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A study on bandwidth manipulation tools in Video Streaming

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Abstract
Nowadays, video streaming is a widely acquiring lot of popularity among television and mobile users. To maintain a high-quality video streaming, several approaches are developed using probing tools like improving bandwidth over a network. The available bandwidth of the link and the path directly impacts the performance and efficiency of throughput in streaming applications. Several tools have been devised already to estimate the available bandwidth while streaming videos. The unpredictability of the available bandwidth over a network makes the design of measurement algorithms very challenging nowadays. Measurements of available bandwidth and link bandwidth on an end-to-end process are getting more important on the Internet. In this paper, I have discussed about the concepts, difficulties and protocols of video streaming over the internet and also study about the probing models and techniques which are used to compute the available bandwidth in the network.

Keywords: Video Streaming, Bandwidth, Probing Models

1. Introduction
The streaming of a video is designed with the aim of affording Quality of Service (QoS) and making efficiency for streaming video over the Internet. Video streaming can be done via several types of communications such as, unicast, multicast or broadcast. The delivered video maybe encoded in real-time or maybe pre-encoded [8]. A lot of videos are streamed today over the internet according to user's favorite but the difficulty is how to make it efficient and improve video streaming quality. Several probing tools which have appeared in recent years are Spruce (Spread Pair Unused Capacity Estimate), PathChirp, Yaz, IGI/PTR, DietTopp, ASSOLO, Pathload, STAB etc., [11]. These tools are used to estimate the available bandwidth in a network based on the transmission of packets between sender and receiver and the quality of video is stabilized according to that bandwidth. These methods are differed in the temporal structure of probe streams and its size. The methods in the way of available bandwidth are derived from the received packets in the transmission path.

2. Video streaming
2.1 Client-Server Architecture
The growth of video compression technologies and the development and popularity of the internet have provoked the concept of video streaming over the internet to a large number of consumers. A number of researches have proposed several video streaming protocols to support Quality of Service efficiently over the internet. Video servers using various protocols in Live Streaming such as HTTP Live Streaming (HLS) and Real Time Messaging Protocol (RTMP) [4]. They also provide synchronization with a client and server and ensure the loss of data packet and maintain a QOS (Quality of Service) mechanism, so that the video is delivered correctly to the user [9].

2.2 Video delivery via streaming
The delivery of the video in video streaming is dividing the video into several parts and transmits these parts to the clients using clock synchronization. It enables the receiver to decrypt the video and playback as these parts are received, without having to wait for the whole video to be received [8]. The channels for video delivering maybe static or dynamic, packet or circuit switched, and constant or variable data transmission. Two types of video streaming communications are used commonly i.e., one-to-one (feedback control) and one-to-many (usually no feedback). Video streaming can contain the following steps: 1) the compressed video can be partitioned into packets. 2) Started to deliver the packets. 3) Decoding the received video and playback at the client side while the video is still delivering.

2.3 Difficulties in video streaming

Video streaming over the internet is difficult because it provides no guarantees on bandwidth, delay jitter or loss rate [2]. Bandwidth is depending on how often the video is viewed and what quality levels of video will be watched by viewers. If the sender transmits the data faster than the available bandwidth in the path or a link then the congestion will be occurring on a network and the packets will be lost, and also there will be a severe reduction in video quality. If the sender transmits the data slower than the available bandwidth in the path or a link then the receiver generates the sub-optimal video quality. The objective to overcome the bandwidth problem in the transmission network is to calculate the available bandwidth in the corresponding path and then match the broadcasted video bit rate to the estimated bandwidth.

The end-to-end delay of a packet occurrence may vary from packet to packet in network. The variation of this delay is called as the delay jitter. When the delay exceeds a certain threshold, it results in hold on and lost some blocks of the video. Jitter reduces the video quality and it is undesirable in video streaming. Different types of losses may occur, depending upon the particular network's speed, threshold and transmission rate. When packet loss occurs, the video decoder cannot able to decode the video stream properly. This will result in the degradation of quality of the video.

2.4 Protocols in video streaming

Several protocols are used to video streaming in best-effort internet. To identify the packet loss and delay jitter during transmissions over a network, a Real-time Transport Protocol (RTP) was proposed for end-to-end real-time transfer of streamed data [6]. RTP was designed with two basic principles: 1) application-layer framing and 2) integrated layer processing. The RTP Control Protocol (RTCP) was designed to check the transmission information, Quality of Service, and to achieve synchronization across multiple streams, and also it is based on User Datagram Protocol. The Real Time Streaming Protocol (RTSP) was designed to create and maintain video sessions between client and server and to provide VCR-style control functionality, allowing users to pause, resume or seek in video streams while playing the videos.

3. Probing models

Many tools have been proposed already for computing the bandwidth while streaming the video. Many of these probing tools are following either the Probe Rate Model (PRM) or the Probe Gap Model (PGM). Both are very effective models for estimating available bandwidth in a network.

3.1 Probe Rate Model

In the Probe Rate Model, a tool is used to modulate the transferring rate as a function of the distribution of packets detected at the receiver. The highest possible rate for minimum dispersion is used as an evaluation of the available bandwidth of a streaming of video in a corresponding network. The probe rate model is based on the model of self-induced congestion. Assume that the sender transmits the probe traffic at a transfer rate lesser than the available bandwidth along with the corresponding path, then the arrival rate of probe traffic at the receiver will compensate their rate by the sender's rate. Once calculate the available bandwidth by probing models at which the probe sending and receiving rates getting matched. Several tools such as Pathload, PathChirp, PTR, and TOPP are used in the probe rate model.

3.2 Probe Gap Model

The Probe Gap Model is proposed as an inconsequential and fast available bandwidth estimation method. Two estimation tools such as Spruce and Delphi are based on Probe Gap Model [10]. These tools insert the trains or pairs of packets at a probing rate equal to the size of the narrow link. Dispersion of the trains or pairs of packets at the receiver is used to infer the rate of cross-traffic at the narrow link. The PGM utilizes the information in the time gap among the arrivals of two successive probes at the receiver. The difference between capacity and the cross traffic of the narrow link is used to estimate the available bandwidth of that particular path [13]. This holds only if the narrow link of a path is also the tight link, which is assumed to be the case in the Probe Gap Model. Comparing other estimation techniques that require number of iterations with different probing rates, Probe Gap Model uses a single probing rate and it deduces the available bandwidth from a direct relationship between the sender and receiver probing rates of measurement packet pairs.

An important hypothesis behind this model is that the measured path has a single bottleneck link which determines the available bandwidth of the end-to-end path [10]. The distance between two packets in a pair can be minimum in the network. The sender and receiver can maintain the system clock using synchronization, and check the dropout of any packets during transmission. Once the packets are delivered to the receiver without any problem, the operating system reschedules the sender program again, gives up sending the second packet, and restarts.

Both the Probe Gap Model and Probe Rate Model approaches accept:

- Average rates of cross-traffic will change gradually and is become a constant for the duration of a single measurement.
- Cross-traffic follows a fluid model i.e., non-probe packets may have an infinite small packet size
- First In - First Out queuing concept is used in all routers along the path.

The probe gap model grants a single bottleneck which is both the narrow link and tight link used to measure the available bandwidth for that path. These assumptions are necessary for the model analysis but the tools might still work even when some of the assumptions do not hold [12]. If the gap between two pairs is increased the bandwidth calculation time also increase and also the data transmission time should be increased.

4. Available bandwidth estimation techniques

The term bandwidth refers to the maximum data transfer rate of an internet or network, and how much data can be sent through a specific connection in a certain amount of time.

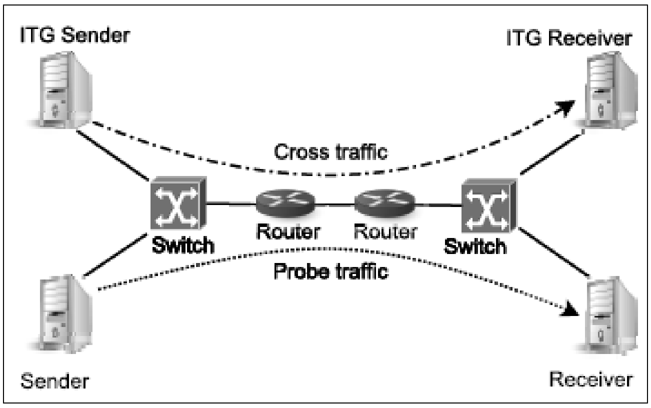

Fig 1: Testbed setup

The available bandwidth (ABW) at a link is its unused capacity. The bandwidth varies according to time. The capacity is the maximum rate at which packets can be transmitted by a link.

- To estimate available bandwidth in the path, by using the formulas $A = min_{i=0..H}$ and $A_i = min_{i=0..H} C_i(1-u_i)$.
- To estimate the available bandwidth in the link *i* by using the formula, $A_i = C_i(1-u_i)$.

Whereas *C* denotes the link bandwidth in bit/s, *u* denotes the bandwidth utilization in bit/s, *H* denotes the number of end-to-end link hops, and A denotes the currently available bandwidth in bit/s. Fig 1: Testbed setup refers to the testbed setup used to compare available bandwidth estimation tools.

4.1 pathChirp

The tool pathChirp is used to estimate the available bandwidth on a communication network path. It uses the concept of self-induced congestion. Methodologies to calculate the chirp bandwidth (see Fig 2) are,

1. Available bandwidth calculation for per packet pairs, E_k (k=packet number)
2. Available bandwidth for per-chirp can be calculated by $D = \frac{\sum_k E_k \Delta t_k}{\sum_k \Delta t_k}$
3. Estimation of smooth per-chirp over sliding window time of size τ.

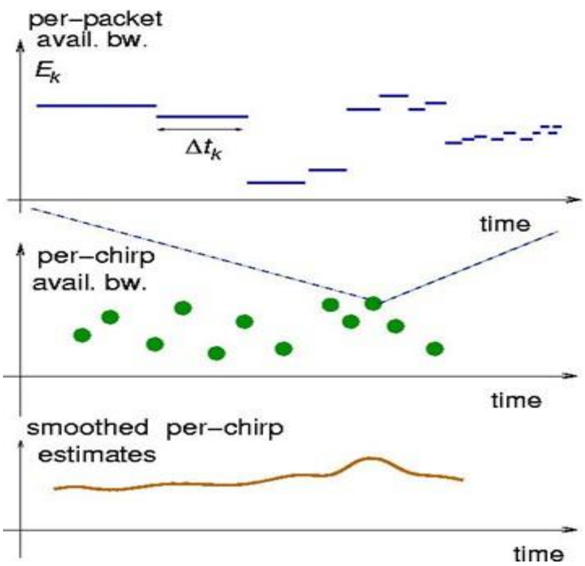

Fig 2: Per-packet, per-chirp, and smoothed per-chirp estimations

The tools pathLoad and pathChirp are called as iterative probing tools. PathChirp transfers the variable bit-rate stream contains the exponentially distanced packets. In [7], the actual unused capacity is indirect from the rate responsible for increasing delays at the receiver side. It provides many advantages on existing probing schemes based on packet pairs or packet trains. By raising the probing rate rapidly within each chirp, pathChirp gets the set of information from which to dynamically calculate the available bandwidth. Here, no clock synchronization is required because only uses relative queuing delay within chirp duration.

4.2 pathLoad

Pathload is based on Self-loading Periodic Stream called as SloPS to measure the effective bandwidth of the end-to-end links and use a constant bit rate stream, sending pairs of trains of packets at a specified rate and varying this rate in every round (see Fig 3).

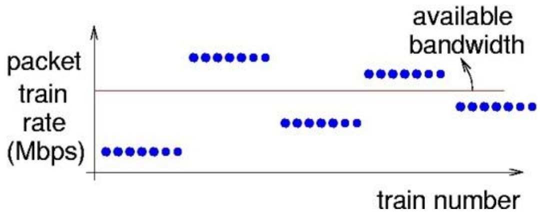

Fig 3: Bandwidth in pathLoad

Each packet train consists of many packets starting with huge sequential gaps between successive packets that reduce towards the end of the packet train. Pathload is based on non-intrusive method and it does not support significant increases in the utilization of network, losses and delays. An effective bandwidth of end-to-end link and the periodic stream sending rate is determined by the distribution of the packet one-way delay in arriving at the receiver side [3].

4.3 STAB

The edge-based probing tool Spatio - Temporal Available Bandwidth estimator tool (STAB) is used for positioning the thin links on a corresponding network path. A thin link is a link which has a less available bandwidth capacity than all the links prior it on the network path. This technique combines the concepts of self-induced congestion, the probing technique of packet tailgating, and probing chirps to efficiently detect the thin links (Fig 4).

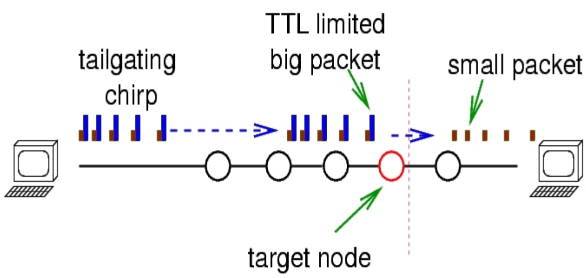

Fig 4: STAB Technique

The theory of self-induced congestion allows the simple technique for estimating available bandwidth *A* to compare with probing bit-rate R. It depends on the following rules: 1) If *R* > *A* then the probe packets become queued at some router, resulting in an increased data transmission time [1]. 2) If the probing bit-rate $R < A$, then the packets encounter no extra delay. The large packets exit the path midway due to limited TTLs but the small packets travel to the destination while capturing important timing information. STAB has the potential to contribute to several applications including network management, load balancing, and anomaly detection [1]. The technique packet-tailgating provides the local information about segments of network paths. It uses special probe trains consisting of large packets interleaved with small tailgating packets.

4.4 Spruce
To measure the available bandwidth for end hosts, the tool Spread Pair Unused Capacity Estimate (Spruce) is used. It is based on the probe gap model (PGM) and it assumes a single bottleneck that is both the narrow and tight link along the path. It illustrates the arrival rate at the bottleneck by sending pairs of packets spread out so that the second probe packet arrives at a bottleneck queue before the first packet departs the queue. It then calculates the number of bytes that arrived at the queue between the two probes from the inter-probe spacing at the receiver. It is a light weight end-to-end tool. In [12], it- computes the available bandwidth as the difference between the path capacity and the arrival rate at the bottleneck. The Spruce method is using the equation 1 to calculate the available bandwidth,

$$A = C \times \left(1 - \frac{\Delta_{out} - \Delta_{in}}{\Delta_{in}}\right) \quad (1)$$

This formula is based on Probe Gap Model (PGM) and it exploits the information in the time gap between the arrivals of two successive probes at the receiver. A probe pair is sent with a time gap Δ_{in}, and reaches the receiver with a time gap Δ_{out}. Spruce computes the available bandwidth according to Equation 1, which requires 3 parameters: C, Δ_{in}, and Δ_{out}. Spruce assumes C is the capacity known, sets Δ_{in} at the sender, and measures Δ_{out} at the receiver. To improve accuracy of the estimate, Spruce performs a sequence of probe-pair measurements and reports the average.

4.5 IGI
The Initial Gap Increasing (IGI) algorithm uses a sequence of about 60 unevenly spaced packets to check the network and the gap between two successive packets is increased until the average output and initial gaps match. Similarly, PTR [7] relies on unevenly spaced packets but the background traffic is detected through a comparison of the time intervals at the source with those found on the destination side. The gap model illustrates that the initial probing gap is a critical parameter when using packet pairs to estimate available bandwidth.
The IGI algorithm sends a sequence of packet trains with increasing initial packet gap. The available bandwidth is obtained by subtracting the estimated competing traffic bandwidth from an estimate of the bottleneck link bandwidth. It uses a sequence of packet trains to identify the average input probing gap for which the average output gap is equal to the average input probing gap [5]. At that point, called the turning point, the measurement errors should be minimal and we can accurately estimate the amount of competing traffic on the bottleneck router.

4.6 Trains of Packet Pairs (TOPP)
In the packet train model, the traffic on the network consists of a number of packet streams between various pairs of nodes on the network. Each node pair stream consists of a number of trains. Each train consists of a number of packets going in both directions i.e., from node A to B or from B to A.

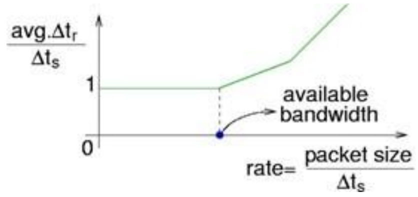

Fig 5: Bandwidth in TOPP

Whereas, Δt_s is a sender packet-pair spacing and Δt_r is receiver packet-pair spacing. Several cross-traffic effects on packet trains are used in TOPP. They are mirror effects, chain reactions and quantification effects. A smart probing technique which is used for monitoring end-to-end available bandwidth on the internet called Packet Train Pair, and its performance has been observed mainly with the estimation error and the amount of probing bits (see Fig 5).

5. Applications of bandwidth estimation
- Rate-based multimedia streaming
- Intelligent routing systems
- Content Distribution Networks (CDNs)
- Service Level Agreements (SLA) and Quality of Service (QoS) verification
- Network Management
- Traffic Engineering

6. Conclusion
Bandwidth estimation in end-to-end delivery is the most significant concept in video streaming. Several tools are used to compute available bandwidth based on Probe Rate Model (PRM) and Probe Gap Model (PGM). This paper discussed about some probing tools such as pathLoad, pathChirp, Spruce, IGI, STAB and TOPP. The tools Spruce and IGI are examples that use packet pairs. PathChirp uses packet chirps; TOPP, Pathload and PTR use packet trains. Comparing to these probing tools, IGI and Spruce are efficient to measure the available bandwidth in the network. In future work, I will use testbeds setup and evaluate these tools practically.

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