A Survey of Computer Network Topology and Analysis Examples

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Abstract

This paper presents an introduction to Computer Network Topology. Definitions of Physical and Logical Topologies are provided. Additionally common Computer Network realizations of Physical Topologies are reviewed. This is followed by a discussion of Graph Theory and its relation to topological analysis. A discussion of analysis examples follows with an emphasis on message routing issues, network sizing, and virus analysis. These examples are discussed to underscore the impotance of topological design when constructing a new computer network, or adding to an existing one.

Keywords:

Physical Network Topology, Logical Network Topology, Minimum Spanning Tree, Graph Theory, Bus Network Topology, Ring Network Topology, Star Network Topology, Tree Network Topology, Mesh Network Topology, Hybrid Topology. Directed Graph, Undirected Graph, Queueing Theory, Combinatorial Trials, Tree-Bus Topology

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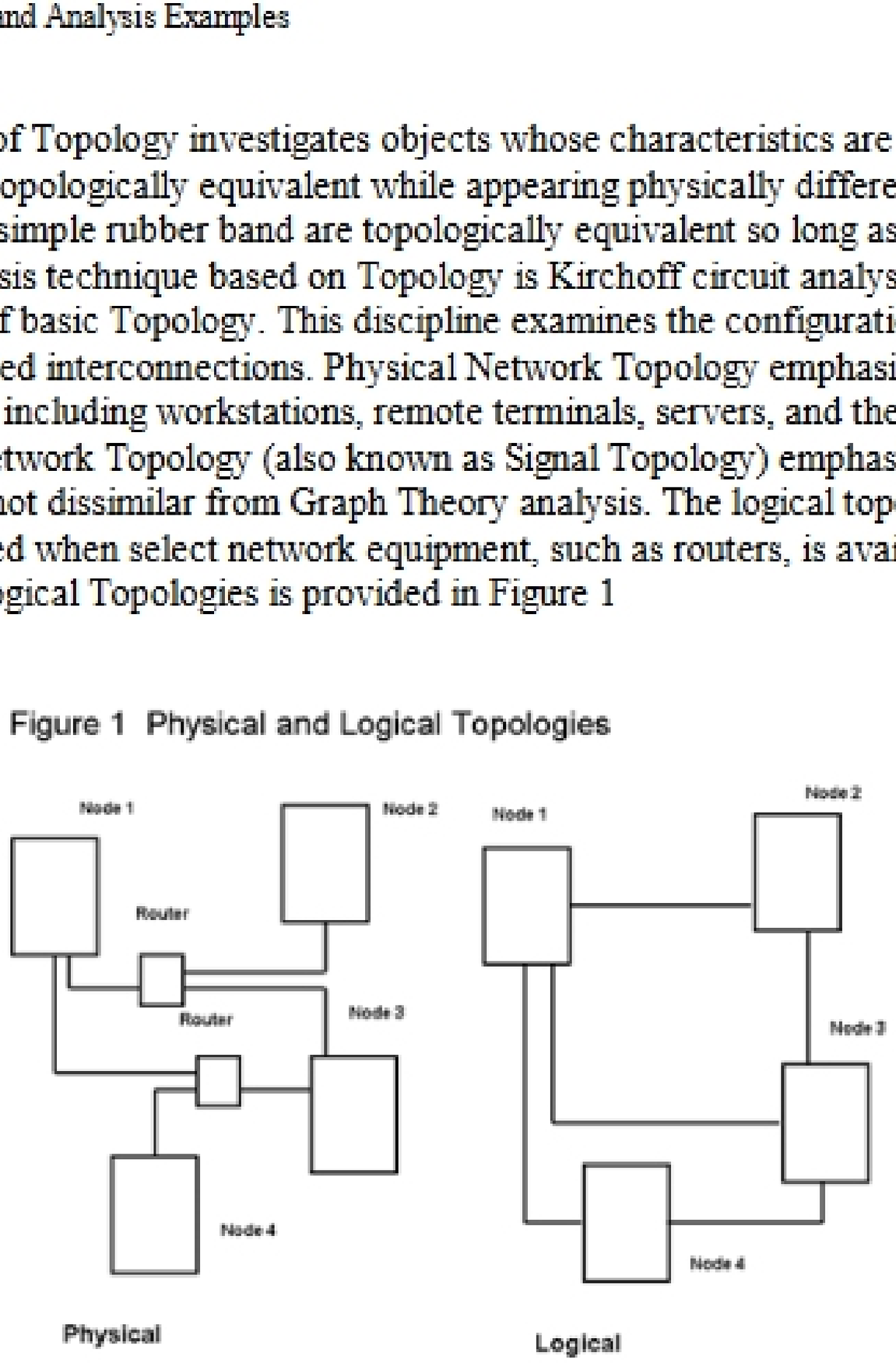
1. Introduction

The mathematical subject of Topology investigates objects whose characteristics are constant through distortion. Objects can be topologically equivalent while appearing physically different. As an example, any two objects formed with a simple rubber band are topologically equivalent so long as the band is not parted. A noteworthy practical analysis technique based on Topology is Kirchoff circuit analysis. Computer Network Topology is an extension of basic Topology. This discipline examines the configuration of computer system elements and their associated interconnections. Physical Network Topology emphasizes the hardware associated with the system including workstations, remote terminals, servers, and the associated wiring between assets. Logical Network Topology (also known as Signal Topology) emphasizes the representation of data flow between nodes, not dissimilar from Graph Theory analysis. The logical topography of a network can be dynamically reconfigured when select network equipment, such as routers, is available. An example comparing Physical and Logical Topologies is provided in Figure 1

Figure 1 Physical and Logical Topologies



Operations Research (OR) performance analysis topics associated with Computer Network Topology tend to be concerned with logical topology instead of the purely physical. This paper will review several performance analysis study examples with the intent of demonstrating the importance of topological considerations in network design. Although the problem set in this survey is limited several of the analysis techniques discussed are applicable to other network analysis problems. Since Logical Network Topology builds upon the underlying Network Physical Topology the set of standard computer physical topologies will reviewed first as background to the performance analysis discussion. This will be followed by a brief description of Graph Theory, and then the network analysis examples.

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2. Physical Network Topologies

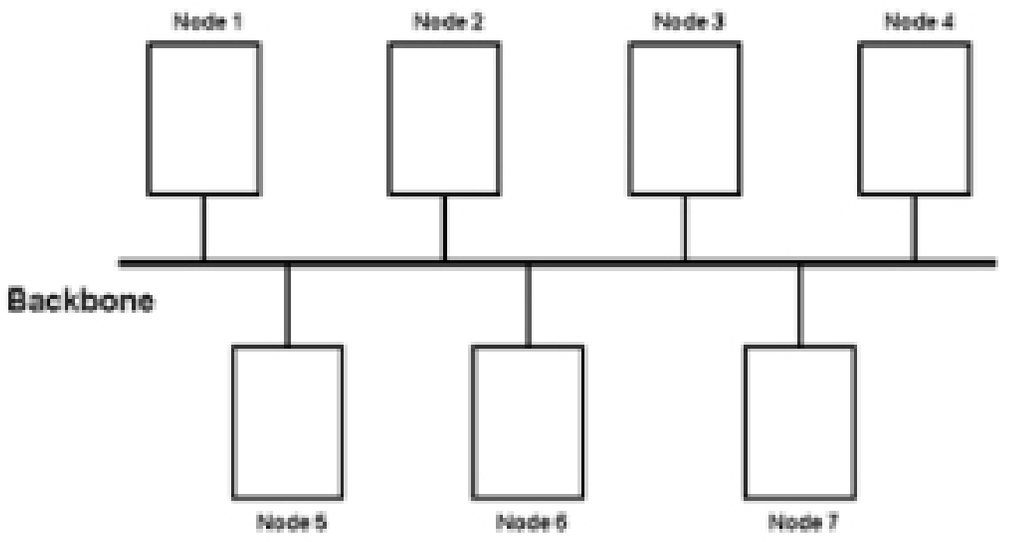
A review of common Physical Network Topologies provides a basis for the analysis discussion presented in section 4. In this section the attributes and problems associated with Bus, Ring, Star, Tree and Mesh Network Topologies are presented.

2.1 Bus Network Topology

In Bus Network Topology a single cable is used to connect all devices on the net. This cable is often referred to as the network Backbone. When communication occurs between nodes the device sending the message broadcasts to all nodes on the network, but only the desired recipient digests the message. Advantages of this

type of Physical Topology include ease of installation and minimization of the required cabling. Further, failure of a node attached to the network has no effect on other nodes attached to the network. Also messages from one node can be seen near simultaneously by all other nodes on the network. Disadvantages of this configuration include performance limits on the number of network nodes, and complete network communication stoppage if the cable fails. Figure 2 shows an example of Bus Network Topology.

Figure 2 Bus Network Topology



2.2 Ring Network Topology

Ring Network Topology has each node in a network connected to two other nodes in the network in conjunction with the first and last nodes being connected. Messages from one node to another then travel from originator to destination via the set of intermediate nodes. The intermediate nodes serve as active repeaters for messages intended for other nodes. Some forms of Ring Network Topology have messages traveling in a common direction about the ring (either clockwise or counterclockwise) while other forms of this type of configuration (called Bi-directional Rings) have messages flowing in either direction with the help of two cables between each connected node. In some cases blocking devices are required in a Ring Topology Network in order to prevent packet storming, the condition where packets not consumed by a network node fall into an unlimited loop about the ring. Ring Network Topology is typically employed in networks where inter node traffic volume is small. A disadvantage of the basic Ring Network Topology is the relatively long transmission time between nodes in the ring as compared with Bus Network Topology. Further, like Bus Network Topology, failure of the cabling between any two nodes has a broader impact on network communication as a whole, possibly leaving no path from message originator to recipient. Relative inter node communication delays are still a disadvantage of the Bi-directional Ring network, however the dual nature of the cabling between nodes allows traffic to be shunted to an alternate path, thereby rectifying connection disruption between any two nodes in the network. This is a considerable reliability advantage over the basic Ring Network Topology or the Bus Network Topology. Ring Network Topologies do have unique disadvantages relative to other topologies concerning expansion or reconfiguration. If a node is added new cabling is required to connect the node to its two neighbors. Networks are not often constructed with pre-wired positions to account for expansion. Figure 3 shows examples of Ring Network Topologies.