On the Assignment of Node Number in a Computer Communication Network

Kamalesh V.N[1], S K Srivatsa[2]

Abstract— **The link deficit algorithm proposed by Steigletiz, Weiner and Kletman is a heuristic to generate a potential network topology. This heuristic begins by numbering the nodes at random. If the nodes are numbered in a systematic manner, the link deficit algorithm yields a starting network which needs relatively lesser amount of perturbation before an acceptable network is found. Few methods for systematic numbering of nodes in a computer communication network have been proposed in the literature. Earlier we have proposed two graph theory based method for systematic numbering of nodes in a computer communication network. The nodes are numbered based on the eccentricity values. However the nodes having the same eccentricity values will end up in a tie. This paper aims to resolve the eccentricity tie.**

Index Terms— **Computer network; Link deficit algorithm, Wireless network, Eccentricity, Minimum spanning tree.**

I. Introduction

The topological design of a network assigns the links and link capacities for connecting the network nodes. This is a critical phase of network synthesis, partly because the routing, flow control and other behavioral design algorithms rest largely on the given network topology. The topological design has also several performance and economic implications. The node locations, link connections and link speeds directly determine the transit time through the network. For reliability or security considerations, some networks may be required to provide more than one distinct path for each node pair, thereby resulting in a minimum degree of connectivity between the nodes [10].

The goal of the topological design of a computer communication network is to achieve a specified performance at a minimal cost [5]. Unfortunately, the problem is completely intractable [1]. The fastest available computers cannot optimize a 25 node network, let alone a 100 node network. A reasonable approach is to generate a potential network topology (starting network) and see if it satisfies the connectivity and delay constraints. If not, the starting network topology is subjected to a small modification ("perturbation") yielding a slightly different network, which is now checked to see if it is better. If a better network is found, it is used as the base for more perturbations. If the network resulting from perturbation is not better, the original network is perturbed in some other way. This process is repeated till the computer budget is used up [2, 3, 5].

One of the many heuristics for generating a potential network topology is the link deficit algorithm [4]. This heuristic begins by numbering the nodes at random. If the nodes are numbered in a systematic fashion, the starting network will need relatively lesser amount of perturbation in order to satisfy constraints. A brief review of the existing methods for numbering the nodes can be found in [10].

One of the most useful measure of a communication network performance is the transmission delay (or time delay) encountered by a message in traveling through the network from its source to its destination. In a store and forward network a message may have to be stored and forwarded by several intermediate processors before reaching its destination. The transmission delay or signal degradation is approximately proportional to the number of edges a message must travel. Thus, minimizing this number obviously leads to more efficient communication networks. Furthermore, the cost of the interconnection among the processors increases with the number of physical lines between two processors in the networks. The distance, eccentricity and diameter of a graph play significant roles in analyzing efficiency of interconnection networks. They provide efficient parameters to measure the transmission delay in the network [8].

In designing a network topology one fundamental consideration is the fault tolerance. There are two types of faults in a system: hardware failures and software errors. Most hardware failures have physical causes such as component wear and electromagnetic interference. Software errors are primarily due to design errors. The former are able to model by a mathematical way and the later are much more difficult to model [8].

The performance of a fault-tolerant system should include two aspects: computational efficiency and reliability. When a component or link fails, its duties must be taken over by other fault-free components or links of the system. The network must continue to work in case of node or edge failures. Different notions of fault tolerance exist, the simplest one corresponding to connectivity (or link -connectivity) of the network, that is, the minimum number of nodes (or links) which must be deleted in order to destroy all paths between a pair of nodes. The maximum connectivity is desirable since it corresponds to not only the maximum fault tolerance of the network but also the maximum number of internally (or link-) disjoint paths between any two distinct vertices. However, connectivity number can be utmost equal to the degree of the network graph [7, 8].

II. OVERVIEW OF OUR EARLIER METHODS

In our earlier method [11] for systematic numbering of nodes in a communication network the geographical positions of the nodes are given. To start with, the nodes are labeled using the symbols. For every node $v \in N$, the eccentricity $E(v)$ is calculated. A table displaying the node and the corresponding eccentricity values is constructed. The vertices are sorted based on eccentricity values. Subsequently, the

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index value of the sorted list is assigned as the representative number for the nodes. This method is a generic method based on graph theoretical approach. However, to compute the distance between a pair of nodes, one has to explore all possible paths between them. This demands computational effort. To overcome this, we proposed an alternative method [12]. In this method, the distance between the pair of nodes is computed using minimum spanning tree topology of the given communication network. Unlike other existing methods [6, 9], our proposed methods have a strong mathematical background and works for any communication network (wired/wireless). In the methods [11, 12] the nodes are numbered based on the increasing order of the eccentricity values. However, the nodes having the same eccentricity value end up in a tie. This paper presents a technique to resolve eccentricity ties.

III. PROPOSED METHOD

This paper presents a technique to resolve the eccentricity tie in systematic numbering of nodes in any communication network, keeping in view of the transmission delay and fault tolerance. Consider the given communication network , N (V, E). The method begins by labeling the nodes using some arbitrary symbols. Find the minimum spanning tree topology T (V, E) of the given communication network N (V, E), for every node $V \in T$ the eccentricity E (v) is calculated. A table displaying the node and the corresponding eccentricity values is constructed. The nodes are sorted based on the eccentricity values, subsequently the index value of the sorted list is assigned as the representative number for the respective nodes. If two are more nodes have same eccentricity value then apply the following procedure to resolve the conflict.

Proposed rules to resolve conflicts:

1. If two nodes say V_i and V_j have same eccentricity values then the node number of V_i is less than node number of V_j if $\sum d(v_i, w) < \sum d(v_j, w)$ for every node $w \in T$
2. If $\sum d(v_i, w) = \sum d(v_j, w)$ for every node $w \in T$, then node number of V_i is less than node number V_j, if degree of V_i in N is greater than degree of V_j. in N.
3. If two nodes V_k and V_l has the same degree in N then node number of V_k is less than node number of V_l, if the sum of the degrees of the neighbors of V_k greater than sum of the degrees of the neighbors of V_l.
4. Upon application of the above three steps and if still there exist a tie then it is suggested to compare the sum of the eccentricity values of the neighbors. The node having the lower eccentricity sum is given a lower value.

Thus the following is the proposed algorithm to label the nodes of a communication network:

Algorithm : Systematic Numbering of Nodes in a communication network.
Input : Unlabeled network N= (V, E), where $|V| = n$
Output : n labels for each n distinct nodes of the network.

Method:
1. Consider a given communication network N(V,E)
2. Name the nodes using some symbols ($V_1\ V_2 \ldots V_n$)
3. Find the minimum spanning tree topology T of the given communication network.
4. For every node $V_i \in T(V)$, Find the eccentricity $E(V_i)$
5. Sort the vertices based on Eccentricity value subsequently assign the index value of the sorted list as the representative number for the nodes.
6. If two or more nodes have the same eccentricity values then apply the above four proposed rules to resolve the conflicts in sequence.

Algorithm End

IV. ILLUSTRATION

Stage by stage illustration of the proposed method is presented in this section.
Let us consider the following network (Fig-1), with cost associated with each link is assumed to be unity.

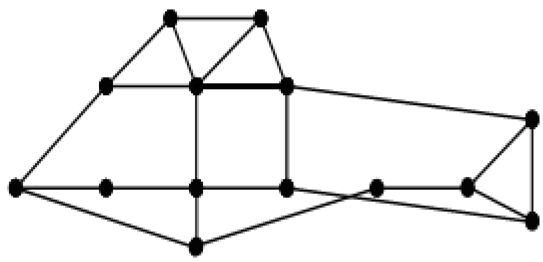

Figure 1. Unlabelled Network Graph

Name the nodes of Network in Fig-1 using some symbols which results with a Network shown in Fig-2.

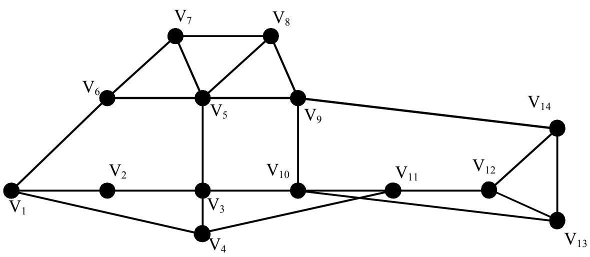

Figure 2: Network graph whose nodes are named using symbols

Consider the Network in Fig-2 and find the minimum spanning tree. The resultant spanning tree topology is shown in Fig-3.

Subsequently, the distance between the various nodes of the tree topology is computed and the same is tabulated in Table-I.

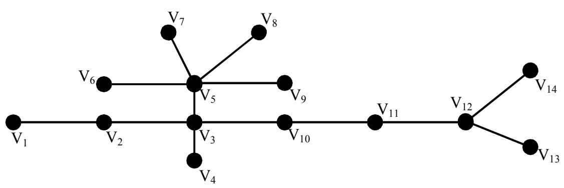

Figure 3: Minimum spanning tree topology of the given network.

Table I: Distance between various nodes of the tree topology

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}	V_{14}
V_1	0	1	2	3	3	4	4	4	4	3	4	5	6	6
V_2	1	0	1	2	2	3	3	3	3	3	3	4	5	5
V_3	2	1	0	1	1	2	2	2	2	1	2	3	4	4
V_4	3	2	1	0	2	3	3	3	3	2	3	4	5	5
V_5	3	2	1	2	0	1	1	1	1	2	3	4	5	5
V_6	4	3	2	3	1	0	2	2	2	3	4	5	6	6
V_7	4	3	2	3	1	2	2	0	2	3	4	5	6	6
V_8	4	3	2	3	1	2	2	0	2	3	4	5	6	6
V_9	4	3	2	3	1	2	2	2	0	3	4	5	6	6
V_{10}	3	2	1	2	2	3	3	3	3	0	1	2	3	3
V_{11}	4	3	2	3	3	4	4	4	4	1	0	1	2	2
V_{12}	5	4	3	4	4	5	5	5	5	2	1	0	1	1
V_{13}	6	5	4	5	5	6	6	6	6	3	2	1	0	2
V_{14}	6	5	4	5	5	6	6	6	6	3	2	1	2	0

Construct a table with attributes; nodes, eccentricity value of every node, sum of the distances from each node to every other node, degree of the node, sum of the degrees of the neighboring nodes corresponding to every node, sum of the eccentricities of the neighboring node corresponding to each node and node number. Table II gives the entries for Network topology shown in Fig-3.

Table II: Node Numbering

Nodes	E(V)	$\sum d(v_i, w)$ for every $w \in T(V,E)$	Degree of the node	$\sum$degree (v_i, u) where u is the neighboring node of v_i	$\sum E(x)$ where x is the neighboring node of v_i	Node Number
V_1	6	49	3	8	16	10
V_2	5	37	2	5	9	6
V_3	4	27	4	14	18	2
V_4	5	39	3	10	14	5
V_5	5	31	5	17	27	7
V_6	6	43	3	11	17	14
V_7	6	43	3	12	13	12
V_8	6	43	3	12	17	13
V_9	6	43	4	15	20	11
V_{10}	3	31	4	16	21	1
V_{11}	4	37	3	11	13	3
V_{12}	5	45	3	9	15	4
V_{13}	6	62	3	9	15	8
V_{14}	6	57	3	10	17	9

Search through the Table II, to find the least eccentricity value. For the example we have considered V_{10} has the least eccentricity value, therefore assign the number **1** to V_{10}.

Search for the next least eccentricity value in Table II and assign the unique label in increasing order till we encounter a tie situation. For the example we have considered the next least eccentricity value is 4. However two nodes V_3 and V_{11} have the same eccentricity value 4 i.e. $E(V_3) = E(V_{11}) = 4$. Therefore there is a tie. To resolve this, as suggested in the algorithm, consider their sum of distances from that node to every other node. In this case we have $\sum d(V_3,W) > \sum d(V_{11},W)$. Hence assign number **2** to V_3 and number **3** to V_{11}.

Continuing like this we have, $E(V_2) = E(V_4) = E(V_5) = E(V_{12}) = 5$, however $\sum d(V_{12}, W) > \sum d(V_4, W) > \sum d(V_2, W) > \sum d(V_5, W)$ therefore assign number **4** to V_{12}, number **5** to V_4, number **6** to V_2 and number **7** to V_5.

Continuing further we have $E(V_1) = E(V_6) = E(V_7) = E(V_8) = E(V_9) = E(V_{13}) = E(V_{14}) = 6$, however $\sum d(V_{13}, W) > \sum d(V_{14},W) > \sum d(V_1, W) > \sum d(V_6, W) = \sum d(V_7, W) = \sum d(V_8,W) = \sum d(V_9, W)$, therefore we assign number **8** to V_{13}, number **9** to V_{14} and number **10** to V_1.

For the nodes V_7, V_8 and V_9 there is a tie at the second level. That is the sum of the distances from that node to every other node is also same. To resolve the conflict, we will make use of degree information of the node as suggested in the algorithm. That is, Degree of V_9 > Degree of V_6 = Degree of V_7 = Degree of V_8 = 3, therefore we assign number **11** to V_9. $\sum$degree$(v_7, u) = \sum$degree$(v_8, u) > \sum$degree(v_6, u), therefore we assign number **14** to V_6. However, the nodes V6 and V7 there is a tie at third level, that is their degrees are same. To resolve this tie. We make use of the sum of the eccentricities of neighboring nodes. In this case, the sum of eccentricities of the neighbors of V_8 > Sum of the eccentricities of neighbors of V_7, therefore assign number **12** to V_7 and number **13** to V_8.

The resultant network graph after application of the proposed rules is as shown in Fig-4. In Fig-4 all the nodes of the network are systematically numbered.

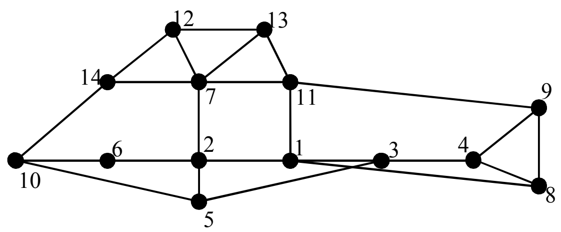

Figure 4: A Network graph whose nodes are numbered.

V. CONCLUSION

This paper presents a generic method for systematic numbering of nodes of any communication network. Most of the existing methods rely heavily on heuristics and lack sound mathematical background. Earlier we had proposed couple of methods [11, 12] based on graph theoretical approach. Those methods work equally well irrespective of the network connectivity number. However, those methods assign arbitrary sequential labels when the two nodes shares common eccentricity value. In this paper we have proposed set of rules to resolve such conflicts. The real beauty of the proposed rules is that they are derived taking into account the transmission delay and fault tolerance with the help of graph theoretical features. The proposed set of rules ensures the conflict resolution to the maximum extent.

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BIOGRAPHY

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