International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 04 April 2024
Page No: 715 - 733
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0102

Performance Evaluation of Congestion Control Algorithm in TCP/IP Differentiated Services During COVID-19 Pandemic Due to Heavy Surge in Real-Time Traffic

Sunil Kumar Kushwaha[1], Dr. Suresh K. Jain[2], Sourabh Dave[3]

[1, 3] Assistant Professor, Computer Science and Engineering, Medi-Caps University, Indore, Madhya Pradesh, India.

[2] Professor, Computer Science and Engineering, Medi-Caps University, Indore, Madhya Pradesh, India.

Emails: *sunilietkushwaha@gmail.com[1], suresj.jain@rediffmail.com[2], sourabh.dave@gmail.com[3]*

Abstract

Numerous nations implemented countrywide lockdowns because of the COVID-19 epidemic, which forced almost all peoples to remain at home. The imposition of confinement restrictions led to an increase in residential users' Internet traffic demands, particularly for distant work, entertainment, commerce, and education. This resulted in changes to the traffic patterns within the Internet core. In this research, we investigate the impact of the countrywide lockdowns on internet traffic based on dscp values by collecting data from class-A, class-B and Class-C ISP.(Three Class-A ISP, Three Class-B ISP and Three Class-C ISP) which leads to heavy congestion in the network and finally the performance valuation is carried out. The overall rise is exponential in nature, we notice that the traffic volume climbed by 15-30% almost in a quarter, which is a significant gain in such a short amount of time. Direct examination of the traffic sources reveals that, although hypergiants continue to account for a sizeable portion of traffic, there has been a greater increase in non-hypergiant traffic as well as in traffic from home-use applications like Web conferencing, VPNs, and gaming. Academic networks show significant overall declines whereas many networks, particularly those serving residential users, pharmaceutical companies, online interaction platform increases in traffic demands. However, we can see significant gains in these networks when we look at applications related to lecturing and remote working. The changes in the nature of use by customers show that there is a sharp difference in application pertaining to usage. Previous to this period, most usage is on YouTube, Facebook and google search. However, after this period most traffic diverted to online platforms such as zoom, google meet, Teams, and others as well as OTT platform comes into the picture. Over the past two decades, there has been a notable shift in user profiles. In the early 2010s, we saw most traffic was inclined on stored video and audio data in continuation with conventional traffic [23, 49, 66], which was followed by content delivery and streaming applications [7, 24, 35, 37, 52], and mobile applications [32, 67] in the 2010s. Even though user profile modifications are a moving target, they usually take years to complete. So, it was possible to stay current, for example, by measurements. The impact of this pandemic created chaotic conditions as most traffic migrated to real time surge data. Thus, the congestion management becomes more complicated as of previous challenges. The ISP forced to provide more bandwidth to real-time traffic which leads to overprovisioning. Thus, an efficient algorithm is required for managing such surge traffic which may especially meet real time traffic as required by most customers. This paper thus focuses on impact of after corona-19 pandemic effect, the shift of traffic by various users and applications the behavior of some existing algorithms in terms of congestion management and finally suggested a balanced method for managing congestion in such heavy surge traffic.

Keywords: *Corona Pandemic, Congestion, ISP, Good put, DSCP, Delay, Packet loss, RED.*

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 04 April 2024
Page No: 715 - 733
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0102

1. Introduction

Congestion is the biggest challenge in the field of networking since the day of inception. In order to manage the congestion a number of methods have been proposed by various researchers. The problem becomes worse after the corona pandemic as the requirement of users has been changed. In order to monitor the challenges and data analysis the drastic changes have been described in the paragraph mentioned below. Figure 1 shows us a notable evolution of traffic in 2020 from many Internet perspectives. The first lockdowns were implemented in mid-March (beginning on 3rd week) after the COVID-19 epidemic arrived in Southern India and moved to North very fast (week 4). As a result, we use the average traffic volume during the first 12 weeks of 2020 (the pre-lockdown period) to normalize weekly traffic volumes. It is evident that there have been significant shifts in the information gathered from various perspectives (see to Section 2 for specifics): in Central India, as well as at a significant IXP in rest part of India. The utilization rose gradually at first during the outbreak before increasing more quickly by over 20% once the lockdowns were implemented. [1, 2, 4] Several weeks after the lockout, the IXP on the India pacific region has shown a rise in traffic that is behind other data sources. Although we witness this behavior from the perspectives of the ISP and the IXP, there is one distinction between the two: the maximum demand of the local network i.e. by the ISP compare to IXP rapidly declines towards July, the relative traffic growth at the IXP appears to last longer. This is in line with the economy's initial partial opening, which includes the reopening of local stores, Universities, and few offices in the middle of July and additional relaxations including the opening of schools in a second wave in October. Our results are consistent with Google's mobility reports [30] and reports from Akamai [42, 43], Comcast [18], Google [31], Nokia Deep field [36], and Tele Geography [14] regarding the rise in digital demand. The significant rise in traffic forced ISP to either increase the resources in Terms of bandwidth or to restrict users within the stipulated resources. The biggest challenges arose as users' demands have made a shift from conventional data traffic or prerecorded video to more real time videos. Also, requirement migrates in terms of entertainment from satellite programs to OTT platforms which get supported by internet services.

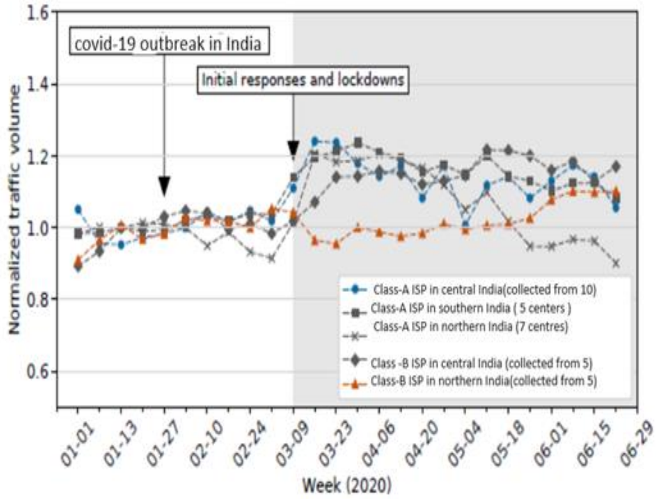


Figure 1 Evolution of Traffic on a Study of Five ISP

All such demand leads to heavy congestion in the network. We had not focused much on the existing multiple algorithms used for congestion management but dealt with algorithms which were designed and implemented for real time traffic control.

1.1. Significant Change in Usage Trends

Given the worldwide COVID-19 pandemic, an increase in traffic is to be expected overall. The precise ways in which consumption patterns are changing—for example, during the working days more traffic is on real time video while on weekends and in night hours customers more demands recorded video i.e. OTT platforms. In order to achieve this, Figure 2 displays the weekly traffic patterns observed in Universities, IT sectors, pharmaceutical Industries and rest users. Weekend traffic patterns on the Internet diverge greatly from ordinary workday traffic patterns [33, 38, and 26]. Figure 3 illustrates how traffic peaks during the workday are focused in the evenings. To be more precise, we refer to a pattern of the traffic as a workday pattern if it peaks in the early night to late night and as a pattern generated for

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 04 April 2024
Page No: 715 - 733
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0102

a week if its primary activity picks up a lot of steam between 9:00 and 11:00 am.

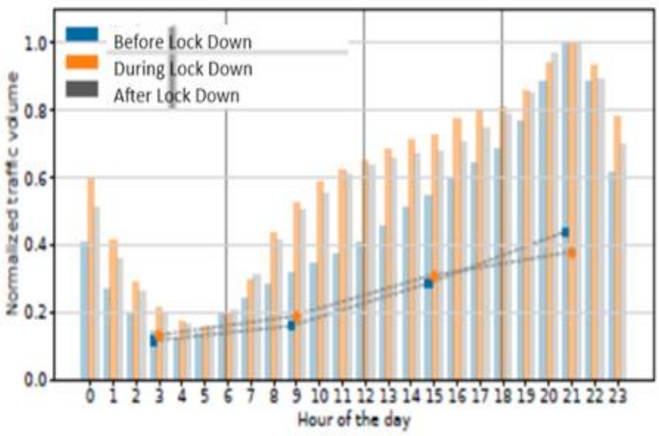


Figure 2 ISP-Gateway: Hourly traffic increase and workday vs. weekend pattern for Before Lock Down, During Lock Down and after Lock Down

We employ an aggregation level of 8 hours and labelled data from mid-2019 for our categorization. Next, we utilize this categorization for every week in 2020 that is accessible. The bars are colored green if the classification matches the current day (weekend or workday); otherwise, they are colored Red. We discovered that most workdays are classified as workday-like days until mid-March, whereas the majority of working days are classified as vacation-like days. Following the implementation of the confinement measures, this pattern radically changes: You could call almost every day a weekend. Given that many individuals are staying at home for various reasons, such as working from home, receiving remote education, engaging in online social activities, or consuming entertainment content, which generate the question of the reason for such notable increase in traffic and change in habits. [29] A growth in hypergiant traffic may be implied by the rising need for entertainment, such as gaming and video streaming. This is in line with a remark made by an NASSCOM advisor, according to which big streaming services started decreasing the resolution of video transmitted to a lower value composition from March 19, 2020 [19, 48]. Around May 12, 2020, some began to enhance their services as well as picture quality to 4K, according to mainstream media [27]. ISP-Gateway: A fixed period traffic increase and workday vs. weekend pattern for Before Lock Down, During Lock Down and after Lock Down. Additionally, the requirement for remote work can mean a rise in the need for cloud, video conferencing, email, and VPN services. The paper emphasizes on the impact of essential lockdowns made by Government of India on the Internet through network data analysis from three ISPs situated in Central and Southern Asia, India, and a large Central Region ISP (ISP-CE), as well as a Central Education University (CEU). This makes it possible for us to investigate the COVID-19 pandemic's effects from both the Internet core (IXPs) and network edge (ISP-CE/EDU) in an all-encompassing manner. The surge generated during this lockdown, which was unexpected by ISP as well as NXP leads to heavy traffic which further leads to congestion in the network. The existing protocols were designed to manage routine traffic but failed to manage and control the emerged congestion problem. Our findings show that: Relative traffic volume changes in response to changing user behavior, resulting in "moderate" increases of 15-20% for the ISP/IXPs during the peak of the lockdown, but declines of up to 55% at the CEU network. The research paper is organized into five sections. Section-I illustrates the datasets collected from various resources. Section-II focused on multiple services used during the pandemic period. Section-III defines the various classes and the traffic shift from conventional one. Section-IV focuses on the traditional methods used for congestion control, their comparison during various time period and its failure on the recent surge. Section V highlights the new algorithm proposed to manage the surge likely to be occur in future under such circumstances.

2. Section-I

Weekend-like traffic patterns are replacing daily patterns

Demand for online entertainment explains the hypergiant traffic increase. However, the necessity of remote working results in a greater than 200%

increase in the day-to-day necessary required information, such as VPN and real time conference software. Simultaneously, other traffic classes saw a significant decline in traffic share, such as traffic pertaining to social media, education, we note an increase in port utilization at the IXP-level. The primary explanation for this phenomenon is an increase in traffic demand from residential customers. Diverse variations in traffic occur; certain network ports see an increase in traffic, while others see a decrease. One instance of the latter is the EDU network, where we see a maximum decline of up to 35% in traffic on gateways especially on workdays following the easing of the lockdown measures. However, there is an increase in incoming traffic for things like email and VPN connections when lecturing and working remotely. The CEU traffic shift contradicts other vantage points' observations while also complementing them.

3. Datasets

In order to compare the traffic in a real scenario a number of resources were taken consisting of Class-B ISP, Class-A ISP and some International Service Providers. Also, the traffic measured is at various time periods. All such data resources are taken into consideration and used for investigation in this section. The network originates from a major ISP in Central Southern India especially from Bangalore, Chennai and Hyderabad that serves over 30 million fixed line customers and runs a Tier-1 transit network. Although the ISP does not own content delivery servers on its network, it has numerous peering arrangements in place at various locations with all the main cloud and content delivery networks. This ISP supports its internal operations at all border routers with Net Flow [13]. In this paper, we believe in two distinct sets of Network Flow records. First, we analyze the effects of shifting subscriber demands using Network Flow data gathered at ISP Border Network Gateways [12]. After this the traffic is analyzed, differentiated as per dscp value and further analyzed. Second, in order to better understand how businesses operating their own ASNs are impacted by these changes, we leverage Net Flow records that are gathered at the border routers of the ISP. Three main Internet exchange points (IXPs) provide a public peering platform via which networks flow. The first one is in Central Southern Asia (IXP-CE), has more than 1500 members, and experiences more than 20 Tbps of peak traffic. The second one is situated in India Pacific (IXP-IP), having more than 400 sub providers, and reaches a maximum traffic rate of almost 2500 Gbps. It encompasses the EDU network's territory. The last one, called IXP-India, is situated on the India Central Region, has 400 members, and can handle more than 1600 Gbps of peak traffic. We use IPFIX data at the IXPs [16]. EDU: Network traffic originate from the academic network RED Imadrid [53], which links sixteen separate universities and research facilities in the Central India. It provides services to around 290,000,000 people, including researchers, professors, students, student residence halls, administrative and support personnel, and Wi-Fi networks. The network operator gave us access to anonymized Net Flow data that was collected over a 200-day period, from March 19 to Sep 8, 2020, at their gateway routers (all ingress interfaces). 25.2B flows entering or departing the educational network are included in the final dataset. We supplement our findings using Net Flow information from a major Central Southern India and mobile operator serving over 400 million users.

Normalization: The data collected were normalized in order to make it easier and further to compare because the traffic characteristics and volumes vary greatly throughout all the data sources. We use the minimal traffic volume to normalize the traffic for plots that only display specific weeks. Depending on the data availability, we normalize the traffic for plots covering a longer time period by using the data collected during the first twelve weeks of 2020 while calculating the average value.

Time interval: To account for the changes that have occurred since the start of the COVID epidemic, we employ two techniques: (a) we collected average data from January 1, 2020, to Aug 14, 2020, for broad trends across time. (b) Based on Table 1's comparison of 7-day intervals from before, during, and well after the 2020 lockdown, we are able to highlight specific developments. All data analyses are carried out on routers/gateways housed at the ISP end, IXP, as well as university network facilities in order to protect user privacy. To stop the transfer of raw data and information leaks, IP addresses are hashed. The combined statistics that are shown in the paper are the results of the analysis. As part of their regular network examination, the ISPs and IXPs gather data. We got network admin approval from the relevant institutions in order to gather and analyze the academic network data (EDU). According to Ministry of Telecom and Information Technology, the usage in India's internet use increased by 15% during the week starting on March 22. The country's population used 680 petabytes (PB) or 680,000 terabytes (TB) of data per day on average. This increase in internet usage was attributed to the statewide lockdown implemented to contain the spread of Covid-19. The two states with the biggest increases were Andhra Pradesh and Bihar, where there was a 12% increase in each. The rise was 7% in Maharashtra, the state with the highest data consumption during the lockdown. According to the Operators Association of India (COAI), operators saw a 30% increase in traffic during the third week of March, with the majority of the traffic coming from users streaming movies. The latest data on Covid-19's influence on global internet access performance, posted on April 15, from Speed Test, a website that studies internet access performance worldwide, indicated a 16% reduction in fixed line speeds and an 18% decline in cellular network speeds when compared to the week of March 2. We examine how the lockdown affected application traffic from two perspectives: the ISP in Central Southern India (ISP-CE) and the IXP in India (IXP-CE). We compile traffic volume data from Sixteen weeks at both networks, as shown in Table 1. We record individual traffic volume statistics for each hour of the day and compare them to the corresponding day and hour of the preceding month to detect trends throughout the day and, more significantly, variations within them.

Table 1 A Synopsis of the Dates Utilized for the Analysis Each Week. In Central India, Dates Varied Because of how the Pandemic is Progressing

	Class-A1 ISP	Class-A2 ISP	Class-A3 ISP	Class-B1 ISP	Class-B2 ISP
Oct 2019-Feb 2020	Jan 10-20	Jan 10-20	Jan 10-20	Jan 10-20	Jan 10-20
March-June 2020	April 10-20	April 10-20	April 10-20	April 10-20	April 10-20
July-Oct 2020	Aug 10-20	Aug 10-20	Aug 10-20	Aug 10-20	Aug 10-20
Nov-Feb 2021	Dec 10-20	Dec 10-20	Dec 10-20	Dec 10-20	Dec 10-20

For every viewpoint point, we plot the most important transport ports. Any slight variations in the volume of traffic at the ISP-CE and IXP-CE, which are dominated by the two most popular ports, TCP/443 and TCP/80, account for 85% and 65% of traffic, respectively, in the plot. Take note that we combine into a single subplot the hours of daylight on each of the seven working days in a week. Although the top ports on the two networks are identical, their distributions and how these distributions evolve over time are extremely different. Next, in order to more precisely attribute general changes in diurnal patterns, we conduct a detailed analysis of individual ports:

4. Section-II

QUIC: QUIC is mostly used for streaming by

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 04 April 2024
Page No: 715 - 733
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0102

companies like Google and Yahoo, and it runs on port UDP/443 [55]. When QUIC traffic volumes are compared to the base week of April and May, there is an increase of 25%–75% at the ISP-CE and roughly 60% at the IXP-CE. The ISP-CE experiences the biggest spike in the early morning hours as well as in evening hours after the lockout is implemented. Additionally, the increase is spread out more gradually throughout the day at the IXP-CE. This is probably how whole families who choose to stay at home behave. The traffic volumes on QUIC are largely consistent in April and July, with certain hours seeing an increase in traffic and others seeing a decrease.

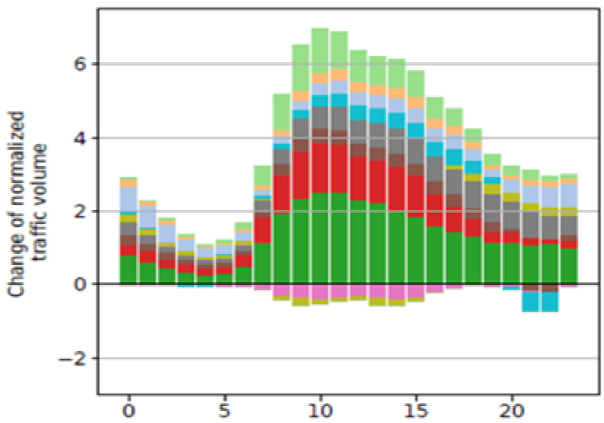


Figure 3 ISP A/B Traffic Difference by Some Most used Ports: Hourly Difference in Normalized Aggregated Traffic Volume Between Workdays of March, June, Aug and Dec

NAT traversal / IPsec / OpenVPN: The default port for OpenVPN is UDP/1194, while port UDP/4500 is registered with IANA for IPsec NAT traversal and is frequently utilized by VPN systems. There has been a rise in the usage of VPNs to access corporate or academic networks by remote workers, as seen by the rise in both ports at the two vantage points in March. While OpenVPN's traffic decreases, UDP/4500's traffic volumes remain higher than those of the February base week in the ensuing weeks of April and June. It's interesting to note that during the lockout in March, GRE and ESP traffic—which carry the real IPsec VPN content—decrease at the IXP-CE, whereas GRE traffic at the ISP-CE slightly increases.

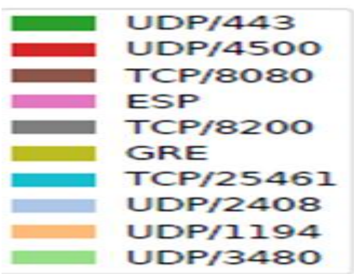
In conclusion, more people are utilizing VPNs from their homes, which raises the demand for NAT traversal. However, over time, VPN connections between businesses—which are the main source of GRE and ESP traffic—become less common.

Streaming TV: Similar to QUIC, we may observe how changes in user behavior impact the traffic profile on port TCP/8200 at the IXP-CE. An internet streaming service for OTT TV channels uses this port. April 2020 is marked by a shift in the traffic profile away from an evening-centric one, with higher traffic volumes observed throughout the day. This is mostly seen at IXP-CE, where a larger and more global clientele is served. Furthermore, the significant growth that occurred in March is not continuing into the subsequent months.

Cloudflare: The CDN Cloudflare uses port UDP/2408 for their load balancing service [17]. We confirm that Cloudflare prefixes are the source of the traffic.

We observe that in March and June of this year, there is a spike in Cloudflare load balancer traffic at the IXP-CE.

Using video conferences: Port UDP/3480 is used by both the online collaboration platform Microsoft Teams and the video communication tool zoom, Google Meet, Skype, most likely for STUN reasons [44, 45]. We validate this by confirming that the addresses are located within Microsoft-owned prefixes. Furthermore, a tiny percentage of non-Microsoft addresses can be seen in our data.



We observe a significant spike in UDP/3480 traffic at the IXP-CE during the March lockout, particularly during business hours on weekdays. It is not displayed among the top 12 transport layer ports at the ISP-CE. Companies can use Zoom, an additional video conferencing option, to transport all meeting

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 04 April 2024
Page No: 715 - 733
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0102

traffic through its on-premises connector, which operates on UDP/8801 [20]. From February to April, the ISP-CE experiences an order-of-magnitude rise in this traffic. Zoom's quick rise in popularity in Southern Asia can be attributed to the lockdown, which made it necessary for businesses to install connectors in their local networks in order to embrace a new application. These alterations serve as further evidence that the Internet traffic profile is altered by remote workers. August sees another decline in Zoom traffic, which may potentially be attributed to fewer online workplace meetings during the holiday [46].

Email: We observe a 60% rise in TCP/993, which is utilized by IMAP over TLS to retrieve emails, at the ISP-CE, particularly during business hours. Even though there isn't as much traffic overall as there is with other services like QUIC, it's still a sign that more individuals are using their homes as their primary place of business communication. Unknown port TCP/25461 could not be mapped to any existing protocol or service. The majority of addresses that use this port are part of hosting company-owned prefixes. In summary, we see notable alterations in the traffic pattern for a few well-known transport-layer ports from both perspectives. This demonstrates how the distribution of traffic is affected by significant shifts in human behavior throughout these weeks. Traffic pertaining to work, and amusement has increased, which is consistent with the lockdown where individuals were required to work and learn from home. The notable change in workday patterns from February to March, when the lockdown started, particularly at the ISP-CE, lends credence to this reasoning. In contrast to the consistent increase seen throughout the entire day in February, the traffic levels, which are primarily made up of residential consumers, climb sharply in the morning as more individuals choose to stay at home [41].

5. Section-III

We now offer a more thorough study of traffic shifts for various application classes, building on the raw port analysis discussed in the preceding section. This is particularly important for traffic that uses protocols like HTTP(S), where a variety of applications and use cases can be concealed by a single transport-layer port number. We use a traffic classification based on a combination of transport port and traffic source/sink criteria to look into application layer traffic shifts. We specify over 50 combinations of transport port and AS criteria in total, drawing from public datasets [47, 51], product and service documentations [11, 28, 44, 45], and scientific research [6, 15]. We combine the filtered data into eight significant application groups that correspond to the daily apps that end users utilise. Web conferencing and phone service (Web conf) includes all of the main suppliers of conferencing and phone service. Online collaboration tools are captured by collaborative working. Email communication is quantified, major video streaming services are covered by Video on Demand (VoD), Major gaming providers' traffic is captured by gaming (cloud and multiplayer), Content Delivery Networks (CDN) categorizes content delivery traffic, Social Media collects traffic from the most relevant social networks, and Educational focuses on traffic from educational networks. It should be noted that social networks, like Facebook, also provide content distribution and video telephony services for their own goods, which might fall under this class but not the more focused other classifications. The IXP-SE perspective of the Gaming class is shown in Figure 4.

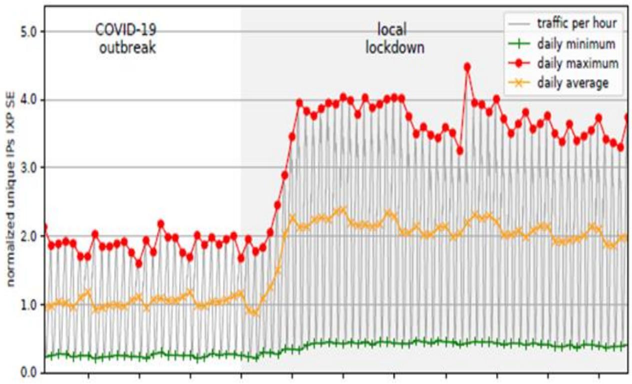


Figure 4 Playing Games both Before and After the Lockdown

Both the number of IPs and traffic volume have sharply increased

We have filtered data from five gaming software/service providers and 57 common gaming transport ports in different combinations for this application class. After that, we employ two metrics to examine the variations in usage behavior: (1) the traffic volume, which allows us to approximate the order of homes, and (2) the number of distinct source IP addresses. When comparing multiplayer and cloud games before and during the shutdown, Figure 4 clearly demonstrates the changes. Following the local government's lockdown in week 10, there was a significant increase in both the delivered quantities and the number of unique IPs observed in the trace, with notable increases in the daily minimum, average, and maximum values. During the first lockdown week, there is a notable two-day drop in the accounted volume to the lowest values recorded during that period. We were able to confirm that this isn't a measuring error. Rather, the decline is associated with a major gaming provider's outage, which could be connected to the unexpected rise in players. We classify applications for the ISP-CE and the various IXP vantage points (IXP-SE, IXP-CE, and IXP-US).4 the vast amount of information is presented clearly by transforming the data in the manner shown below. Comparing the several stages of the COVID-19 measures as they were implemented across Southern India over a period of three weeks, we center our analysis on four weeks, a base week that occurred well in advance of the lockdown. Applications connected to communication: From every angle, Web conferencing applications exhibit a sharp rise of over 200 percent during business hours, and at the ISP-CE, IXP-SE, and IXPUS on the weekends as well. The ISP-CE in this category grows at the fastest rate during the whole day in March, immediately following the lockdown. This tendency is less noticeable in June, when individuals are gradually returning to their offices. At the ISPCE, we observe a significant increase in collaborative working on Thursday and Friday mornings that lasts until June. This may be because work partners coordinate ahead of time. Collaborative working is most prevalent at the ISP-CI and the ISP-SI. We observe a significant rise at the ISPCE on Thursday and Friday mornings that lasts until June; this could be because of work coordination. Partners prior to the weekend. In a state of lockdown, one may anticipate a great deal more email correspondence, we observe a distinct tendency. Email truly declines at the IXP-CE and IXP-SE. stays lower than it was in June and during the lockdown. Prior to the lockdown. Email, however, ascends at the ISP-CE it, but not as high as other traffic categories like online meetings. One potential a possible cause is that a lot of businesses begin connecting their virtual private networks (VPNs) and users for distant workers use the VPN to connect to the mail systems. Applications connected to entertainment: The use of VoD streaming applications is increasing at a high rate of up to 100% at Central-India IXPs. It's interesting to see that ISP-CE only has a 10% increase in traffic during the shutdown, but in June—long after the lockdown—traffic volume returns to its February level. Remember that by mid-March [48], the biggest streaming services in Central-India had lowered their streaming resolution for a 30-day period. Regarding the ISP-CE, which includes the week of March in addition to the week of April.5. In the United States, the trend is reversed. Notably, the measurement of the VoD class at the IXP-US may be biased because it is based on just three ASes, one of which is particularly large. As a result, the decline might be the result of a major AS's traffic engineering choice, such as setting up a private network link rather than peering. Particularly during the day, the robust growth of gaming applications is more consistent from all three IXP perspectives. Even though the ISP-CE increases significantly in the morning, it normally tends to decline. Keep in mind that the abnormally high traffic levels in this category in February are the primary driver of this effect. Previously limited to usage on the weekends or in the evenings, gaming apps are now available anytime, anywhere. In June, the trend begins to level off; this could be related to people taking more time off or going on vacation. Furthermore, during the week of March, we observe a rise in traffic to social media applications at the IXPs; however, this effect quickly fades in April. The ISP grows by 74% in March and remains high till June then gradually slows down in July, though not

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 04 April 2024
Page No: 715 - 733
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0102

as much as at the IXPs. The results in this class are consistent with the progressive relaxation of lockdown regulations throughout Central-India: as people are free to return home and engage in social activities, there is a decline in traffic. From every angle, social media usage in June is back to levels that are marginally lower than those of March. Other apps: From every angle, educational networks and applications operate entirely differently. As would be expected for students who attend classes from home, traffic at the IXP-CE stays rather steady, but at the ISP-CE, it jumps sharply by up to 200%. The fact that certain Central-India school networks offer video conferencing could be the reason for this growth. We exclude this category at this time since the IXP-India does not have any associated educational networks Similarly, CDN traffic rises but does not increase in Central-India. Considerably in the US—even occasionally declining. At the vantage point, there is a skewed distribution of CDNs, much like with VoD. In summary, more applications connected to communication are used during working hours, particularly for Web conferencing. Applications linked to entertainment, such gaming and video on demand (VOD), are also used throughout the day as demand for them increases during lockdowns. Social media has a sharp rise at first, then gradually declines. These insights reinforce and supplement those mentioned in Section 4. When taken as a whole, they show the enormous influence that the COVID-19 pandemic's profound behavioral shift.

6. VPN Traffic Shift

In reaction to the corona pandemic, a lot of companies requested that their staff members work remotely. Using VPN services is a common method of connecting from home to internal company infrastructure. We therefore anticipate a spike in VPN usage following the lockout [40]. Categorization based on ports. We use two methods to determine VPN traffic. The only significant VPN protocols that we concentrate on detecting TCP/443 VPN use. However, as many VPN services tunnel VPN traffic using TCP/443, this traffic cannot be distinguished from HTTPS using a pure port-based identification approach. We remove candidates from our list if the *vpn* domain's returned address matches the www domain's address. This method restricts the misclassification of web traffic intended for the www domain as VPN traffic to the *vpn* domain in cases where the IP address of the two domains is shared. We are left with 1.7 million potential VPN IP addresses after eliminating shared IP addresses. Traffic sent to these VPN addresses over TCP/443 is categorized as VPN traffic. VPN usage is increasing. We provide our results utilizing the port-based and domain-based VPN traffic detection methods in Figure 5 and 6. We aggregate four weeks of traffic data into workdays and weekends from the IXP in Central Mid India. It's interesting to see that port-based VPN traffic virtually stays the same before and after the lockout.

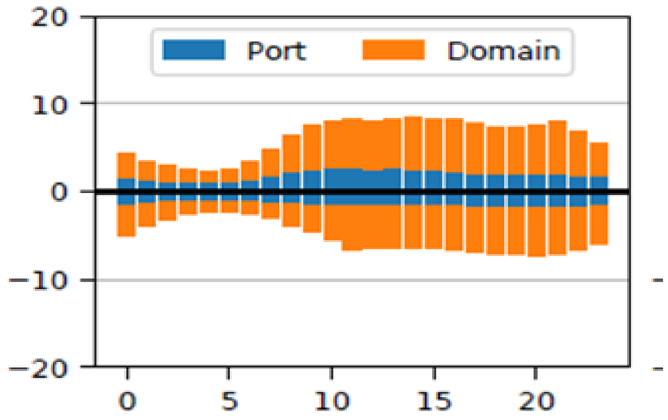


Figure 5 Weekly Study in March 2020

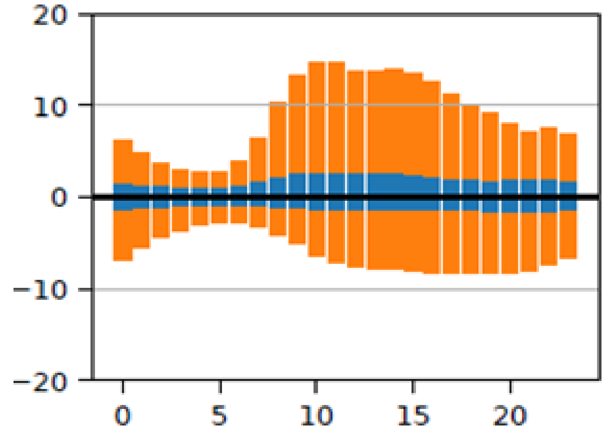


Figure 6 Weekly Study in July 2020

Weekend increases are not as noticeable as daytime increases, which suggests that modifications in user

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 04 April 2024
Page No: 715 - 733
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0102

behavior—such as people working from home—are the cause of these traffic swings. Though not as much as in March, we nevertheless observe an increase in VPN traffic throughout the week of April as compared to February. Although there is a further decline in VPN traffic in June when compared to prior months, the usage of internet services during Monday to Friday is still significantly higher than what was seen during the base week of February. There were presumably less persons working from home in Aug than in March because of the gradual easing of lockdown restrictions in India and the start of the summer vacation season. In conclusion, we observe a distinct trend of increased VPN traffic during business hours as a result of lockout limitations. Additionally, since the discernible rise in VPN traffic was restricted to TCP/443 on *vpn* domains, we contend that identifying VPNs purely based on transport ports significantly underestimates the amount of real VPN activity. We suggest leveraging domain data to distinguish ostensibly HTTPS flows from VPN traffic in order to lessen this issue. This makes it possible to get a more realistic view of the VPN market.

7. Educational Network

This part of research examines the significant alterations brought about by the lockdown measures, as observed by a vast Southern Asian educational and research network that links sixteen separate universities and research facilities inside the Madrid metropolitan area. The regional government declared on March 9, 2020, that the whole school system will close on March 11 in reaction to the epidemic. Users of this network, including instructors, staff, researchers, and students, were thereby compelled to modify and go on with their research and teaching from home. The only personnel permitted on site were those needed for security and essential maintenance duties. The nationwide state of emergency was proclaimed shortly after, on March 13, and it went into effect the following day. Analysis of traffic volume. We compare three crucial weeks to examine how the lockout measures affected the amount of traffic at the academic as well as home network: Four weeks were used: (1) the week before the corona pandemic specially effecting home network, as well as educational University (from 1st week of February to third week of March), which served as a baseline; (2) the time period during the lockdown (March third week to June mid-week), which allowed for the observation of the transitioning effect; and (3) the last time period during which the lockdown was withdrawn by government of India during which most universities switched to fully offline lectures[49]. The normalized total traffic volume for the three weeks under consideration. Between the baseline week and the other two weeks, we see a notable decline in the volume of traffic on working days, with a maximum decrease of up to 55% on Tuesday and Wednesday. On the other hand, there was a minor rise in traffic on the weekends: 14% on Saturday and 4% on Sunday. Given that fewer people are utilizing the academic network on campuses and in research facilities, the decrease in traffic during the workday is anticipated. Once more, we see that the overall amount of traffic on work and weekend days is getting more comparable. This might be the outcome of a new weekly work schedule that lessens the distinction between the two kinds of lockdown-related days. Comparably, a detailed examination of the hourly traffic pattern shows that between 9 p.m. and 7 a.m., traffic increases from 11% to 24%. The reason for this could be attributed to users working at odd hours more often, but it could also be caused by international students who use these resources from home (mostly from Latin America and East Asia, as indicated by the AS numbers from which these connections originate).

Analysis of the traffic in/out ratio. The traffic ratio for ingress against egress, demonstrating a significant shift in the ratio following the lockdown has been studied. Before the shutdown, during workdays, the amount of incoming traffic may be up to 15 times more than the amount of exiting traffic. The ratio halves during the transition phase, reaching its lowest point during the third week of online lectures, when the weekend vs. workday trend is no longer discernible. The nature of remote employment explains this shift in traffic asymmetry. The rise in outbound traffic can be attributed to users connecting to the network services primarily to access resources. Analysis at the connection level. We conduct a connection-level analysis, concentrating on particular traffic classes, to gain a deeper understanding of the traffic movements. We use the AS numbers of all endpoints, interfaces, and port pairs to identify if the connections are inbound or outgoing. An "incoming" connection, for example, is one that is made from a home internet provider to an HTTPS server that is located within the school network. 39% of the flows at this academic network, many of which seem to be P2P-like applications, rudimentary protocols, and unknown port numbers, for which we are unable to reliably detect the directionality. Comparing the pre-lockdown baseline (ratio of median daily connections before and after March 11, 2020) to the total number of connections following the state of emergency proclamation, the median number of connections increases by 24%. The typical variations between workdays and weekends also diminish, but they are still discernible over the Easter holiday [50]. When examining the directionality of the connections, we see that following the lockdown, the median number of incoming connections doubles while the number of outbound connections is nearly half. This confirms the findings from the volumetric study and is a direct result of users needing to access services hosted at academic networks from the outside. There was a significant change in the traffic observed for both uploading and downloading internet services, as was indicated in the volumetric study. Although there is still a discernible shift in the typical working hours, such as a decrease in connections at lunch, a sizable portion of users now access these services both late at night and early in the morning following the COVID-19 epidemic. Time zone variations are actually apparent. From 10 a.m. to 9 p.m., national users can access university-hosted web resources, with a valley between 2:00 and 4:00 p.m. Users from Maharashtra, Delhi, Rajasthan begin to join about 5:00 p.m. displaying a peak from 7 P.M. to midnight (the peak hours are 8 and 9 P.M. It's interesting to note that although the time trends for VPN, web, and SSH traffic patterns are erratic, and remote desktop are associated Conclusion. Academic networks see sharp changes in traffic patterns because traffic volume, directionality ratios, and source in relation to COVID-19and destination have drastically changed since COVID-19. This behavior is opposite to the one seen yet complementary to it in ISPs for homes.

8. Section IV

8.1. Congestion Management

The problem of congestion is since day of inception of network and will remain forever, however the techniques to manage the congestion needs to be change as per requirement. The definition of congestion has not yet been defined by anyone; however, the best definition says that it is prospective of the user. Whenever a user experience slow browsing in the network one may conclude that the network is congested. The interesting thing is that the management of congestion is not under the control of user. The management is getting carried out at ISP end or by the management devices mounted at either ISP end or user end. The first algorithm proposed by Van Jacobson which is getting used till date in number of domains state that whenever congestion occurs slow start exponential growth will take place which manages the traffic to a large extent. From this algorithm to till date a number of algorithms has been suggested and implemented out of which some are listed below: -

1. Random Early Detection (RED),
2. Adaptive RED (ARED),
3. Gentle RED (GRED),
4. Adaptive GRED (AGRED),
5. Dynamic GRED (DGRED),
6. Best Linear Unbiased Estimator (BLUE),
7. Dynamic threshold-based BLUE (DT BLUE),
8. GREEN,
9. Adaptive CHOKE,
10. ERED,
11. Subsidized RED (Sub RED)
12. Non-linear Random Early Detection (NLRED)
13. Reconfigurable Non-Linear Gentle Random Early Detection (RNLGRED) and many more [6].
14. CUBIC (Cubic Binary Increase Congestion control)

The problem with all such algorithm is that they were define and designed for the statistic which was happened in past but none of them were designed for the surge traffic generated during Corona pandemic and traffic which may likely to happen in forthcoming days if such scenario may generate. Thus, in order to manage such heavy unpredictable traffic, especially which may consume more bandwidth with less latency and jitter a real time self-adaptive algorithm is proposed which may manage the above-mentioned problems. An analysis of five existing algorithms has been carried out based on certain parameters and based on data collected from various resources as well as through Wireshark Version 4.2.2 (v4.2.2-0-g404592842786) a comparative study has been carried out. After analysis using data before corona pandemic period, during the pandemic period and after the pandemic it has been concluded that most of the ISP fails to support the requirement of the customer during the pandemic period. The congestion control algorithm did not support the problem that occurred due to surge traffic generated during the period. For this experiment data available at https://www.statista.com and is made publicly for research and analysis purpose has been used. The comparison of some working protocols has been carried out under this scenario. For this the ISP routers, Gateways, Firewall or UTMs were used which were using various protocols for management of congestion [51]. It is also found that most of the devices were using static as well as predefined algorithms which show different results during, previously and after the pandemic period. We used a fixed delta value in our first test, which was a competitive mode-free implementation of Computer Operating and Programming Assistant (COPA). The findings below, which we evaluated with the CUBIC and BBR [53] v1 congestion control algorithms, show that a delta value of 0.06 offers a suitable quality vs. latency trade-off for the application. Linux's default congestion control method, CUBIC, is widely used. It increases CWND until packet loss occurs, at which point it backs off by multiplicatively decreasing CWND. However, it has certain known problems, notably buffer bloat, which causes latency, and the saw tooth-like, erratic transmission pattern it offers. Google's more recent BBR algorithm modifies sending rate to find the ideal balance between bandwidth and delay after modelling the network path using bottleneck bandwidth and RTT. In our QUIC (Quick UDP Internet Connections) implementation, all three implementations (COPA, CUBIC, and BBR) are available.

9. Results

The bulk of sessions for Facebook Live videos came from the United States, Mexico, India, Indonesia, Vietnam, and Thailand. We conducted A/B testing to evaluate the effectiveness of Facebook Live videos from all over India. We concentrated on the following application metrics for every video in our experiments: Total application bytes transferred during broadcast divided by broadcast duration yields the average good put. Please be aware that Facebook Live sessions can last anywhere from a few seconds to several minutes, and that the program modifies bit rate based on queue sizes and good put measurements. Our ability to deliver better quality increases with increased good put. Retransmissions result in lower good put since the bytes don't reflect any new application bytes, so they don't boost good put. An approximation of the average application seen latency is the live ingest latency. The application sends a little fake payload to the server once every second and watches for a response. To get the average app round-trip time (RTT), we measure this and average it over the course of the session. Diminished app RTT translates to reduced video ingest delay if bit rate is the same or greater. Using the application observed RTT, we were able to evaluate video latency in our experiments, and we discovered that COPA consistently offered lower latency than CUBIC. BBR reduced more than COPA for sessions with an apparently decent network and low latencies already calculated. Zoom App RTT decreased by 7 percent with COPA and 12 percent with BBR, from 378 ms for CUBIC to 368 ms for COPA and 342 ms for BBR. COPA, however, significantly reduced latencies for sessions with weaker networks. Zoom App RTT decreased by 24% with COPA, from 6.4

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 04 April 2024
Page No: 715 - 733
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0102

seconds for CUBIC to 4.9 seconds for COPA, while BBR reductions began to taper down [52]. In the majority of real-world situations, sacrificing some quality allows us to lower latency. When there are network bottlenecks, video latencies will automatically decrease if we reduce video bit rate, that is, write less on the wire and reduce quality. The good put figures for the three groups were compared, and we discovered that COPA and BBR outperformed CUBIC in terms of good put. This indicates that in addition to lowering application latency, COPA and BBR enabled the program to provide higher-quality video. The number of videos seen overall changed as a result of this development, which was substantial. Google meet, and online video App good put was enhanced by 8.2 percent by COPA and 6.8 percent by BBR. The good put was increased by 6.8 percent by BBR and 19.8 percent by COPA.

It should be noted that although the benefits appear to decrease for online video conferencing and some others, this is just because the encoder bit rate for this experiment was limited to 100 Mbps. Let's take a look at some lower-level indicators to see where these increases originated. We concentrated on calculating the QUIC transport's RTT and retransmission overhead during the transport implementation. Keep in mind that the round-trip time of a packet is measured by the application RTT after it leaves the application layer, whereas the round-trip time of a packet is measured by the former after it is written over the wire. Additionally, the application RTT conceals retransmissions; that is, in the event of a packet loss, multiple roundtrips at the transport layer will be required [39].

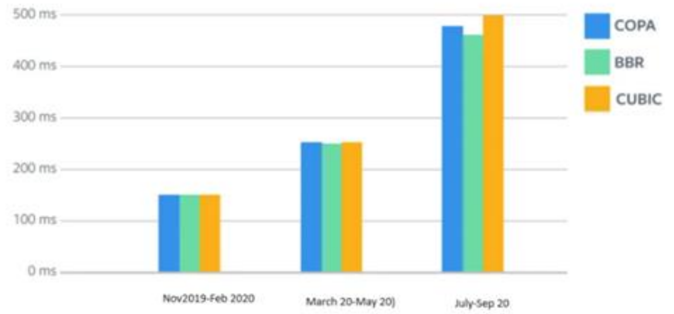


Figure 7 Best Connections

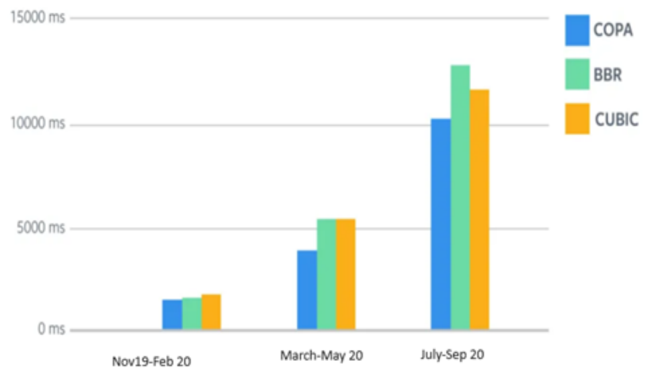


Figure 8 Worst Connections

9.1. Average Transport RTT Comparison

For the best connections (three ISP and three IXP), BBR gave us the lowest transport RTTs, continuing the trend of improvements in application RTT. However, as the RTTs for those customers were already quite low, the drop wasn't that significant. It is evident from the most data that COPA gave the lowest values in this case. Whereas COPA reduced RTT by 36 percent, BBR reduced it by 12 percent. The conventional traffic was lowered even more significantly: BBR lowered it by 18%, while COPA lowered it by an astounding 40%. Some of the observed improvements in video delay can be explained by lower transport RTT. It's important to remember that application RTT (video latency) is also influenced by the amount of data the application sends based on ABR, which has an impact on the amount of data queued in the transport send buffer. It is therefore plausible that some of the latency reduction from reduced transport RTT was offset by greater quality output from the ABR due to enhanced transport. However, after a packet leaves the transport, the amount of data queued in the underlying network determines how much the transport RTT varies. Figure 7, 8 and 9 shows the Comparison of Goodput at various intervals.

9.2. RTX Overhead Comparison

We examined the amount of data that is lost and retransmitted in order to better understand the behavior of the transport system. This metric's precise definition is as follows: Total bytes retransmitted by the transport / Total bytes

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 04 April 2024
Page No: 715 - 733
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0102

acknowledged equals RTX Overhead [54]. It was discovered that BBR had less overhead overall for all users than CUBIC. For about 90% of users, it's about half that of CUBIC. The variance in overhead between COPA and CUBIC is significant. For about 75% of users, COPA has a quarter of the overhead. It begins to rise as you get into tail cases, surpassing CUBIC to become four to five times more for tail cases. When COPA detects an increase in queueing delay, it proactively lowers CWND rather than treating loss as a congestion indicator. The concept is that COPA's queuing delay measures will rise when a bottleneck queue fills, allowing us to detect congestion before any loss occurs. Therefore, for COPA, we should always experience considerably lesser packet loss. In fact, this is what we observe for almost 80% of users. Nonetheless, the final 20% of users had significantly higher loss, suggesting that there was no correlation between loss rates and queueing delays for these users. We looked at these cases' behavior in greater detail and discovered evidence of network policing, which is covered in the section that follows.

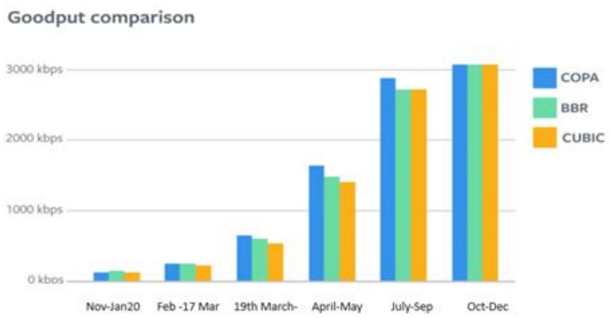


Figure 9 Comparison of Goodput at Various Intervals

Suggested algorithm for management of congestion

Network policing is the process of isolating and monitoring traffic from a single source in order to throttle it at a specific rate. Any additional packets that are above that rate will be tail dropped by the provider under the standard policing procedure [55]. This leads to a few traits that set it apart from losses brought on by congestion:

- Reliable throughput or Goodput
- Extremely large losses
- Reduced RTT and waiting times

While COPA had a larger tail retransmission overhead than CUBIC and BBR, tail RTT was lower. This fit with a few aspects of traffic enforcement. Since traffic policing typically differs greatly by ASN provider, we first broke down the results by ASN to make sure the same may get implemented easily. As it turned out, RTX overhead did differ significantly amongst ASNs. We discovered evidence of significantly increased RTX overhead for COPA in some ASNs, where we also observed indications of traffic policing in an independent analysis. We displayed the link between RTT, queuing time, and RTX overhead to validate our theory. The graph's first half shows how, with COPA, RTX overhead rises along with RTT and queuing delays. Given that these losses are accompanied by longer wait times, it is evident that traffic is the real cause of the congestion in this area. However, in the second half of the graph, RTT and queuing delays begin to decrease after reaching a maximum. In reality, users notice relatively little delay in the location with the largest RTX overhead. This supported our hypothesis that network policers are probably to blame for the large losses. Though the network properties and remedies are extremely similar, note that short buffers might also be the cause of this. However, as RTX overhead rises for CUBIC, RTT and queuing delays keep getting longer. This suggests that congestion is the cause of all user losses, which makes sense as CUBIC interprets loss as a signal for congestion and adjusts CWND appropriately.

10. Discussion

The requirement mostly on online services at the start of the pandemic caused network operators to worry about, among other things, maintaining the smooth operation of networks, particularly for vital institutions like hospitals, defense and pharmaceuticals [5]. According to our investigation from every angle, the pandemic actually raised demand for such congestion management algorithms that facilitate remote learning, video conferencing

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 04 April 2024
Page No: 715 - 733
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0102

without delay and jitter buy supporting required bandwidth and work to ensure social separation. Because cloud services are elastic and flexible, and because cloud providers are becoming more connected, the Internet can handle this additional demand [7, 10, 37, 58, and 25]. Our findings verify that cloud-based applications account for the majority of those with the biggest absolute and relative gains. Moreover, the seamless transition to the new normal was made possible by the implementation of best practices for network design, operation, and provisioning. It was able to handle the rise in demand because of the advancements in high speed and ULSI based hardware with self-learned and decision making network [21]. Most ISP as well as IXP fails to manage the heavy demand initially and hence the internet services hampered in first few days but later on manage the same. All such mismanagement occurs due to heavy demand in video and audio services. The various functioning algorithms tries their best to manage the congestion occurred at routers, gateways, firewalls or UTMS but fails to manage in full fleshed manner. Mostly made a trade-off between various parameters such as In conclusion, our research shows that in order to create resilient networks that can withstand sharp and unforeseen fluctuations in demand, over-provisioning, network management, and automation are essential in order to reducing the rise of traffic. In this research, we report a 15-20% spike in traffic within a few days of the lockdown starting. This is consistent with reports from IXPs [56], CDNs [18, 35, 42, 43], and ISPs [34, 36]. ISPs and CDNs are usually ready for a thirty percent growth in traffic in a single year [8, 14, and 39]. Although these are annual plans, the epidemic brought about significant changes in a matter of days. ISPs were therefore forced to either add capacity very fast or take advantage of over-provisioned capacity, for example, to accommodate unanticipated traffic surges like attacks or flash-crowd events. At the IXP-CE alone, we saw port capacity increases of about 1,500 Gbps (3%) across numerous IXP members. Outside of our datasets, several networks disclosed in the open that the pandemic's effects on traffic shifts caused partial connectivity problems and necessitated the creation of additional linkages [22, 57]. We see that the growth is significantly smaller when we focus on traffic peaks. On one side it is concluded that the pandemic effect the traffic especially in video, audio and OTT platform which affect our vantage points' network operation; on the other hand, some links see large surges in traffic, far above the average 15-20%. Some network operators may find themselves in need of port improvements as a result of these sudden surges. Conversely, the perspectives presented in this study span from very big to moderately sized organizations with ample resources and a wealth of network resilience and provisioning expertise. From an operational standpoint, the pandemic response has necessitated certain port capacity upgrades, but not significantly. The fact that network operators can swiftly expand capacity, when necessary, shows how well the Internet infrastructure functions overall, even with the lockdown's restrictions on access to data centers. This is a notable change in Internet traffic that, based on our experience, the Internet core as a whole is able to handle surprisingly effectively. This is presumably because a large number of operators are ready and able to respond swiftly to new demands Although the pandemic is an extreme and unique instance, it may be argued that as the Internet and contemporary life become more intertwined, these kinds of events could happen more frequently. Either way, the COVID-19 epidemic emphasizes how quickly user behavior may shift and how network operators must be ready with unforeseen demand fluctuations [9].

Conclusion

The COVID-19 pandemic is an uncommon event that, hopefully, will only happen once in a lifetime. It significantly altered social and work patterns for billions of people. Nevertheless, life went on because of our societies' greater digitalization and resilience, with the Internet serving as a vital source of support for social connections, commerce, education, and entertainment. In this paper, we examined network flow statistics from several angles: three IXPs situated in Central India and the western part which serve as the core, while a sizable academic network and a sizable ISP are situated at the periphery. When taken as a whole, they help us comprehend how Internet traffic in more developed nations is affected by lockdowns. Our research highlights the significance of utilizing many perspectives to completely comprehend the COVID-19 pandemic's effects on traffic. Traffic is heavier in the mornings and late at night. The differences between workday and weekend traffic patterns are becoming less and less noticeable. Traffic to VPN and video conferencing apps for distant work and education has increased by more than 200%. In some areas of the Internet, like educational networks that service college campuses, we observe a sharp rise in some apps that facilitate distant learning and working, but a sharp decline in traffic needs because of user absence. We note that traffic ratios for several networks, both sources and destinations, change significantly from what would be expected in a world prior to the COVID-19 epidemic these findings emphasize how crucial it is to approach traffic engineering from a perspective that considers "essential" applications for remote working in addition to popular traffic classes and hypergiant traffic. The data collected from various resources during the research it has been concluded that Internet traffic is intended and unseen surge traffic with variation in dscp traffic pattern However, related research revealed a decline in performance in less developed areas [3]. The unexpected traffic shifts brought about by the imposition of confinement measures highlight how crucial the distributed character of the Internet is for facilitating civil responses to such incidents and bolstering societal resilience. In overall as the traffic has migrated to real time video and audio demand which is totally different from the time period previous to pandemic period the solution to manage the congestion needs to be modify. In the forthcoming days the conventional entertainment channel will migrate towards OTT platform, academics will be on hybrid mode, meetings will be more on on-line platforms ChatGPT, and others force researchers to develop a more robust algorithm.

References

[1]. N. Bayat, K. Mahajan, S. Denton, V. Misra, and D. Rubenstein. 2020. Down for Failure: Active Power Status Monitoring. ArXiv, https://arxiv.org/abs/1912.03357.

[2]. J. Blendin, F. Bendfeldt, I. Poese, B. Koldehofe, and O. Hohlfeld. 2018. Dissecting Apple's Meta-CDN during an iOS Update. In ACM IMC.

[3]. T. Boettger, G. Ibrahim, and B. Vallis. 2020. How the Internet reacted to Covid-19- A perspective from Facebook's Edge Network. In ACM IMC.

[4]. R. Bogutz, Y. Pradkin, and J. Heidemann. 2019. Identifying Important Internet Outages. In IEEE Big Data.

[5]. T. Böttger, F. Cuadrado, G. Tyson, I. Castro, and S. Uhlig. 2017. A Hypergiant's View of the Internet. ACM SIGCOMM CCR 47, 1 (2017).

[6]. T. Böttger, F. Cuadrado, and S. Uhlig. 2018. Looking for Hypergiants in Peering DB. ACM CCR 48, 3 (2018).

[7]. C. Labovitz. 2019. Internet Traffic 2009-2019. APRICOT 2019.

[8]. C. Partridge, P. Barford, D. D. Clark, S. Donelan, V. Paxson, J. Rexford, and M. K. Vernon. 2003. The Internet under Crisis Conditions: Learning from September the National Academy Press.

[9]. M. Candela, V. Luconi, and A. Vecchio. 2020. Impact of the COVID-19 pandemic on the Internet latency: A large-scale study. Computer Networks 182 (2020).

[10]. Y. Chiu, B. Schlinker, A. B. Radhakrishnan, E. Katz-Bassett, and R. Govindan.2015. Are We One Hop Away from a Better Internet?. In SIGCOMM HotNets.

[11]. K. Cho, C. Pelsser, R. Bush, and Y. Won. 2011. The Japan Earthquake: the impact on traffic and routing observed by a local ISP. In ACM CoNEXT SWID workshop.

[12]. Cisco.2012.https://www.cisco.com/c/en/us/td/docs/routers/asr9000/software/asr9k_r42/bng/configuration/guide/b_bng_cg42asr9k/b_b

ng_cg42asr9k_chapter_01.pdf.
[13]. Cisco. 2012. Introduction to Cisco IOS NetFlow - A Technical Overview.https://www.cisco.com/c/en/us/products/collateral/ios-nx-os-software/iosnetflow/prod_white_paper0900aecd80406232.html.
[14]. Cisco. 2020. Cisco Annual Internet Report. https://www.cisco.com/c/en/us/solutions/executive-perspectives/annual-internet-report/index.html.
[15]. Cisco. 2020. Network Requirements for Webex Teams Services. https://help.webex.com/en-us/WBX000028782/NetworkRequirementsfor- Webex-Teams-Services.
[16]. B. Claise, B. Trammell, and P. Aitken. 2013. RFC 7011: Specification of the IPFIXProtocol for the Exchange of Flow Information.
[17]. Cloudflare. 2020. General best practices for load balancing at your origin with Cloudflare. https://support.cloudflare.com/hc/en-us/articles/212794707-\Generalbest-practices-for-load-balancing-at-your-origin-with-Cloudflare.
[18]. Comcast. 2020. COVID-19 Network Update. https://corporate.comcast.com/covid-19/network.
[19]. European Commission. 2020. Commission and European regulators call on streaming services, operators, and users to prevent network congestion.https://ec.europa.eu/digital-singlemarket/en/news/commission-and-europeanregulators-calls-streaming-services-\operators-and-users-prevent-network.
[20]. Zoom Video Communications. 2020. Configure Meeting Connector Controller Port Forwarding. https://support.zoom.us/hc/en-us/articles/204898919-Configure-Meeting-Connector-Controller-Port-Forwarding.
[21]. DE-CIX. 2020. DE-CIX Virtual Get-together - Focus Middle East & Asia 22 Apr 2020.https://www.youtube.com/watch?v=DfPt10aopns
[22]. DFN. 2020. German National Research and Education Network: COVID-19 Newsticker.https://www.dfn.de/alle-meldungen-aus-dem-newsticker-zur-covid-19-pandemie/
[23]. M. Dischinger, M. Marcon, S. Guha, K. Gummadi, R. Mahajan, and S. Saroiu. 2010. Glasnost: Enabling End Users to Detect Traffic Differentiation. In NSDI.
[24]. F. Dobrian, A. Awan, D. Joseph, A. Ganjam, J. Zhan, V. Sekar, I. Stoica, and H.Zhang. 2011. Understanding the Impact of Video Quality on User Engagement. In ACM SIGCOMM.
[25]. Z. Durumeric, E. Wustrow, and J. A. Halderman. 2013. ZMap: Fast Internet-Wide Scanning and its Security Applications. In USENIX Security Symposium.
[26]. T. Favale, F. Soro, M. Trevisan, I. Drago, and M. Mellia. 2020. Campus Traffic ande-Learning during COVID-19 Pandemic. https://arxiv.org/abs/2004.13569.
[27]. Forbes. 2020. Netflix Starts to Lift Its Coronavirus Streaming Restrictions.https://www.forbes.com/sites/johnarcher/2020/05/12/netflix-starts-to-liftits-coronavirus-streaming-restrictions/#7bcba5bf4738.
[28]. Riot Games. 2020. League of Legends: Troubleshooting Connection Issues. https://support-leagueoflegends.riotgames.com/hc/en-us/articles/ 201752664-Troubleshooting-Connection-Issues.
[29]. J. L. Garcia-Dorado, A. Finamore, M. Mellia, M. Meo, and M. Munafo. 2012. Characterization of ISP Traffic: Trends, User Habits, and Access Technology Impact. IEEE Transactions on Network and Service Management 9 (2012). Issue 2.
[30]. Google. 2020. COVID-19 Community Mobility Report. https://www.google.com/covid19/mobility/.
[31]. Google. 2020. Keeping our network

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 04 April 2024
Page No: 715 - 733
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0102

infrastructure strong amid COVID- https://www.blog.google/inside-google/infrastructure/keeping-our-networkinfrastructure-strong-amid-covid-19/.

[32]. J. Huang, F. Qian, Y. Guo, Y. Zhou, Q. Xu, Z. M. Mao, S. Sen, and O. Spatscheck.2013. An In-depth Study of LTE: Effect of Network Protocol and Application Behavior on Performance. In ACM SIGCOMM.

[33]. BLINC: Multilevel Traffic Classification in the Dark. 2005. T. Karagiannis and D. Papagiannaki and M. Faloutsos. In ACM SIGCOMM.

[34]. ITU. 2020. Press Release: New 'State of Broadband' report warns of stark inequalities laid bare by COVID-19 crisis. https://www.itu.int/en/mediacentre/Pages/PR20-2020-broadband-commission.aspx.

[35]. S. S. Krishnan and R. K. Sitaraman. 2012. Video Stream Quality Impacts Viewer Behavior: Inferring Causality using Quasi-Experimental Designs. In ACM IMC.

[36]. C. Labovitz. 2020. Pandemic Impact on Global Internet Traffic. NANOG 79.

[37]. C. Labovitz, S. Lekel-Johnson, D. McPherson, J. Oberheide, and F. Jahanian. 2010. Internet Inter-Domain Traffic. In ACM SIGCOMM.

[38]. A. Lakhina, K. Papagiannaki, M. Crovella, C. Diot, E. D. Kolaczyk, and N. Taft.2004. Structural Analysis of Network Traffic Flows. In ACM SIGMETRICS.

[39]. T. Leighton. 2020. Can the Internet keep up with the surge in demand?https://blogs.akamai.com/2020/04/can-the-internet-keep-up-with-thesurge-in-demand.html?

[40]. A. Lutu, D. Perino, M. Bagnulo, E. Frias-Martinez, and J. Khangosstar. 2020. A Characterization of the COVID-19 Pandemic Impact on a Mobile Network Operator Traffic. In ACM IMC.

[41]. G. Maier, A. Feldmann, V. Paxson, and M. Allman. 2009. on Dominant Characteristics of Residential Broadband Internet Traffic. In ACM IMC.

[42]. M. McKeay. 2020. Parts of a whole: Effect of COVID-19 on US Internet Traffic.https://blogs.akamai.com/sitr/2020/04/parts-of-a-whole-effect-of-covid-19-on-us-internet-traffic.html.

[43]. M. McKeay. 2020. The Building Wave of Internet Traffic. https://blogs.akamai.com/sitr/2020/04/the-building-wave-of-internet traffic.html.

[44]. Microsoft. 2020. Prepare your organization's network for Microsoft Teams.https://docs.microsoft.com/en-us/microsoftteams/prepare-network.

[45]. Microsoft. 2020. Which ports need to be open to use Skype on desktop?https://support.skype.com/en/faq/FA148/which-ports-need-to-be-open-touse-skype-on-desktop.

[46]. Mozilla Foundation. 2020. Public Suffix List. https://publicsuffix.org/.

[47]. RIPE NCC. 2020. RIPE Database Query. https://apps.db.ripe.net/db-web-ui/query.

[48]. Netflix. 2020. Reducing Netflix traffic where it's needed while maintaining the member experience. https://media.netflix.com/en/company-blog/reducingnetflix-traffic-where-its-needed.

[49]. J. S. Otto, M. Sánchez, D. Choffnes, F. Bustamante, and G. Siganos. 2011. on Blind Mice and the Elephant: Understanding the Network Impact of a Large Distributed System. In ACM SIGCOMM.

[50]. R. Padmanabhan, A. Schulman, D. Levin, and N. Spring. 2019. Residential Links Under the Weather. (2019).

[51]. Peering DB. 2020. Peering DB. https://www.peeringdb.com.

[52]. E. Pujol, I. Poese, J. Zerwas, G. Smaragdakis, and A. Feldmann. 2019. Steering Hyper-Giants' Traffic at Scale. In Proceedings of ACM CoNEXT 2019.

[53]. RED Imadrid. 2020. RED Imadrid.

https://www.redimadrid.es/.
[54]. M. H. Ribeiro, K. Gligoric, M. Peyrard, F. Lemmerich, M. Strohmaier, and R. West. 2020. Sudden Attention Shifts on Wikipedia Following COVID-19 Mobility Restrictions. https://arxiv.org/abs/2005.08505.
[55]. J. Rüth, I. Poese, C. Dietzel, and O. Hohlfeld. 2018. A First Look at QUIC in the Wild. In PAM.
[56]. B. Sanghani. 2020. COVID-19 & IXPs. RIPE 80, https://ripe80.ripe.net/wpcontent/uploads/presentations/27-ripe80-covid-ixp-1.pdf.