A Mathematical Model for the Fusion of Graph Theory and Web Service Composition

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Abstract:

In India, the healthcare sector faces a challenge of raise in demand for healthcare infrastructure due to the increase in population. Hence the immediate need is to identify the locations where the health care centers should be established through a scientific methodology. A solution has been suggested through an inter-disciplinary approach by using Graph Theory as the conceptual base and using Information Technology as part of concrete solution that is practically applicable. Vertex-Edge domination concepts in Graph theory help to identify the least number of locations with minimum effort will cover huge population. Web Service Composition helps to create high-level business process by connecting the web services required to concretize the concept suggested by Graph Theory. This paper provides a prototype of mathematical model for web service composition to establish minimum number of Cancer Care Centers between two cities in Tamilnadu.

Keywords: Vertex – edge domination; Web service composition; Business Process Model and Notation; Sequence diagram; Unified Modeling Language.

1. Introduction:

Healthcare industry is one of the fastest growing industries in the world and has a huge impact on our life as it cures us from ailments. One of the most important supports required for a patient is to have the easy access and availability of healthcare centers in the country or in a particular area. An attempt is made to apply the concept of Vertex – edge domination sets in graphs and web service composition as part of studying the application viability in a healthcare scenario that is, how to decide to set up a centre for delivering super specialty healthcare services in a pre defined area that covers a sizable population with least distance travelled to reach the healthcare centre.

Graph theory has a wider application in the real word offering solutions to complex problems faced by the world. The concept of Vertex-Edge Domination Sets in Graphs in particular has a far reaching impact in offering solutions for such problems. Especially reducing the number of resources and maximizing the usage is one of the most important applications of domination sets in graphs. This in turn offers the most significant aspect of calculating and knowing of how to maximize the productivity using minimal resources.

IT services are being used to make this graph theory application into a functional format. It is a comprehensive representation of the technical tools that are used for the purpose of the application of the graph theory and to illustrate how the research concept can be made into simple practice. The web services are the most commonly used in such large net work services because of its least interruption, easy accessibility and availability, strong service net work and cost effectiveness. Service Composition provides an open, standards-based approach for connecting web services together to create higher-level business processes. Standards are designed to reduce the complexity required to compose web services, hence reducing time and costs, and increase overall efficiency in businesses.

This paper suggests a method to decide the locations of healthcare centers in a predefined area in which the location of the centre has the easy accessibility to the local population who are otherwise forced to travel a distance of more than 150 – 200 kilometers even for a simple consultation. The Coimbatore – Chennai route is chosen as a case study and the vertex-edge domination sets in graph theory is applied to determine the location of setting up the healthcare centre. An algorithmic approach is used to identify the vertex-edge dominating vertices[3] and demonstrated the application of the same with web services which has a significant benefit to the target population.

2. Motivation for fusing Graph Theory and Web Service Composition:

Cancer is one of the dreadful diseases of the human kind and it requires a continuous treatment and a lot of follow up as cancer is a chronic disease. India has one of the fastest growing cancer populations in the world and it is reported that every year more than 200,000 patients are histopathologically confirmed cancer cases and the treatment centers for cancer is not spread across for very many reasons. As we all know that cancer is a chronic disease and has the possibility of recurrence even after treatment. Cancer treatment requires continuous visits, follow ups for many procedures. The immediate need of a cancer patient is to have the easy access and availability of cancer treatment centers in the country or in a particular area.

It is possible to mathematically provide a solution for such a problem as a concept and validate the solution by logical proof. However technology is required to realize the solution which is efficiently provided by the Web Services. The web services can be composed together to execute a business process flow. The semantically annotated web services, as a component of Semantic Web Services enable automation in discovering, composing and executing the web services.

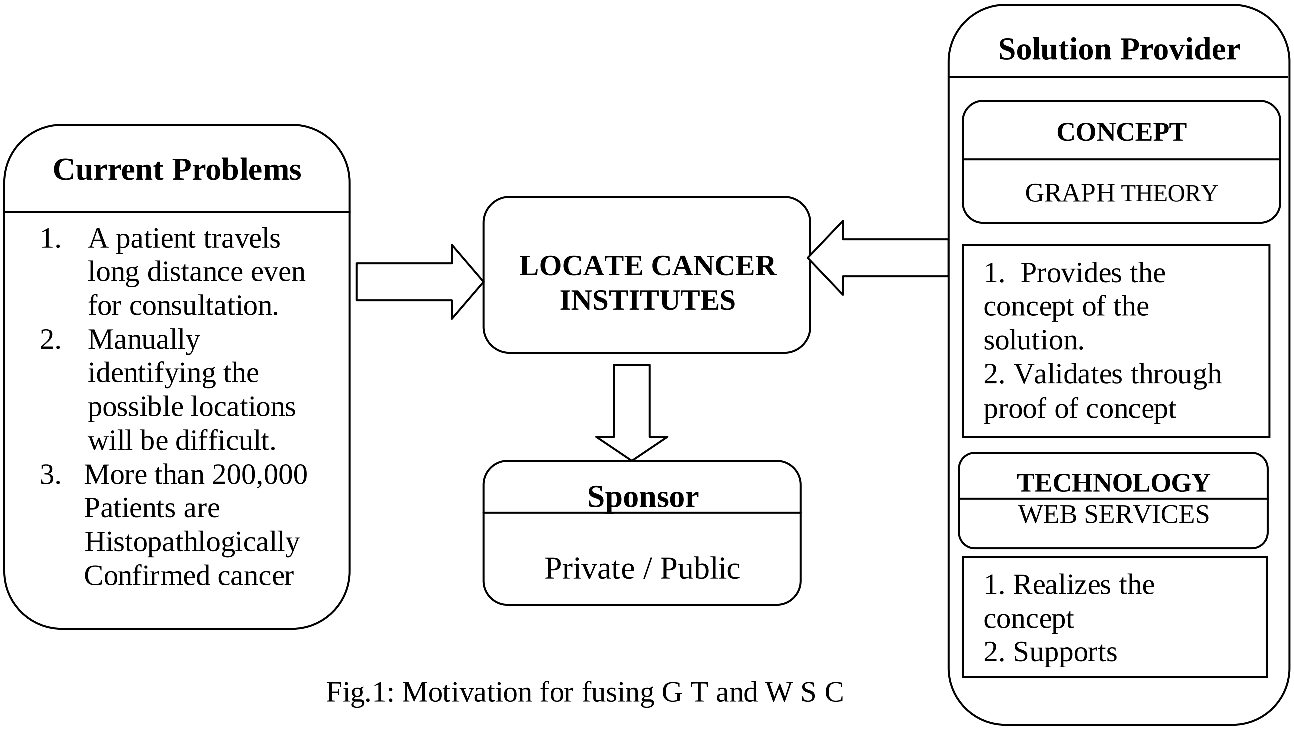

Fig.1: Motivation for fusing G T and W S C

2.1 Methodology:

The concept from graph theory should be implemented as a web service. The logic behind the web service to find the vertex-edge dominating vertices is given as an algorithm in Fig. 2. The two cities C_1 and C_2 between which the location should be identified are given as input to the algorithm. The vertex edge dominating criteria D is calculated. Initially first two districts (vertices v_a and v_b) nearer to C_1 are considered and a Panchayat (vertex v_i) is selected such that its distance from both the districts is less than D.

Another Panchayat (vertex v_k) is selected and if its distance from v_i is less than D than the panchayat is retained; otherwise it is removed from the vertex set V (G). It is possible to have a panchayat that is connected via v_k to v_i. Such Panchayats are also considered (as vertex v_t), such that if the distance between $(v_t v_k) + (v_k v_i)$ is less than D then v_t is retained; otherwise it is removed from the vertex set V(G). The above steps are repeated for next two districts in the set until the last district C_2 is chosen. This is deployed as a web service and utilized in the business flow required to identify the locations.

Input: C1, C2
Web services required: Find Distance, Find Districts, Find Panchayats, Find Number of Major junctions, Calculate Dominating Criteria, Calculate Dominating Vertices
Output: A set containing Vertex – edge dominating vertices

Identify - Locations (C_1, C_2)

a. Let C_1 and C_2 be two cities between which the locations for cancer treatment centers should be identified.
b. Let V(G) = The major districts indexed 1 and panchayats indexed 2 between those two cities and E(G) = Edges connecting the two cities. Let $S \subseteq V(G)$ is the vertex-edge dominating set. Initially $S = \varphi$.
c. Vertex-edge domination criteria(in kilometers)
   D = Distance between two cities / Total number of main junctions between them.
d. Let i = 1
e. Consider two vertices v_a and v_b with index = 1
   i. Choose a vertex v_i with index = 2 from V(G) which is between v_a^1 and v_b^1 such that $v_a^1 v_i$ and $v_b^1 v_i \leq D$. $S = \{v_i\}$.
   ii. Choose a vertex $v_k \in V(G)$
      If weight of $v_i v_k \leq D$ then
         $v_k \in V(G)$ /*vertex retained*/
      else
         Remove v_k from V(G)
   iii. Choose a vertex $v_t \in V(G)$
      If weight of $v_t v_k + v_k v_i \leq D$ then
         $v_t \in V(G)$ /*vertex retained*/
      else
         Remove v_t from V(G)
   iv. i = i + 1
   v. Consider next two vertices v_a^1 and v_b^1. Repeat steps (i) through (iv) until last district is chosen.

Fig.2 Algorithm to identify the cancer treatment centers

2.2 Illustration:

The motivating scenario can be illustrated using the sequence and business process diagrams of UML 2.0. A *sequence diagram* in a Unified Modeling Language (UML) is a kind of interaction diagram that shows how processes operate with one another and in what order. It is a construct of a Message Sequence Chart. A sequence diagram shows object interactions arranged in time sequence. It depicts the objects and classes involved in the scenario and the sequence of messages exchanged between the objects needed to carry out the functionality of the scenario. Sequence diagrams typically are associated with use of case realizations in the Logical View of the system.

Business Process Model and Notation (BPMN) is a graphical representation for specifying business processes in a business process model and also used as a standard for business process modeling that provides a graphical notation for specifying business processes in a Business Process Diagram (BPD), based on a flowcharting technique.

The primary goal of BPMN is to provide a standard notation readily understandable by all business stakeholders. These include the business analysts who create and refine the processes, the technical developers responsible for implementing them, and the business managers who monitor and manage them. Consequently, BPMN serves as a common language, bridging the communication gap that frequently occurs between business process design and implementation.

The sequence diagram in Fig. 3 shows how the web services interoperate and the order in which they operate. It also depicts the messages exchanged between the web services. In this model the lifelines represent user and set of web services.

The business process diagram in Fig. 4 gives the flow of the web services in this business process model. It provides two pools one for user point of view and the other one for the internal process of the business model.

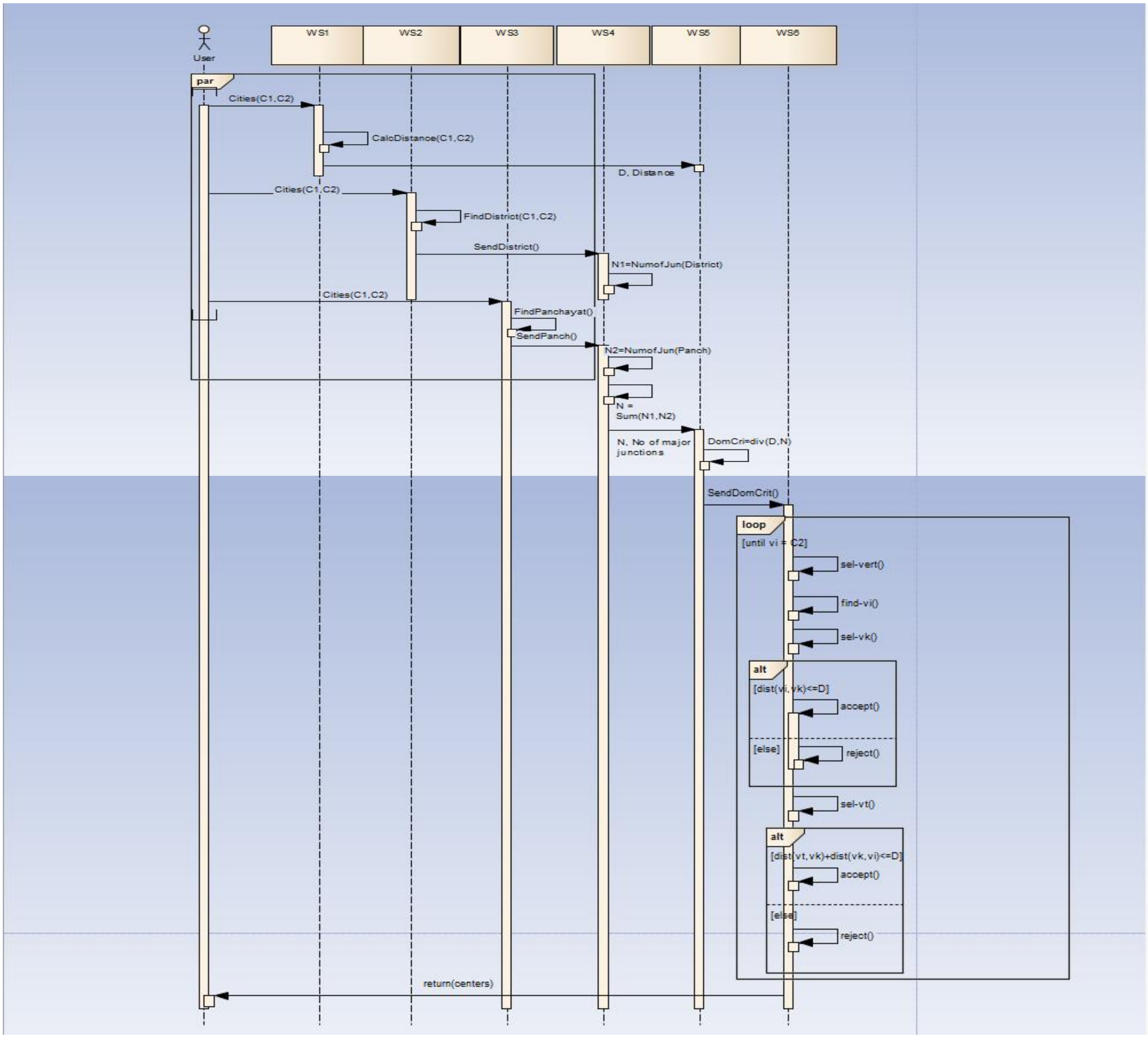

Figure 3: Sequence Diagram for Locating Healthcare centers

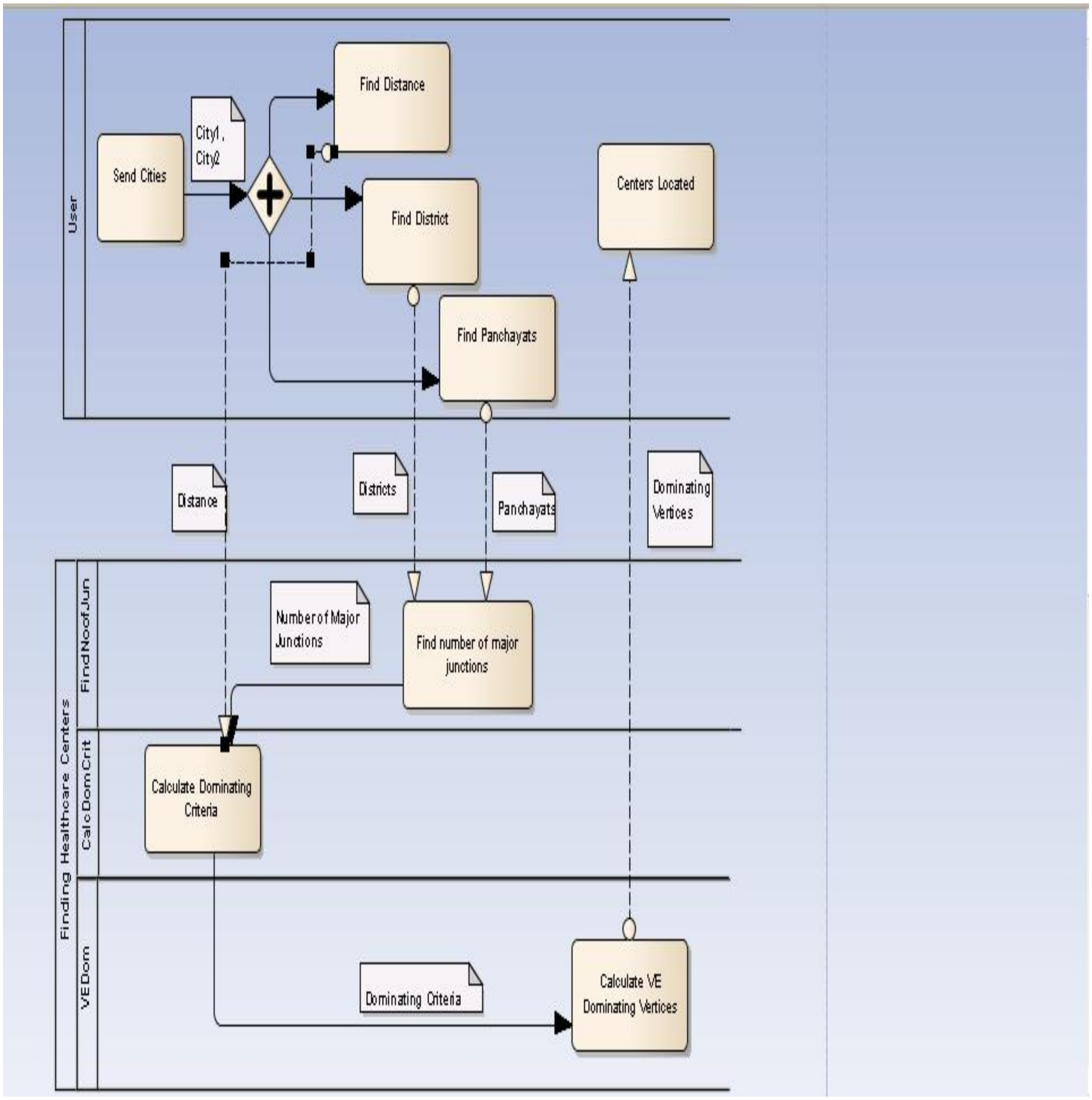

Figure 4: Business Process Diagram for Locating Healthcare Centers

2.3 Proof of Concept:

Let $\mathfrak{S} = \{ \mathscr{A}, \mathfrak{B}, \mathfrak{C}, \mathfrak{D}, \mathfrak{E}, \mathfrak{F} \}$ be the set of available web services in the registry such that each element of $\mathfrak{S}$ is a family of web services.

Let $\mathscr{A} = \{a_1,a_2,a_3,\ldots..a_n\}$be the set of web services used to calculate the distance between two cities C_1 and C_2.

Let $\mathfrak{B} = \{b_1,b_2,b_3,\ldots..b_n\}$be the set of web services used to find the districts between two cities and districts are the vertices indexed 1that belongs to V(G).

Let $\mathfrak{C} = \{c_1,c_2,c_3,\ldots..c_n\}$be the set of web services used to find the panchayats between two cities and panchayats are the vertices indexed 2 that also belongs to V(G).

Let $\mathfrak{D} = \{d_1,d_2,d_3,\ldots..d_n\}$be the set of web services used to find the major junctions between the cities C_1 and C_2.

Let $\mathfrak{E} = \{e_1,e_2,e_3,\ldots..e_n\}$be the set of web services used to calculate the domination criteria D = distance between two cities C_1 and C_2 / Number of major junctions.

Let $\mathfrak{F} = \{f_1,f_2,f_3,\ldots..f_n\}$be the set of web services used to find the vertex – edge domination set S.

Let $A \subset \mathscr{A}$ such that $A = \{ a_i,a_{i+1},a_{i+2},\ldots..a_r / a_i< a_{i+1} < ,\ldots..< a_r\}$, omit all a_i's and retain a_r in $\mathfrak{S}$. Similarly

$B \subset \mathfrak{B}$ such that $B = \{ b_i,b_{i+1},b_{i+2},\ldots..b_r / b_i< b_{i+1} < ,\ldots..< b_r\}$,omit all b_i's and retain b_r in $\mathfrak{S}$.

$C \subset \mathfrak{C}$ such that $C = \{ c_i,c_{i+1},c_{i+2},\ldots..c_r / c_i< c_{i+1} < ,\ldots..< c_r\}$, omit all c_i's and retain c_r in $\mathfrak{S}$.

$D \subset \mathfrak{D}$ such that $D = \{ d_i,d_{i+1},d_{i+2},\ldots..d_r / d_i< d_{i+1} < ,\ldots< d_r\}$, omit all d_i's and retain d_r in $\mathfrak{S}$.

$E \subset \mathfrak{E}$ such that $E = \{ e_i,e_{i+1},e_{i+2},\ldots..e_r / e_i< e_{i+1} < ,\ldots..< e_r\}$, omit all e_i's and retain e_r in $\mathfrak{S}$.

$F \subset \mathfrak{F}$ such that $F = \{ f_i,f_{i+1},f_{i+2},\ldots..f_r / f_i< f_{i+1} < ,\ldots..< f_r\}$, omit all f_i's and retain f_r in $\mathfrak{S}$.

Thus the web services set $\mathfrak{S} = \{a_r, b_r, c_r, d_r, e_r, f_r \}$ are with least interruption, easy accessibility and availability. Here $\{a_r, b_r, c_r\}$ are the set of web services used parallel and are independent, but {dr, e_r, f_r }are the set of web services used sequentially and are depends on the web service a_r.

Hence let us define a function $f : a_r \rightarrow d_r$, $g : d_r \rightarrow e_r$ and $h : e_r \rightarrow f_r$ such that the vertex edge domination set S can be calculated by $h \circ (g \circ f) : a_r \rightarrow f_r$, this can be simply denoted as $h \circ (g \circ f)(x)$.

From the composition of functions it is clear that the image of x can be arrived under f, image of f(x) can be arrived under g, and image of g [f(x)] can be arrived under h. If the range of f is domain of g then only $(g \circ f)(x)$ will exist, from the above discussion it is true and range of g is domain of h then only $h \circ (g \circ f)(x)$ will exist this is also true from the above statements.

Let us show the correctness of composition of functions using the theory of inferences.

Consider the following premises: $a_r : D_1$, $d_r : N$, $e_r : D_1 \wedge N \rightarrow D$, $f_r : D \rightarrow S$, conclusion : S

Step	**Derivation**	**Rule**
(1)	D_1	P
(2)	N	P
(3)	$D_1 \wedge N$	T (Simplification ,from (1) &(2))
(4)	$D_1 \wedge N \rightarrow D$	P
(5)	D	T (Modus Ponens, from (3) &(4))
(6)	$D \rightarrow S$	P
(7)	S	T (Modus Ponens from (5) &(6))

This clearly shows that conclusion will be arrived only by these steps, if the steps are reversed, the equivalences, implications formulae will contradict the results.

2.4 Realization – Fusion of GT and WSC:

In order to suggest minimal number of cancer care centers Vertex Edge Domination concept is employed and that logic is deployed using semantic web services. Locating the centers is a high level business process that is realized by composing a set of Semantic Web Service Composition.

The user will provide the two major cities between which the cancer centers should be located. The major processes involved are (i) Find the distance (D_1), (ii) Find the districts between the two cities (iii) Find the Panchayats between the two cities (iv) Find the number of major junctions (N) by considering the districts and panchayats, (v) Calculate the dominating criteria $D = D_1 / N$, (vi) Find the VE dominating vertices.

The processes are carried out with existing web services for the first three processes and new web services were created for the remaining processes. The registry consists of 'n' number of services out of which 'r' relevant services were discovered for each process. These 'r' services are ranked according to the Quality of Service (like availability and accessibility) provided by those web services. The best ranked service should be selected and assigned for each process.

The case study is illustrated by identifying the locations for cancer care centers between "Coimbatore" and "Chennai". C1 = Coimbatore C2 = Chennai

Major districts = {Coimbatore, Tiruppur, Erode, Salem, Dharmapuri, Krishnagiri, Vellore, Chennai}.

Main junctions = {Coimbatore, Tiruppur, Erode, Salem, Morappur, Jolarpettai, Ambur, Katpadi, Walajah, Arakkonam, Perambur, Chennai}

Number of main junctions (N) = 12,

Distance between C1 and C2 is D_1 = 428 kms.
Therefore Dominating Criteria (D) = D_1 / N ≈ 35 kms.
The Vertex - edge dominating set of our graph is
S = {Avanashi, Idappadi, Papparapatti, Jolarpet, Katpadi, Adyar}.

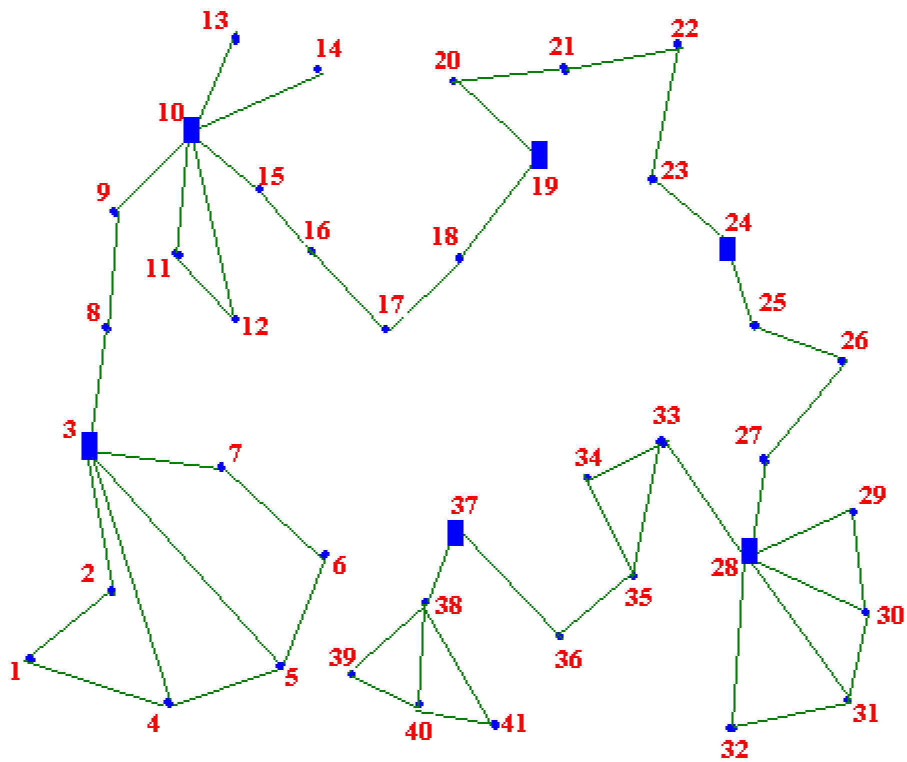

Figure 5: weighted graph with vertex edge dominating set

The vertex edge dominating set S = {3, 10, 19, 24, 28, 37}. [5][6]
The vertex edge domination number $\gamma_{ve}(G)$ = 6.
w (edge 1 2) =14.73 kms ; w(edge 1 4) =7.51 kms ; w(edge 2 3) =16.95 kms ;
w (edge 3 4) =24.72 kms ; w(edge 2 5) =24.6 kms ; w(edge 3 7) =16.78 kms ;
w (edge 7 6) =11.73 kms ; w(edge 4 5) =19.02 kms ; w(edge 5 6) =14.07 kms ;
w (edge 3 8) =33.55 kms ; w(edge 8 9) =18.08 kms ; w(edge 9 10) =28.89kms;
w (edge10 11)=13.4 kms ; w(edge10 12)=24.02 kms ; w(edge10 13)=12.23 kms;
w (edge10 14)=13.4 kms ; w(edge10 15)=18.88 kms ; w(edge15 16)=12.22 kms;
w (edge16 17)=9.8 kms ; w(edge17 18)=45.79 kms ; w(edge18 19)=14.28 kms;
w (edge19 20)=9.44 kms ; w(edge20 21)=20.83 kms ; w(edge21 22)=10.72 kms;
w (edge22 23)=23.59 kms ; w(edge23 24)=11.02 kms ; w(edge24 25)=13.47 kms;
w (edge25 26)=14.33 kms ; w(edge26 27)=25.88 kms ; w(edge27 28)=29.13 kms;
w (edge28 29)=26.19 kms ; w(edge28 30)=23.51 kms ; w(edge28 31)=22.37 kms;

w (edge28 32)=27.65 kms ; w(edge29 30)=24.59 kms ; w(edge30 31)=3.71 kms;
w (edge31 32)=5.42 kms ; w(edge28 33)=91.71 kms ; w(edge33 34)=17.59 kms;
w (edge33 35)=19.32 kms ; w(edge33 35)=17.48 kms ; w(edge35 36)=17.05 kms;
w (edge36 37)=11.32 kms ; w(edge37 38)=10.41 kms ; w(edge38 39)=3.17 kms;
w (edge38 40)=4.78 kms ; w(edge38 41)=2.16 kms ; w(edge39 40)=2.15 kms;
w(edge 40 41)=4.73 kms;

The web services related to this case study were developed and registered in an open source registry. Membrane SOA Registry is open source software for Web Services management. A public deployment of the registry is available at www.service-repository.com. Membrane registry allows registration of services by providing the hosted WSDL, allows defining of dependencies among services, periodically checks for availability of the service and raises events on availability changes, maintains service availability statistics, stores a copy of the service metadata such a WSDL, XSD.

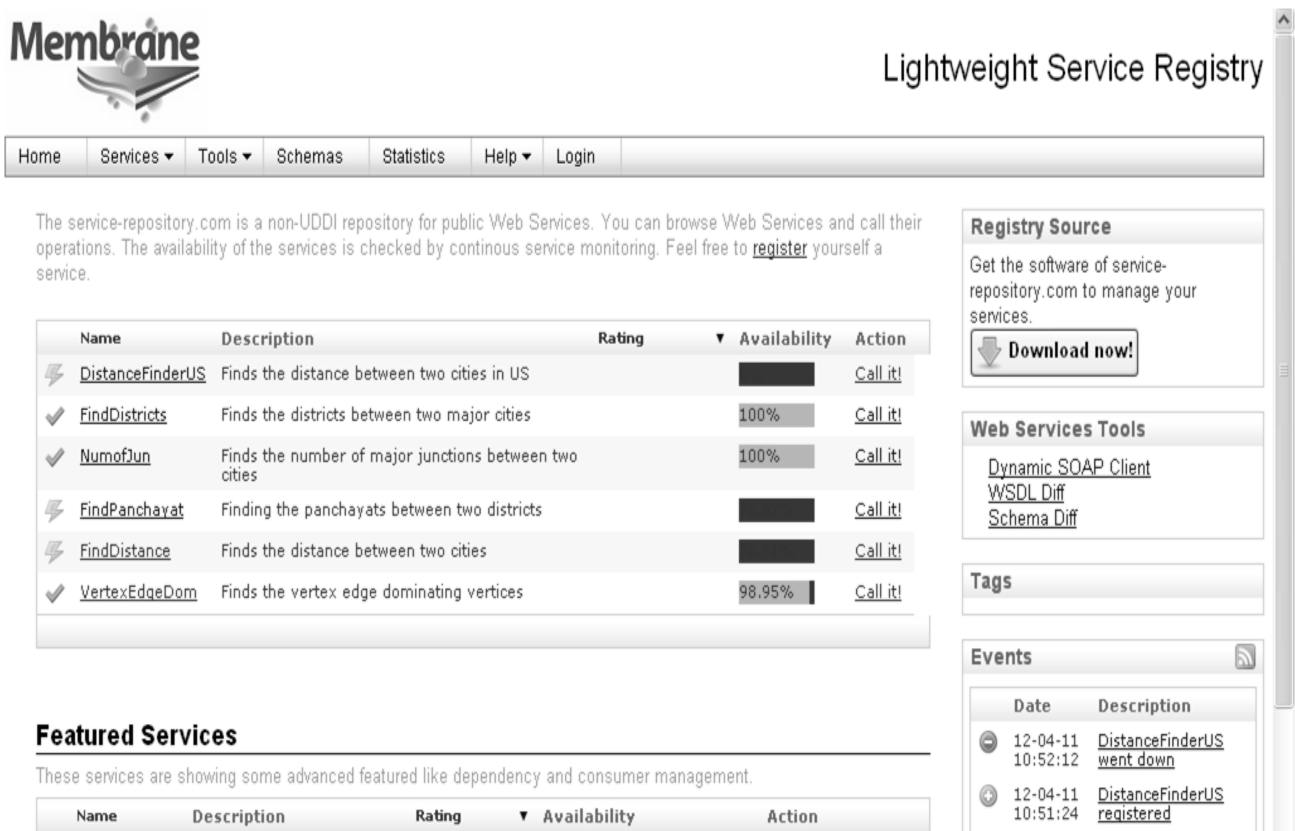

Fig. 6: Web Services in a registry

As shown in Fig. 6 web services name, description and availability are maintained in the registry. The events section in Fig. 6 shows the event “DistanceFinderUSwentdown” is raised when the service “DistanceFinderUS” availability reaches zero. For the available services the registry provides the metadata Web Service Description Language (WSDL) which acts as access point of the web service.

As discussed earlier in Section 2 to automate the process of discovery and composition these web services should be converted into semantic web services. Semantic web services are described using the most commonly used OWL-S (Web Ontology Language for web services). OWL-S description as shown in Fig. 7 has a Service Profile, Service Model and Grounding information of a web service. Service Profile presents the information about “What the service does” with the details about the service parameters namely input, output, precondition and effect. Service model describes the service parameters in detail and specifies “How the service works”. Service Grounding describes “How to access” the service with the details of transport protocols.

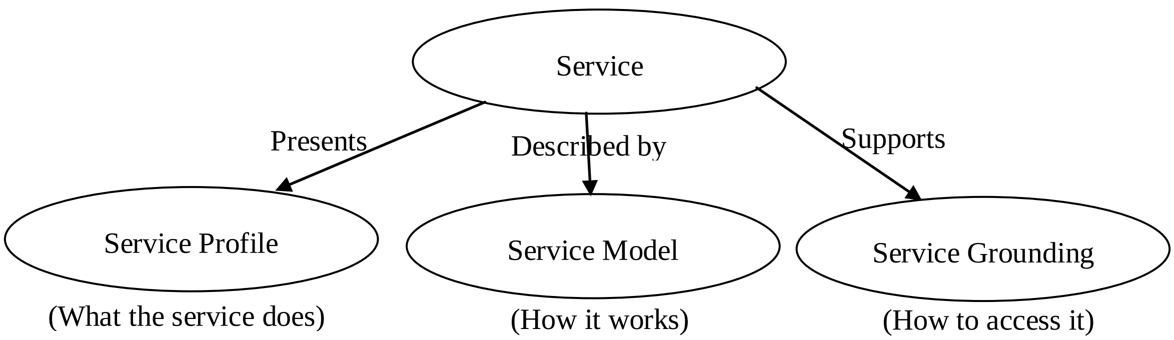

Fig7: OWL-S for a web service

The service model of the FindDistance web service is given in Fig. 8.

```
<profile:has_process rdf:resource="FINDDISTANCE_PROCESS"/></profile:Profile>
<!--<process:ProcessModel rdf:ID=" FINDDISTANCE __PROCESS_MODEL">
<service:describes rdf:resource="# FINDDISTANCE __SERVICE"/>
<process:hasProcess rdf:resource="# FINDDISTANCE __PROCESS"/>
</process:ProcessModel>-->
<process:AtomicProcess rdf:ID=" FINDDISTANCE __PROCESS">
<service:describes rdf:resource="# FINDDISTANCE __SERVICE"/>
<process:hasInput  rdf:resource="#_CITY1"/>
<process:hasInput  rdf:resource="#_CITY2"/>
<process:hasOutput rdf:resource="#_DISTANCE"/>
<process:hasPrecondition> <expr:SWRL-Condition rdf:ID="CitiesAvailability">
<expr:expressionLanguage rdf:resource="http://www.daml.org/services/owl-s/1.1/generic/Expression.owl#SWRL"/>
<expr:expressionBody rdf:parseType="Literal">
<swrl:AtomList> <rdf:first> <swrl:ClassAtom>
<swrl:classPredicate rdf:resource="http://127.0.0.1/ontology/ontosem.owl#be-available"/>
<swrl:argument1 rdf:resource="#_CITY1"/>
<swrl:argument1 rdf:resource="#_CITY2"/>
</swrl:ClassAtom> </rdf:first><rdf:rest rdf:resource="http://www.w3.org/1999/02/22-rdf-syntax-ns#nil"/>
</swrl:AtomList></expr:expressionBody></expr:SWRL-Condition></process:hasPrecondition>
<process:hasResult>
<process:Result rdf:ID="DistanceFound">
</process:Result></process:hasResult></process:AtomicProcess>
```

Fig 8: OWL-S Service Model of FindDistance

3. Related Work:

3.1 Graph Theory:

Let $G = (V, E)$ be a simple connected graph with a vertex set $V(G)$ and edge set $E(G)$. The set D is a dominating set if every vertex $v \in V$ is either an element of D or is adjacent to an element of D. There is several ways to define a dominating set in a graph, for every vertex $v \in V - D$, $\left|N(v) \cap D\right| \geq 1$ that is every vertex $v \in V - D$ is adjacent to at least one vertex in D. The minimum cardinality dominating set of G is said to be domination number and is denoted by $\gamma(G)$.The maximum cardinality of a minimal dominating set of a graph G is called the upper domination number and is denoted by $\Gamma(G)$.[9][10]

We can informally define vertex- edge domination by saying that a vertex v dominates the edges incident to v as well as the edges adjacent to those incident edges. Vertex- edge domination set is simply called as VE-dominating set.[12]

The minimum cardinality of a vertex-edge dominating set is called vertex-edge Domination number of a graph G and is denoted by $\gamma_{gve}(G)$.

The maximum cardinality of a global vertex-edge dominating set is called as upper global vertex-edge domination number and is denoted by $\Gamma_{gve}(G)$.

In this paper let us consider $G = (V, E)$ as a simple connected weighted graph with a vertex set $V(G)$ and edge set $E(G)$.Let w be the weight , such that which is the distance between two vertices in the graph is the weight of an edge e and is denoted by $w(e)$. [9][10]

A set S $\subseteq$ V(G) is a vertex – edge dominating set if for all edges e $\in$ E (G) , there exist a vertex v $\in$S such that v dominates an edge e such that $w(e) \leq$ D, D is the assumed domination criteria, Other wise for a graph G = (V, E) a vertex u $\in$ V(G) vertex – edge dominates an edge vw $\in$ E (G) if

(i) u = v or u = w (u is incident to vw), $w(vw) \leq$ D or [4][5][6]

(ii) uv or uw is an edge in G (u is incident to an edge that is adjacent to vw), $w(uv + vw) \leq$ D or $w(uw + vw) \leq$ D.

3.2 Web Service Composition:

Web Service composition is a process of selecting and aggregating a set of appropriate services to automate a business process [7], [8] when no existing service can satisfy the user request. By choosing appropriate web services offered by different web service providers, specifying their coordination plan, and implementing the plan through an orchestration engine, the composite web service can provide more valuable and complete service than a single web service. This also enhances the reusability of web services. Web service composition is facilitated by semantic web services [11] as they extend the web service descriptions with semantic annotations about properties, capabilities, interfaces, and effects. Such a semantic annotation of web service description, stated as Service ontology, provides a conceptualization of set of services related to a particular domain. Semantic web service composition helps in automating discovery, planning and execution of a set of services required to accomplish a complex task.

4. Discussion and Conclusion:

This paper illustrates the fusion of mathematical modeling by using graph theory and web services composition for identifying the location of a healthcare centre in a pre- defined area. The outcome of this work suggests that graph theory can successfully be applied in solving a real life problem with the help of web service composition.

The advent of Web services lead to a major paradigm shift from tight coupling to loose coupling with advantages like reuse, granularity, modularity, composability, componentization and interoperability. The next revolution is adding semantics to the web services which enabled the automation in service invocation, discovery and composition. The research in this direction by authors [1],[2],[3] is explored by applying semantic web services composition in various scenarios. One such real time scenario considered in this paper is to identify the locations where the health care centers should be established.

To identify the locations, Graph theory concept is used, since Graph theory has many faces of mathematical versions, like fuzzy graphs, distance graphs, coloring, labeling, domination sets in graphs and so on. The authors [4],[5],[6] have chosen vertex – edge domination sets in graphs to express the concept in a logical sequence.

This work aptly describes the ways and means of identifying and implementing a solution in an absolute functional format that can be put into use any time. Also the work provides a huge scope for futuristic work for solving a problem by employing minimum efforts to achieve maximum results. Also the work throws open an opportunity for applying the same work on a larger issue to be resolved, whose outcome can be validated successfully. Thus the paper concludes that fusion of Graph theory and web services compositions can provide solutions to vital issues in our day today life.

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