AVAILABLE END-TO-END THROUGHPUT MEASUREMENT TOOLS

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Summary

Various types of applications working in the network are sensitive to the amount of data transferred in a period of time, which directly influences their performance and end user satisfaction. In order to ensure that the network is capable of providing sufficient resources, end-to-end achievable throughput should be measured between two end nodes. A variety of tools have been developed for providing throughput measurement and most widely used out of them are evaluated in this work. General throughput measurement mechanisms are assessed, which is followed by evaluation of each of these tools, their advantages and limitations. A comparative analysis is performed in terms of accuracy, intrusiveness and response time of active probing tools. An overall conclusion is made for the applicability of these tools.

Keywords: throughput. Bandwidth. Active probing. TTCP. NetPerf. Iperf. Bwping. Pathchar. Pipechar Pathload. PathChirp.

1. Introduction

Throughput is defined as an average rate of successful data delivery between end nodes in IP networks. This data may be delivered over a physical or logical link, or pass through a certain network node. The throughput is usually measured in bits per second, and sometimes in data packets per second or data packets per time slot. Acquiring an accurate measurement of this metric can be decisive for achieving application performance and end user satisfaction. The available bandwidth is also a key concept in congestion avoidance algorithms and intelligent routing systems.

The available bandwidth measurement mechanisms can be divided into two main groups - passive and active measurement. The passive measurement is performed by observing existing traffic without disturbing the network. In order to gather flow information, a full load of the link has to be processed and access to all intermediary nodes in the network path needs to be performed. Good examples of passive monitoring protocol are NetFlow and Ipfix [1] Active measurement on the other hand, directly probes network characteristics by generating the traffic needed to perform the measurement. Although, the active probing mechanisms inject additional traffic on the network path, it is still more suitable to be used for end-to-end available bandwidth measurement. A broad variety of active probing techniques and tools have been developed and assessed.

An overview of available throughput measurement techniques is demonstrated and a comparative analysis of active probing tools is made for accuracy, intrusiveness and response time.

2. Terminology

Bandwidth is the speed at which a network device is able to forward packets. It can be described with two properties that are physical and available bandwidth, and both of them are independent of end nodes and protocol used. Physical bandwidth, or capacity (C), is the maximum number of bits per second a network element can transfer. The physical bandwidth of an end-to-end path is determined by the slowest network element along the path. Utilization (U) is the capacity percentage currently being consumed by an aggregated traffic on a link or path:

$$U = \frac{Traffic}{C}$$

Available bandwidth (A) is calculated by subtracting utilization over a given time interval from capacity. The following formula can be used for calculating available bandwidth on the path:

$$A(t_s, t_e) = \text{Capacity} - \text{Traffic} = C \times (1 - U) \neq A(T_{window})$$

$$T_{window} = t_s - t_e\ ,$$

t_s stands for starting time of measurement; t_e stands for ending time of measurement.

Throughput can be described as an amount of data that is successfully transferred from one host to another via a network. It can be limited by a hardware and software of every component along the path from source node to destination. Four different parameters are applicable in the context of "maximum throughput", which identifies the "upper limit" conceptual performance of multiple systems. They are "maximum theoretical throughput", "maximum achievable throughput", "peak measured throughput" and "maximum sustained throughput". They represent different aspects and when comparing different "maximum throughput" values, the same definitions must be used. If the path consists of several links in series that have different bit rates, the maximum throughput of the overall path is lower than or equal to the lowest bit rate. The link with the lowest value in the series is called a bottleneck.

A. Maximum theoretical throughput

This number is closely related to the channel capacity of the system, and is the maximum possible quantity of data that can be transmitted under ideal circumstances. In some cases this number is reported as equal to the channel capacity, though this can be deceptive, as only non-packetized systems (asynchronous) technologies can achieve this without data compression. Maximum theoretical throughput is more accurately reported to take into account format and specification overhead with best case assumptions. This value, as well as the term "maximum achievable throughput", which is described below, is primarily used as a rough calculated value, such as for determining bounds on possible performance early in a system design phase.

B. Peak measured throughput

The above values are theoretical values. However, peak measured throughput is a value measured by a real or a simulated systems. Throughput measurement value is calculated over a short period of time. Mathematically, this is the limit taken with respect to throughput as time approaches zero. This number is useful for systems that rely on burst data transmission.

C. Maximum sustained throughput

Maximum sustained throughput determines a value that is calculated and averaged over a long period of time. It is defined as the asymptotic throughput when the load is very large. In packet switched systems where the load and the throughput are always equal, the maximum throughput may be defined as the minimum load in bit/s that causes the delivery delay to become unstable and increase towards infinity. This value can also be used deceptively in relation to peak measured throughput to conceal packet shaping.

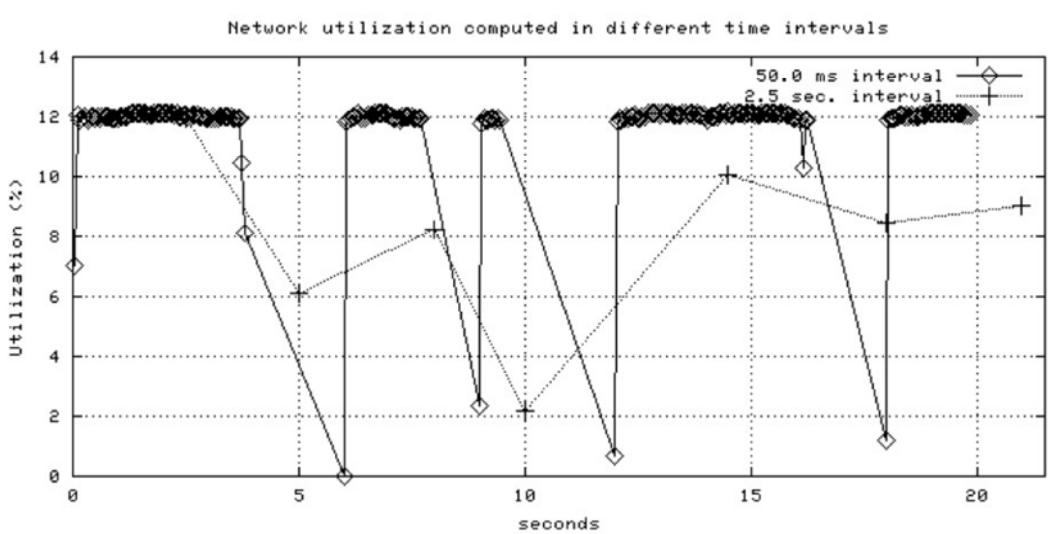

Fig.1. Available bandwidth at 2 different time intervals [2]

D. Maximum Achievable throughput

Maximum achievable throughput can be considered as an amount of data transferred between two end nodes under predefined conditions, such as a transmission protocol, end host hardware, operating system, tuning method and parameters, etc. These parameters represent a performance that an application in specific conditions can achieve. Since the bottleneck could occur in the end node, achievable throughput may or may not correspond to available bandwidth [2].
Determination of the available bandwidth strictly relies on the measurement time interval. Figure 1 gives an example, where the network utilization is measured with both 50 ms and 2.5s time intervals. However, the available bandwidth is not an indication of what an application can actually obtain. For this purpose, the achievable throughput is a more accurate measurement option.

3. Tools to measure throughput

TTCP, NetPerf, and Iperf

TTCP, NetPerf, and Iperf are all the tools which are used for throughput measurement. They use a measurement technique of large TCP transfers for distinguishing an available end-to-end throughput. A socket buffer sizes and therefore the maximum window size of the data transfer can be managed by a user. The tool TTCP has been known in industry for quite a long time. However, the measurement process has been enhanced by developing new tools as NetPerf and Iperf, which are able to manage multiple simultaneous transfers [3]. All of these tools involve an access at both end hosts, which can be a limitation in certain scenarios.

BWPing

BWPing is a tool for response time and bandwidth measurement between two nodes. It uses an ICMP protocol that is based on the echo request and echo reply mechanisms. The nature of this tool is relatively simple since it does not have any special requirements, only ability to respond to ICMP echo request messages.

On the other hand, BWPing has some certain requirements to the network infrastructure and to the performance of the end hosts. In particular, there should be no ICMP packet filtering along the path. The quality of service (QoS) mechanisms as packet shaping and rate limiting, should not be affecting the ICMP packets traversing each node along the path. Also CPU resource availability should be considered at both ends in order to be able to process the ICMP packets. The measurement results can be considered accurate only if all the criteria given above are fulfilled. To achieve an adequate bandwidth estimation results, the test packets should be matching the quality of service class of the application flows. BWPing is a very convenient tool for bandwidth measurement in a scenario where a far end node is out of the management domain.

Pipechar and pathchar

In order to identify a bottleneck of the path, another set of tools as Pipechar and pathchar can be used. They both give a similar performance results in identification of the bottleneck. However, it is important to distinguish that they are targeting different goals. Pathchar accurately reports characteristics of the bandwidth and packet loss of each hop along the path. On the other hand, pipechar identifies the slowest hop based on its interface speed. Therefore, the final test result of the segments beyond the static bottleneck cannot be considered as accurate. However, if the bottleneck of the segment is dynamic, pipechar will assess the slowest node and evaluate characteristics of rest of the links based on it. For instance, if we have five hops, and the third one is the slowest, pipechar testing results for all other segments in the path will be based on the speed of the third hop. This behavior can be used by the applications that use TCP protocol in order to adjust their window sizes [4]. A run time of these tools represents another important aspect which differentiates them. Let us take another example where a WAN path consisting of 8 hops is assessed. The basic pipechar operation can take up to 2 minutes, and the advanced one takes 3-4 minutes longer. However, pathchar can need much more time to do the same operation, sometimes even up to 1 hour. From this example we can see that pipechar is a good choice when the goal is to determine the optimal size of TCP window.

Pathload and PathChirp

Another tool for estimating end-to-end bandwidth of the path between two nodes is Pathload. The available bandwidth between two hosts represents the maximum IP-layer throughput that a flow can get along the path. This can be accomplished without decreasing of the rest traffic rate. Although, Pathload, which utilizes the SLoPS methodology [5], requires an access to both end nodes along the path, it does not require any superuser privileges since it only sends UDP packets. An estimation range is reported by Pathload rather than a single calculation. The middle point of this range is the average of the available bandwidth during the measurements. However, the range in turn determines a variation of the available bandwidth estimated during the measurement [4].

Another active probing tool has also been developed for estimation of the available bandwidth. It is pathChirp, which modifies the “self-loading” methodology of TOPP or SLoPS. This involves using different patterns of the probing packet stream, called a chirp. PathChirp increases the probing rate within each chirp, which provides sufficient information for dynamic estimation of the available bandwidth. The main advantage of using pathChirp comparing to pathload is similar accuracy with reduced measurement time [6].

4. Conclusion

IP networks do not provide explicit feedback to end hosts regarding the load or capacity of the network. Instead hosts use active end-to-end measurements in an attempt to estimate the bandwidth characteristics of paths they use. The ability to measure metrics such as link bandwidth and end-to-end achievable throughput is essential for high performance of an application. In this work, we presented latest tools and methodologies for such measurements and distinguished their advantages and limitations. As a result, such tools can be integrated into the application based routing system for the purpose of application performance monitoring and choosing a path with highest available capacity.

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კვანძთაშორის ხელმისაწვდომი გამტარუნარიანობის საზომი ინსტრუმენტები

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რეზიუმე

ქსელში მომუშავე ბევრი აპლიკაცია მგრძნობიარეა დროის ერთეულში გადაცემული ინფორმაციის რაოდენობის მიმართ, რაც პირდაპირ ზეგავლენას ახდენს მათ წარმადობასა და მომხმარებლის მომსახურების ხარისხზე. ქსელის საკმარისი რესურსების ხელმისაწვდომობაში დასარწმუნებლად საჭიროა კვანძთაშორის მიღწევადი გამტარუნარიანობის შემოწმება. ამ ამოცანის გადასაწყვეტად შემუშავებულია მრავალფეროვანი საზომი ინსტრუმენტები. სტატიაში განხილულია მათ შორის ყველაზე ხშირად გამოყენებადი ინსტრუმენტები. განხილულია გამტარუნარიანობის ზოგადი საზომი მექანიზმები, საზომი ინსტრუმენტები და აგრეთვე, მათი უპირატესობები და ნაკლი. გარდა ამისა, წარმოდგენილია აქტიური სინჯების სიზუსტის, მათი ქსელში ინტერვენციის და რეაგირების შედარებითი ანალიზი. გამოტანილია ზოგადი დასკვნები ამ ინსტრუმენტების გამოყენების შესაძლებლობებზე.

ИНСТРУМЕНТЫ ИЗМЕРЕНИЯ ДОСТУПНОЙ МЕЖ-УЗЛОВОЙ ПРОПУСКНОЙ СПОСОБНОСТИ

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Резюме

Многие приложения работающие в сети чувствительны к количеству информации передаваемой за единицу времени, что в свою очередь воздействует на их производительность и на качество обслуживания пользователей. Для того, чтобы убедиться, что сеть способна предоставить необходимые ресурсы, нужно измерять меж-узловую достигаемую пропускную способность между конечными узлами. Разработаны различные инструменты для измерения меж-узловой пропускной способности. Самые широко используемые из них рассмотрены в данной работе. Разобраны общие механизмы измерения, а также рассмотрены преимущества и недостатки этих инструментов. Проводится сравнительный анализ точности, уровня интервенции и времени реакции инструментов активных проб. В заключении рассматривается применяемость данных инструментов.