A New Metric for OSPF Based On the Heavy Tailed Behavior of Internet Traffic

S.A Kalim, Dr Lionel Sacks
Department of Electronic Engineering
University College London

Abstract

This paper describes the work done in investigating and constructing Optimised Multi-path (OSPF-OMP) metric link state for the purpose of load balancing that considers heavy tailed distributions. Simply as the buffer overflow probability increases this metric would increase for this link. The paper provides an update on the work presented last year. This is a work in progress and describes theoretical solutions devised by authors. The paper also details the work that is in progress for the project and the results of simulations carried to date and the work that is to be completed.

1. Introduction

A large number of studies of traffic measurements from working packet networks including, Ethernet LANs, WANs, CCSN/SS &, ISDN and VBR video over ATM have been collected and analysed. The results reported in [1] [2] have convincingly established the presence of significant features that are characteristics of fractal invariant processes. These characteristics are observed with some reproducibility and independently of the precise setting of the network under consideration [3]. Of particular interest in packet traffic modelling is a property called Long-range dependence (LRD) which is marked by the presence of correlations that can extend over many time series. For example there is considerable evidence that network work loads such as file sizes and web object sizes are described by distributions which decay according to a power law. This has considerable impact on queuing performance and is a dominant characteristic for a number of Tele-traffic engineering problems such as buffer dimensioning and capacity allocation. For analytic results and simulation in this area see [4,5,6,7]

In [8] we have simulated and modelled self-similar traffic by aggregating ON/OFF Pareto sources in order to study the impact of LRD traffic on queue size when compared to exponential sources to show its pervasive impact on queuing performance. Also we looked at a technique based on Wavelet analysis [9] to measure the presence of LRD present in traffic and how this might be used for the purpose of load balancing. Although several works have analysed the self-similar nature of internet traffic control mechanisms for self-similar traffic have not yet been fully investigated.

In [10] it has been shown how theory of large deviation [11] for connection admission control can be used to derive expressions for the management of heterogeneous self-similar sources using very simple assumptions about the network for admission procedures. They derive a frame work for computing probabilistic delay bounds for a deterministic queuing system as a model of an ATM network This new traffic characterisation has made possible a more intuitive understanding of the dynamics of the queuing system and we try to extend this to work out a metric for the purpose of load balancing.

This paper summarises the investigation into the development of an intelligent network monitoring system which can apply dynamically adaptive network strategies. Given a set of sources with mean x, standard deviation s, and Hurst parameter H, to determine the link capacity needed based on some queue overflow probability. This will allow to, optimise the network and its use of services by providing a continued level of throughput to service that require them. This will be achieved by the improvement of the routing process which considers the heavy tailed nature of internet traffic. The protocol that is most commonly used for the routing process across LANs is OSPF.

2. Self-Similarity & Long-range dependence

Self-similarity is defined as the scale-invariant property of the traffic. The term self-similar was first used by Mandelbrot [12] during the 1960's. It refers to the scaling behaviour of the finite dimensional distributions of a continuous or discrete time process. This means in contrast to traditional packet traffic models, aggregate packet streams are self-similar or fractal in nature; that is network traffic looks the same when measured over time scales ranging from milliseconds to minutes and hours. This is mostly to do with the statistical nature of traffic processes, and does not address in depth issues of the relevance of these features to queuing performance or practical traffic management.

A stationary process is long range dependent (LRD) if its autocorrelation function r(k) is non sum-able therefore the definition of long-range dependence applies only to infinite time series [13]. A long-range dependent process has a hyperbolically decaying autocorrelation function that decays as a power of the lag time; meaning the sum of the autocorrelations diverges even though the high lag autocorrelations are individually small and become negligible their cumulative effect is off importance giving rise to the heavy tailed behaviour. This is different to a Short-range dependent (SRD) process where the corresponding autocorrelation function decays exponentially fast. A discrete-time wide sense stationary process with mean μ and variance σ squared and autocorrelation function,
This function decays slowly at large lags and is given by;

$$\Gamma_x(k), k \geq 0, \sim c_\Gamma k^{-b}, k \to \infty$$

Where Cr is a positive constant and $0<\beta<1$
For each m = 1, 2, 3,…, let denote a new wide sense stationary time series obtained by averaging the original time series x over non-overlapping blocks of size m.
Samples are given by;

$$x_i^{\ m} = \frac{1}{m}(x_{im-m+1} + \ldots.. + x_{im}), i \geq 1$$

A process x is said to be exactly self-similar with parameter ß (0 < ß < 1) if for all m = 1, 2, we have;

$$\mathrm{var}(X^{(m)}) = \sigma^2 m^{-\beta}$$
$$r^{(m)}(k) = r(k), k>=0$$

The parameter ß is related to the Hurst parameter as H = 1 - β/2 for a stationary stochastic process ß = 1 and the variance of time average decays to zero exponentially 1/m. For a self similar process the variance of the time average decays more slowly. The Hurst parameter represents the degree of self-similarity in the observed traffic. When the value of the Hurst parameter is between 0.5 and 1 the traffic is said to be self-similar values of H closer to 1 indicate a high degree of self-similarity.

2.1. Heavy tails

The simplest heavy tailed distribution is the Pareto distribution with probability density function

$$f(x) = \frac{a}{k}\left(\frac{k}{x}\right)^{a+1}$$

The parameter α is the shape parameter. As the value of alpha decreases the more of the probability mass is located in the tail of the distribution.

3. OSPF (Open Shortest Path First) Routing Protocol

OSPF is a link-state protocol [14] based upon the shortest path first algorithm devised by E.W Dijkstra [15]. The term link-state refers to a database contained in each node that operates the link-state protocol. This database contains a complete map of the network which is regularly updated. This allows the node to compute the shortest path to all other nodes this usually takes a fraction of a second.

When a link goes down, the protocol must adapt quickly and rebuild the link-state database with updated values. This is achieved through a “flooding” protocol. The routers that first detect the change of state in a link will immediately update the corresponding records in their link state database, and than transmit the changes to all adjacent routers, who will in turn update their data base and transmit it on, until all routers have the updated database. In order to ensure that changes received are accurate and not an old message which could come back and pollute the database, the updated data will have a time stamp or message number attached to it. Assuming the initial convergence of the database is assigned the value 1, the modified values will be sent out with the message number 2, and so on.

OSPF has the ability to use an “Equal Cost Multi-path” algorithm (ECMP) to allow traffic to be split over two paths that are of equal cost. At the moment ECMP algorithm does not consider link loadings based on the heavy tailed nature of internet traffic. There maybe two equal cost paths between source and destination, this could be exploited my intelligently load balancing traffic which considers the heavy tailed nature of traffic. These are some of the considerations behind the development of the

OSPF Optimised Multi-path (OSPF-OMP) protocol draft [16]. OSPF-OMP is an IETF internet draft from 1999, which specifies load balancing techniques to bring knowledge of the link loading to the routers, thus allowing traffic to be diverted away from the most congested links. This loading information will be flooded within an OSPF area using Opaque LSAs [17].

4. Simulation Tools

In order to test any new protocols simulation software is needed. We are looking into the use of simulation software such as SSFnet/OPNET for this purpose. It allows the testing of different algorithms for network assessment and simulation of wide range of scenarios. At present simulations for simple scenarios not involving link-state routing have been performed with the NS-2 [18] simulator from the VINT group. It was mainly used to model and simulate aggregate self similar traffic and to investigate its impact on queuing mechanism. This software is designed for testing and simulation of algorithms and development protocols and not intended specifically for the simulation of industry standard protocols such as OSPF. It does have a link-state module which gives an approximation of a generic link-state protocol but with certain limitations when compared to OSPF. Specifically it does not support hierarchical routing, multicast, designated routers, hello, IP address, masking and more [19].

5. Future Work

We have described the limitation of the current protocol in use when dealing with self-similar traffic and suggested some modifications. This includes deriving and calculating the values for the probabilistic bounds for IP traffic in order to determine the cost metric. Extending the amount of information stored in a router will be a balancing act so that the routing tables do not get too large.

The next stage will be to learn SSFnet/OPNET simulation software to simulate and modify OSPF to obtain the desired results.

6. References

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