DECISION SUPPORT SYSTEM FOR NETWORK ROUTING OPTIMIZATION PROBLEM

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Abstract

Routing involves two basic activities: determining optimal routing paths and transporting information groups through a network from a source to a destination. Networks routing is considered as a short path problem and optimized within different constraints like time, distance, cost and traffic. In this research a decision support system (DSS) is designed to facilitate optimal routing and network management. Dijkstra algorithm using distances and centrality as constraints has been used as optimization model. System database has been collected from routers and nodes to build a graph of the network which shows the locations and links of routers and nodes within the network. A friendly interface has been developed to help network administrators in network management.

1. Introduction

The routing problem in communication networks is concerned with the task of guiding incoming traffic from the various source nodes of the network to the destination nodes. The design of algorithms that accomplish this task is quite challenging, because such algorithms have to be distributed in nature, it should be able to adapt to change input traffic conditions, and even able to cope with changes in the network topology [1]. In this paper we develop an optimization model using decision support system with routing algorithm that cater to applications involving bulk-data transfer from various source nodes of the network to the corresponding destination nodes. Routing algorithms for such applications essentially involve the construction of routing tables at the nodes of the network. The routing table at a node is used to decide, for an incoming packet bound for a particular destination node, which outgoing link to direct the packet to. We consider Dijkstra Routing Algorithm for such application. While implementing Dijkstra Algorithm, the router has the complete knowledge of the network [2].

In section two we gave different definitions of decision support system and its architecture. In section three we discuss network routing algorithm characteristics and algorithm types. In section four we apply Dijkstra routing algorithm to obtain optimal shortest path between two nodes in the given network.

2. Decision Support System

The concept of a decision support system (DSS) is extremely broad and its definitions vary depending on the author's point of view [3]. It can take many different forms and can be used in many different ways [4]. On the one hand, DSS defined broadly as "a computer-based system that aids the process of decision making" [5].

DSS couple the intellectual resources of individuals with the capabilities of the computer to improve the quality of decisions. Also DSS are "interactive computer based systems that help decision makers utilize data and models to solve unstructured problems" [6]. On the other hand "there can be no definition of Decision Support Systems, only of Decision Support" to claim that it is impossible to give a precise definition including all the facets of the DSS [6].

2.1 Decision Support Systems Architectures

The decision support system consists of four basic components; user interface; knowledge based subsystems; data management module and model management module. Figure-1 illustrates DSS architecture.

The user interface is a component that provides the communication between the user and the decision support system. The proper design of this component is really important, as it is the only one the user actually deals with [7].

The knowledge base is where all the information is stored by the DSS. Knowledge base can be categorized into two simple groups:

- Facts: represent what we know to be true at a given time.
- Hypotheses: represent the rules or relationships we believe to exist between the facts [8]

The data management module is a subsystem of the computer-based decision support system, and has a number of subcomponents of its own. Figure-2 illustrates data management module components.

- The integrated decision support system database, which includes data extracted from internal and external sources, data which can be maintained in the database or can be accessed only when is useful.
- The database management system; the database can be relational or multidimensional.
- A data dictionary, implying a catalog containing all the definitions of database data; it is used in the decisional process identification and definition phase.
- Query tools, assuming the existence of languages for querying databases.

The model management module consists of the following components; Figure-3 illustrates these components.

- The model base that contains the quantitative models that offer the system the capability of analyzing and finding solutions to problems.
- The model base management module that is meant to create new models by using programming languages.
- The model dictionary, that contains the models' definition and other information related to them.
- The creation, execution and integration module of models that will interpret the user's instructions according to models and will transfer them towards the model management system.

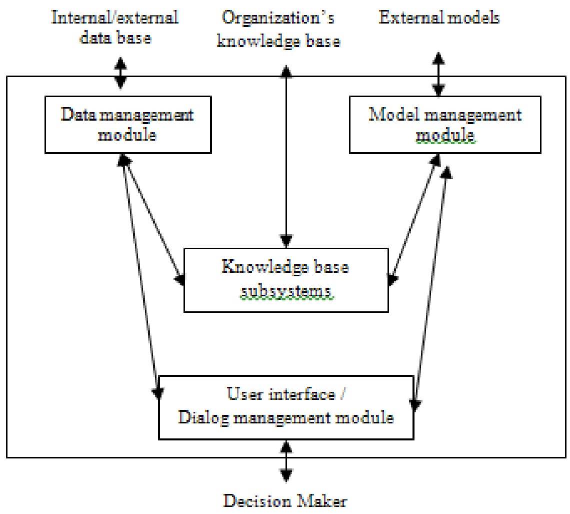

Figure-1 Decision Support Systems' Components

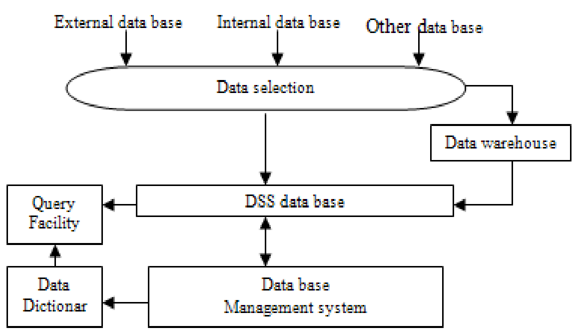

Figure-2 Data Management Module

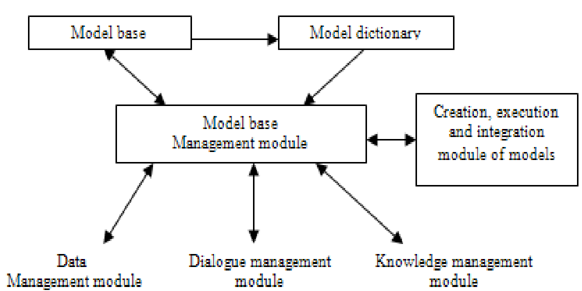

Figure-3 Model Management Module

3. Network Routing Algorithms

The routers in a network are responsible for receiving and forwarding packets through the interconnected set of networks. In particular, the router must avoid the portion of network that has failed or has too much congestion. At the heart of the router there is an algorithm which takes the dynamic decisions and directs the datagram from source to the destination. This is better known as Routing Algorithm [9].

3.1 Routing Algorithm Types

Routing algorithms can be classified by type. Key differentiators include [10]:

a. Single-path versus multi-path.
b. Flat versus hierarchical.
c. Host-intelligent versus router-intelligent.
d. Intradomain versus interdomain.
e. Link state versus distance vector.
f. Static versus dynamic.

3.2 Shortest Path Algorithms

A variety of methods and algorithms are available such as A*, Bellman ford, Breadth-First Search, Depth-First Search and Dijkstra algorithms, for the solution of shortest path problems depending on the type of network and costs involved, and source/destination pairs of nodes for which we need solution[11].

3.3 Dijkstra's Algorithm

Dijkstra's algorithm, when applied to a graph, finds all shortest paths from the source to all destinations. This is known as the single-source shortest paths problem [2]. Dijkstra algorithm is Adaptive routing algorithms, which require that any link cost change be broadcasted to the entire network [9]. Adaptive routing with constantly updated information is helpful in avoiding congested routes [12].

The choice of Dijkstra algorithm for our work is used due to its characteristic of running just on non-negative arc length, helps the network to be stable, find quality route and upgrade the performance. Load is one of the factors that affect on finding optimum shortest path. To solve this problem we use centrality.

3.4 Centrality

Over the years network researchers have introduced a large number of centrality indices, measures of the varying importance of the vertices in a network according to one criterion or another [13]. Perhaps the simplest centrality measure is degree, which is the number of edges incident on a vertex in a network. A more sophisticated centrality measure is closeness, which is the mean geodesic distance between a vertex and all other vertices reachable from it. Closeness can be regarded as a measure of how long it will take information to spread from a given vertex to others in the network [14]. Another centrality measure is eigenvector, which is accords each vertex a centrality that depends both on the number and the quality of its connections [15]. Also Betweenness is a measure of the centrality of a node in a network, and is normally calculated as the fraction of shortest paths between node pairs that pass through the node of interest [22]. Vertices that occur on many shortest paths between other vertices have higher Betweenness than those that do not [23].

Consider a graph $G = (N, E)$ consisting of N nodes and E edges, *let* $|SP_{jk}|$ denote the number of shortest paths between nodes j, $k \in N$ *and* $|SP_{jk(i)}|$ the number of such paths leading through node $i \in N$. Betweenness centrality of the node i is defined as follows [16]:

$$c_i^b = \sum_{\substack{j,k \\ j \neq k \\ j,k \neq i}} \frac{|sp_{jk(i)}|}{|sp_{jk}|} \qquad \ldots (1)$$

4. System Implementation

As discussed in section two, decision support system consist of interfaces, knowledge base, data module and model module. Figure-4 illustrates the building block diagram of the components of the system.

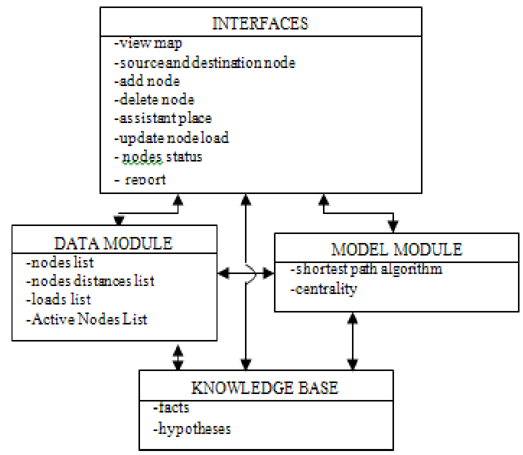

Figure-4 Building Block Diagram of the Components of the System

4.1 Interfaces

The main interface screen contains a list of all the functions of the system as illustrated in Figure-5. Other interfaces are:

4.1.1 View Map

Display Baghdad map, drop 30 nodes and drawing paths between these nodes along with their distance as shown in Figure-6. The map can be replaced by any map that covers the network.

4.1.2 Source and Destination Nodes

This interface screen is used to update the connections between nodes by identifying source and destination nodes, and apply the following functions:

- Add connections (connect source and destination).
- Delete connections (disconnect source and destination).
- Display map with updated information.
- The shortest path between source and destination is shown in text showing all the intermediate hops along with total number of activities. The same is displayed graphically by connecting the intermediate nodes. All the other

links of the original network are hidden.

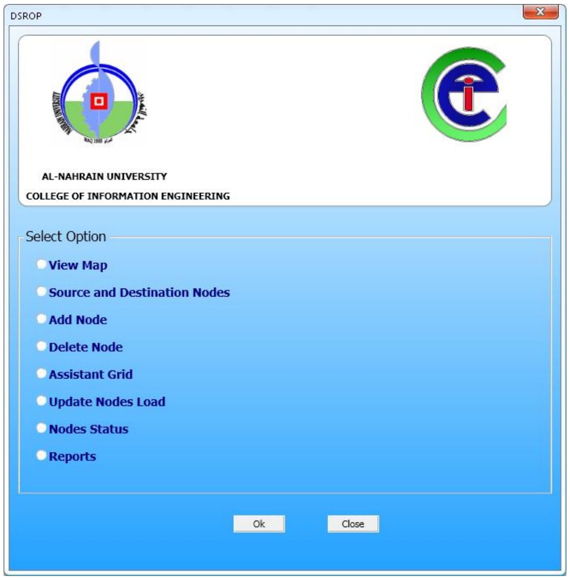

Figure-5 Interface Screen

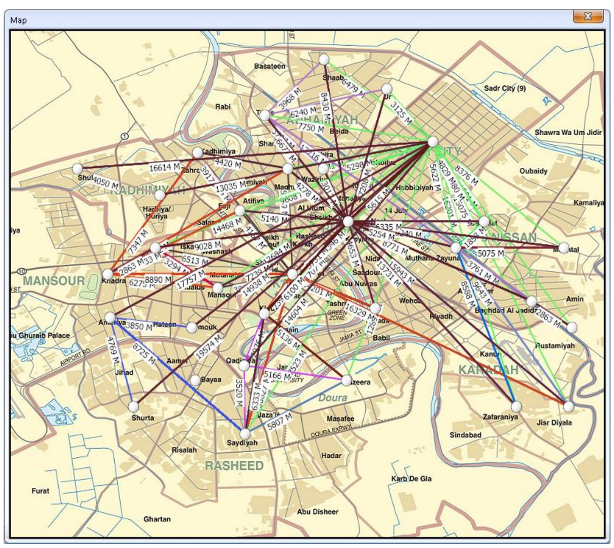

Figure-6 Baghdad Map with Nodes Connections

4.1.3 Assistant Grid

This function help us to determine the sites of the nodes to be configured using Baghdad map which is denoted by the horizontal and vertical deportation extracted from Google map as shown in Figure-7.

4.1.4 Update Nodes Load

Calculate load whenever an update is done on nodes or communication between nodes.

4.1.5 Node Status

Present active and inactive nodes along with their load values.

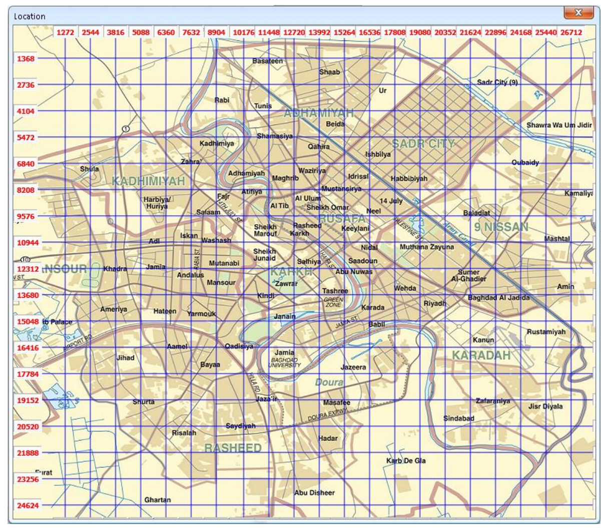

Figure-7 Assistant Grid

4.1.6 Reports

This interface is used to print report such as:

Nodes Table contains nodes number, nodes name and nodes connections.

Load Table contains nodes number, node name and nodes load.

4.2 Data Module

This module contains the following data tables:

4.2.1 Nodes List

Contain nodes name, X-Axis and Y-Axis of a specific node.

4.2.2 Nodes Distances List

Contain source node, destination node and distance which is calculated using the following equation:

$$D=\sqrt{(X_2-X_1)^2+(Y_2-Y_1)^2}$$
… (2)

4.2.3 Loads List

Contain nodes name and their loads.

4.2.4 Active Nodes List

Contain nodes name with the value 1.

4.3 Model Module

This model represents the optimization model that has been used to calculate the optimal path. It consists of the following mathematical models:

4.3.1 Shortest Path Algorithm

As we mentioned in section three, Dijkstra Algorithm is used to calculate shortest path which is one of the most common shortest path algorithms and can be applied to network routing.

4.3.2 Centrality

As we mentioned in section three there is four types of centrality that can be used to calculate the importance of a specific node, for our work Betweenness centrality is used to calculate load on each node in the network by applying equation (1) that discussed earlier in section three.

4.4 Knowledge base

Knowledge base module consists of the following tables:

4.4.1 Facts

All nodes used in our project represent communication towers of Asia Cell Company along with their real distances are taken from the network profile.

4.4.2 Hypotheses

If source and destination nodes are active then optimum shortest path is found by applying Dijkstra Algorithm and the load on the resulting path is found using Betweenness centrality. We have implemented the Dijkstra Algorithm in such a way that under the context of link failure it will provide the next shortest path from the available alternate paths that has been calculated along with the optimum path itself. As a result there is no need to execute the algorithm again, and if any change happened to the network such as adding or deleting nodes, creating or deleting connections, the load of each node will be changed, so we can solve this problem by running Update nodes load command.

5. Conclusions

In this research the following conclusions has been highlighted:

1. The main purpose of using DSS is to support managers in decision making process, to improve the quality of their decisions and to reduce the necessary time to make a decision.
2. Dijkstra Algorithm has been implemented, which provides easy understandability and hence its chances of failure is negligible. Also traffic monitoring and controlling are supported by calculating load on each node in the network by computing the importance of nodes using Betweenness centrality.
3. Damaged nodes and breakdown connections between nodes produce intermittent faults and lead to packet dropping, such faults can be avoided by choosing alternative path that Dijkstra Algorithm support.
4. Providing multiple routes is beneficial in improving the quantity of service.
5. Quality of service, quantity of service and speed are the three most important performance measures for any routing algorithm.
6. Provide network load distribution system enabling optimum load distribution taking the entire network into consideration in order to improve transmission efficiency, reliability, performance of the network and avoid routing holes problem.

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الخـــــــــلاصـــة

يشمل التوجيه نشاطين أساسيين: تحديد مسارات للتوجيه الأمثل ونقل المعلومات خلال الشبكة. من مشاكل التوجيه في الشبكات هو إيجاد اقصر طريق بين نقطتين ولحل هذهالمشكلةيمكن الاعتماد على عوامل مختلفة كالوقت ,المسافه ,الكلفة، وكثافة المرور. في هذا البحث تم تصميم نظام دعم القرار لتسهيل ادارة الشبكة وايجاد التوجيه الامثل. تم استخدام خوارزمية ديكسترا مع المسافه والبينية المركزيه كنموذج لتحقيق الأمثليه في الشبكة. تم جمع قاعدة البيانات من الموجهات والعقد لأنشاء رسم بياني للشبكة واللذي يوضح المواقع والاتصالات بين الموجهات والعقد في الشبكة. واجهه التطبيق الرسومية طورت لمساعده مشرفي الشبكة في ادارة الشبكة.