Designing an IP Link Topology for a Metro Area Backbone Network

John G. Klineciewicz, AT&T Labs, Middletown, NJ, USA
David F. Lynch, AT&T Labs, Middletown, NJ, USA

ABSTRACT

Massive increases in IP (Internet Protocol) traffic have led to rapid deployment of IP-based networks in metropolitan (metro) areas. In order to facilitate this deployment, computer-based design tools are needed. One of the most difficult decisions that engineers face in designing an IP network is choosing the IP link topology (i.e., the set of router-to-router connections). This is especially complicated when it is also necessary to route these IP links over an underlying physical network of optical fibers. In this paper, the authors describe a new heuristic for simultaneously designing a backbone IP link topology for a metro area network, and routing these IP links over a given physical network. The IP network must be designed for survivability in the event of a network failure (i.e., the loss of a physical link, router or IP link). Initially, they employ a Construction Heuristic that explicitly considers the number of router-to-router connections that would be carried over each physical link. In this way it seeks to minimize the impact of any single physical link failure. An optional Local Search routine then attempts to improve on the solution by a sequence of topology changes. IP link routings are adjusted at each topology change. This heuristic is readily able to be incorporated into an interactive design tool. Some computational experience is described.

Keywords: Heuristics, Internet Protocol Networks, Network Design, Operations Research, Optimization Methods

INTRODUCTION

In recent years, the massive increase in IP (Internet Protocol) traffic has led carriers to consider expanding IP-based networks into metropolitan (metro) areas (Autenrieth et al., 2007).

Several trends have been driving this development. First, Ethernet services such as Virtual Private LAN Service (VPLS) and point-to-point Ethernet Virtual Circuits (EVCs) are increasingly being used to replace traditional telecommunications services, such as private line, ATM and Frame Relay. VPLS enables customer LANs in different locations to be interconnected and appear as one large private LAN to the customer, even if the locations are in different metro areas. EVCs can be used to replace many metro private-line services currently provided by Time Division Multiplexing (TDM) technologies.

DOI: 10.4018/jitn.2013010103
Additionally, EVCs can also be used to provide links (often referred to as *wireless backhaul*) between cellular base stations and Mobile Telephone Switching Offices (MTSOs). With the continued growth in cellular telephone traffic (both voice and data), upgrading the speed and reliability of wireless backhaul represents a critical need for carriers.

In addition, as consumer broadband networks migrate from providing basic broadcast television service to more data-intensive internet applications, carriers will need to route increasing amounts of IP traffic to/from homes and neighborhoods within the metro area.

Since these metro area IP-based networks can be used to consolidate various legacy access networks (i.e., ATM, Frame Relay and TDM technologies), they are sometimes referred to as *IP aggregation networks*. The rapid deployment of these networks requires the development of new network planning and design tools (Wang, et al., 2010).

In particular, an engineer planning a network for a given metropolitan area typically must create many different designs for that single area. These designs correspond to various scenarios, such as different demand forecasts, different numbers and locations of backbone and access routers, or different cost projections. The availability of computer-based tools for creating these designs would be advantageous in reducing both the time and cost of network deployment.

In this paper, we describe a heuristic for designing an IP link topology (i.e., the set of router-to-router links) for IP-based metro area networks, and routing these links over an underlying physical network of optical fibers. An IP network (within a metro area, or otherwise) consists of a number of routers that are interconnected by a set of communication links. Packets of data are then transmitted over these router-to-router links between various origin-destination router pairs. Since not every pair of routers is directly connected, some router pairs must send packets over a series of router-to-router links in order to exchange traffic.

Typically, IP networks have a hierarchical structure, in which a “backbone” or “core” network interconnects various “access” or “edge” networks. The routers that comprise the backbone network are referred to as “backbone routers.” In this paper, we focus on the design of the backbone IP network within a metro area.

Deciding on a backbone IP link topology is one of the most difficult decisions that engineers face when designing an IP network. It represents a complicated combinatorial problem. It is especially complicated when it is also necessary to decide how to route these various IP links over an underlying physical network. These decisions determine both the cost and performance of the IP network.

The underlying physical network consists of nodes interconnected by optical fibers. Each optical fiber connection (which we term a “physical link”) can carry multiple optical wavelengths. The communication links (or circuits) between router pairs are established using wavelengths routed over this physical network. A set of circuits between the same pair of routers constitutes an IP-layer link, or, simply, an *IP link*. (In the literature, this is also sometimes referred to as an *IP link bundle*.)

For a given set of available IP links, traffic between a specified pair of routers would utilize a particular path (i.e. sequence of IP links) in keeping with the particular IP routing protocol being used. For example, a commonly-used protocol is OSPF (Open Shortest Path First). In this protocol, there is a “weight” associated with each IP link; traffic between a pair of routers would use a sequence of IP links corresponding to the minimum-weight path. In our computational experiments in this paper, we assume an OSPF protocol. However, other protocols, such as IS-IS or MPLS-TE, are also possible. (For example, section 4 of Chiu, et al. (2012) includes an outline of an MPLS-TE routing and sizing procedure for the case of a given link topology.)
Digital Convergence and Home Network Services in Korea: Part 1 - Recent Progress and Policy Implications
Hyun-Soo Han, Heesang Lee and Yeong-Wha Sawng (2009). Handbook of Research on Telecommunications Planning and Management for Business (pp. 222-233).
www.igi-global.com/chapter/digital-convergence-home-network-services/21667?camid=4v1a

Secure Buffer-Based Routing Protocol for WMN
www.igi-global.com/article/secure-buffer-based-routing-protocol-for-wmn/180321?camid=4v1a