Internet Bandwidth and its Impact on Quality of Service and Quality of Experience

El Ancho de Banda de Internet y su Impacto en la Calidad de Servicio y Calidad de Experiencia

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According to Statista, Internet usage has increased to connect approximately 66% of the world's population [1]. Consequently, this growth of global users and an increasingly Smart society (Internet dependent), added to the increase in digital inclusion, continues to be a significant problem to be solved [2], [3]. For example, in Colombia, by 2023, the mobile Internet penetration rate will reach 86.09 per 100 [4].

The Internet has become an essential tool that has permeated all human activities [5], [6]. Therefore, it is necessary to keep your access active 24/7/365 of the year [7]. Consequently, there is a primary activity that allows the services offered through the Internet to be maintained actively. This activity is the <<monitoring>> of the operation of telecommunications links and equipment [8]. Monitoring telecommunication links and equipment allows you to know the status of the communication network, showing its speed, type of traffic, applications used, and undue access, among others. [9], [10]. This is measured in Quality of Service (QoS) and Quality of Experience (QoE) when using Internet services [11], [12].

To know the status of a communication network, several metrics are analyzed, such as link capacity, available bandwidth, lost packets, and interferences, among other metrics [13], [14]. However, the Available Bandwidth (Av_bw) is the metric that provides information on the status of a telecommunications link in real-time so that network and telecommunications service managers can make decisions for the optimization of the platforms that offer Internet services, thus improving QoS and QoE indicators[15].

For monitoring the status of telecommunication services, proprietary tools (paid) and others based on free software (free) can be used to monitor the behavior of telecommunication links and network services.

Among the proprietary ones is ManageEngine NetFlow Analyzer, the most widely used monitoring tool for network traffic analysis, which monitors users' bandwidth utilization by collecting data on metrics such as packet size and latency. [12]. Paessler PRTG [16] is based on a network monitoring system for better management and analysis of your infrastructure. PRTG monitors network traffic using Simple Network Management Protocol (SNMP) packets because it allows you to ensure complete monitoring of any network link. WhatsUp Gold (Applying ICMP Protocol (Ping); It will enable knowing the connection status of a network device and logging the device's connection on a website, which facilitates monitoring and generating alerts about possible problems with telecommunications connections or links [17].

On the other hand, tools based on open source, such as iperf, are multi-platform tools that actively measure the maximum bandwidth on a network link using IP. This tool can support TCP, UDP, and Stream Control Transmission Protocol (SCTP) packets in IPv4 and IPv6 versions. iPerf3 has been developed mainly by ESnet/Lawrence Berkeley National Laboratory and was released under a three-clause BSD license [18], [19]. Pathload is a tool designed for active end-to-end measurement of network links. Pathload allows the estimate of the Av_bw of a network path. The tool uses the unidirectional delays of a periodic flow of packets that show an increasing trend when the flow speed is greater than the available bandwidth [20].

Traceband [21] is a tool based on a technique called hidden Markov model for estimating and monitoring the Ab_disp. This tool evaluates the state of a network link from end to end. It offers performance metrics such as measurement time and overhead, allowing it to be used in different telecommunication scenarios. TraceTCP is a tool that estimates the Ab_disp using the active traffic of the TCP transmission control protocol in a computer network. The method uses the Probe Gap Model (PGM) estimation approach. It takes advantage of the advantages the approach must take in managing and obtaining the delays of the packet pairs when interacting with Cross-Traffic (CT). This method determines the Ab_disp without inserting packets into the network and working only on the Receiver side without intervening with the transmitter, obtaining an easy-to-use method [22].

Maintaining Internet access poses many challenges related to computer security (Availability, Accessibility, and Integrity) [23]. First, user requirements must be known regarding minimum throughput levels to provide optimal QoS and maintain QoE at high satisfaction levels. Second, by understanding those user requirements, administrators and analysts of telecommunication systems and services should use Av_bw monitoring and estimation tools with better accuracy to determine the status of telecommunication links. Finally, with the information on the status of network links, network administrators can detect improvement opportunities that optimize the performance of network services and network infrastructure management, both logically and physically.

Additionally, maintaining optimal services that comply with QoS standards (for example, [24], [25] state that to maintain a quality video call, it is necessary to have an Av_bw between 1.0 and 4.0 Mbps approximately) is the task of administrators, who must monitor, process and analyze the behavior of different network flows to make decisions about the current configuration (robustness and security) of telecommunications equipment and servers that provide access to different Cloud-based services (known as hardening). Consequently, on the other hand, users experience the changes made by administrators through QoE, which allows measuring the level of user acceptance of the service provided (for example, the optimal levels of a video streaming platform must offer connections of at least 1.0 Mbps in different network architectures, in addition to the improvement of buffering techniques [26], [27]).

Finally, novel network architecture based on virtualization of network services facilitates their management and optimization, such as Service Design Network (SDN) [28], Network Functions Virtualization (NFV) [29], and the future of Internet-based services Named Data Networking (NDN) [30]; which open a wide spectrum of challenges in the monitoring of telecommunication links, not only at the level of their physical and logical state but also in security aspects [23].

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