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A Survey on Search Algorithm for Complex Networks

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Abstract: Today, complex networks have attracted increasing attention from various fields of science and engineering. Many practical applications require search algorithms such as searching for the shortest relationship link in social communication networks, searching web sites on the Internet, and finding specific files in data sets. The main issue in performing the search is how to achieve a fast search. Traditional algorithms cannot solve this problem effectively. This paper introduces a highest degree likelihood approach with k hunters looking for the target simultaneously. A state transition matrix is applied to explain this proposed method. We then further discuss some applications and future challenges.

Keywords: State transition matrix, search steps, query information, Complex network model.

I. INTRODUCTION

A complex network is a large set of interconnected nodes, in which a node is a fundamental unit that can have different meanings in different situations, such as microprocessors, chemical substrates, computers, companies, schools, webs, people, papers and so on. Examples of complex networks include the Internet, food webs, the World Wide Web, electric power grids, cellular and metabolic networks, etc. These large-scale complex networks often display better cooperative or synchronous behaviors among their constituents.

Traditionally, complex networks were studied by graph theory, where a complex network is described by a random graph, for which the basic theory was introduced by Erdos and Renyi [1]. Recently, Watts and Strogatz (WS) [2] introduced the concept of small-world networks to describe a transition from a regular lattice to a random graph. WS networks exhibit a high degree of clustering as in the regular networks and a small average distance between two nodes as in the random networks. Moreover, the random graph model and the WS model are both homogeneous in nature. However, according to Barabasi and Albert [2], empirical results show that many large-scale complex networks are scale-free, such as the Internet, the WWW, and metabolic networks, among others. Notably, a scale-free network is inhomogeneous in nature; that is, maximum nodes have very few connections but a small number of particular nodes have many connections.

Since the search capability of complex networks was proved, numbers of search strategies have been researched. The simplest one is a greedy algorithm which was used in the famous small-world experiment called "Six Degrees of Separation," where each node passes information to the node, which is supposed closest to the target; obviously, this algorithm cannot have globally optimal solutions. Another frequently used method is Random Walk (RW) [2] which passes the query information to a random node until the target node is reached. Based on different kinds of complex networks, different RW's are employed.

In this paper, we present a highest degree likelihood approach with *k* different hunters looking for the target. In each step, hunters deliver their own query message to neighbours, which have the highest possible degrees. In order to reduce query information, repetitive visits are avoided. Our method is able to detect the topological structure of complex networks and obtain important parameters, such as average path length and betweenness centrality.

II. Proposed Algorithm Theory : Highest Degree Likelihood Search Algorithm With K Hunters

For getting the desired search result i.e. the shortest distance between source and destination within network, two basic things required: one is to lower the number of search steps and other is to make best use of relationship link.

The *degree* (or *connectivity*) k_i of a node *i* is the number of edges incident with the node, and is described in terms of the adjacency matrix A as:

$$k_i = \sum_{j \in \mathcal{N}} a_{ij} \ . \qquad (1)$$

If the graph is directed, the degree of the node has two components: the number of outgoing links

$$k_i^{\text{out}} = \sum_j a_{ij} \qquad (2)$$

And the number of incoming links

$$k_i^{\text{in}} = \sum_j a_{ji} \qquad (3)$$

The total degree is then defined as

$$k_i = k_i^{\text{out}} + k_i^{\text{in}} \qquad (4)$$

III. Description of proposed Mode

In our algorithm, we focus on lowering the number of search steps and exploiting the relationships in the network. To achieve these goals, additional hunters are employed, and each hunter searches for the neighbor with the highest possible degree. In this way, we can accelerate the search speed and obtain more information from the highest possible degree node.

Specifically, a hunter indicates one query message, and *k* hunters try to seek the target at the same time by moving synchronously with every step. In other words, when hunter is searching in the fourth step, hunter is also in the fourth step ($1 \leq x \leq k$, $1 \leq y \leq k$). During search process, all hunters try to send the message to their neighbors with the highest possible degrees.

Three problems we face in this model, and have to overcome those:

1. To avoid repetitive visits and endless loops, each node in the network can be accessed only once in one search progress;
2. If all neighbors of the current node have been accessed, we return to the preceding one to select a new current node;
3. When hunters send queries to the same neighbor, the hunter with a lower subscript number has the higher access priority.

IV. State transition Matrix for Proposed Model

In this subsection, the derivation process of a state transition matrix for our proposed algorithm (HDLS) is presented with example

Undirected Graph

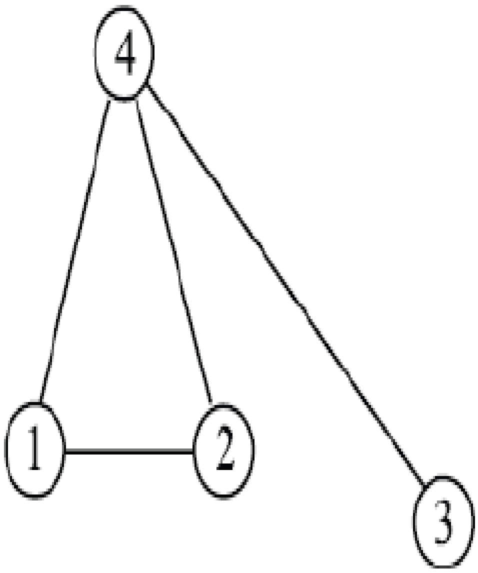

Figure 1: State Transition Diagram
(Undirected graph)

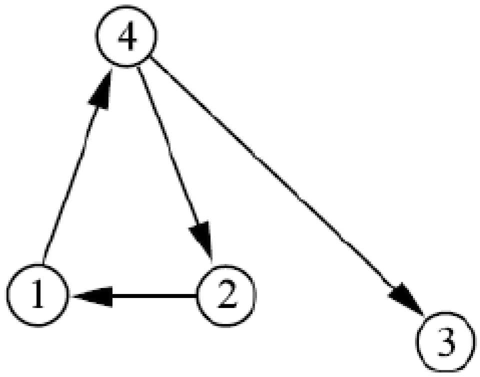

Figure 2: State Transition Diagram
(Directed Graph)

Assuming the number of network nodes is N, the general form of an adjacency for a complex network is $A=\{a_{ij}\}_{N*N}$, denoted :

$$sumd_{ij} = \begin{cases} \sum_{k=1}^{N} a_{kj}, & a_{ij} \neq 0; \\ 0, & a_{ij} = 0, \end{cases} \qquad (5)$$

So, the adjacency matrices for graphs in figure 1 and 2 are as below

$$A = \begin{pmatrix} 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{pmatrix}$$

Adjacency matrix for Figure 1
(Undirected graph)

$$A = \begin{pmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 \end{pmatrix}$$

Adjacency matrix for graph if Figure 2
(Directed Graph)

Now, for further calculations this adjacency matrix is given as input to Highest Degree Likelihood Search Algorithm. The algorithm is as follow:

Algorithm:

Input: Adjacency matrix of the networks.

Output: The complete path from source node to target node.

Step 1: Initialization

Calculate the degree of each node by adjacency matrix;

Determine the source and target nodes;

Denote source node as the current node α_0;

Step 2: Beginning

Start from current node α_0;

If target node is one of its neighbors

Goto **Step 4**;

else

Search for the highest degree neighbor of α_0 by hunter β_1,

denoted as $\alpha_{1;}$

Search for the second highest degree neighbor of α_0 by hunter β_2,

denoted as $\alpha_{2;}$

. . . .

Search for k^{th} the highest degree neighbor of α_0 by hunter β_k,

denoted as $\alpha_{k;}$

Goto **Step 3**;

End If

Step 3: Searching

Start from current nodes α_1, α_2,... α_k;

If target node is among their neighbors

Goto **Step 4**;

else

search for the highest possible degree neighbor of α_1 by hunter β_1,

denoted as $\gamma_{1;}$

Search for the highest possible degree neighbor of α_2 by hunter β_2,

denoted as $\gamma_{2;}$

. . . .

Search for the highest possible degree neighbor of α_k by hunter β_k,

denoted as $\gamma_{k;}$

Let nodes γ_1, γ_2, ... γ_k be new current nodes α_1, α_2,... α_k;

Goto **Step 3**;

End If

Step 4: Ending

Stop, write the final path.

V. CONCLUSION

This survey paper included the description of proposed search algorithm in wireless networks. Instead of using traditional search algorithm like linear search, selection search, prediction search etc. the proposed algorithm i.e. *"HDLSA"* gives the best output according to theoretical concepts and mathematical calculations. We presented the information about the proposed algorithm, this system would be more complicated and expensive for real time implementation, but it is important to develop convenient way for searching nodes in complex networks.

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