Collaborative Decision Support Systems for Primary Health care Managers

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Abstract

In this paper, a collaborative DSS Model for health care systems and results obtained are described. The proposed framework [1] embeds expert knowledge within DSS to provide intelligent decision support, and implements the intelligent DSS using collaboration technologies. The problem space contains several Hub and Spoke networks. Information about such networks is dynamically captured and represented in a Meta-data table. This master table enables collaboration between any two networks in the problem space, through load transfer, between them. In order to show the collaboration the sample database of 15 health care centers is taken assuming that there are 5 health care centers in one network.

Keywords: *Decision Support Systems, Decision Process, Hub & Spoke Model, Collaboration, Collaborative DSS, HUB and SPOKE Model, Meta Data.*

1. Introduction

In this paper, Hub & Spoke model and metadata information concept is used to facilitate decentralization and load balancing which facilitates collaboration. Collaboration between any 2 such networks is implemented through transfer of patient load. Its advantages include providing more flexibility to system design and implementation, simplifying the decision-making process, and empowering decision makers at the operational level. Decision Support system algorithm is used for demonstrating the collaboration between different health care services in this paper.

The concept of Meta-data is used to represent information about Hub and Spoke networks, in a Meta data table. This Meta-data table is searched to facilitate collaboration between two different networks. Thus the main objective of this research work is to show how the collaboration can be implemented between health care services in a region. Collaboration means load transfer between two networks in given problem space.

2. State of Art

Three major challenges faced in health care are: 1. How good is good enough? 2. How is modeling linked to the decision-making? 3. What are the other cultural barriers?[2]. The challenges in health care are high patient load on primary health services and how to decongest and decentralize health services in a system.

A rule based DSS using a suitable model can help the doctors in addressing the challenges stated above.. It can help health planners in simulating management plans that can be used to implement decentralization, collaboration and outsourcing decisions in health care [3]. At the primary care level, the decentralization of outpatient health care services can be achieved through the HUB & SPOKE model that is helpful in facilitating decentralization, dynamic load balancing and planning deployment of manpower and medical equipment [4]. For comparative analysis of different hospitals and different service providers CASE MIX is used. It enables classification of patients based on disease profiles. These factors help in hospital budgeting [5]. In rule based DSS, decisions are made by applying a set of rules, which apply on the knowledge base to return the answers to the queries asked by nursing staff , usually advice , during telephonic consultation, provided by a call center. A rule based DSS, is used especially in out hours for counseling patients [6]. DSS can help in monitoring disease patterns and implement patient segregation, thereby contribute to more effective monitoring and budgeting of hospital expenditure. [7]. For providing end-to-end response or outsourcing business real-time decision support systems (RT DSS) are required. But real-time decision support systems are complex because they must combine elements of several different types of technologies: enterprise integration, real-time systems, workflow systems, knowledge management, and data warehousing and data mining. To deal with all the challenges an approach based on message brokering paradigm for enterprise integration, workflow management, knowledge management, and dynamic data warehousing and analysis was developed. This also

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enabled integration of data, applications and processes from distributed and heterogeneous environments. [8]. Collaboration is one of the major requirements in today's life and business. Collaborative systems may be complex, distributed, open, and dynamic applications; on the other hand, the human factor plays a very important role with respect to other application fields. Collaboration between different organizations can be achieved by the openness of the systems, a feature that could lead to global collaboration [9].
Collaborating in health care leads to greater utilization of existing infrastructure including doctors and equipment. To deliver lower costs service to the patients by avoiding costly duplicate tests, current service providers must share patients fragmented medical record to obtain a collaborative advantage[10]. Collaboration enables decentralized planning of primary health care in a region, sharing of resources, manpower and equipments of identification of hubs for proper control of health care services.

3. Development of DSS Model for Collaboration

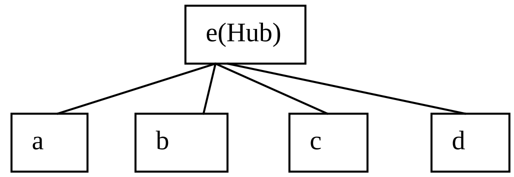
3.1 Description of HUB & SPOKE Model

Hub and Spoke Model [4] is a DSS model that can be used in Load Balancing, Manpower Planning and Equipment Planning etc. As an example we can show how load balancing can be achieved.

Table 1 : Hub & Spoke Model Input

Name Of dispensary	**No. Of doctors**	**Present load / day**	**Capacity of dispensary**	**Excess load=present load-capacity**
a	2	200	144	56
b	1	150	72	78
c	2	250	144	106
d	1	300	72	228
E	2	400	144	256

We assume a OPD slot of 6 hours per day and 5 minutes per patient per doctor. Therefore a dispensary with 1 doctor has a capacity of 12 patients per hour or 72 patients per day for a slot of 6 hours. The Hub is selected to absorb all excess load (total excess load=724) transferred from the spokes while by design the spokes are constrained to their capacity. The Hub is selected according to load (volume). So the center with the highest load i.e. dispensary e is the hub. This results in a hub and spoke model.



SPOKES
Fig 1: HUB & SPOKE Network

Table2: New load distribution

Name of centre	New loads on centre	No. Of Doctors
a	144	2
b	72	1
c	144	2
d	72	1
e	72+144=868	12

The number of Doctors needed in Hub (e) is therefore 12.The hubs can also be chosen according to the distances between the dispensaries. Once a hub and spoke model is created, further requests for patient servicing can be satisfied by: The present hub or its spokes (if they have free capacity). However if the present network is full, the requests for patient servicing must be redirected to the nearest hub and spoke network. Again search is performed in that network to determine if the request can be satisfied by the hub or by its spokes.

3.2 Collaboration

Collaboration between two networks is of great advantage in terms of effective cost utilization, decentralization, load balancing and load sharing etc.. Collaboration is transfer of patient load between 2 networks. This is guided by metadata about the network. Two tasks that must be done before the computation so that collaboration for a particular network starts with another network. These tasks are as follows:
(1). To prepare the 'Metadata Table' for the entire networks in the problem space: The information contained in the metadata table for a network is got by traversing through the HUB & SPOKE structure, corresponding to that network. This data is then entered into m-data table for the network. This cycle is repeated for all the networks in the problem space. The set of all such m-data tables is maintained in the master meta-data table which is accessed by the controller.

Name of HUB	Name of Spokes	Free capacity at HUB	Free capacity at spokes

Fig 2: Metadata table for the network

(2). To prepare the distance matrix that indicates the distance of health care center from other health care centers. The nearest distance hub from a requesting HUB center is its collaborating network.

The Following steps are involved in development of collaborative DSS model (Fig 3).

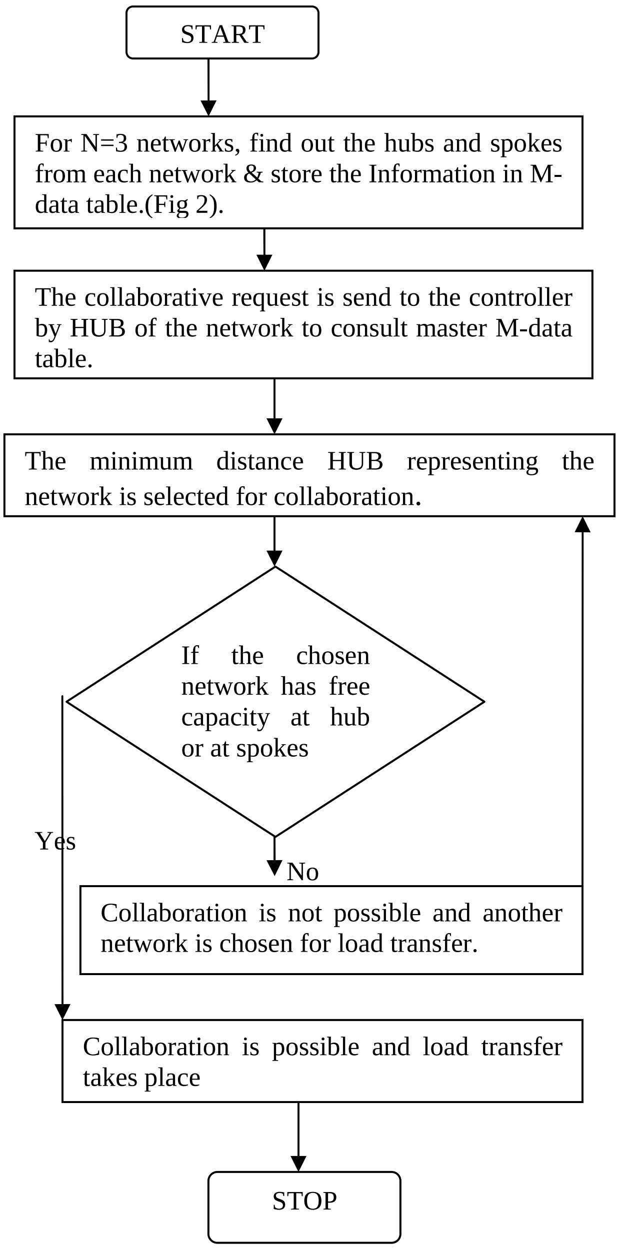


Fig 3: Steps in algorithm

3.3. Computation

Implemented in Prolog and two types of data i.e. static data and dynamic data is described.

(i) Static Data: -
pload (cname, patient load), /here pload has 2 arguments cname and patient load/
disp (cname, no.of doctors),
Hub=load(centre) with maximum patient load.
Hub is selected by max patient load on a center.
If pload (a, l1), pload (b,l2), ………pload(n,ln) then max (l1,l2……..ln)=M.
pload (H, M)=H is obtained as the hub with maximum patient load.
Excess load of a center= patient load-capacity of the dispensary.
If Excess load is positive then it is called overloaded center and if excess load is negative , then it is called under loaded center.
T_{free}=freecap $_{HUB}$+freecap $_{SPOKES}$. / where T_{free} is total free capacity in the network, freecap $_{HUB}$ is the free capacity in hub and freecap $_{SPOKES}$ is the free capacity in spokes. This information is stored in tables as shown in fig 2.

(ii) Dynamic Calculation of capacity:
Capacity of a centre & excess load of a center asserted dynamically in the database.

```
:-dynamic calculatecapacity / 0
calculatecapacity:- disp(X,Y),
                    pload(X,Z),
                    getcap(X,Y,C),
assert(capacity(X,Y,C)),
E is Z-C.
assert ( excess (X,E)),
fail.
calculatecapacity:-!
getcap(X,2,C):- C is 144.
getcap(X,1,C):-C is 72.
```

New load distribution constraints (in the network):-
(a) $N_{SPOKE} <= C_{SPOKE}$ where N_{SPOKE} is new load on a spoke and C_{SPOKE} is capacity of a spoke. (b) $N_{HUB}= C_{HUB}+ T_{EXCESS\ LOAD}$ where N_{HUB} is new load for a Hub, C_{HUB} is capacity of Hub and $T_{EXCESS\ LOAD}$ is total excess load in the network.

(iii)To find out the nearest hub (for collaboration)

```
hubdistance:-
bagof(_Number,_Name ^ dist(_X,_Y,_Z),L),
minlist(L,M),
dist(_H,M,_P),
write('selected hub by distance '),
write(M).
minlist([X],X).
```

```
minlist([X,Y|Rest],Min):-
minlist([Y|Rest],Minrest),
minlist(X,Minrest,Min).
min(X,Y,X):-X=<Y.
min(X,Y,Y):-X>Y.
```

3.4 Implementation of Algorithm

For the data taken in table 1

Name of HUB "e"	Name of Spokes " a, b, c, d"	Free capacity at HUB—"not free" Overloaded=4	Free capacity at Spokes—"spokes are full".

Fig 4: The M-data table for network 1

For 2nd Network

Table 4.1: HUB & SPOKE Model Input for Network 2

Name Of dispensary	No. Of doctors	Present load / day	Capacity of dispensary	Excess load
f	1	125	72	53
g	2	150	144	06
h	2	200	144	56
i	2	300	144	156
j	2	250	144	106
Total excess load in the network				377

Table 4.2. New load distribution for 2nd network

Name of centre	New loads on centre	No. Of Doctors
F	72	1
G	144	2
H	144	2
I	144+377=521	7
J	144	2

Structure of M-data for 2nd network

Name of Hub "i"	Name of Spokes "f, g ,h, j"	Free capacity at HUB---" not free", overloaded=17	Free capacity at spokes----"spokes are full".

Fig 5: The M-data table for network 2

For 3rd Network

Table 5.1. HUB & SPOKE Model Input for Network 3

Name Of dispensary	No. Of doctors	Present load / day	Capacity of dispensary	Excess load
k	3	175	216	-41
l	3	180	216	-36
m	2	195	144	+51
n	1	200	72	+128
o	5	300	360	-60
Total excess load in the network				+42

Since the excess load is –ve at spokes "k" & "l" & at hub "o", therefore this network is under loaded.

Table 5.2. New load distribution for 3rd network

Name of centre	New loads on centre	No. Of Doctors
k	175	3
l	180	3
m	144	2
n	72	1
o	360+42=402	6

Structure of M-data for 3rd network

Name of HUB-"o"	Name of Spokes-"k, l, m, n"	Free capacity at hub—"o" under loaded=30	Free capacity at spokes—" k=41 & l=36".

Fig 6: The M-data table for network 3

It is assumed that there are 3 networks in the problem space, for purpose of analysis. Since these networks are named by their respective hubs, they are: e, i, and o. Accordingly, the distance matrix can be formulated giving the distance of hubs from each other as shown in table 6 .The nearest distance from a requesting HUB center is its collaborating network. Figure below shows how communication occurs between the collaborative networks. Here M1, M2, M3 represents metadata information (fig 4, 5, 6) with the help of which a network will find a meta data for another network. Also a network determines its adjacent network using the distance matrix described below.

Master –data table

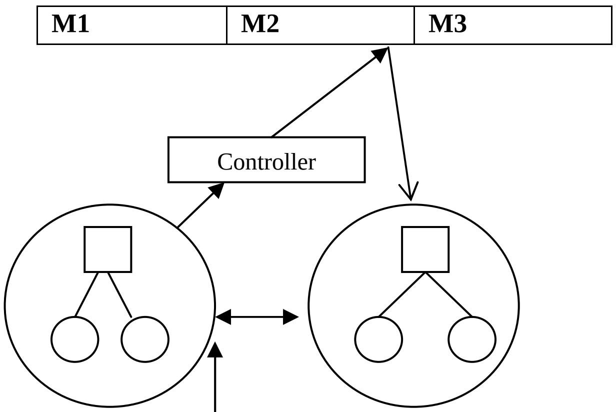


Fig 7: Communication between 2 networks using metadata information

From the table it is clear that for Hub "e", hub "i" is the nearest hub. Accordingly, metadata for the network named by Hub "i" is displayed and free load can be estimated, facilitating collaboration through load transfer, between these two networks table 7.

Table 6: Distance Matrix Showing HUB Connectivity

	e	i	o
e	0	3	5
i	3	0	4
o	5	4	0

Table 7: Distance Matrix from One Hub to another

From	To	Distance
e	i	3
e	o	5
e	r	7

Since there is no free capacity at Hubs and Spokes of 2nd network. Therefore the controller will consult the M-data table. The Hub and some of spokes in 3rd network are under loaded; therefore "e" will collaborate with "o" as shown in fig 8 below.

4. Results and Discussions

We have taken 3 networks and 5 health care centers in each network. According to the distance matrix shown above the HUB e choose the HUB i because it has minimum distance i.e. 3 as compared to o. Since "hub i" has no free capacity, therefore next network is searched for the load transfer. Therefore HUB "e" will distribute its excess load to "o" thus utilizing its resources also.

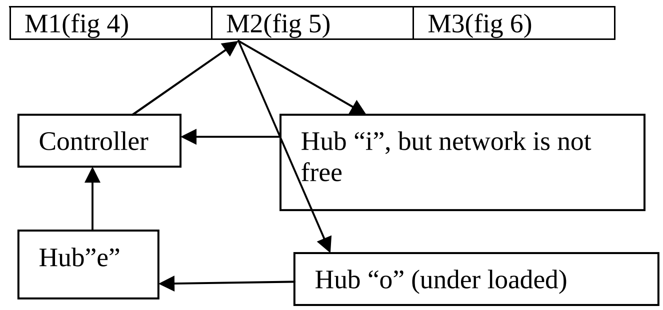


Fig 8: Collaboration of "e" with "o"

A request for collaboration is directed to Metadata Table by a controller, which controls the collaborative process. By searching the metadata table, the collaborative network is obtained for the requested network. After that free capacity computation is done for the networks which facilitate collaboration through load transfer. The metadata tables can be suitably updated after load transfer has taken place.
Hub "e" determines that hub "o" is its collaborative network and free capacity available in this network is as follows:

Table 8: Total free capacity in network 3

Name of Centre	Type of Centre	Free capacity
k	Spoke	41
l	Spoke	36
o	Hub	30

Therefore total free capacity is 117. This is the patient request that this network can satisfy, in reference to the requesting network headed by hub "e".
The significance of this architecture lies in the fact that it is the hub in a network that determines the rules for collaboration. The spokes cannot take this decision at their level.

5. Conclusions

The existing HUB & SPOKE Model is used as the basis for collaboration. The concept of metadata and controller is illustrated. If no free capacity exists in minimum distance hub network, then the next minimum distance network is selected as the candidate network for the collaboration. In addition request satisfaction can be done dynamically by maintaining a queue of request in real time. The concept of priority can be used to designate some networks as priority networks which will satisfy only priority requests and this concept can be implemented by priority scheduling algorithm using a priority field in Meta data for the network. Thus the Meta-data template is extensible.

The code for the implementation of this model can be written in any programming language. In this paper, code for Hub selection was written in prolog, which can be extended to cover selection of spokes and the creation & manipulation of metadata. This results in the design of a knowledge based system that involves dynamic database updation. The chosen hubs can also be used for providing telemedicine facility and financial planning for the network they represent.

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