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A Heuristic Algorithm for the Reliability Optimization of a Distributed Communication Network

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Abstract. A heuristic algorithm for reliability optimization of a distributed network system is developed so that the reliability of a large system can be determined efficiently. This heuristic bases on the determination of maximal reliability set of maximum node capacity, maximal link reliability and maximal node degree.

Key Words: *Distributed network system, Reliability, Optimization, Class of N-P hard, Heuristic algorithm, Capacity, Sub network*

1. INTRODUCTION

A distributed network system (DCN) is a connected graph formed by a collection of processor-memory (nodes) pairs connected by a communication link (arc). The probability of the sub networks are connected is the reliability of the DCN.

The optimization to be considered in this paper is to find a sub network with total capacity meet the minimum requirement while the reliability of DCN is maximized. The exact solution algorithm of this optimization problem is in the family of NP hard. The solution of this optimization problem can be difficult to find when the system becomes sufficient large. Under this circumstance, to develop an efficient heuristic is necessary and this is our main concern of this paper to be done in the sections latter.

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2. MODEL AND OPTIMIZATION

Let a graph $G=(N,A)$ be connected where $N=\{1,2,\mathrm{K}\ ,n\}$ and $A=\{(i,j):i,j\in Q\subset N\}$ are the node set and arc set, respectively. This graph is a distributed communication network if node set and arc set are processor-memory pairs and communication links as mentioned above.

The following notations are used in this paper. The reliability of arc (i,j) is denoted by $r(i,j)$ and the capacity of node i is denoted by C_i. The algorithm is developed under the assumption that the nodes are perfectly reliable and each link is either in the **ON** state or in the **OFF** state.

The optimization problem is to find a specified subset M of nodes in DCN such that the total capacity of the system of data files to be allocated is no less than a given requirement while the reliability $R(M)$ is optimized amount the collection C of all possible subsets of nodes. This can be described as a mathematical model as follows.

$$\max_{M\in C} R(M) \quad \text{s.t.} \quad \sum_i C_i \geq L \tag{2.1}$$

where L is a given lower bound.

This model can be formulated as an integer program and true optimal can be reached. However, this problem belongs to the class of NP-hard, naturally, to solve this type of problem which suggests the necessity of an efficient heuristic algorithm. Eventually, one would consider the following conditions so that the reliability is maximized while the capacity meets the required lower bound L at least

(1) maximum node capacity
(2) maximum arc reliability
(3) maximum number of node connections

The above (1), (2) and (3) will be the main ideas. Based on these ideas an algorithm with three independent parts is developed. These independent parts executes simultaneously. Finally, each part reports a solution. The maximum among three is chosen and the sub network is selected.

3. ALGORITHM

The following is the algorithm:

A.

1. Select a node n_0 with maximum capacity
   $C_{MAX} = \max\{C_i : i \in N\} = n_0 \in N$.
2. Amount all nodes adjacent to n_0, select one node with maximum capacity amount all adjacent nodes then check total capacity if total capacity is great than or equal to the given lower bound L, then go to 3.
   If total capacity is smaller than L, then select one with maximum capacity amount all adjacent and not been selected nodes, repeat this process until capacity constraint is satisfied, then go to 3.
3. Calculate the reliability of the sub network = RA.

B.

1. Select an arc with maximum reliability $L_{MAX} = \max\{r(i,j) : (i,j) \in A\} = r(p_0, q_0)$. Find the total node capacity of the nodes connect to the selected arcs. If the total capacity is greater than or equal to the given lower bound L then go to 3, else, go to 2.
2. Find one arc with maximum reliability amount all unselect arcs connect to the selected arcs. Check total capacity, if it is greater than or equal to the given lower bound L go to 3, else repeat the same process until capacity lower bound is reached.
3. Calculate the reliability of the sub network = RB.

C.

1. Select a node with maximum number of arcs: connections
   Let $NA(i)$ denote the number of arcs connect to node *i*.
   $$NA_{MAX} = \max\{NA(j) : j \text{ adjcent to a selected node}\}$$
   $$= NA(j_0)$$
2. Select an adjacent node with maximum number of arcs connect to it
   If the total capacity is greater than or equal to the given lower bound $\boldsymbol{L}$ .then go to 3, else, repeat the same process until the capacity constraint is met. Go to 3
3. Calculate the reliability of the sub network.= RC
   II The final result from the algorithm.
   $$R_{FINAL} = \max\{RA, RB, RC\}.$$

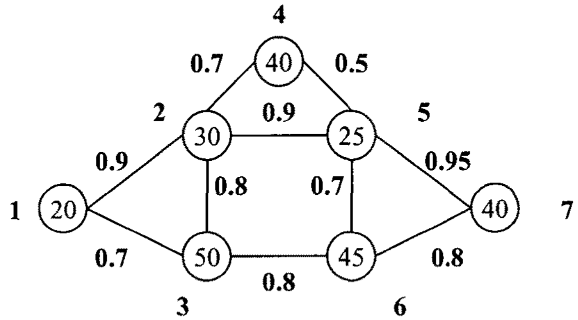
The one with maximum reliability will be chosen as the "sub network" which is the heuristic solution of this particular problem.

4. CONCLUSIONS AND AN EXAMPLE

The algorithm proposed in this paper is both efficient and accurate. These two are very important requirement when dealing with a large system. For instance choosing a sub network of the metropolitan area network, the execution time can be too long and so as to be infeasible when one is solving the problems using an Exact Method. The proposed heuristic algorithm made a great improvement on this mentioned weakness of the traditional exact method. Hence the heuristic algorithm is considered as a better method when solving a problem with a large system due to the computation advantage of this heuristic algorithm.

This following example demonstrates how the proposed method works to conclude this paper.

Example 4.1



$G = (N, A)$ is a distributed communication network, where $N = \{1, 2, 3, 4, 5\ 6, 7\}$, and $A = \{(1, 2), (1, 3), (2, 3), (2, 4), (2, 5), (3, 6), (4, 5), (5, 6), (5, 7), (6, 7)\}$.

Node capacity

Node	1	2	3	4	5	6	7
Capacity	20	30	50	40	25	45	40

Arc reliability

$r(1,2) = 0.9, r(1,3) = 0.7, r(2,3) = 0.8, r(2,4) = 0.7$

$r(2,5) = 0.9, r(3,6) = 0.8, r(4,5) = 0.5, r(5,7) = 0.95,$

$r(5,6) = 0.7, r(6,7) = 0.8$

Given capacity require lower bound L=100

Solution:

A: Max Capacity

Node	3	6	7	Total
Capacity	50	45	40	135>100

B Max Reliability
r(2,5)=.0.9 r(2,3)=0.8

Node	2	3	1	Total
Capacity	30	50	20	=100

C. Max Number of Connections

Node	5	2	3	Total
Capacity	25	30	50	105>100

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REFERENCES

Aggarwal, K. K., Chopra, Y. C. and Bajwa, J. S. (1982). Topological layout of links for optimizing the S-T reliability in a computer communication system. *Microelectronics & . Reliability,* **22**, 341-345.

Chen, D. J. and Huang, T. H. (1992). Reliability Analysis of Distributed Systems based on a Fast Reliability Algorithm. *IEEE Trans. on Parallel and Distributed Systems,* **3**, 139-154.

Chou, T. C. K. and Abraham, J. A. (1983). Load redistribution under failure in distributed systems. *IEEE Trans .Comput.*, **32**, 799- 808.

Hwang, G. J. and Tseng, S. S. (1993). A heuristic task assignment algorithm to maximize reliability of a distributed system. *IEEE Trans. on Reliability*, **42**, 408-415.

Hariri, S. and Raghavendra, C. S. (1984). SYREL: A Symbolic Reliability Algorithm based on Path and Cutset Methods, *USC Technical Report.*

Kumar, A., Rai, S. and Agrawal, D. P. (1988). Reliability evaluation algorithms for distributed systems, *Proc. IEEE INFOCOM88*, 851-860.

Prasnna Kumar, V.K., Hariri, S. and Raghavendra, C. S. (1986). Distributed program reliability analysis, *IEEE Trans. Software Eng.*, **12**, 42-50.

Satyanarayna, A. and Hagstrom, J. N., (1981) New algorithm for reliability analysis of multiterminal networks, *IEEE Trans. on Reliability*, **30**, 325-333.