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MULTI AGENT SYSTEM BASED SCHEME FOR REVISED NATIONAL TUBERCULOSIS CONTROL PROGRAM

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Abstract: The rising prevalence of tuberculosis (TB) has economic repercussions not only for the patient's family but also for the country. According to the survey conducted by World Health Organization (WHO), the Philippines ranks fourth in the world for the number of cases of tuberculosis and has the highest number of cases per head in Southeast Asia. Almost five million people are infected yearly by tuberculosis in our country. The rise in the occurrence of tuberculosis has been due to the low priority accorded to anti-tuberculosis activities by many countries. The unavailability of anti-TB drugs, insufficient laboratory networking, poor health infrastructures, including a lack of trained health personnel, have also contributed to the rise in the incidence of the disease.
We start by reviewing the till date statistics of the tuberculosis effect worldwide as well as in India. Then we discuss about the programs undertaken worldwide for restraining the effect of TB, where we have given brief account of National TB Control Programme as well as the Revised National TB Control Programme (RNTCP) undertaken worldwide as well as in India. The rest of the paper deals with our main research work which deals with the development of an automated, intelligent, easy-to-use computerised system for an easy diagnosis of TB ,which is advantageous over the paper-pen based programmes undertaken. Our system is implemented using Multi Agent System.
Keyword: Intelligent agent, multi agent system, knowledge base, DOTS.

INTRODUCTION

Tuberculosis (TB)[1] is an infectious disease caused by Mycobacterium Tuberculosis. Pulmonary TB accounts for more than 85% of all case. In 2006, about 9.2 million new cases and 1.7 million deaths were reported due to TB globally. 80% of the TB cases are in 22 high burden countries. One fifth of global TB incidence is in India. Every Year 1.9 million new cases occur in India, of these 0.8 million are infectious. As per WHO estimates in 2006 , nearly 3.2 lakh deaths occurred in India due to Tuberculosis (mortality rate 28 per lakh). As per the survey conducted by WHO, India is the highest TB burden country accounting for about one-fifth of the global incidence. A pie chart for the distribution of TB all over the world is given below for convenience.

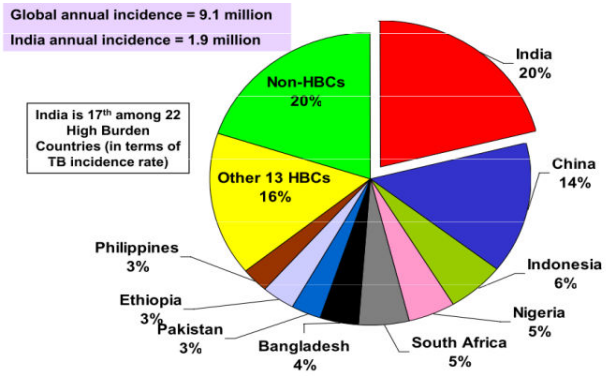

Fig. 1 (Source: WHO Geneva; WHO Report 2008: Global Tuberculosis Control; Surveillance, Planning and Financing)

Deaths due to tuberculosis exceed the combined deaths from all other communicable disease and account for 26% of all avoidable adult deaths. Annual risk of infection is about 1.5%. It's higher in urban areas, at 2.2% than rural areas, at 1.3%. Prevalence of infection is 30% in all age groups combined. The prevalence of TB has been estimated at 3.8 million bacillary cases for the year 2000. One sputum positive case infects 10-15 individuals in a year. Life time risk of development of disease in a newly infected young child is 10% and half of the risk falls within first 5 years following infection. The risk of progression from latent disease is 10% - 60% if co-infected with HIV infection. Prevalence as well as incidence of disease increases with age. Two peaks in incidence are observed – the first in 1-4 year age group, reflecting progression from recent TB infection and the second in adolescents and young adults. The disease incidence is highest in the most economically productive age group of 15-60 years. The disease is 3-5 times more common in males. Prevalence of disease is similar in rural and urban areas. However, it is more common in urban slums.

Since the introduction of the National Tuberculosis Control Programme (NTP) in 1962, the prevalence of tuberculosis has not changed in the country. There was decline in morality from 80 per lakh in 1971 to 53 per lakh population in 1993. Consequent to implementation of Revised National Tuberculosis Control Programme(RNTCP)[2], number of deaths is estimated to be 3,22,000 per year as against 5 lakh deaths occurring here.

The present TB control program hugely depends on manual labours and paperwork, which is erroneous and hard to manage when distributed over a large area. Considering the present

system, we propose a System that will digitalize the whole RNTCP program to manage it in a better and error free way as well as it makes statistics available with just a click of button.

REVISED NATIONAL TB CONTROL PROGRAMME

In 1992, GOI , SIDA and WHO jointly carried out an in-depth review of NTP(National Tuberculosis Programme) and concluded with a number of deficiencies:

- Inadequacy in budget allocation.
- NTP suffered from managerial weaknesses
- Over-dependence on X-ray with low case detection.
- Poor treatment compliance.
- Inadequate health infrastructure in the urban areas.
- Impending threat of HIV worsening the scenario of TB.

Following the 1992 review and a tremendous success in the pilot projects, RNTCP was launched which was based on internationally recommended DOTS strategy[3]. The programme was expanded in a phased manner and by March 2006, the whole country was covered under the programme. Phase-I of RNCTP in India has been completed in 2006 with expansion of DOTS to cover the entire country. Phase-II(2006-11) aims to further increases the access of services to marginalized groups in hard-to-reach areas through continuation of activities of phase-I and with intensive monitoring, supervision and evaluation. The main programme goals of RNTCP included:

- To reduce mortality and morbidity from tuberculosis
- To interrupt chain of transmission

The basic objectives taken up by the programme included :

- To cure at least 85% of all newly detected infectious cases of pulmonary tuberculosis
- To detect at least 70% of estimated new smear positive pulmonary tuberculosis cases

DOTS

DOTS , Directly Observed Treatment Short-course, is a five point strategy, which includes the following points :

- Political and administrative commitment
- Diagnosis by microscopy
- Adequate supply of short-course drugs
- Directly Observed Treatment
- Systemic monitoring and accountability

A DOT centre can be located at a facility run by government, private or NGOs. The idea is to provide directly observed treatment to patients at a place convenient to them. Anybody except family members of a TB patient can be DOTS provider, like health workers, private practitioners, AWWs and link workers like ASHA.

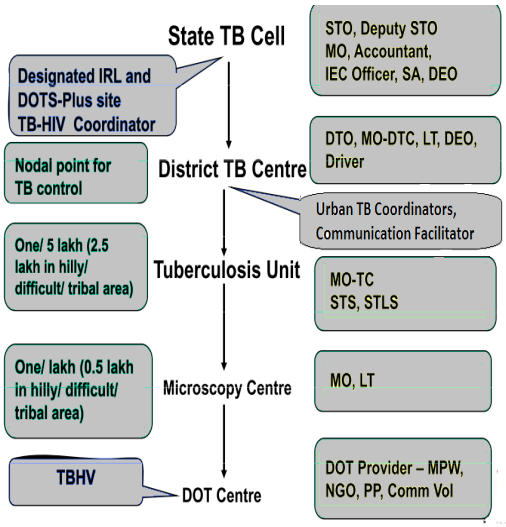

Figure 2. Operational structure of RNTCP in the state of India

In major states of the country, a State TB Training and Demonstration Centre (STDC) support's the State TB cell. The STDC has three units – A training unit, Supervision and monitoring unit and an Intermediate Reference Laboratory (IRL)[1] supporting an effective Quality Assurance system of the RNTCP Sputum smear microscopy network in the State. The State TB Cells have been provided with equipment, infrastructure and contractual staff to carry out its activities. The staffs at the STC are the State TB Officer, Deputy State TB Officer, Medical Officer STC, State IEC Officer, State Accountant, Secretarial Assistant, Pharmacist and Data Entry Operator. State Drug Stores (SDS) for anti-TB drugs are essential for effective management of drugs logistics. For the long-term sustainability of the programme, decentralization of many aspects of drug management to the states has been done.

The district is the key level for the management of primary health care services which performs functions similar to those of the state level in its respective area. The Chief District Health Officer (CDHO) / Chief District Medical Officer (CDMO) or an equivalent functionary in the district is responsible for all medical and public health activities including control of TB. The District Tuberculosis Centre (DTC) is the nodal point for TB control activities in the district. In RNTCP, the primary role of the DTC has shifted from a clinical one to a managerial one. The District TB Officer (DTO) at the DTC has the overall responsibility of management of RNTCP at the district level as per the programme guidelines. The DTO is also responsible for involvement of other sectors in RNTCP and is assisted by an MO, Statistical Assistant and other paramedical staff. For each district, there should be a full-time DTO, who is trained in RNTCP at a central level institution.

A major organizational change in RNTCP is the creation of a sub-district level (Tuberculosis Unit). The Tuberculosis unit (TU) will consist of a designated Medical Officer-Tuberculosis Control (MO-TC) who does tuberculosis work in addition to his/her other responsibilities, as well as two full-time supervisory staff for tuberculosis work—a Senior Treatment Supervisor (STS) and a Senior Tuberculosis Laboratory Supervisor (STLS). The TU will have one Microscopy Centre for every 100,000 population (50,000 in tribal, desert, remote

and hilly regions) referred to as the Designated Microscopy Centre (DMC)[1]. MOTC at the TU has the overall responsibility of management of RNTCP at the sub-district level and is assisted by the STS and STLS.

For the purpose of RNTCP, a PHI(Peripheral Health Institutions) is a health facility which is manned by at least a medical officer. At this level are the dispensaries, PHCs, CHCs, referral hospitals, major hospitals, specialty clinics / hospitals (including other health facilities) / TB hospitals / Medical colleges within the district. All health facilities in the private/NGO sector participating in RNTCP are also considered as PHIs under the programme.

Situation demands that the existing system must be modernize with the help of computer science and information technology. This is because the present working system depends hugely on paperwork and manual labours which is hard to manage when distributed over a large area. If the RNTCP may being automated and intelligent either fully or may run the whole system parallel with the human intervention, then it may work far beyond the limitations that are stated above. An agent based system is necessary to improvise the entire tuberculosis control programme not only in the Indian context but also worldwide. Intelligent multi-agent system based RNTCP is the better solution for both the patients as well as the persons who are dealing with improper infrastructure of the community health-centres especially in the developing countries like India.

It is evident in the present context that it has been tried to design a system which will take care of the initial check-up of the patient, do the treatment and then generate the report or solution for the patient.

SIGNIFICANCE OF USING MULTI AGENT SYSTEM[7]

Agent and multi-agent system can be defined in a number of ways. According to Michael Woolridge[4], 'an agent is a computer system that is capable of independent action on behalf of its user or owner'. In other words, an agent[5] can figure out for itself what it needs to do in order to satisfy the design objectives, rather than having to be told explicitly what to do at any given moment. On the other hand, a multi-agent system[8] is a one that consists of a number of agents, viz. multiple agents, which can interact with one-another, typically exchanging messages through some computer network infrastructure (typically known as message passing technique). Generally, the agents in the multi-agent system will be representing or acting on behalf of users or owners with different goals and motivations. For a successful interaction, these agents will thus require the ability to cooperate, coordinate and negotiate with each other, in a much same way in which we, the living beings cooperate, coordinate and negotiate with each other in our everyday lives.

Multi-agent systems are referred to as 'self-organized' systems as they tend to find the best solutions for best solutions for their problems 'without intervention'. The main feature which is achieved when developing multi-agent systems, if they work, is flexibility, since a multi-agent system can be added to, modified and reconstructed, without the need for detailed rewriting of the application. These systems also tend to be rapidly self-recovering and failure proof, usually due to the heavy redundancy of components and the self managed features. They may be considered as the latest software engineering paradigm in the recent era. This kind of systems may be used in those domains which consist of the following features:

- Knowledge is distributed in different locations
- Several entities, while keeping their autonomous behaviour , have to join their problem-solving abilities to be able to solve a complex problem
- The problems in the domain may be decomposed in different sub-problems, even if they have, some kind of interdependencies[6]

If we analyze the medical diagnosis and healthcare system, we shall find that the knowledge required for solving a problem as well as the knowledge required for detecting a problem is spatially distributed in different locations. For example, diagnosis of tuberculosis differs from eyes, or cardiology section. Tests (specially sputum test) for detection of tuberculosis are carried out at different locations with the help of some different set of knowledge. According to the test results further diagnosis are to be done under the supervision of the medical practitioners as different cases may arise. Giving solution to a particular case involve a better coordination between different individuals with their different skills and functionalities. It is obvious that such a diagnosis system is a complex system and there is no straightway software engineering standardization. A multi-agent based system may be a better approach in such a context. Moreover, to make the information about the statistics of tuberculosis effect at a place globally to carry out a survey easily with just a click of a button, multi-agent based system is the best option.

CONCEPT BEHIND

In this paper, a multi-agent system (MAS) based scheme for Revised National Tuberculosis Control Programme (RNTCP) has been presented which can be implemented in developing countries like India very easily. Figure 3 shows the basic structure for the MAS based scheme as proposed in this paper is given.

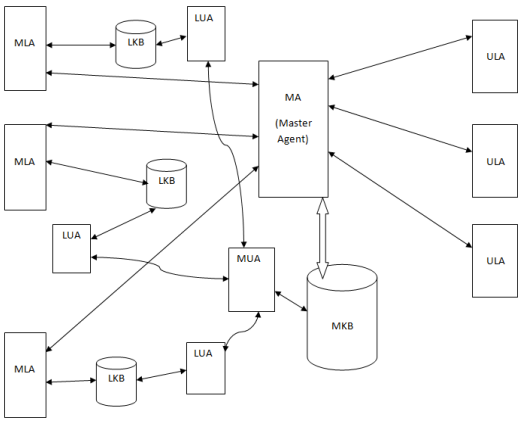

Figure 3. MAS based scheme for National TB Control Programme

As it is seen from the Figure 3, the proposed system comprises of a number of agents namely the Master Agent (MA)[9], Medical Local Agent (MLA), User Local Agent (ULA), Local Update Agent (LUA), Master Update Agent (MUA). The working of each agents and related knowledge bases have been given in the following sections.

MLA or Medical Local Agents are interactive agents with user interface which would be situated at different Health Centres. They are to be operated by medical health workers and require minimum knowledge to operate. Each MLA has its own LDB (Local Database) and LKB (Local Knowledgebase). Each MLA and thereby each Health Centre has its unique Health Centre ID. Medical Local Agents takes input as raw data about patients from its user interface and stores it to the LDB. It then processes the data with the help of MA and its User interface to knowledge and stores it to the LKB as well as updates the MKB. The data stored in LKB is typically like Patients unique Registration ID, Health Centre ID he is registered, detailed personal information, and also in detail information about his treatment process (e.g. Results of each sputum test at the end of each stage) etc. The total working of the MLA can be shown in the Figure 4.

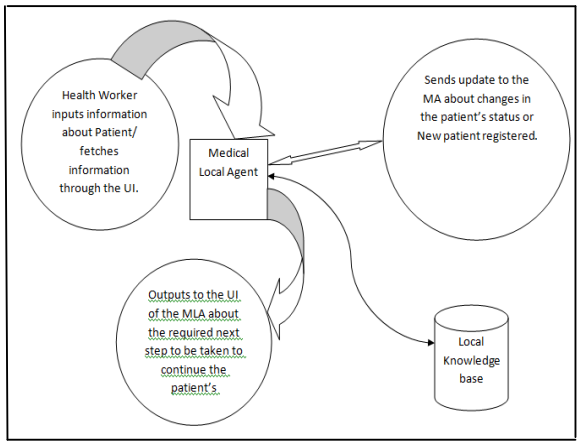

Figure 4. Role of Medical Local Agents (MLA)

MA or Master Agent is the Back-end agent responsible for coordination between different MLAs and also acts as a gateway between ULA (User Local Agent) and MLA (Medical Local Agent). It has a backend Knowledgebase named MKB (Master Knowledgebase). The MKB holds information about the updated TB Control Program treatment structure from which every MLA matches and updates it treatment process periodically. The MKB holds information about each patient all over nation, who is under T.B Control Program. Essentially the MLA store in LKB more detailed information about each patient than in MKB. MKB contains basic info about a patient like his unique registration ID, Health Centre ID, and his current treatment stage. The working of Master Agent is depicted schematically in the Figure 5 given below.

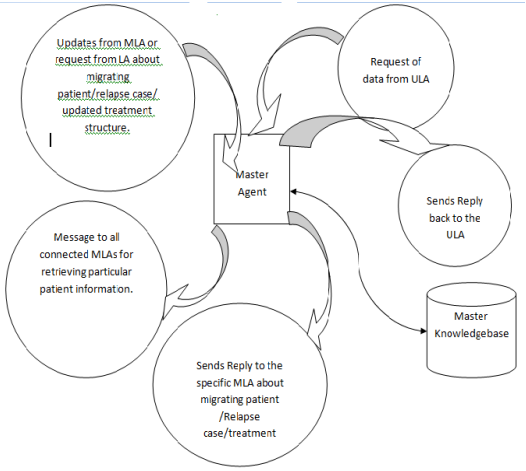

Figure 5 . Role of Master Agent (MA)

ULA or User Local Agent is the agent which acts as a user interface for naïve users like medical students , Medical researchers, Doctors etc., to generate different kinds of statistical reports on The T.B Program as well as to fetch information about any individual patient. This Agent doesn't have decision making of its own. It just works as an interface. Whenever there is some request it receives, it forwards that to the MA. Depending On the request type the MA either sends an immediate reply or sends out query to MLAs. For e.g. when detailed about a particular patient is requested through ULA, MKB takes the persons reg. ID and finds it Health Centre ID from its knowledgebase. It then sends request to that MLA to fetch detailed information about the patient. When the reply is received it forwards it to ULA. Therefore network connectivity is crucial to ULA's operation. The schematic representation of the roles of User Local Agents (ULA) is depicted in Figure 6 below.

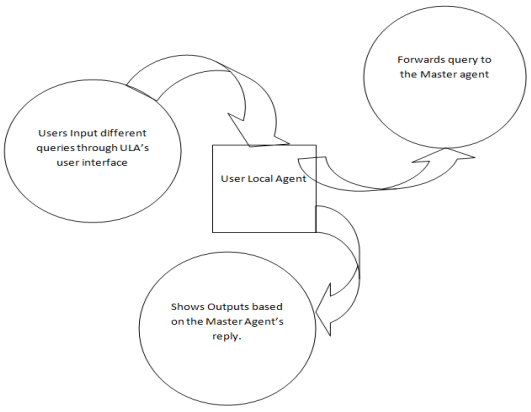

Figure 6. Role of User local Agents (ULA)

Local Update Agent or LUA is responsible for update operations both in MLA and MA. Whenever there is some change in MKB regarding patient status, it updates the Master Knowledgebase to reflect changes. It also checks periodically for update in treatment structure of the program by communicating with MUA. If there is any Change it updates

the Local knowledgebase to reflect the changes. The schematic representation of the Local Update Agent (LUA) is depicted in Figure 7 below.

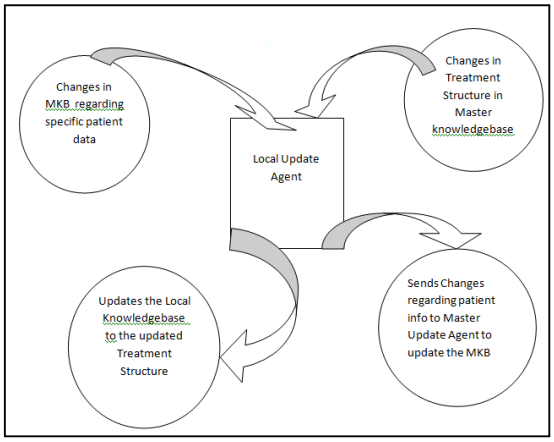

Figure 7. Role of Local Update Agent (LUA)

Master Update Agent or MUA administers update over the Master Knowledgebase. Whenever it receives updates from MLAs it updates the MKB to reflect Changes. It notifies all MLAs if there is any change in Treatment Structure. And whenever any MLA requests the updated Treatment Structure it sends it to requesting MLA. The schematic view of the role of Master Update Agent (MUA) is depicted in Figure 8 below.

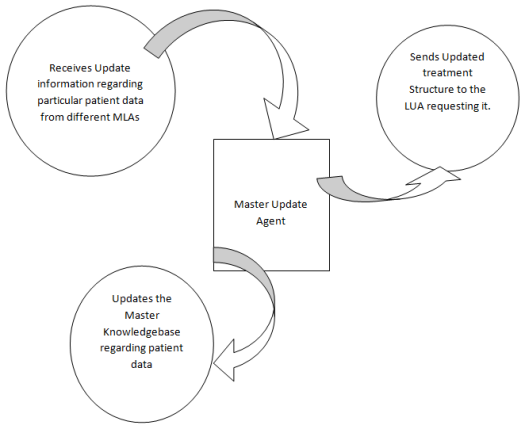

Figure 8. Role of Master Update Agent (MUA)

CONCLUSION

This paper has presented here a Multi-agent System based scheme for RNTCP, which can do a proper patient diagnosis and treatment with ease and a just a click of a button. The present working of RNTCP has been discussed above in the paper. It hugely depends on manual labours and paperwork, which is erroneous and hard to manage when distributed over a large area. Considering the present system, the proposed system will digitalize the whole RNTCP program to manage it in a better and error free way as well as it makes statistics available with just a click of button. There are several advantages of the proposed system over the present working system which are listed as follows :

- Better management of data distributed over thousands of DOTS centre.
- Digitalization of data makes it less prone to errors and secured from unwanted hazards resulting in data loss.
- Easy to follow steps for DOTS workers to treat patients with basic knowledge about computer handling.
- Administration of the RNTCP program nationwide easily and identifying areas where special care is needed. With the ability of monitoring the complete program from a single computer helps to increase productivity and reach RNTCP program goals.
- Easily retrieve data about a single patient or Generate Detailed statistical report over a large area or nationwide.
- Helps medical researchers and students to understand the current condition of the program and get statistical report of current condition of disease control nationwide or in a particular area.

The RNTCP is unique amongst TB control programmes in high TB-burden low-income countries, in its capacity to compile, process, analyse, and feedback data and information to the peripheral and intermediate health care levels, and to place programme data and information out into the public domain, in such a timely fashion. The MAS Based RNTCP System helps the RNTCP managers to answer the questions asked by the operational (input, process and output) indicators. Future developments in the System should further enhance the program's capacity to perform this task and take RNTCP initiative to new heights of success.

FUTURE LINES OF WORK

The proposed MAS based SCHEME for National TB Control Program not only helps the RNTCP to be managed in a effective error free way, but also helps it to achieve RNTCP's Priority objectives of 85 percent cure of new smear-positive PTB cases and 70 percent detection of such cases. There are various possibilities for the proposed System in future and as technology progresses new possibilities emerge. Some of the noted future possibilities are :

- The best thing about this proposed system is that is not only designed to manage RNTCP but also it can be implemented to manage any other National Health program like AST Surveillance, National Leprosy Eradication Program, Vector Borne Disease Control Program with small to medium scale changes in the software.
- Virtualization of the RNTCP to make patients avail guidance even when he is mobile.
- Increased accessibility by implementation of User Local agent in various platforms including cell phones, PDAs, website etc.

- Automatic monitoring of high disease spreading areas and taking special care in those zones.
- In future if implied properly it can omit the need of Directly Observed Treatment to be replaced by intelligent Agents.

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