Performance Measurement of BitTorrent Networks

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Abstract

A variety of methods aid in the behavioral study of network traffic .Trace analysis is one such method that reveals patterns of traffic elements, computes usage, measures feature deployment, and identifies limitations of a protocol. The performance metric plays a vital role in choosing the applications over the internet. In this paper, we focus on models for performance monitoring of large-scale data sets such as in BitTorrent systems. The paper analyzes BitTorrent Network's performance mechanisms, based on extensive measurements and trace analysis. The analysis provides immense data about the performance metrics such as the average file downloading time, popularity of the file, arrival rate of peers, departure rate of peers, link utilization and fairness of service.

Keywords-Internet performance, network monitoring, traffic measurement, trace analysis, BitTorrent systems.

Introduction

Internet is a massive network of interconnected networks. In an Internet based application a user on one end can communicate with other users or programs on the other end with a connection to the internet. Traffic is generated in the internet with data transmission from one end to the other. Internet applications are guided by protocols. One such protocol is the BitTorrent communication protocol that allows users to share large amounts of data. BitTorrent falls under the suite of P2P (Peer-to-Peer) sharing protocols. There are few major differences that make BitTorrent more efficient than other P2P protocols. It maintains a list of files that are currently available for download which makes the searching of files easier. BitTorrent employs a file-level sharing policy instead of the directory-level sharing policy. It also provides a trading mechanism among the clients who are downloading the same file [1].BitTorrent's success lies in its scalability that makes is popular among other file sharing protocols. The basic concept is to divide the file into blocks allowing the peers to download blocks of the file and upload the files that other peers require in parallel. Although BitTorrent appears to be popular there are several factors to be examined in the execution process to measure its performance. One such factor is the optimality. The system is said to be optimal if a peer can download as many blocks as it uploads.

Performance refers to all aspects of Internet behavior. The performance metric of most interest is the user throughput, which is mainly affected by the packet loss ratio. For real-time applications, an end-to-end packet delay variation is also an important performance metric. Traffic characteristics are strongly correlated with performance. For example, traffic can be profiled according to its protocol composition (mixture of TCP/UDP, HTTP, SMTP, DNS, FTP, and other protocols) and statistical characteristics (average utilization, burstiness, flow durations, packet lengths) [2].In general, performance of an application over the network depends on many aspects of performance metric such as the bandwidth or throughput, loss of data packets, round-trip delay time. Performance can be measured by different methods. Trace analysis is one such method which gives the details about an application's performance over a network. In P2P systems like BitTorrent, the network performance can be measured by the average file downloading time and the size of the network can be characterized by parameters such as the number of peers, the arrival rate of peers, etc, [3]. In the following sections, we analyze different methods for BitTorrent performance mechanisms.

Background

Effectiveness of BitTorrent system is measured by several metrics. Some important metrics are as follows**:**

Download performance

Download time refers to the time taken by a client for a complete download. It also provides information about the change of peers from downloading and uploading peer to being a seed [4]. The download performance determines the relation between the size of a file and the time needed for downloading it.

Popularity of file

Popularity of a file is measured by the total number of users accessing it over a certain period of time.

Availability

Availability refers to the prevalence of the BitTorrent systems over the internet. Availability depends on several factors such as the multi-tracker or the DHT (Distributed Hash Tables) infrastructure, the amount of information they store, patterns of tracker and network failures, and the amount of information shared across trackers and peers [5].

Arrival rate of peers

The rate at which the peers join the BitTorrent session is called as the arrival rate of peers.

Departure rate of peers

Departure rate of peers is defined as the rate at which the peers leave the BitTorrent session.

Fairness

Fairness means that volume of data served by different peers should be the same. The system should be fair in terms of the number of blocks served by the individual peers. No peers should be compelled to upload much more than it has downloaded [6]. Fairness is a crucial factor in deciding the effectiveness of the overall network. Any unfairness in the system would reduce the efficacy of the system.

Link utilization

The utilization is computed as the ratio of the aggregate traffic flow on all uplinks/downlinks to the aggregate capacity of all uplinks/downlinks in the system; i.e., the ratio of the actual flow to the maximum flow possible [6].Link utilization is defined as the mean utilization of the peers' uplinks and downlinks over a certain period of time.

There are many performance related metrics for BitTorrent analysis. Efficiency and stability are two important parameters. Efficiency is defined as the fraction of peer upload bandwidth utilized for content distribution while stability is defined as the existence of a steady state [13]. In context of BitTorrent, it means that arrival rate of peers should be balanced by their departure rates.

The rest of the paper is structured as follows: Section I describes the BitTorrent protocol. Section II demonstrates various methods available for analyzing BitTorrent performance mechanisms. Section III illustrates trace analysis approach. Section IV summarizes the discussion on benefits and limitations of trace analysis and various models. Section V presents the conclusion. Section VI suggests future work essential to verify the benefits of trace analysis.

I BitTorrent Protocol

BitTorrent is among the very few P2P file-sharing systems that have stood the test of intensive daily use by a very large user community. It has evolved as the most popular network. BitTorrent contributes the 53% of all the P2P traffic in June 2004[8].

Peers and tracker communicate using the tracker protocol on HTTP. Peer issues HTTP GET request and tracker replying query in HTTP response. Peer request to tracker is used to locate other peers in distribution swarm and to allow tracker to record statistics of swarm. Peer protocol for communication among peers operates over TCP and uses in-band signaling. Once a TCP connection is established between Peers, they use handshaking operations to exchange information including peer ID and info (Fig 1).

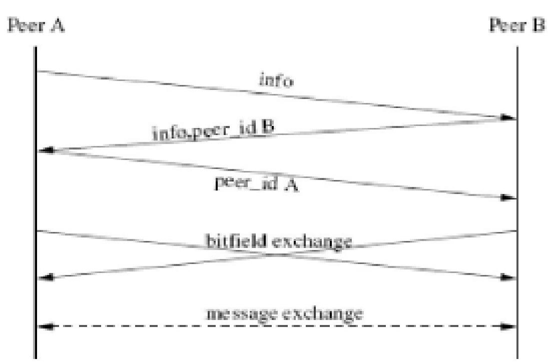


Fig 1. BitTorrent handshaking operation

A user starts a BitTorrent client as a downloader at the beginning to download file chunks from other peers or seeds in parallel (Fig 2). A peer that has downloaded the file completely also becomes a seed that could in turn provide downloading service to other peers. All peers in the system, including both downloaders and seeds, self-organize into a P2P network, known as a torrent. The initial seed can leave the torrent when there are other seeds available. The content availability and system performance in the future depend on the arrival and departure of downloaders and other seeds.

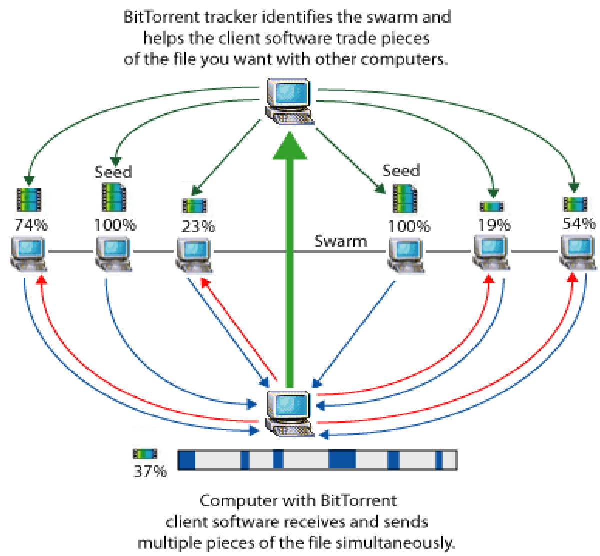


Fig 2. BitTorrent Network

BitTorrent applications contribute to the demand for high speed broadband access, they also contribute to the undesirable 80/20 effect wherein 80% of bandwidth is used by 20% of the users [9].

II Related work

Many researchers have studied the BitTorrent like systems through trace analysis and modeling. There have been analytical as well as measurement-based studies of the BitTorrent system. At the analytical end, Qiu and Srikant [3] have considered a simple fluid model of BitTorrent. Their main findings are: (a) the system scales very well, i.e. the average download time is not dependent on the node arrival rate, and (b) file sharing is very effective, i.e. there is a high likelihood that a node holds a block that is useful to its peers. Their study did not consider some of important BitTorrent parameters like node degree, maximum concurrent uploads, and environmental conditions (e.g., seed bandwidth, etc.) that could affect uplink bandwidth utilization. Fluid model studied the performance of file-swarming networks. The model demonstrates the aggregate behavior of the system using two types of peer arrival patterns [12].

Izal et al. [10] and Pouwelse et al. [11] present measurement based studies of BitTorrent using tracker logs of different torrents. The main findings of these studies are: (a) the average download rate is consistently high; (b) as soon as a node has obtained a few chunks, it is able to start uploading to its peers (the local rarest first policy works); (c) the node download and upload rates are positively correlated (tit-for-tat policy works); and (d) nodes might not stay on in the system (as seeds) after completing their download. So it is the few long lived seeds that are critical for file availability.

A.R. Bharambe et al. [6] used simulation based approach for comprehending BitTorrent performance. The study focused on fairness to peers. The approach considered utilization of the upload capacity of nodes and fairness served by nodes as major metrics in measuring performance. The main findings are: (a) BitTorrent's rate-based Tit-For-Tat (TFT) policy fails to prevent unfairness across nodes in terms of volume of content served. This unfairness arises principally in heterogeneous settings when high bandwidth peers connect to low bandwidth ones. (b) The combination of pairwise block-level TFT and the bandwidth matching tracker (almost eliminates the unfairness of BitTorrent with a modest decrease in utilization. (c) It is critical to conserve seed bandwidth, especially when it is scarce; it is important that the seed node serve unique blocks at first (which it alone can do) to ensure diversity in the network, rather than serve duplicate blocks (a function that can be performed equally well by the leechers). (d) The Local Rarest First (LRF) policy is critical in eliminating the "last block" problem and ensuring that new leechers quickly have something to offer to other nodes.

III Trace Analysis of BitTorrent

In order to better understand BitTorrent traffic over the Internet, the BitTorrent meta file downloading trace are used. These file can be collected from large commercial server farm hosted by a major ISP and a large group of home users connected to Internet by cable company. These traces include IP packets of all HTTP downloading of the .torrent files which includes the timestamp when the packet is captured or in other words the downloading time of .torrent file.

Figure 3 shows the complementary CDF(CCDF) distribution of time after torrent birth for requests to all fully traced torrents in the tracker trace. Figure 4 shows the CCDF distribution of the time when a .torrent file was downloaded in the server farm. Both these curves show that after the torrent is born, the number of peer arrivals to the torrent decreases exponentially.

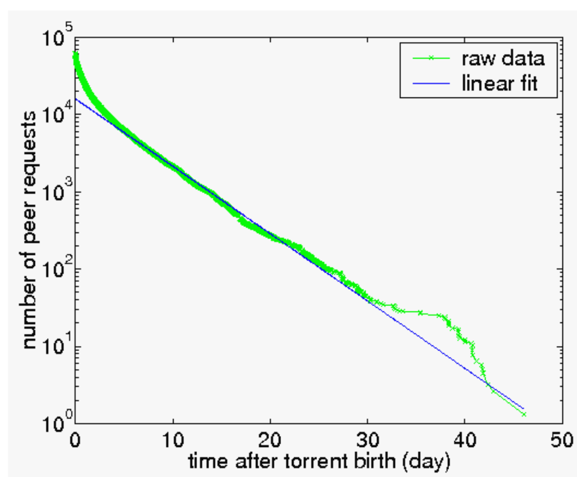


Fig 3.Tracker trace

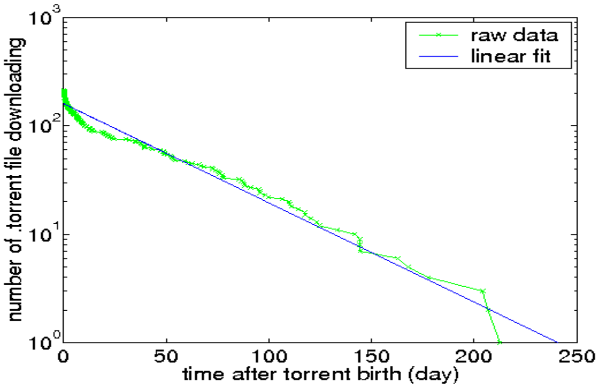


Fig. 4. Server farm trace

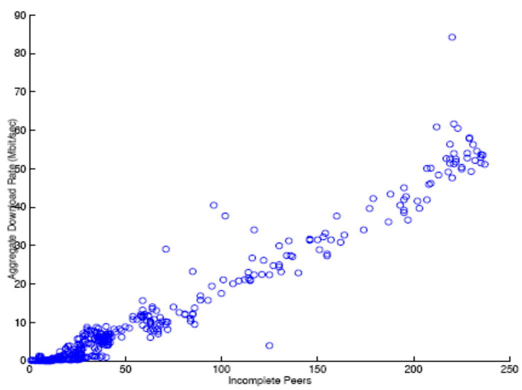


Fig. 5. Aggregate performances do not degrade as more peers connect to torrent.

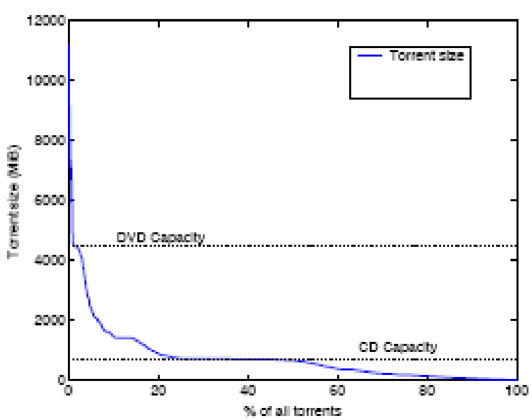
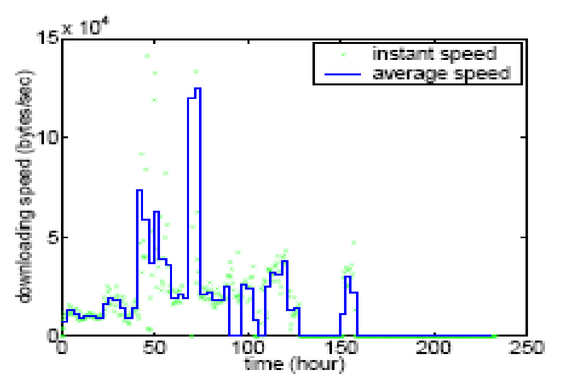


Fig. 6. Torrent sizes are widely distributed and large

One observed characteristic of torrent is that the transfer rate scales with the downloads and it scales better than the single-source downloads as shown in figure 5. Another important characteristic is that BitTorrent files vary in size extending from 10 MB to few GB as shown in figure 6.

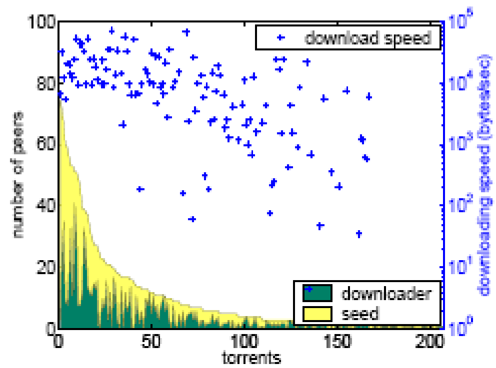
It has been observed that fewer users tend to acquire the torrent in a single session for larger torrents, possibly suggesting a limit on how many bytes users are willing to transfer per session.

Figure 7(a) shows the performance variation for the instant speed and the average speed. The instant speed is defined as the mean downloading speed of all the peers in the torrent at that instant while average speed is defined as the average of instant speed over typical downloading time. This can be concluded that client downloading speed at different time stages is diverse and can affect the client downloading time. The downloading speed plays important role in downloading performance. Figure 7(b) shows that peers in torrent with large population have relatively high and stable downloading speed while speed in torrents with less population is highly disperse.



(a) The downloading speed in the lifetime of a typical torrent

Fig. 7



(b) The downloading speed (in log scale) and the number of downloaders/seeds for each torrent at a time instant

Fig. 7

IV Discussion

BitTorrent is remarkably robust and scalable at ensuring high uplink bandwidth utilization. It scales well as the number of nodes increases, keeping the load on the origin server bounded, even when nodes depart immediately after completing their downloads[6].Trace analysis focus on the evolution of single-torrent systems and the inter-relation among multiple torrents over the internet, revealing the limitations of current BitTorrent systems [12].Trace analysis and modeling effectively studied the debut of a new file in the BitTorrent system but failed to measure the overall client performance in the lifetime of a torrent during which the file popularity changes. The change of file popularity is an important metric in BitTorrent where the service availability relies purely on the voluntary participation of peers.

V Future Work

Tcpdump is a packet capture tool that is a popular monitor for network performance. It is widely used in UNIX and TCP/IP environments. It provides tremendous amount of information about each packet that is captured. Some of the data that can be extracted from the trace are packet arrival time, source and destination of the packet and the amount of the data that is sent and received. Scientific visualization is used to understand data sets from large scale simulations. AVS (Advanced Visual Systems) is a visualization system that graphically displays the normalized data from the tcpdump trace. In AVS, each packet is represented as a vector and the coordinates of the vector (X,Y,Z) are defined as (packet number, interarrival time, ack)[13]. With the integration of the network monitoring tool such as the tcpdump and visualizing systems like the AVS, researcher can get better insight of the data with multiple network parameters. Hence Future Work that involves the incorporation of these tools would contribute to the analysis of the large scale data sets like BitTorrent.

VI Conclusion

In this paper we have analyzed BitTorrent performance mechanisms using fluid model, simulation based approach and trace analysis approach. It is found that trace analysis combined with extensive measurement provides profound details about the behavior of the BitTorrent systems. The trace analysis indicates that BitTorrent systems provide poor service availability, fluctuating download performance and unfair services to peers.

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