Optimization of Computer Networks

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Abstract

Computer Networks have pervaded our life like anything. They are present in all aspects of our life. Information transmission like Internet usage uses computer networks. As more and more people use computer networks, traffic increases. This puts a heavy toll on the infrastructure delivering the data from one point to another. Consequently the design issues in a network need to use the optimized parameters to deliver quality of service. This paper attempts to find a mathematical model for optimization of a computer network.

1. Introduction

The development of computer networks has given rise to the Internet, where millions and millions of data bytes are transferred every second. When a web page is accessed, a transport layer virtual connection is established from the user computer to the web server. This request starts data transfer from the web server to the user computer in blocks known as packets. These packets travel though a number of switches and routers. When a million of users perform the same task, the packets generated do not travel through the same set of switches and routers. There may be a set of common set of switches and routers but it will not be identical.

The quality of service (QOS) is generally measured in the time required by these packets take to reach the user from the source. It also involves measuring the data loss that takes place between the source and the target. These factors can be improved upon by optimizing the network parameters.

Networks generally have ingress traffic and egress traffic. Depending on the traffic volume, the network will respond with a specific delay. Packets will hop between various nodes. The number of hops and the traffic between the nodes affect the time of the arrival of the packets at the target. During this transmission, loss of packets can take place. Packets can also be delayed depending on network traffic and capacity.

Traffic in a network changes over time, whether by microseconds, seconds or days depends on the traffic dynamics. Traffic volume is linked to the economics of cost. So it makes sense to have high volume of traffic. If high volume of traffic is a necessary even, the QOS can be improved by improving the communication, or to be precise, the bandwidth of the network channels. If the channel is full to capacity, packets may not be accepted to be transported over the network, leading to packets being dropped.

Such a scenario may be valid for a particular route or for a section of the entire route. Technically speaking, the channel capacity in a computer network consists of channel capacity between nodes of the network. Consequently, there will be a number of paths available between two nodes for the packets to flow.

The channel on one path may experience high volume of traffic, while another between the same nodes may experience lesser traffic volume. Packets can then be diverted to flow through the path having the least amount of traffic.

To find the paths with the least amount of traffic on a real time basis, the network should be mathematically modeled. The mathematical model will help obtain, on a real time basis, the path with the least amount of traffic volume between the nodes.

A mathematical model will also help us answer a few question which can design a better network to reduce the loss or packet drop. Some quests which a mathematical model can provide answers to are;

(1)What are the alternative routes available for packets to flow.
(2) Which channel requires more bandwidth.
(3)When and where new nodes need to be added.
(4)What level of abstraction of the network can help us develop a better mathematical model.

(5)Whether network protocol or its inherent property can affect the decision making process.

2. Network Overview

When a network request is made, the request processed by a number of networks and through a number of network service providers. The packets that are generated from the source travel through the network by a path specified by the network parameters and protocols. The packets from the target travel back to the source in the same path unless and until the network provides a different path for some or the other reasons. The path traveled by the packets is obtained by switching through different networks of different network service providers. This is known as packet switching.

When two or more networks are involved in transferring packets, there must some amount of co-ordination between them. This co-ordination is known as peering. When a packet switches from one network to another network, it enters a network through a specific point. This specific point is known as the gateway. Within two gateway lies the network which carries the packet. Hence ny optimization takes place in this network only. This network is known as the backbone network.

3. Building a mathematical model

We build our mathematical model on a hypothetical three node network which can then be extended to a multi node network.

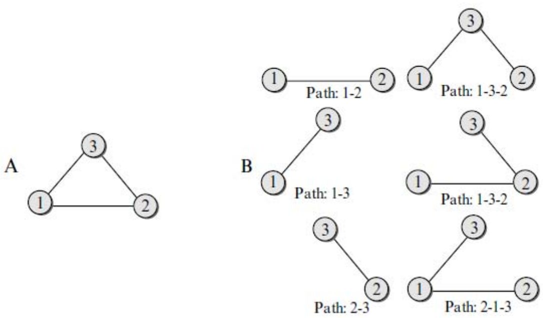

Figure A : Three node Figure B: Possible paths in the network

Demand volume represents the required bandwidth between a pair of nodes, depending on the considered type of network. Such a pair of nodes is called a *demand pair*, or simply *demand*. Suppose that the demand volume between nodes 1 and 2 is 5, between nodes 1 and 3 is 7, and between nodes 2 and 3 is 8 (units). Note that the demand is assumed to be bi-directional (undirected), given as “between” rather than “from-to”.

The demand volume is then represented as

$$\hat{h}_{12} = 5,\ \hat{h}_{13} = 7,\ \hat{h}_{23} = 8$$

Where $\hat{h}$ is associated with demands of the nodes.

The demand volume for a pair of nodes can possibly be routed over two paths in this
three-node network. For example, for the demand pair with end nodes 1 and 2 (to be denoted as _1,2_), its demand volume can be routed over the direct-link route 1-2, and the alternate route 1-3-2 via node 3 . How much of the demand volume will be routed on each path really depends on the network design objective. So, if we use $\hat{x}$ *with* an appropriate subscript identifier to denote the unknown *demand path-flow variables* (flow variables, or flows, in short), then for demand pair _1,2_, we can write:

$$\hat{x}_{12} + \hat{x}_{123} = 5 = \hat{h}_{12}$$. Similarly for other routes we have

$$\hat{x}_{13} + \hat{x}_{123} = 7(\hat{h}_{13})$$

$$\hat{x}_{23} + \hat{x}_{213} = 8(\hat{h}_{23})$$

Now that the demand requirement has been fulfilled, we need to check the capacity of the link channel. This is also referred to as link bandwidth.

Let the link bandwidth or link capacity be defined as $\hat{c}_{12}, \hat{c}_{13}, \hat{c}_{13}$ respectively. To prevent packet drop and enhance QOS, we should have the demand volume to be less than the link capacity or link bandwidth. The inequalities that is obtained are as follows ;

$$\hat{x}_{12} + \hat{x}_{123} + \hat{x}_{213} \le c_{12}$$

$$\hat{x}_{132} + \hat{x}_{13} + \hat{x}_{213} \le \hat{c}_{13}$$

$$\hat{x}_{132} + \hat{x}_{123} + \hat{x}_{23} \le \hat{c}_{23}$$

Where “c” represents the corresponding channel capacity.

Assuming for example $\hat{c}_{12} = \hat{c}_{13} = 10, \hat{c}_{23} = 15$, the linear equations that can be generated from the above inequalities are

$$
\begin{array}{llllllll}
\hat{x}_{12} & +\hat{x}_{132} & & & & & = & 5 \\
 & & \hat{x}_{13} & +\hat{x}_{123} & & & = & 7 \\
 & & & & \hat{x}_{23} & +\hat{x}_{213} & = & 8 \\
\hat{x}_{12} & & & +\hat{x}_{123} & & +\hat{x}_{213} & \leq & 10 \\
 & \hat{x}_{132} & +\hat{x}_{13} & & & +\hat{x}_{213} & \leq & 10 \\
 & \hat{x}_{132} & & +\hat{x}_{123} & +\hat{x}_{23} & & \leq & 15
\end{array}
$$

$$\hat{x}_{12},\ \hat{x}_{132},\ \hat{x}_{13},\ \hat{x}_{123},\ \hat{x}_{23},\ \hat{x}_{213} \geq 0.$$

The above system will have multiple feasible solutions on a real-time basis. Which feasible solution is the best for the network depends upon the goal that we have set. Certain situations may require the above to be minimized while certain goals may require the above to be maximized.

4. References

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