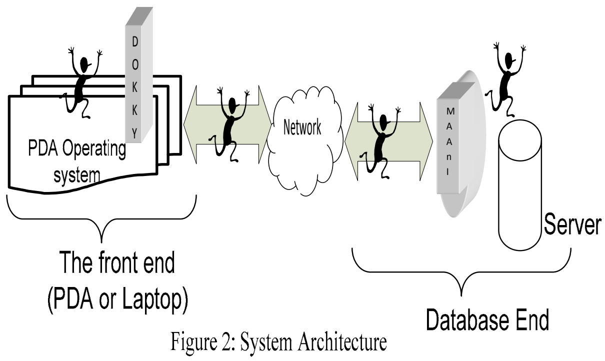

Figure 2: System Architecture

It is important to note that each mobile agent carries the digital signature of the team leader for any remote computation. This policy ensures data integrity and privacy. Any changes on the patients' prescription records and comments of the medical team will be recorded in the name of the team leader. Prescription of drugs can be changed from time to time by the team consultant as the case may demand through the mobile agent. But before this could be done all the necessary information (name of the doctor, Status, Security number and password) must be registered with the MAAnI module.

IV. Mathematical Model Development

The mathematical model is in two folds: (i) Model for Mobile agent and (ii) Manual Record Transmission model. The models described the variables involved in manual and electronic information communication in quantitative form that are used to simulate the performance metrics of both systems.

A. Mathematical Model for Mobile Agent

This is given as

$$\boldsymbol{\Psi} = f\,(\text{ß}, T_r) \quad (1)$$

Where **ß** is the total load transmitted over the network and $\mathbf{T_r}$ is the service response time. In this architecture, the mobile agent move across the network with its code and the request to the destination node.

Agent and request are given as:

$$\mathbf{m_g = d + q} \quad (2)$$

where $\mathbf{m_g}$ is the total weight that is moved across the network, **d** is the agent size, and **q** is the request size.

For a return trip, we have:

$$\mathbf{m_r = d + r} \quad (3)$$

where $\mathbf{m_r}$ is the returned weight, **r** is the result of the search. Addition of Eq(4.2) and Eq(4.3) gives:

$$\mathbf{M_t = 2d + r + q} \quad (4)$$

The total load over the network for the simulation period:

$$\text{ß} = \sum_{i=1}^{n} (2d + r_i + q_i) \quad (5)$$

where **i= 1,2,3,……..,n** is the number of times the agent moves round the network.

Assuming that the cost of available bandwidth (**y** bps) transmitted in a unit of time is **z** unit, the cost is express as:

$$\boldsymbol{\Psi} = z\left(\sum_{i=1}^{n} (2d + r_i + q_i)\right)/y \quad (6)$$

The response time, which is the time to transmit data across the network and to receive the reply, is express as:

$$T_{Agr} = \left(\sum_{i=1}^{n}(2d + r_i + q_i)\right)/\,y + \in \quad (7)$$

where $\in$ implies electricity outage which increases the overhead required for information transmission. There are hospitals that have provision for alternative power supply, however, break in transmission and reconnection will elongate response time. This is a reality in many developing nations.

B. Manual Record Transmission Model

The manual record processing is modeled using queuing model concept for M/M/1which is a single server [24]. The arrivals of patients are assumed to happen in a poisson process with rate λ and the service time with rate μ. This indicates that the numbers of customers Z(t) (in our system, the customers are patients or cards) arriving during a time interval (0, t] has a poisson distribution

$$P[Z(t) = j] = e^{-\lambda t}\,\tfrac{(\lambda t)^j}{j!},\ j = 0,1,2.... \quad (8)$$

The inter arrival times have an exponential distribution with probability density

$$d(v) = \lambda e^{-\lambda v},\ v > 0. \quad (9)$$

We assumed also that the service times of the system have an exponential distribution with probability density

$$c(v) = \mu e^{-\mu v},\ v > 0 \quad (10)$$

In manual record processing, the discipline is **First in First out (FIFO)**. Which means the patients are attended to as they arrive. It should be noted that emergence cases are referred to emergence ward which is not represented in this work. The waiting time for the first patient is zero, the waiting time for the next patient is the time required to attend to the first patient. It should be cleared, emergence cases are normally referred to the emergency ward, we do not provide for emergency in our system. When there n patients in the system, since service times are exponential with parameter μ the total service time of n patients is expressed as

$$f_n(v) = e^{-\mu v}\,\tfrac{\mu^n v^{n-1}}{(n-1)!} \quad (10)$$

We modeled our system as a single server system of the type (M/M/1): (FIFO/∞/20) which denote exponentially distributed interarrival time, markovian service time and arrival time (M/M/1), one server with FIFO priority rule, and with twenty patients on the queue.

The cost of information retrieval in manual record processing is a function of the following parameters

$$\text{ß}_T = f\,(\text{ß}, T_{mr}) \quad (11)$$

Where **ß** is the summation of expenses incurred by the hospital management board which includes: workers' wages involved in medical records processing, necessary stationary (**S**), logistics (**L**) etc., and the total number of times a worker is engaged in records retrieval process in a day(**T**). $\mathbf{C_d}$ is the number of days in a month the worker attends to information retrieval work (workers may be assigned other duties apart from information retrieval, especially, when the number of workers on ground are more than required). The mathematical model for the cost implication of manual record processing in the hospital is expressed as:

$$\text{ß}_T = \sum_{i=1}^{n} \{(\text{ß}_i * T_r * C_d) + S + L\} \quad (12)$$

where **i = 1,2,3,……,n** is the number of people employed in record retrieval duties for a period of time.

The response time for manual record processing is expressed as the time required getting the information at the table of the medical personnel requiring such information to perform his/her official duty.

$$T_{mr} = W^t + R_T + T_T + \square. \quad (13)$$

The manual record transmission time $\mathbf{T_{mr}}$ is a function of the record waiting time $\mathbf{W^t}$, record retrieval time $\mathbf{R_T}$, the transmission time $\mathbf{T_T}$ plus □ which is a factor of logistics involved information dissemination. Factor that can affect □ are (i) Staff lateness to the office, (ii) Staff distraction, (iii) Electricity outage during record retrieval.

V. Simulation Experiment

The simulation program was written in JAVA programming language. Java has become an adopted platform for mobile agent because of utilities offered by the language. There is provision for code serialization, dynamic class loading, security mechanisms are enhancement etc. The simulation experiment was carried out in an environment that fairly represent the real life situation surrounding records processing and electronic record processing in many developing countries especially, Nigeria. Two experimental programs were allowed to run separately but in same environment. The program that simulates the manual records processing incorporated some of the shortcomings associated with the operations. For example, lateness of members of staff to official duties, lack of enthusiasm to official duties or negative attitude to official work (negligence of duty), etc are well addressed in manual model. These conditions further aggravate problems associated with manual information processing in many developing nations. Also, in the simulation of the Mobile Agent scheme, important issues such as electricity outage, LAN inoperability due to faults, etc., were considered.

Tiny mobile agents were developed using Java programming language for the purpose of this experiment. The intelligence required by the agents was kept in a notepad file at a remote system where the agents carried out computational task. The agents were deployed into the network where the codes for their intelligence were stored in the systems. The agents got to the expected remote systems, download the required intelligence and upgraded themselves before computational task begins. The mobile agent used in this work with its migrating facilities is not more than 25KB. The different systems where intelligence were kept for agents' upgrading are the servers where medical information (laboratory tests, drug prescriptions, patient card etc) are kept and this spans geographical distance in the complex.

The Manual method program is developed using Java programming language. Since, the model follows queuing systems, the Java program used markovian number generator for arrival of the patience and the service time in the system. Patients were treated in batches of 20 and the system is single server system.

VI. Agent Authentication Algorithm

It is common phenomenon in mobile agent systems for agents to present proper identity before gaining access to information on the agent server. In our system, it is required of every mobile agent to unique identify itself both at the server side and mobile device side before admittance is given to it. The identity of each agent dedicates the degree of access right that should be given to the agent especially in a multi-agent system. Our agent authentication algorithm simply identified mobile agent so as to guide against malicious agent from gaining access to the medical personnel mobile devices or the remote server where medical records are kept. Therefore, the goal of this section is to offer protection mechanism for mobile devices in this network so that no strange agent can masquerade any medical personnel for malicious work. Also, the medical record server is secured against unauthorized access by foreign agent or malicious code. We implemented digital signature which is embedded in the mobile agent system. The digital signature provides an efficient away of uniquely identifying an object sender and to be sure that the object is not modified while on transit. The digital signature consists of alpha numeric string that presents the medical personnel who holds the mobile device from where the agent is emanating. The agent posses the unique identity of the personnel and the type of responsibility attached to the personnel. The category of duties used in the work includes: Diagnosis by medical doctors, Medical test by Laboratory Scientists, Administer Drugs by Nurses and Drug prescriptions by Pharmacist. Each of these duties has its which is attached to the identity of each personnel on duty.

When a mobile agent is about to move from the mobile device, the DOKKY (a static agent) on the mobile device on which the agent is running digitally append a signature on the mobile agent. The digital signature is an encrypted code well understood to MAAnI. The agent is transported to the destination server with its state, code and digital signature. The encrypted code is decrypted by MAAnI and compared with agent authentication key table with it. If the key matches any of the authentication keys with MAAnI, the agent is allowed into the system for information retrieval else the agent is rejected. Also the process is repeated on itinerary back to the mobile device. Figure 3 illustrate the security measure for the agent in this system.

```
……
Agent agent =new Agent();
  agent.gets_duty_code();
  agent.receives_personnel_Identity();
   agent.encrypt(data);
   agent.transmits(state, data);
   agent.decrypts(data);
//MAAnI request agent identity
  if (Manni.request_Identity(agent)==true)
  {  agent.grantPermission();
     agent.performComputation();
   }
   else
   agent.reject_entrance();
………
```

Figure 3: Algorithm for Agent Security

VII. Result Discussion

A. Cost Implications for the Schemes

The cost of using the Mobile Agent Scheme is more than twice cost-effective than the manual information processing in the simulation. It is clear from the simulation, that as the number of requests increased, the cost implication increases, the rate of increase in mobile agent scheme is lower than the manual information processing. Figure 3 illustrates the graphical presentation of simulation result data of cost implications for the two schemes. In Figure 4 Mobile agent is synonymous to lightweight agents, this should not be confused.

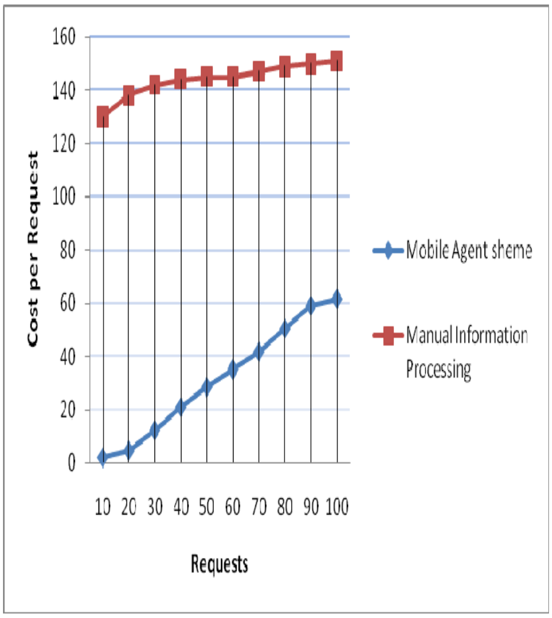

Figure 4: Cost Implication of the two schemes.

Employees involved in manual records processing in the hospital are full time. The wages are constant, and an increment is gotten by few additional casual workers co-opted to the unit when information processing work overwhelms the staff on ground. This accounts for the little increase noticed on the manual information processing. The increment in the mobile agent scheme is very significant because the agents handled request in batches.

There is in minimum number of request handled at every time. For the mobile agent scheme we assumed that all patients' information is fully automated. There seems to be a close gap in the cost analysis of the two schemes as requests increases, there is a minimum increase that will cause the hospital management board to initiate fresh staff recruitment.

B. Response Time of the Scheme

Response time can be defined as the time interval between the time the end user enters a request on a computer system and the time the feedback is perceived at the terminal. In our system, which is data processing system, response time is defined as the time interval between the receipts of a request message and the instant of transmitting the result of the request to the user. The response time of mobile agent scheme is obviously better than the manual information retrieval scheme as depicted in Figure 5. While the two schemes experienced degradation in response time as the number of request increases, the increase in manual information processing is more than twice the increase in mobile agent scheme. The difference in response time of mobile agent system and manual record processing becomes wider as requests increase. This is due to delay and error involved in manual record processing. As the number of request increases, the likelihood of delay and error increases. The mobile agent scheme performed efficiently better than the manual record processing as expected. During the simulation, we assumed the availability of alternative power source if there is electricity outage. The minimal time taken for changing the power source is also taken to consideration in the simulation.

VIII. CONCLUSION

The need for affordable communication system in the developing countries hospital complex cannot be under estimated. Many valuable lives which should have been saved if timely information were available at the appropriate time are rarely saved. The design of this system has been very modest and cost effective for system implementation for developing nations. The used of lightweight agents optimized bandwidth usage which very important to developing nations. The system promises to enhance the productivity of medical personnel by providing accurate information necessary for health care delivery in a timely fashion in developing nations' hospitals. The system also supports the mobility of medical personnel which is necessary during their operation. The manual or partial automation which is very cumbersome will have been eliminated. This will reinforce the confidence of people in national health care delivery system.

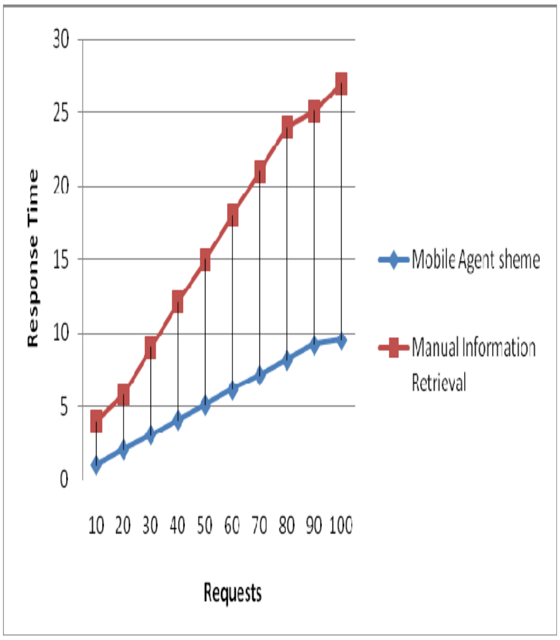

Figure 5: Response time of the two schemes.

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