Mobile Based Clinical Decision Support System

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Abstract

One of the greatest hurdles a care provider faces is availability of proper information at the point of care. This becomes more critical if the patient is in emergency condition and fighting with his life. Availability of the information at the place of requirement is the need of the time. Mobile solutions can bridge this gap and can arm the care providers with right information at the right time. A clinician needs to be able to capture, store and receive clinical data no matter where he is physically located. More often than not clinicians have patients in various physical locations that are geographically apart. It helps him immensely if the data is available to him from all locations in one place irrespective of whether he is in a specific place or is moving from one place to other. Hand held devices powered with strong and multi-faceted applications can be of immense use for the clinicians to collect the information, analyze them and send the decisions to the point of care within a very short span of time. This paper brings out the solution architecture to be used to cater the care provider with full control of his patient's data along with alerts. This paper also suggests a possible clinical decision support through pre-set rules and possible knowledge discovery. The contents of this paper is mainly from the experiences of the authors and the inferences drawn thereof.

1 Introduction

Presently, hand held devices like mobile phones, PDAs, Palm Tops have become a necessity in different walks of life. The affordable cost, the unlimited connectivity and the larger memory availabilities have made these devices more useful than being used. Presently, the hand held devices are being used only for sending/receiving mails or other documents, organizing the information available in the device and for mobile communication. They are not used for transactions and decision making which they are capable of. A number of initiatives have been started in different industries to use the maximum capability of these hand held devices.

Though some of the industries have started using the hand held devices to their advantage, health care industry is left behind. At the same time, the care providers in a health care industry are still using the clip boards and normal level of communication to pass critical information at the time of requirement. Healthcare has come up with modern techniques for detection of diseases, imaging and even in the field of medicine. But, they could not cross this last mile which can make the care provider's life much easier. It is imperative today to allow a clinician to receive life critical data at a time and place when he requires it. Deployment of a mobile platform in a healthcare environment can connect the clinician to larger systems and allow him to access the critical data and help him to perform all the time and machine critical data management. The efficiency and productivity of a care provider then would definitely take a quantum jump [1, 2].

The healthcare providers are highly mobile in nature, moving from one patient to another, from one hospital to another, even from one location to another while performing their duties. Many hospitals installed in-house hospital management systems to manage huge amount of data generated within the hospital. These information are available within the network and access is given at certain locations in the hospital so that care providers can get the required data. But, at a critical situation, the care provider does not get sufficient time to access the network and collect data for analysis. This becomes more critical if the care provider is not available at the premises. A hand held device can help the care provider to gather all the information on his palm and take the decision accordingly.

In this paper, we describe the present scenarios in a hospital to show how difficult the life of a care provider is in today's hospitals. Different challenges faced by clinicians are explained. The manner in which this situation may be altered using the proposed solution is presented as a viable alternative. The paper describes the solution architecture of the mobile platform being proposed.

2 Present Scenario in a Healthcare Provider Environment

The clinician of today is a much-tried man. He has to provide care to a number of patients, provide information, advice and guidance to the patient's relatives and friends, be in touch with his subordinates in the form of junior doctors, nursing staff, the administrative staff of the various hospitals that he is attached with, staff in his clinic, etc., preferably simultaneously. If he is a general (or primary) practitioner, or dealing with critical care patients, then this requirement of him increases manifold.

Let us consider one scenario where we have a general practitioner as the protagonist. He has a clinic that he attends from 0900 hrs to 1300 hrs and 1800 hrs to 2100 hrs. He also attends upon his clients at his house from 0700 hrs to 0830 hrs. He does home visits when either of his clinic or house timings are not in conflict with the timings for these visits. He does routinely refer his critical patients to two nursing homes and all pertinent as well as requested information regarding all his patients who are managed at the principal referral multi-speciality hospital in the neighbourhood are routinely communicated to him on a daily as well as ad hoc basis. He has a system that allows him to capture, store, retrieve, forward and display details regarding his patient's health status. The nature of this system is made up mostly as a hybrid of telephonic conversations with the various stakeholders, notes written on papers that are usually filed but sometimes some of which are lost, patient records, charts, and reports including discharge summaries, etc.

Critical care patients emanate critical information which need quick turnaround time. Also, pertinent information regarding routine care patients who have been referred to a nursing home or hospital needs to be available to the general practitioner. The General Physician too needs to inform the current care provider valuable and often life-saving information regarding the patient like his current medication, the last five blood pressure and pulse rate readings, last serious health complaint, etc.

The challenges that the General Physician, his patients and the other stakeholders face are how to effectively get the information across to each other. The General Physician has to make and attend individual phone calls, shift through reams of papers, charts, pictures, reports, letters, etc., make logical sense out of them and get the "broad-view picture" that will make some clinical sense. Although, access to mobile phone have eased his ability to access the latest information no matter where he may physically be, trying to get the "big picture" not only remains a considerable challenge but supplying the right information at the moment of requirement remains an even bigger one.

3 Altered Scenario with Proposed Solution

The doctor in question has a hand-held device that he can synchronise with his desktop both at home and his workplace. He can use an ordinary telephone line or a mobile phone to connect this hand held device to a central server to which his desktops as well as the Hospital Information Systems of all the healthcare provider institutions that he has a relationship with are connected.

The situation changes dramatically. Now he is able to capture and display patient's information, send data for storage, retrieve both synchronously and asynchronously the patient's and other relevant data, receive alerts and warnings, some of which may be rule-based that were created as general rules or were created by him for a specific patient, evaluate outcomes of a group of patients having similar profile as his patient, find out statistics related to evidence based medicine like numbers needed to treat, relative odds, absolute risk reduction, and *posteriori* of a fact according to Bayes rule – regarding the value of investigations or a particular mode of treatment [3].

The doctor in question would be able to monitor the progress of his patients while at home or clinic using his desktop. When he is leaving. He can synchronise the required information with his PDA so that the information within this device would be current. Using his hand-held device he can set, re-set or cancel rules. When a query is received from a third-party regarding some information regarding one of his patients, he can accomplish this at the click of a button or even he can pre-set rules that would allow a known or expected request to be handled in a specific manner. Though the request is received and the rule is processed using the hand-held device, the actual data processing, retrieval and forwarding will be handled by the central server through appropriate desktops/systems. If he wishes to perform calculations or get some facts reported based on pre-set formula, he can very easily perform these using a similar methodology that has been enumerated above.

In this manner, whether the doctor is static in his chamber or at the home of his patients or on the move in his car, he will be able to be "in touch" with the well-being of his patients and have the most current information at his fingertips. If he wishes to print a report or a prescription or an advice he can use mobile technology to have it printed either at the respective person's place or at a place most convenient for the person concerned.

The system to be used by the care providers should be ergonomically designed to allow the doctor to interact with the system with the minimum of efforts. All the screens are designed in such a way that with least number of clicks the clinician is able to perform his actions. In

order to achieve this end a browser is designed for the hand held devices.

4 Mobile Platform for Healthcare Industry

Mobile based clinical decision support system is an integrated solution designed specifically for healthcare industry and addresses an important and compelling need of care providers specifically when they are on move. It allows the care providers to take timely decisions using their handheld devices. If integrated with the Hospital Information System, this solution not only provides "anytime anywhere" access to comprehensive patient information but also allows the care provider to take decision and send the decisions to the point of care through handheld devices like PDA's and mobile phones.

To enable secure passage of information over handheld devices, end to end security based on Public Key Infrastructure (PKI) or Wireless PKI (WPKI) concepts has been incorporated into our solution [4, 5]. This ensures confidence in all the players and takes care of the provisions of data security and confidentiality requirements (like Health Insurance Portability and Accountability Act or HIPAA) that transactions cannot be fraudulently generated or altered, that transactions are legally binding and that confidentiality of private information is adequately protected.

By providing this solution to the hospitals, clinics and other health institutions, the care providers will increase customer satisfaction by providing value added services like any time anywhere access to information and decision taking capability, thereby increasing the number of patients and reducing churn. It will also improve the care provider's productivity due the availability of real time information.

4.1 Solution Architecture

The solution architecture of mobile based clinical decision support system is shown in figure 1. It is specifically designed for healthcare industry where retrieval of real-time patient information is very important. This architecture is highly scalable and can be extended for other hand-held devices with minimal cost extension.

The mobile based clinical decision support system consists of the following modules:

- Analytical Engine – takes care of the alerts, warnings and recommendations
- Transaction Engine – displays data, search data and process data on the basis of the request
- Supplemental Engine – processes clinical data for data warehousing
- Security Module – takes care of the confidentiality and privacy requirements
- Interfaces – connects the system with the Hospital Information System, Wireless Network & Data Warehouse.

The details of each system explained below:

4.1.1 Analytical Engine

The Analytical Engine analyzes the patient data, interprets them and send Alerts, warnings or recommendations to the care provider depending on the requirement.

Alerts are normally rule-based and pre-set and could include such rules as "Alert me whenever the heart rate of <patient name> crosses 140 beats per minute" or "Alert me whenever there is a serum creatinine level crosses the value of 1.5 for any of my patients". These are those classes of messages that a clinician needs to know on a priority basis in order to provide a higher level of care and they require a certain degree of analysis of the relevant data before reported. They also have a pre-condition wherein the clinician may not proceed further either without having acknowledged its existence or by acting as a follow-up action in the form of performing some task as looking up the patient's chart displaying his current vitals like heart rate, blood pressure, body temperature, respiration rate, partial pressure of oxygen, etc.

Warnings are also rule-based like alerts. The prime difference being that normally it is not mandatory for the clinician to acknowledge or act upon it. Warnings could be "Warn me if I prescribe a drug that causes drug interaction with an already prescribed drug", or "Warn me if the cost of the total prescription exceeds a limit of <currency>."

Recommendations are various calculations of evidence based medicine and outcomes analysis based upon clinical observations and historical data. The historical data is sourced from a clinical data warehouse while the clinical observations are sourced from the clinical data

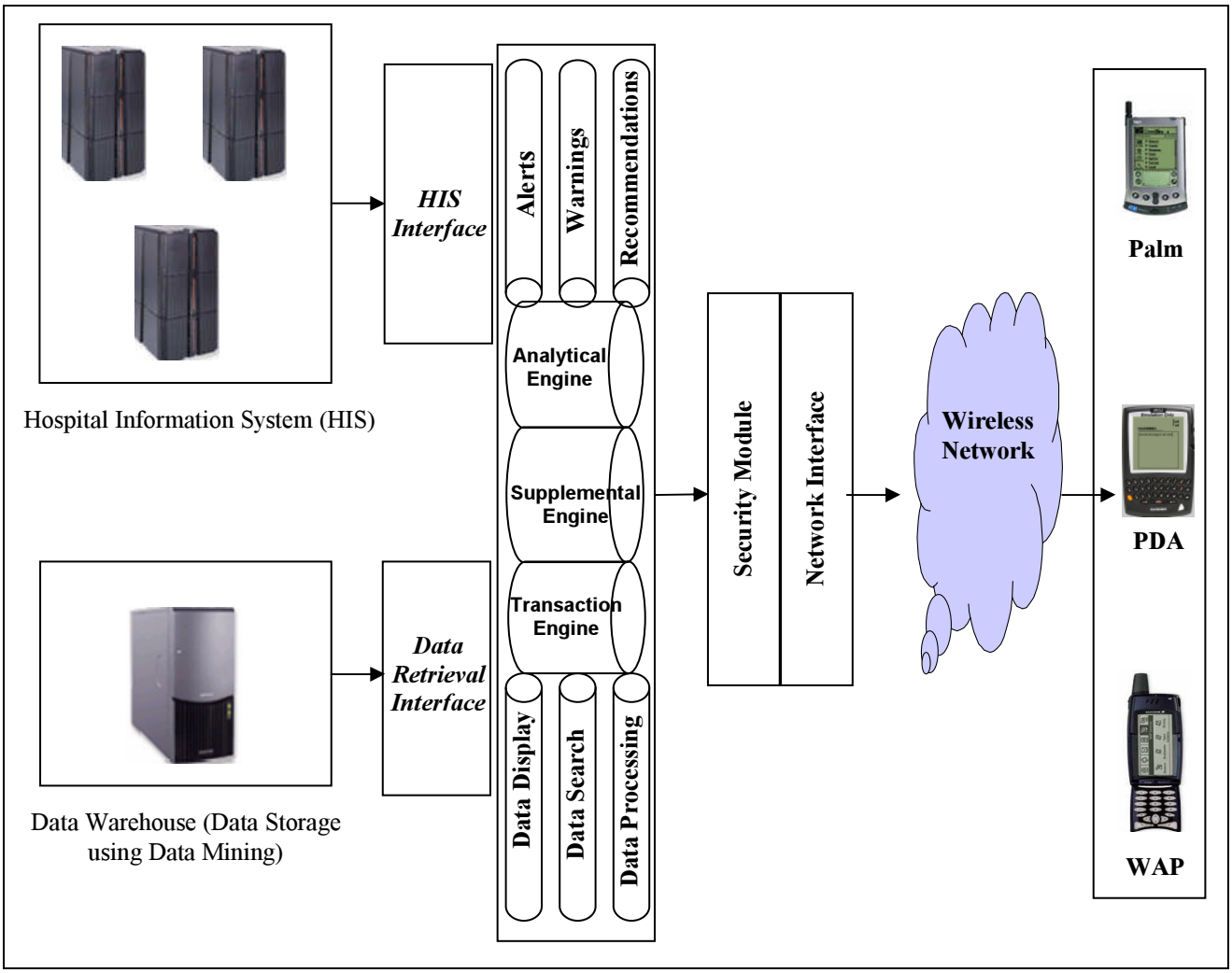

Figure 1. Solution architecture of Mobile Based Clinical Decision Support System

bases. The pertinent data to be retrieved is rule-based and pre-set by the clinician or by the system administrator during setting up of the recommendations module. Let us consider an example. A patient is having a condition X. There are certain known drugs that may be prescribed for this condition. To understand better as to which drug is currently known to be most effective, the analytical engine may be pre-informed to fire a set of queries to retrieve the relevant data regarding the effectiveness of all the known drugs in a similar set of patients with condition X. The equations are pre-set and the relevant calculations are performed using the data retrieved. The results of these calculations are then interpreted according to pre-set rules for interpreting them, like if the Absolute Risk Reduction index of Drug Z is more than any of the others, recommend Drug Z as the drug of choice, etc.

4.1.2 Transaction Engine

The data processing process handles requests made by the clinician to retrieve and display data that require no analysis. The Transaction Engine retrieves this data from the clinical data base using the patient's information as a context. The data might lie in several databases that are physically located in a distributed manner over a large geographical area that may even be halfway across the world. Such searching using patient context is handled through the CCOW (Clinical Context Object Workgroup: Health Level Seven Standard Context Management Specification). The search module decides which data to retrieve and when. For example, the clinician may ask for the blood pressures of a patient in context over a period in time to be displayed on the screen. The search is handled

by the search process and the appropriate data is retrieved and displayed in the manner requested.

4.1.3 Supplemental Engine

The Supplemental Engine processes clinical data for clinical data warehousing. The star schema and the procedures for data cleaning, scrubbing and formatting are deployed within this engine. The engine on an asynchronous basis will run at specified periods that may range from every 1 nanosecond to once a year, depending on the system requirement and the hardware capabilities. This engine retrieves data from the clinical database, clean, scrub, reformat the retrieved data, and deploy it into the clinical data warehousing according to the star schema. It also performs anonymisation of the data wherein all patient identifiable data is stripped off. It maintains, in a secure manner, pointers that allows the reconstruction of the patient data with the patient identifiable data. This allows for a secondary source of data for data recovery purposes in cases of disasters.

4.1.4 Security Module

The Security Module takes care of the confidentiality and privacy requirements. Patient information is sacrosanct and owned by the patient himself. All other bodies to whom such information is revealed are mere safe custodians of the same. Clinicians guard the information revealed by their patients to them with all their might. There is a medical requirement for this. Unless the patient is satisfied beyond any doubt, reasonable or otherwise, he has a natural desire to suppress such information that he is reluctant to part with without such guarantees. Unfortunately, more often than not, such information proves vital for diagnosis and treatment. Consequently, no clinician will have anything to do with a system that does not guarantee protection of confidentiality and privacy of the data captured. Such a security module takes care of RBAC (Role Based Access) using unique user identification and password with some biometric control like fingerprint identification or voice recognition or retinal scan. This also implements session time-outs after a pre-set period of inactivity, not allowing logins from more than one location, audit trail of each activity (including viewing activity) with electronic signature and date-time stamp, etc. Conformance to such governmental guidelines as 45 CFR 160, 162, 164 of US government (HIPAA) is a definite requirement.

4.1.5 Interfaces

Hospital Information System allows the capture of end to end data that is generated as a consequence of a patient's visit to the clinician or institution. Such data are patient administration related as well as complete clinical information related. Therefore, they allow a clinician to source all clinical data related to a particular visit or a series thereof.

Clinical data warehouse stores de-identified patient data (both administrative and clinical). No individual patient data can be sourced from such data warehouses. But population data can. This allows a statistical analysis to be run on a subset of the data based on their location, age distribution, sex, weight etc. This data warehouse is crucial for any clinical decision support system where a particular patient's observed data is matched with historical data lying in the data warehouse and appropriate conclusion drawn from such analysis [6].

The HIS Interface allows the message transactions between the Engines and the distributed data bases related to Hospital Information System. The Data Retrieval Interface handles all historical data retrieval messages and connects the system with the clinical data warehouse. The network interface converts the system calls to the wireless protocol so that they are recognized by the wireless network.

4.2 System Architecture

The system is designed for care providers who need the patient information, on-line decision making and transaction of the decision. The system provides user interface to the System Administrator, Care Providers and other Users to perform various functions. The system is designed for Palm OS, PDA and WAP enabled devices. The system architecture is shown in figure 2.

The system consists of the following subsystems:

- Mobile Device Browser
- Remote Access Server
- Authentication Server
- Application Server
- Database Server
- Interfaces

Mobile Device Browser is the presentation software installed on the hand held devices. This subsystem provides the optimized look and feel and the capability to customize the screens for individual needs. The browser also enables the user to view the real time information, helps in decision making and sends the requests from the user to the application server.

The Remote Access Server allows the user to connect to the application server. The user is connected through the Authentication Server. The Remote Access Server consists of multi-slot chassis with interface cards.

The Authentication Server uses the distributed security solution called RADIUS (Remote Authentication Dial In

User Service). RADIUS provides distributed security environment that separates user authentication from the communication process and enables the use of a single, central location for user authentication data.

Application Server contains all the engines and the support modules. This is the heart of the system. Database Server stores the data and allows the user all the data management facility as available in any Relational Data Base Management System (RDBMS). Interfaces are used to connect the system to other systems that are required to collect the information and pass the information to them.

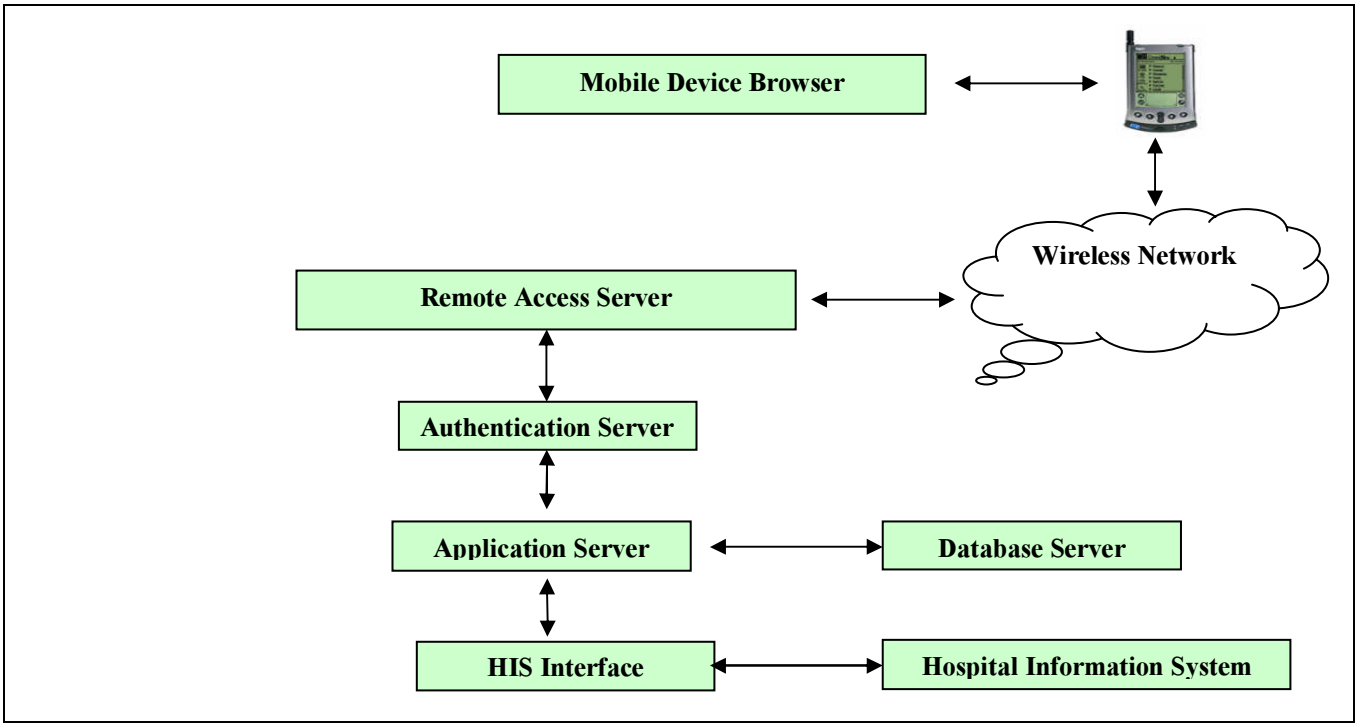

Figure 2. System Architecture of Mobile Based Clinical Decision Support System

5 Conclusion

Although Mobile Based Clinical Decision Support System is not commercially available as a product in market, they are being used in different provider's space as pilot projects. These systems improve the productivity of the care providers immensely. These systems also allow the clinicians to take pre-emptive measures so that impending disasters can be prevented from happening. As his physical location no longer matters for him to be an effective care provider, he can attend on patients who are physically removed from him. Constraint of time required to reach the patient is removed which effectively increases his productivity without compromising efficiency.

The most important challenge that is faced by a clinician like a general practitioner is that he needs to have most of the important information available to him to pass on to various stakeholders. Such stakeholders range from super-speciality consultants to junior doctors on duty to attending nurses and the friends and relatives of the patient. He needs to act as the focal point for most of the information dissemination as well as pass on life-critical information at the moment of requirement. Possessing a mobile computing system of the nature described above would not only go a long way to address the issues mentioned but also allow him to monitor on a real time basis the progress of his patient thereby preparing the family of the patient for the most likely outcome of medical interventions being undertaken wherever the patient is being treated.

The advantages, availability of data and usefulness for patient care are well established. Unfortunately, the lack of suitable software and hardware especially in the area of connectivity is proving to be a serious hindrance in

making this concept a success. Successful addressing of these technical bottlenecks would go a long way in allowing the successful partnership between care providers and system developers to their common goal of making healthcare available for all a real possibility.

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7 Author Profile

Bhudeb Chakravarti brings with him more than 17 years of experience in IT field ranging from Requirement Management, Object Oriented Analysis and Design, UML, Rational Unified Process to Project Management and Delivery Management. He has worked in prestigious organizations like Computer Associates, Rational Software, Defence Research & Development Organisation and Schlumberger SEMA before joining Satyam Computers Services Limited. Being both an Electronics and Communication Engineer and an MBA, he is able to have a proper mix of technology and management. He has vast requirement and design experience using UML, OOAD and RUP and is an expert in case tools like Rational ROSE, RequisitePro etc. He has more than 20 publications including 8 publications in International journals and conferences.

Dr. Suman Bhusan Bhattacharyya is a MBBS medical doctor from Calcutta University, Calcutta, India, MBA in International Management from European University, Antwerp, Belgium and also holds an advanced diploma in hospital administration from Institute of Heath Care Administration, Madras, India. He has more than seventeen years of experience as a general practitioner and more than five years as hospital administrator (medical superintendent). Since early 2002 he has been working in the IT industry as a healthcare domain expert. His principal area of interest in the IT space is in medical informatics, particularly in the areas of electronic medical records, evidence based medicine, outcomes analysis, use of artificial intelligence through Bayesian Belief Networks for clinical decision support, clinical data warehousing, clinical data mining, and clinical knowledge discovery in databases. He is currently the healthcare domain expert responsible for public and provider health in the healthcare life and pharma division of Satyam and is based out of Hyderabad.