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A Review of Computer Network Topology and Analysis Examples

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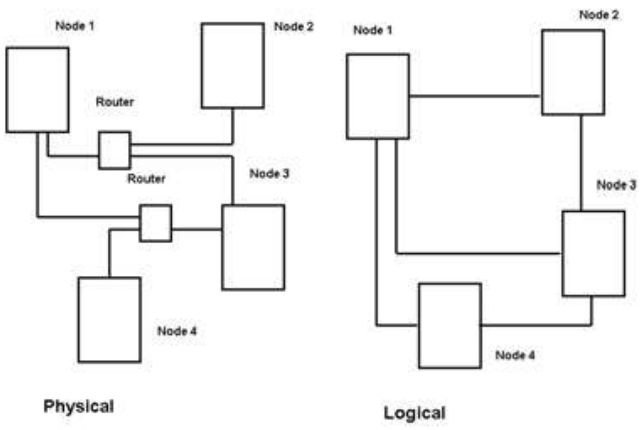
ABSTRACT
This paper introduces the topology of computer networks. Physical and logical model definitions are also provided. In addition, the realization of computer networks of physical types is also reviewed. This is followed by a discussion of graph theory and its relationship to topological analysis. This is followed by a discussion of sample scans focusing on mail routing, network sizing, and virus scanning issues. These examples are discussed to emphasize the importance of topological design when building a new computer network or adding to an existing network.

Keywords: Different types of Network Topology, Directed Graph and Undirected Graph, Queuing Theory, Combinatorial Trials, Tree-Bus Topology

I. INTRODUCTION

Topology is a branch of mathematics that studies the distortion of objects with constant properties. Even if they appear physically different, two objects can be topologically equivalent. As an illustration, given that the rubber band is not broken, any two items created with it are topologically equal. Kirchhoff circuit analysis is a remarkable application of topology-based practical analysis. Basic Topology is expanded upon in computer network topology. This field looks at how computer system components are connected together and how they are configured. Topology is a branch of mathematics that studies the distortion of objects with constant properties. Even if they appear physically different, two objects can be topologically equivalent. As an illustration, given that the rubber band is not broken, any two items created with it are topologically equal. Kirchhoff circuit analysis is a remarkable application of topology-based practical analysis. Basic Topology is expanded upon in computer network topology. This field looks at how computer system components are connected together and how they are configured.

Figure 1 Physical and Logical Topologies



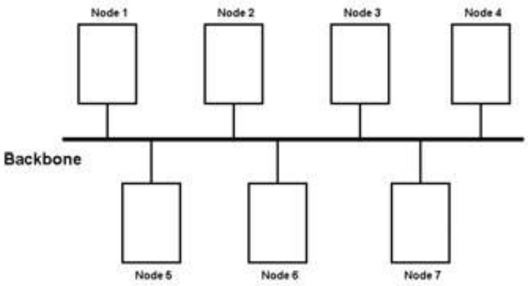
Operations research (OR) performance analysis topics related to computer network topology tend to be more concerned with logical topology than purely physical topology. This article will review some examples of performance analysis studies with the aim of demonstrating the importance of considering topology in network design. Although the problem posed in this study is limited, many of the analytical techniques discussed can be applied to other network analysis problems. Since the logical network topology is based on the underlying physical network topology, a set of standard computer physical topologies should first be considered as the basis for the performance analysis discussion. This is followed by a brief description of graph theory and then examples of network analysis.

II. PHYSICAL NETWORK TOPOLOGIES.

A review of common physical network topologies provides the basis for the analytical discussion presented in Section 4. In this section, bus, ring, star, tree-related properties and problems and the mesh is presented.

2.1 Bus Network Topology

Figure 2 Bus Network Topology



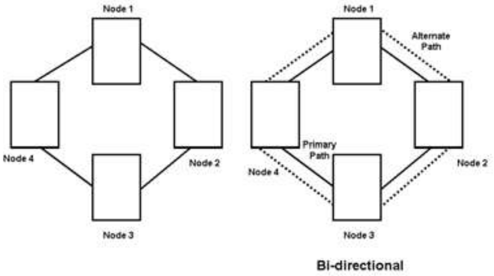
In a bus network topology, a single cable is used to connect all the devices on the network. This cable is often referred to as the network backbone. When communication occurs between nodes, the device sending the message is broadcast to all nodes in the network, but only the intended recipient understands the message. The advantages of this type of physical topology include ease of installation and minimal cabling required. Furthermore, the failure of one node attached to the network does not affect other nodes attached to the network. In addition, messages from one node can be seen simultaneously by all other nodes in the network The disadvantages of this configuration include performance limitations on the number of network nodes and network connectivity being completely shut down in the event of a cable failure. Figure 2 shows an example of a bus network topology.

2.2 Ring Network Topology

A ring network topology has each node in the network connected to two other nodes in the network in conjunction with the first and last connected nodes. Messages from node to node then travel from sender to destination through all intermediate nodes. Intermediate nodes act as active repeaters for messages destined for other nodes. Some types of ring topologies have messages going in one direction around the ring (clockwise or counterclockwise) while others of this type of topology (known as bidirectional rings).) have messages go in both directions using two cables between each connected node. In some cases, interceptors are needed in a ring topology to prevent packet pooling, a condition in which packets not consumed by a node fall into an unlimited loop. around the ring. Ring network topologies are commonly used in networks with low inter-node traffic.

One disadvantage of the basic ring topology is the relatively long transmission time between ring nodes compared to the bus topology. Also, like the bus network topology, a failure of the cabling between two nodes has a broader effect on the entire network communication, which may leave no path between the sender of the message and the receiver. Relative communication delays between nodes have always been a drawback of bidirectional ring networks, but the dual nature of cabling between nodes allows traffic to be redirected to an alternate path, thereby overcoming disruptions. connection between two network nodes. This is a significant reliability advantage over a basic ring network topology or a bus network topology. Ring network topologies have unique disadvantages compared to other topologies in regards to expansion or reconfiguration. If a node is added, new cabling is required to connect the node to its two neighbors. Networks are typically not built with pre-wired locations to accommodate expansion. Figure 3 shows examples of ring topologies.

Figure 3 Ring Network Topology



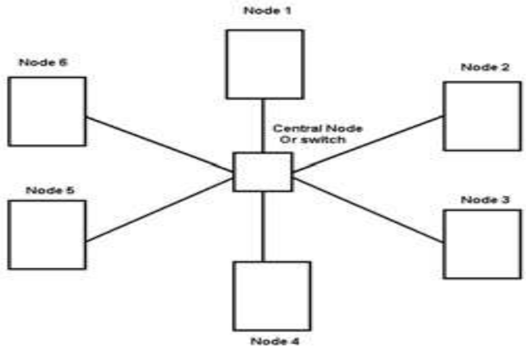
Bi-directional

2.3 Star Network Topology

The star network topology requires the use of a top-level central node to which all other nodes are connected. This higher level node can be a calculator, a simple switch, or simply a common connection point. The message received by the higher-level node can be broadcast to all subordinate nodes or, if the higher-level device has high enough fidelity, only to the desired subordinate node. The messaging delay between nodes is reduced with this configuration. A significant advantage of a star network topology comes from the localization of cabling failures guration. A connection failure between a higher-level node and any of its subordinate nodes, or failure of one subordinate node, will not affect the entire network. Because the star topology is often used in LANs with larger geometrical area than the ring or bus topology. One downside to this configuration is the need for more wires. Another downside is the top level node. Any failure of this device will disrupt all communication on the network. An additional limitation of the star network topology is the limited number of higher-level node connections.

Figure 4 shows an example of star network topology.

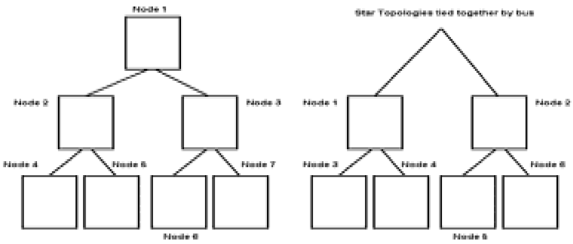
Figure 4 Star Network Topology



2.4 Tree Network Topology

Tree topologies are built by creating a set of star topologies below a central node or by connecting a set of star topologies directly through a bus, thus distributing the central node's functionality among several higher-level star topologies. network. knot. Figure 5 provides an example of each configuration. The top-level nodes of each star network are elements connected via a bus in the second arrangement. In a simple tree topology, none of the subordinate nodes of the star topology are connected to the bus. Messages in a tree topology can be broadcast from the central node to all interconnected networks or targeted to selected networks. One of the main advantages of a tree topology is the ease with which the network can be scaled. Expansion can be as simple as attaching an additional star network topology to the bus. Also, like the star network topology, there is cabling fault location with this configuration. However, if a higher-level node of the star network fails or the cable connection to it fails, then the entire network portion will be lost to communication, as opposed to a single subordinate node as in the topology. pure star network topology.

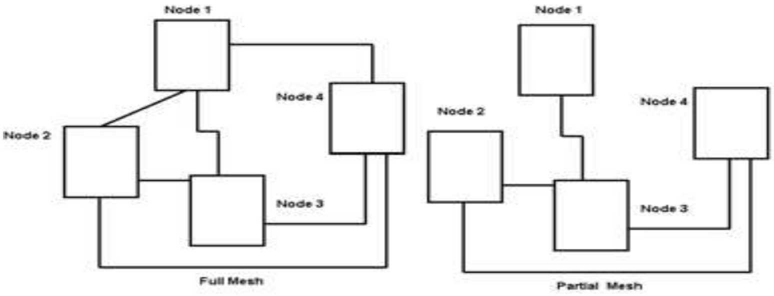
Figure 5 Tree Network Topology



2.5 Mesh Network Topology

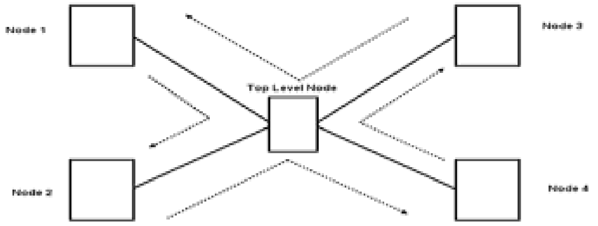
Mesh topologies take advantage of path redundancy. This topology is preferred when traffic between nodes is high. Part of the nodes of this type of network has multiple paths to another destination node. With the exception of the bidirectional loop (and that's only when the error is detected), each topology discussed so far has only one path from the message source to the message destination. Therefore, the probability of single point network failure is greatly reduced with the mesh topology. A key advantage of mesh topology is that source nodes determine the best route from sender to destination based on connection factors, speed, and pending node tasks. The network topology takes advantage of path redundancy. This disadvantage of network topology is the high cost of setting up the network. Another disadvantage of this type of network is that each node needs a routing algorithm to compute the path. A full mesh is described as each node being directly connected to all other nodes in the network. This type of topology is usually limited to networks with a small number of nodes. A mesh section is described as having a number of network nodes that are indirectly connected to other nodes in the network. Figure 6 provides an example of a full and partial network. The Internet uses a network topology.

Figure 6 Mesh Network Topology



It should be noted that variations of the described network are common. Many networks are described as hybrid topologies, which combine the features of two or more of the above networks. Figure 7 provides an example of a wired star network topology. Here, the top-level node of the basic star topology only acts to route messages in a circular sequential fashion to the lower-level nodes, as if there were a physical ring topology at place.

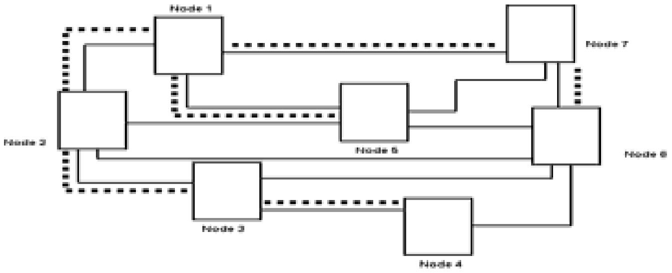
Figure 7 Star Wired Ring Network Topology



III. GRAPH THEORY

Graph theory is the study of a set of points called vertices or nodes and all the lines connecting them, called arcs. Typically, a cost or capability is associated with each arc. A directed graph on every arc is called a directed graph, while a non-directed or multidirectional graph is an undirected graph. Graph theory has applications in real network flow and routing problems. These applications using undirected graphs are concerned with the topology of computer networks. One of these routing problems involves sizing the arc power to meet traffic demand. Another way is to determine the possible and necessary linkability of the nodes. The third is to take a subset of the global graph, called a Spanning Tree that connects each desired node with a path, but no path can start and end on the same node (path This is called a cycle). Spanning Trees constructed with the constraint of minimum cost are called Minimum Stretch Trees. The skeleton tree of an example mesh topology network is shown in Figure 8.

Figure 8 Minimum Spanning Tree



In simple cases, the Minimum Spanning Tree problem is solved by an algorithm consisting of choosing an arbitrary node and connecting it to a neighboring node while preserving the lowest cost, then repeat this process by connecting a single unconnected neighbor with the lowest cost to the master. However, this process may be too basic for real-world networks, and other more complex algorithms may be substituted.

IV. NETWORK ANALYSIS TOPICS

Analysis topics related to network topology can be as diverse as possible. In this article, the discussion will focus on the examples available in the literature related to the topics of network routing, network sizing, and network corruption analysis. From these examples, the reader can extrapolate other analytical techniques to apply to topological problems.

V. ROUTING ANALYSIS

Reference 1 discusses an analytic approach to compute the minimum spanning tree while minimizing network latency. Although Ref 1's intended objects are LAN and MAN configurations, this approach can also be applied to network topologies. The motivation for this calculation is to prevent network packet duplication, i.e. receive packets no more than once at a given node. The minimum spanning tree topology chosen by this attempt remains constant for node-to-node message propagation until an error occurs at some point in the underlying network, at which point the minimum spanning tree topology is evaluated. with the remaining operating assets. The basic objective function chosen for minimization can be generally described by:
Minimize Delay = Summation of Tree Nodal

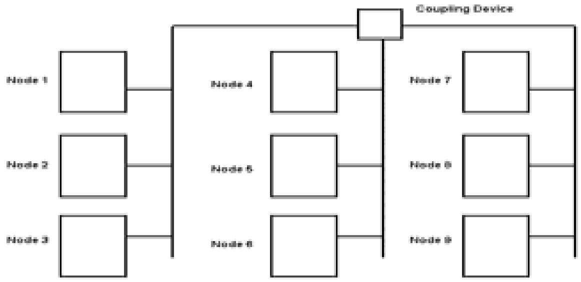
Processing + Summation of Arc delays

Arc delays can develop from routers, bridges, or other traffic devices. According to this equation, each node in the network is represented by an MX/M/1 queue. Using this representation and the Littles formula, the delay at each node can be calculated. The arc delay can be calculated from the traffic level requirements. Therefore, the score with which the minimum spanning trees will be compared can be calculated through the application of queuing theory combined with combinatorial tests. As described in ref 1, computing the minimum spanning tree minimizes the delay in the set of candidate trees. Depending on the number of nodes and arcs, the common minimum may not be realistic. Of particular concern is the requirement that the algorithm switch to a high-fidelity configuration when the tree search is stopped, rather than minimal local overhead. This is achieved through the use of an annealing algorithm, which is an efficient local area search that can accept sub-optimal trees to get rid of local cost minimization. Optimal tree acceptance is performed with decreasing probability (annealing) used after determining that the lag associated with the candidate tree is smaller than that of the currently considered minimal spanning tree. We are interested in this article in candidate selection method Minimum spanning tree. At the end of processing the current candidate tree, the next tree is selected from the set that has all branches in common with the current tree except one. This selection criterion ensures that successive trees located in the same local search area are considered by the annealing algorithm. It should be noted that the methodology described in ref. 1 can be applied to other topology networks at a cost not necessarily equal to latency. Slight modifications to the methodology can also be made, which will allow it to be tailored to a particular analysis. For example, reference 1 indicates that other queuing models can be considered for nodes, which can increase the processing time of the algorithm. Other candidate tree selection alternatives may also be considered. Reference 7 also discusses a computational algorithm for optimizing routing in mesh topology networks. However, in this analysis, packet transmission time is not the focus; instead, the cost of hardware cabling between nodes should be minimized. The scope of this study is at the internode load level and not at the individual packet level. In this analytical approach, the network is first decomposed into a configuration of point-to-point links, one-way rings, and two-way rings. The following constraint equations are determined to take into account the maximum demand for links and rings, and the maximum bandwidth between nodes. The network load assignments are then determined taking into account the constraints and costs associated with these tasks are recorded. This process is then repeated with different sets of payloads. When the pool of possible tasks is exhausted, the list of tasks that load the least cost will serve as the basis for routing optimization on the network.

VI. NETWORK SIZING

Reference 8 discusses the Tree-Bus topological network concept. The key to this concept is that there isn't any intermediate processing, there's no active component on the network between any two given nodes except for some signal power amplification devices. Any packet sent from one node will be sent to all nodes in the network. Figure 9 illustrates the basic topology at work. Although the reference is written with fiber networks in mind, it is a good example of the impact of topology on network size.

Figure 9 Tree-Bus Topological Network



The advantage of a Tree-Bus topology is that its ability to support a network is much greater than that of a simple bus topology due to the power and intermediate signal amplification

characteristics inherent in the signal lamp compared to the signal. electronic. The network size calculation is then reduced to a signal loss analysis problem. As shown in Reference 8, the following variables are defined.
Xdb = difference between transmitted signal and minimum detectable signal at any node
Cdb = signal loss at coupling device tying together any two busses
Bdb = signal loss at a node

K = number of nodes on all parallel Bus Networks

If the sizing is concerned with just one level of the tree:

$2*(C + B* K) \leq X$

Or

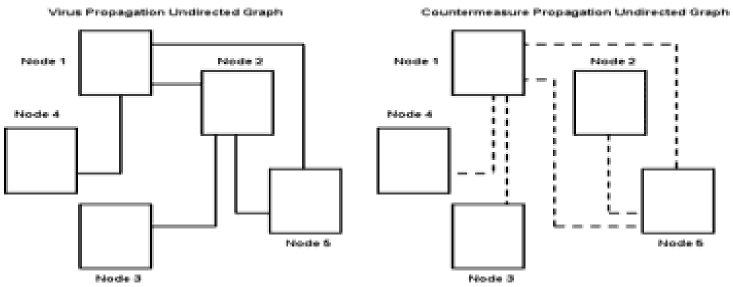
$K \leq X/(2*B)$ minus C/B

This formula passes the number of nodes in the network as a function of signal loss and minimum delta. Note that the introduction of power amplifiers into the intermediate node can significantly increase the number of nodes in the network.

VII. NETWORK CORRUPTION

Network viruses are small pieces of code that will replicate themselves in other host processes to cause runtime inefficiencies or system failures. Reference 2 describes an analytic approach to studying virus behavior across different network topologies when a countermeasure (apparently an upgrade of the virus definition) spreads concurrently. . Again, graph theory provides a starting point for analysis. The network is represented by two undirected graphs. Each node of the real network is represented on each graph, that is, the rules and structure of the arc differ between the two graphs. The first graph represents the virus propagation network, its arc rules related to the type of virus being propagated (email connection mining would be an example). The second graph represents the network of countermeasures, whose arc rules are governed by the protective diffusion strategy. A small-scale example of this graph theory representation is provided in Figure 10.

Figure 10 Corruption Undirected Graphs (Example)



The two graphs are linked together through two state variables to represent the common node. The first variable represents the state of the virus in the node. The second variable represents the state of the countermeasure in the node. The first variable moves between sensitive, infected and removed states from further consideration. Acceptance of countermeasures is probabilistic and is required to go from sensitization to inhibition. Nodal infection is necessary to go from being susceptible to infection. The second variable moves between non-alert, warning, and warning states broadly following the response's acceptance state. Once the state transition rules have been defined for the two variables and a set of initial conditions are determined for the case in question, a simulation is used to run the model until the network reaches the state. stability. Regardless of the results, ref 2 indicates that the primary value collected for each case in the study consists of the quotient = (maximum percentage of infected nodes) / stabilization time . This value is then compared with the values of other simulations to arrive at a decision on an optimal method for distributing countermeasures.

VIII. CONCLUSION

The topology of a computer network offers inherent advantages and disadvantages to any system studied. A description of some of the advantages and disadvantages of several standard physical topologies has been provided in this article. Performance analysis studies OR focus not only on the physical topology but also on the logical topology. Graph theory provides a useful tool for pursuing these analyses. This article has provided some examples of analytical approaches to dealing with topology related problems. These areas include routing analysis, network sizing, and network corruption. The techniques covered in this discussion can be adapted to the relevant computer network applications. Understanding computer network topology is fundamental to any network analysis effort and can prevent wasted effort in pursuing less efficient analysis methods.

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