ADAPTIVE RESOURCE ALLOCATION AND INTERNET TRAFFIC ENGINEERING ON DATA NETWORK

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ABSTRACT

This research paper describes the issues of bandwidth allocation, optimum capacity allocation, network operational cost reduction, and improve Internet user experience. Traffic engineering (TE) is used to manipulate network traffic to achieve certain requirements and meets certain needs. TE becomes one of the most important building blocks in the design of the Internet backbone infrastructure. Research objective: efficient allocation of bandwidth across multiple paths. Optimum path selection. Minimize network traffic delays and maximize bandwidth utilization over multiple network paths. The bandwidth allocation is performed proportionally over multiple paths based on the path capacity.

KEYWORDS

Network Protocols, Internet, Network, Traffic Engineering, Network, Bandwidth, Allocation, Multipath

1. INTRODUCTION

In the last decade, business usage of the Internet has gone exponentially [1]. Taking North America as an example, 79% of the population is Internet users. North American usage growth was 152% between the years 2000 and 2011, compared with the world growth which was 32% during the same period. As result of these dramatic changes, it is no surprise that the Internet has become one of the major use and research area in the last decade. Research in the areas of hardware and application development, users are demanding expecting reliable throughput and trusted transport from their service providers. In addition to traditional Internet application, new multicast, multimedia and voice service applications are in the rise. New applications are developed constantly. These applications have increased the demand for bandwidth support and dictate the need for newer services. Along with the exponential growth of the Internet, these new services place ever-increasing strain on the existing resources. The Internet Protocol (IP) [2] has proven to be limited in scope of provide the functions necessary for today's Internet application and data demand. The network performance and resource allocation issues spawned the need for traffic engineering.

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2. Issues of Bandwidth Allocation

Network traffic delays and congestion are two of the main issues that faces today's Internet. Hybrid and adaptable bandwidth allocation can be seen as one solution to this type of problem. This issue will be addressed in this paper through traffic engineering based on link capacity, bandwidth availability, jitter, and other network configuration variables.

Equal and unequal traffic distribution across multi-paths should be based on the dynamic and changing network needs and recoverable network resources. For instance, a single MPLS network ingress LSR is connected an egress LSR across n parallel LSRs. Once network traffic enters at the ingress LSR, packets are typically distributed among available links and multiple paths based on the underlying link capacity, speed, throughput, and other network parameters.

As the network state changes, so does traffic distribution and bandwidth utilization. Bandwidth allocation can be discussed in two broad categories:

a) Allocation of network traffic with equal payload distributed across n multiple paths
b) Allocation of network traffic with unequal payload distribution across n multiple paths.

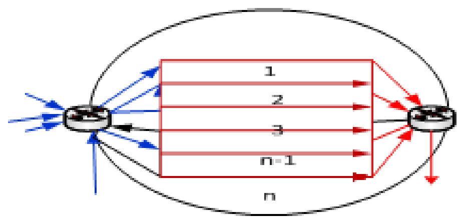

Figure 1: Bandwidth Allocation across an MPLS Network

3. Related Work

3.1. Traffic Engineering:

Traffic Engineering (TE) has become the primary method of Internet traffic treatment [3]. Boarder Gateway Protocol (BGP) [4] as the main Internet Exterior Gateway Protocol (EGP) is responsible for transmitting packets across areas and autonomous systems (AS). BGP doesn't support traffic engineering as it becomes a necessity to optimize the Internet backbone. Traffic engineering can be a manual or automated process through a number of network resource controls [5] such as data resources, control mechanisms, and management tools. Initially, traffic engineering was implemented in IP networks, now it becomes part of the MPLS domain. TE is used to manipulate network traffic to achieve certain requirements. For instance, network utilization of a link is determined by the ratio of used bandwidth in relation to the allocated bandwidth. This can be accomplished by a uniform distribution of network traffic across the network. On the other hand, traffic engineering may be implemented to optimize scarce resources utilization. As one of traffic engineering objectives is to allocate available link bandwidth in relation to the required connection, avoiding congested and oversubscribed links. Load balancing will be handled in both resource allocation and optimal routing choices. [6].

Traffic engineering extensions were implemented in some of the link state routing protocols such as OSPF-TE and Resource Reservation Protocol (RSVP) [7] [8]. Bandwidth Allocation for Minimizing Resource Usage with Restoration (BAMRUR) introduced in [9] claims to obtain an optimal set of valid paths and traffic distribution by linear programming. BAMRUR objective function is to minimize the bandwidth assigned to a path with certain constraints related to the bandwidth assigned to an active path and the total bandwidth needed.

3.2. Multi-protocol Label Switching (MPLS)

MPLS addresses network routing issues, scalability, and network performance [10]. MPLS works with heterogeneous network infrastructure such as IP backbone networks, Asynchronous Transfer Mode (ATM) networks, and other technologies. MPLS maps an IP address to a fixed length tag known as a label for network packet forwarding. It works with protocols at both the data link and the network layers of the OSI Model. An MPLS router is called a Label Switch Router (LSR); it inspects the label and the additional fields in forwarding the packet.

At the ingress LSR of an MPLS domain, IP packets are routed based on the information carried in the IP header.

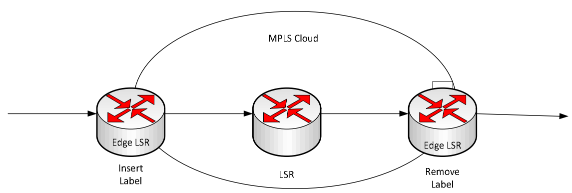

Figure 2: MPLS Network Framework

3.3. Equal Cost Multipath (ECMP)

ECMP, two well-known routing protocols namely; Open Shortest Path First (OSPF) [11] and Intermediate System to Intermediate System (IS-IS) [12] support Equal-Cost Multipath (ECMP) [13]. ECMP is a routing protocol for transmitting data packets across multi-paths with equal cost from source to destination.

Load balancing over multiple paths is one of the mechanisms that Internet Service Providers use to balance network payload. Load balancing has several benefits: it helps in capacity planning, it reduces traffic congestions, and it offers a reliable fault tolerance, since network traffic can pass across alternative multiple paths [14]. ISPs are striving to provide the maximum available bandwidth between networking nodes.

Load balancing requires the use of a key inserted in an available field in the packet. Finding the right field in a packet to use for load balancing is difficult. In the past, the extra encapsulation required fairly deep packet inspection to identify the right field at every hop that the packet traverses. The Entropy Label [14] concept was introduced to eliminate the need for deep packet inspection. The key information would be extracted once, at the entry of the MPLS LSP, and encoded within the label stack itself. The benefits of the introduction of the entropy label are discussed in [14]. Figure 3 shows load balancing of network payload between node *X* and node *Y*. The payload enters the network via the Ingress LSR and is load balanced to the next two LSRs, and then to the next three LSRs across the MPLS network until it reaches to the destination node *Y*.

For all the LSRs in the path, the ingress LER receives the incoming flow with the most contexts, for instance incoming traffic trunk for an IP or L2TP tunnel to be carried over an LSP. Packet data payload is beyond the TCP ports, which is where the deep inspection is needed.

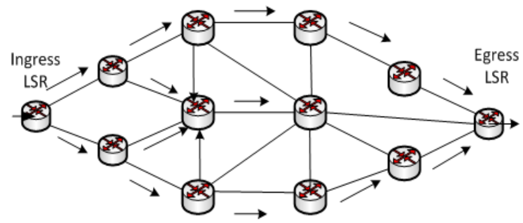

Figure 3, ISP network with load balancing from the Ingress to Egress LSR

3.4. Resource Allocation and Traffic Engineering

With today's Internet traffic demand and the need for efficient and optimize bandwidth utilization, multipath routing and optimal resource allocation should be considered for extensive research in the coming years. The Internet infrastructure should be the primary source of data for this type of investigation. The development and the implementation of multipath routing involve four major steps:

1. Find the shortest path or paths between two end-nodes,
2. Find the set of paths that meets certain requirements.
3. Find the capacity needed to handle network traffic flow between the two end nodes.
4. Allocate network traffic flow among the set of multiple paths.

This model aims to introduce proportional and efficient bandwidth allocation scheme to distribute network traffic flows across multiple paths with the objective to minimize network congestion and delays and maximize links bandwidth utilization.

Given available network capacity, in a traditional network setting traffic would take the shortest path from the source node to the destination node. With the development of the MPLS technologies in today's Internet demands and to support needed features such as load balancing and fault tolerance, many service providers have implement multipath technologies such as ECMP. Such techniques route traffic across multiple paths but doesn't take into account network congestions and network bottlenecks. Such problem may leads to underutilization and over unitization of link's capacities which leads network performance degradation and inefficient use of network resources.

This research will focus on resolving this problem by allocating network traffic flow across multiple paths based on the link's capacity and taking into account bandwidth availability and network congestion conditions.

1. A source *s* receives network traffic flow sourced from node *s* heading to destination *d*.
2. *s* has multiple paths to destination *d*.
3. Each of these links may have different bandwidth capacity *C*. This research assumes multiple links may have identical or different bandwidth capacities. More emphasis will be put on the latter.
4. The research environment assumes a packet-switching communication network such as a WAN network or an Internet backbone.
5. Two types of broadband links can be assumed here: (a) The WAN side connections can be configures as multilink PPP [15], to combine multiple T1 circuits (1.5 Mbps) bonded as one logical connection. Theoretically a single customer premise equipment (CPE) can handle up to 12N x T1. Which can build 3 set of multilinks - MU1, MU2, and MU3 - with 3MB, 6MB, and 8MB of bandwidth capacity respectively.

(b)The network backbone with high speed optical fiber network links carried on SONET fiber optic networks transmission rate based unit is 51.84 Mbit/s. The speed ranges from OC1 (51.84 Mbit/s), OC3 (155.52 Mbit/s, OC12 (622Mbit/s), OC24, etc.

6. Multiple links and multipath routing exists between source/destination (*s/d)* pair, where the data packets traverse the network via intermediate nodes that connect the *s/d* pair.
7. Network traffic control, bandwidth capacity allocation, and user request distribution is managed at the ingress of the network.
8. User data transmission requests enter the network through the source node. All requests are buffered in store-and-forward fashion.
9. Connection-oriented mechanism is used to support network connectivity between nodes.

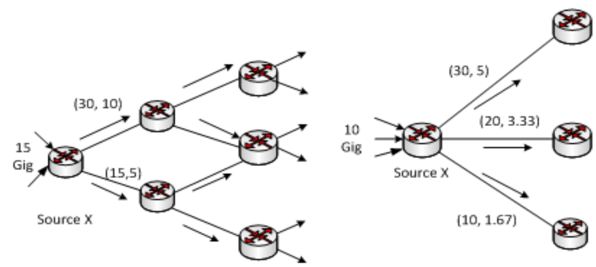

Figure 4: Network Traffic Flow Prototype

3.5. Network Optimization Construction

Capacity assignment problem and flow assignment problem. Both problems have constraints to satisfy and objective function to attain.

Capacity assignment problem (CA), chooses the optimum link capacity for an incoming given network traffic flow that would minimize cost and satisfy user's network payload request.

Traffic Flow assignment problem (TFA) objective is to match the user traffic flow with the available link's capacity. To minimize traffic delays for that user's network payload flow request. The question is how to select the optimum path [links] capacity that meets the user flow requirements for efficient traffic flow and minimize traffic delays.

Generally Link Available Capacity can be defined in the following simple equation:

$$LAC = TLC - LRC - LBC$$

Where:

LAC: Link Available and Usable Capacity.
TLC: Total Link Capacity
LRC: Link Reserved Capacity
LBC: Link Busy Capacity.

In a multipath environment the objective is to assign network traffic flow (User request) to the appropriate capacity. The user's traffic need to be optimized and mapped across multiple paths.
In general, network components are: source node *s*, destination node *d*, link *l* between *s* and *d* with intermediate nodes *i*. multiple paths may exist between every *s and d* pairs.

The average traffic flow between *s-d* is (Υ_{sd}/μ) should be more than link's capacity *C*.
Let π_{sd} denote the path between *s-d*

Υ_{sd}= User's traffic flow between nodes *s-d* (packet per second)

λ = Average number of messages flow per second traverse the i^{th} channel.

The sum of all the network traffic packets traverse the network is the summation of the average number of message flow traverse the network [16].

For simplicity we consider all delays equal *0*. In real network design all delays should be taken into account and factored into the capacity equation.

The total user traffic flow that originates from source node *s* to destination node *d*, traffic flows takes Poisson distribution process as presented in [16].

All network incoming traffic messages are assumed to be independently drawn and take exponential distribution function with the mean of *1/μ* (bits) X_{sd} represents expected network delay that affects network performance or message sourced from node *s* with node *d* as the destination.

Given the cost of the network Q (dollar), i.e. the cost of network links, equipment, and channel fees ... etc

$$Q = \sum_{i=1}^{M} q_i \left(C_i\right) \quad [16] \quad (2)$$

Network delays represent the total time that takes network packet to traverse the network.

Network delays such as: transmission delay, propagation delay and queuing delay … etc.

Let assume that R_{sd} is the average for a network packet to traverse the network form source *s* to destination *d*.

Given the network capacity *C,* we are interested in finding the optimum message flow interval for each connection that would achieve the minimum average delay.

This research will take this optimization problem further by mapping network traffic flow based on network capacity and availability.

With a predetermined network channel capacities we need to find the optimum traffic flow to minimize the average network delay. So traffic flow sourced from *s* and to *d* needs to be adjusted and distributed across *n* paths. That implies the average available channel capacity C_{sd} must be more than the average traffic flow (user request) λ_{sd}.

To allocate network bandwidth across multiple paths, this paper proposed the following approach: First, calculate the k-shortest path from source node to the destination node.

Second, then calculate the Constraint Shortest Path first (CSPF).

Third, choose the paths that meet the bandwidth constraints requirements.

Forth, an algorithm will calculate the network traffic requirements.

Fifth, another algorithm will distribute the network traffic requirements across the chosen paths.

Sixth, the network traffic requirements will be distributed across the chosen paths proportionally.

Seventh, distribute network traffic payload across paths proportionally based on links bandwidth capacity.

4. CONCLUSIONS

The general overall objective of corporate network management is to minimize the cost function on network spending, seeks efficient traffic flow and minimizes network traffic delays, and optimized network performance. The goal of this research is to work toward achieving some of these novel objectives. In summary, this research uses the k-shortest path to identify the shortest paths. Implement the Constrained-base Shortest Path First (CSPF) to choose those shortest paths meet certain requirements. Allocate the network payload across the multiple paths proportionally base on each path capacity.

This framework can be implemented in network fault tolerance, load balancing, and MPLS traffic engineering with Entropy Label [14].

In future papers I will describe in details the framework building blocks and provide numerical examples of the framework implementation.

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