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Network Design for a Multi-POP ISP

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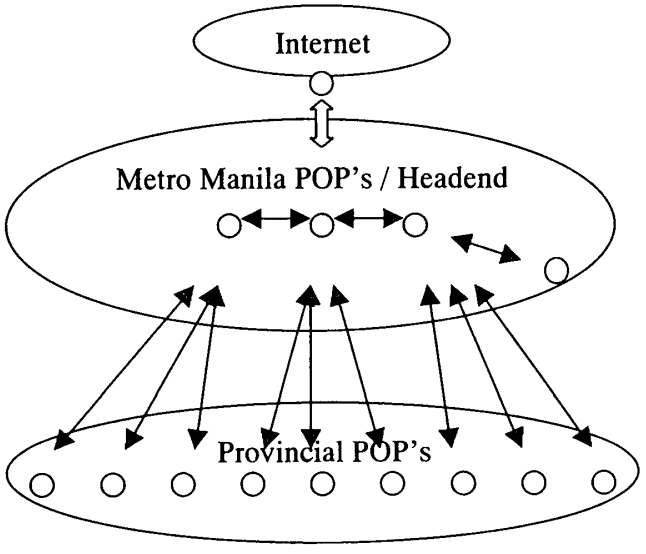
1.0 SkyCablenet, Inc.: A Background

SkyCablenet is a member of the Lopez Group of Companies, one of the largest conglomerates in the Philippines. It is tasked to provide the Engineering and Technical Support for IP (Internet Protocol) - based products being offered by Sky Internet (dial-up service – regular Internet service), SkyCable (ZPDEE cable modem service – Internet over the cable TV network), and BayanTel (leased line service – point-to-point links to connect geographically distant offices), three of its sister companies.

One of its main functions is to manage the IP network used by Sky Internet's 12 POP's (points-of-presence where subscribers can make a local call to gain Internet access) and SkyCable's Headend (POP counterpart for cable modem service). Adding the Internet as a node, SkyCablenet needs to design/redesign a network for 14 nodes.



2.0 Problem

Because of the complexity in designing a network with at least 14 nodes (each pair of nodes can be linked using any of 21 possible speeds), network optimization has been accomplished only at the node level. System-wide optimization is just too large a problem using conventional means. Moreover, with the rising need for one-link survivability of specific segments of the network, a design tool is needed to take these additional constraints into consideration while addressing the objective of minimizing costs. (N-link survivability is the ability of a network to remain functioning despite N links being down.)

In summary, the objective of such a tool is to generate a network design detailing which nodes need to be connected at what speeds so that bandwidth requirements at each and every POP is satisfied at a specific level of survivability while minimizing total domestic and international link costs.

3.0 Current Method

At present, SkyCablenet's network design follows a star topology. Very minimal thought is given to costs except for obvious best value options. Links to the Internet have always been put up in Metro Manila where the largest POP's are found, bandwidth requirements are consolidated, and most services (proxy, mail, news, etc.) are managed. Although technically feasible, direct Internet connections through satellites from any of the smaller POP's have not been tried.

International and domestic link costs have reached as high as $400K per month, around 60% of operating expenses. Any reduction in this expense has a direct impact to the bottom line.

4.0 Proposed Method

The problem lends itself easily to Operations Research tools. It is a classic Network Optimization case that can be solved either through a heuristic approach or through an Integer Programming formulation. Because of the limited time allotted for this project and the availability of a large-scale MIP solver (Xpress-MP), the IP formulation seems to be the better option.

Two models are needed to aid in the decision-making for the network design: the base model and the survivability model.

The base model is needed to generate designs that can be implemented in the current business environment. No survivability is required yet. The primary objective is to minimize total link costs while the secondary objective is to keep hops to the Internet at a minimum. (Hops are intermediate connections in a string of connections. The more hops there are, the longer it takes for data to go from source to destination.) Constraints that need to be met are 1) downstream requirements of each POP need to be satisfied by inbound links, 2) upstream requirements (estimated at ¼ of downstream) of each POP need to be satisfied by outbound links, and 3) particular international links need to be kept because of strategic importance. The resulting model has thousands of variables and constraints.

The survivability model is more for future planning when QoS-specific products will be offered. (QoS or Quality of Service is a networking term that specifies a guaranteed throughput level.) In this model, several more variables and constraints are added to take care of survivability requirements for each POP. At this time, only one-link survivability is being considered.

With the help of these decision tools, network planning personnel can create network designs much faster and with less effort. No bias is given to any topology. Whichever design results to a minimum total cost, that is the model that will be generated. If needed, the user can add rules to take subjective criteria into consideration. Examples of such are preferences for specific link vendors, intermediary nodes, and prioritization of Metro Manila traffic, among others. With some minor adjustments, designs can be generated as quickly as market conditions and cost of bandwidth change.

5.0 Test Results

Based on initial test results, link costs for the base model can go down to $300K per month or a 25% reduction, a savings of $1.2 million per year. The deployment of satellite-based connections in POP's outside of Metro Manila appear in some runs but is not the ideal in most cases. Run-time is anywhere between 15 minutes to 4 hours using a Pentium II 400 Mhz machine with dual processors running Windows NT 4.0.

For the survivability model, 80% survivability at every node can be achieved without incurring additional costs. Run-time is anywhere between 6 hours and several days.

6.0 Future Directions

Next steps include identifying more precise upstream requirements and survivability parameters for each POP. If needed, two-link survivability can also be addressed. It will also be helpful to fine-tune the model to get shorter run-times.

Further on, the model can also be expanded to include the locating of servers (proxy servers, mail servers, etc.) to further optimize not only the network design but the network traffic as well.

7.0 References

Wolsey, Laurence. Integer Programming

Williams, H.P.. Model Building in Mathematical Programming

Myung, Young-Soo; Kim, Hyun-joon; Tcha, Dong-wan. "Design of Communication Networks with Survivability Constraints," unpublished manuscript