An Approach to Solving the Survivable Capacitated Network Design Problem

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ABSTRACT

Survivability refers to keeping a system partially or fully operational when one or more of its components fail. Survivability in telecommunication networks is crucial, as failure of a network component can potentially bring down the whole communication network, as happened in some real-world cases. Adding redundant network components increases the survivability of a network, but cost of the network also increases. In this paper, we consider the design of survivable telecommunications network architecture that uses high-capacity transport facilities. The model considers selection of capacitated links and routing of multicommodity traffic flow in the network that minimizes overall network cost. Two node disjoint paths are selected for each commodity. In case of failure of the primary path, a portion of the traffic for each commodity will be rerouted through the secondary path. The methodology presented in this paper can be used by the network designer to construct cost-effective survivable networks.

Keywords: network capacity planning; Lagrangian relaxation; network design; network topology; optimization methods; survivability; telecommunication

INTRODUCTION

Optic fiber and high capacity transmission facilities are being increasingly deployed by telecommunication companies for carrying voice, data, and multimedia traffic. Local (sometimes referred to as basic) telecom service providers are spending tens of billions of dollars on fiber-based equipment and facilities to replace or augment the existing facilities to provide high bandwidth transport. This has led to sparse networks with larger amounts of traffic carried on each link compared to traditional bandwidth limiting technologies which deployed dense networks. Because of their sparse nature, these networks have less reliability. Failure of a single node or
link in the network can cause disruptions to transporting large volumes of traffic, if alternate paths are not provided for routing the affected traffic. Though backup links can be provided to improve the reliability of such sparse networks, it could increase the cost of the networks substantially. The challenge is to improve the reliability of the networks at minimal cost. Researchers have looked at methods of improving reliability of such networks. Detailed discussions on the importance of survivability in fiber network design can be found in Wu, Kolar, and Cardwell (1988) and Newport and Varshney (1991).

Networks with ring architecture are also increasingly deployed in high capacity networks to provide survivability. Synchronous Optical Network (SONET) uses a self-healing ring architecture that enables the network to maintain all or part of communication in the event of a cable cut on a link or a node failure. SONET networks are increasingly deployed between central offices of the telecommunication companies and between Point of Presence (POP) of traffic concentration. SONET-based transmission facilities are also being deployed increasingly to provide broadband facilities to business customers and government agencies. Operationally, such self-healing ring networks divert the flow along an alternative path in the ring in case of failure of a node or link.

For a discussion of the use of rings in telecommunication networks, the reader is referred to Cosares, Deutsch, and Saniee (1995). Cosares et al. (1995) describes the implementation of a decision support system called SONET toolkit developed by Bell Core for constructing SONET rings. The SONET toolkit uses a combination of heuristic procedures to provide an economic mix of self-healing rings and other architectures that satisfy the given survivability requirements. Chunghwa Telecom, the full service telecommunications carrier in Taiwan, has developed a tool for planning linear and ring architectures of high capacity digital transmission systems (Shyur & Wen, 2001). The tool reduces planning and labor costs by 15% to 33%. Goldschmidt, Laugier, and Olinick (2003) present the case of a large telecommunication service provider who chose SONET ring architecture for interconnecting customer locations.

Survivable networks are also being deployed in campus networks. Interconnected Local Area Networks (LANs) consist of a set of bridges switches between LAN segments. Campus network managers seek to build a survivable internetwork with redundant switches so that in case of failure of a bridge or a LAN in the network, connectivity can still be maintained through an alternate path. The IEEE 802.1 committee specified a transparent bridge protocol using Spanning Tree algorithm (IEEE 802.1D) and Rapid Spanning Tree algorithm (IEEE 802.1w) for such networks. The spanning tree scheme maintains connectivity of the interconnected LANs by including each LAN segment in a loopless graph. This is done by automatically disabling certain bridges switches. The interconnecting devices are however not physically removed. The spanning subgraph is dynamically configured if bridges switches fail.

Organizations still use leased T1/T3 transmission facilities, especially in developing countries where the bandwidth is scarce, to construct private networks. These asynchronous transmission facilities use Terminal Multiplexers at customer premises, and the multiplexers are interconnected using leased or privately owned links. Because of the flexibility offered by
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