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# Tele-Everything and Its Impact to The Network

A Technical Paper prepared for SCTE•ISBE by

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# 1. Introduction

The COVID-19 (2019 novel coronavirus) pandemic caused governments around the world to issue shutdown orders resulting in a sudden shift in network traffic patterns as subscribers started using their broadband connections for tele-everything – working from home, remote learning, entertainment, social interactions, and commerce. As part of the crisis management effort, and to keep the public and various levels of government informed, operators posted reports of the status of their broadband networks in handling the increased usage.

To develop these reports, cable operators shared aggregated anonymized data with NCTA – The Internet & Television Association. In this paper, we first look at the data that the cable operators shared with NCTA as well as similar data from wireline and wireless operators. We then cross-reference the cable data with other third-party data to make some additional observations on the performance of the broadband access networks.

# 2. Cable Network Dashboard

NCTA worked with nine of the U.S.'s leading cable companies[1] to collect and aggregate anonymized network performance data for a publicly accessible network performance dashboard (NCTA, 2020). The dashboard reported on two metrics:

1. change in peak utilization
2. service group utilization grouped by state

The dashboard went live on April 4, 2020 and was still active at the time of the writing of this paper in August 2020. The data set for the dashboard includes data going back to March 1, 2020 – prior to when states started issuing shutdown orders. This was in order to measure and report on the impact of the orders on the network. The dashboard also provided insights into what happened when states started re-opening in late April 2020.

Change in peak utilization was chosen as the primary metric for the dashboard because networks are engineered for peak capacity, and this single metric provided the best snapshot of how well the networks were performing. Figure 1 shows the overall change in the peak utilization for both the upstream (US) and downstream (DS) traffic going back to March 1, 2020 to show the change from pre-shutdown levels. It is important to note that the change in utilization is not directly analogous to the change in consumption because the overall capacity of the networks are fluid; operators could be adding capacity each week. Even though a change in utilization is not the same as consumption, it still provides a good proxy for how data consumption changed as a result of the shutdown.

Peak upstream utilization occurred the week ending April 18, 2020, with a 35% increase over the pre-shutdown levels. For downstream traffic, the largest change in peak utilization occurred for the week ending March 28, 2020, at 20%.

[1] Companies who shared data included: Altice, CableOne, Charter, Comcast, Cox, GCI, Mediacom, Midco, and Sjoberg's.

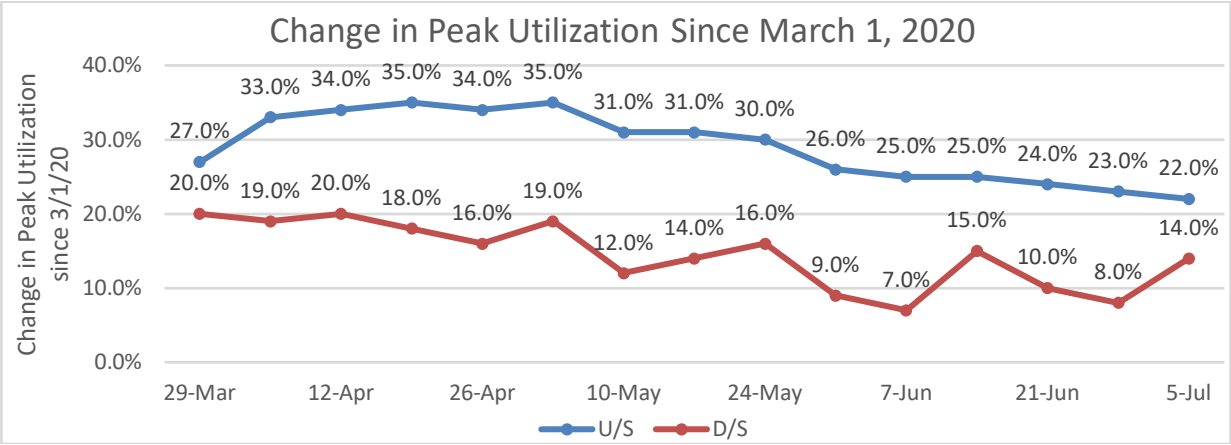



**Figure 1 - National peak utilization growth. Source: NCTA**

Figure 2 shows the week-over-week change in the peak utilization. The largest week-over-week change for the upstream occurred the week ending March 28, 2020, with a 7.3% increase and for the downstream the week of June 13, 2020, with a 7.8% increase. Again, it is important to note that this is the relative utilization of available capacity for that week.

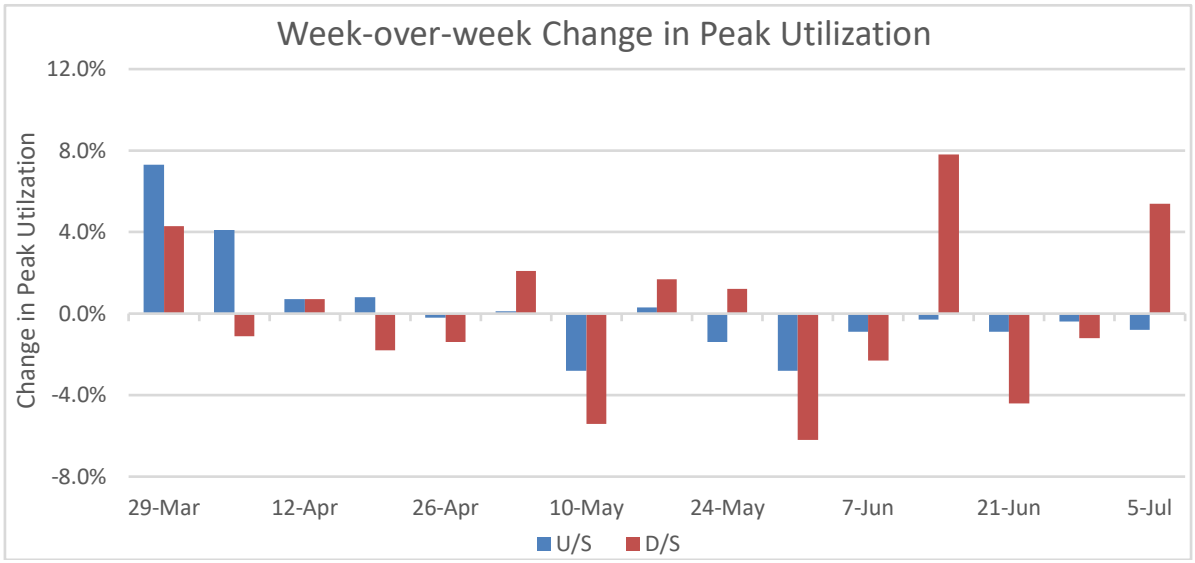



**Figure 2 - Week-over-week change in peak utilization. Source NCTA**

In addition to the aggregated change in peak utilization at the national level, MAC (medium access control) domain service groups utilization were collected. A DOCSIS (Data Over Cable System Interface Specification) service group is either a MAC domain upstream service group or a MAC domain downstream service group. A MAC domain downstream service group refers to the set of downstream channels from a port on a CMTS (cable modem termination system) line card that reach a fiber node and a MAC domain upstream service group refers to the set of upstream channels from the same MAC domain that are reached by a single cable modem. Operators shared the peak utilization levels for each service group and further grouped these by utilization level (<85%, 85%-95%, 95%-99%, and >99%) as shown in Table 1 and in Figure 3

Less than 0.35% of the service groups were ever above 95% utilization. For the dashboard, the service groups were aggregated by state to show how well the DOCSIS network was operating on a regional basis as shown in Figure 4.

**Table 1 - Aggregated service group utilization.**

| | Service Group Utilization Level | | | |
|---|---|---|---|---|
| ***Week*** | **< 85%** | **85% - 95%** | **95% - 99%** | **>99%** |
| *14* | 95.8% | 3.9% | 0.29% | 0.04% |
| *15* | 95.8% | 3.8% | 0.29% | 0.06% |
| *16* | 96.3% | 3.5% | 0.22% | 0.02% |
| *17* | 96.4% | 3.4% | 0.16% | 0.01% |
| *18* | 96.0% | 3.7% | 0.23% | 0.03% |
| *19* | 97.1% | 2.7% | 0.12% | 0.05% |
| *20* | 97.1% | 2.8% | 0.13% | 0.01% |
| *21* | 97.0% | 2.8% | 0.16% | 0.02% |
| *22* | 97.9% | 2.0% | 0.09% | 0.00% |
| *23* | 98.1% | 1.8% | 0.07% | 0.02% |
| *24* | 97.7% | 2.1% | 0.13% | 0.03% |
| *25* | 98.3% | 1.6% | 0.07% | 0.01% |
| *26* | 98.5% | 1.4% | 0.05% | 0.02% |
| *27* | 98.3% | 1.6% | 0.08% | 0.01% |

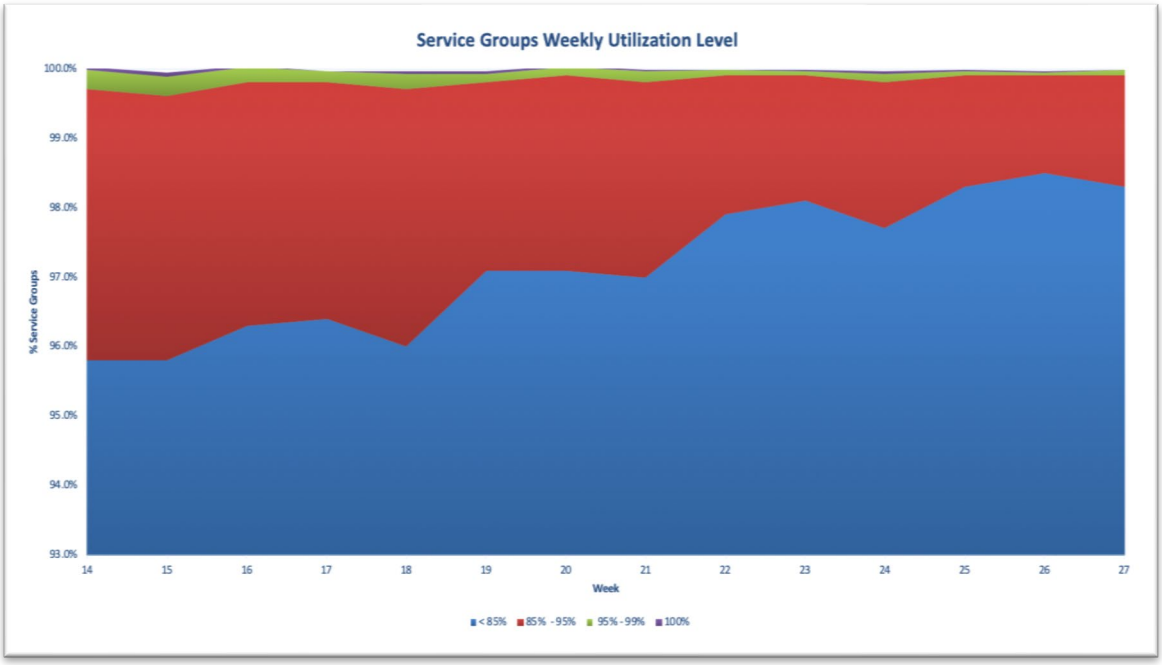



**Figure 3 - Aggregated service group utilization. Source: NCTA**

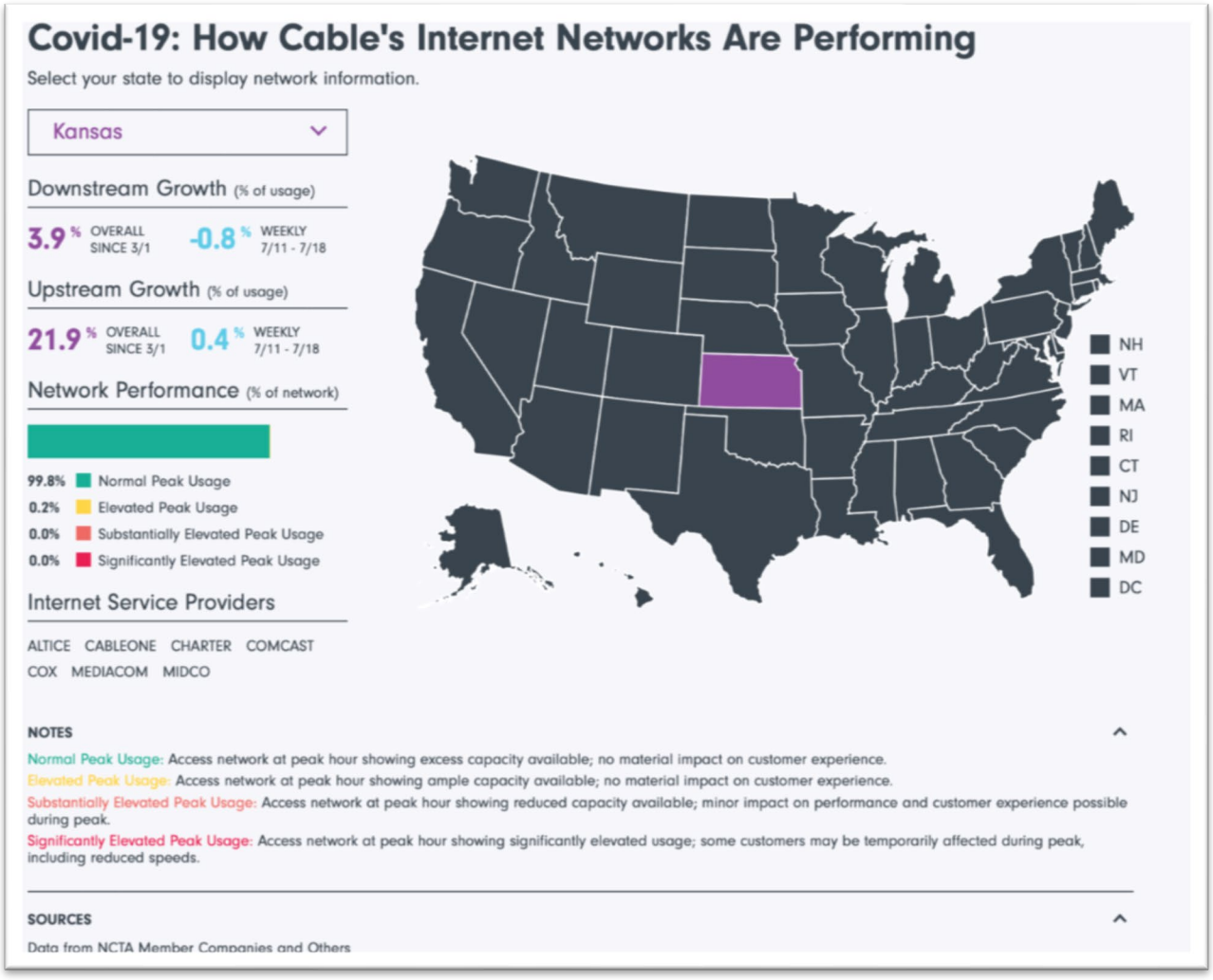



**Figure 4 - Example of the state level service group peak utilization used in the NCTA Network Performance dashboard. Source: NCTA**

## 3. Other Open Source Data

The mobile wireless and wireline carriers, along with small cable operators, also shared network performance data via their respective trade associations.

### 3.1. Mobile Wireless

CTIA reported on the cellular network performance (CTIA, 2020). Mobile data use peaked at 22.6% above the pre-shutdown average on June 22, 2020.

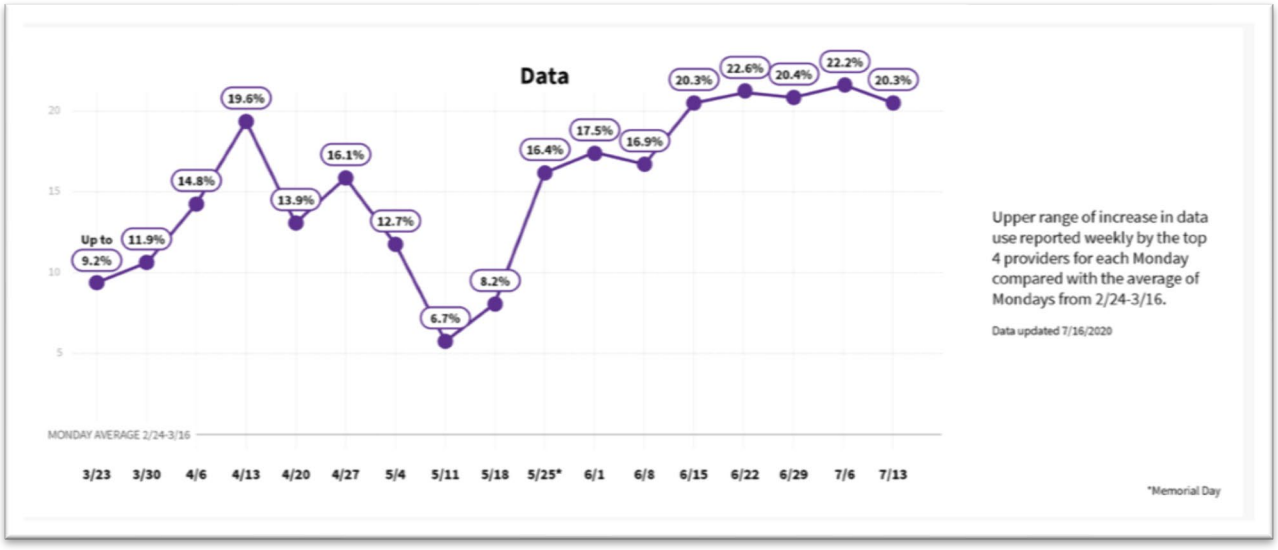



**Figure 5 - Wireless data change from baseline. Source: CTIA**

## 3.2. Wireline

USTelecom reported on the wireline (DSL, fiber) network performance by reporting on the change in traffic (aggregated upstream & downstream) compared to the pre-shutdown level (USTelecom, 2020). The peak traffic change occurred the week of April 16, 2020, at 27% higher than the baseline, and then trended down to about 12%.

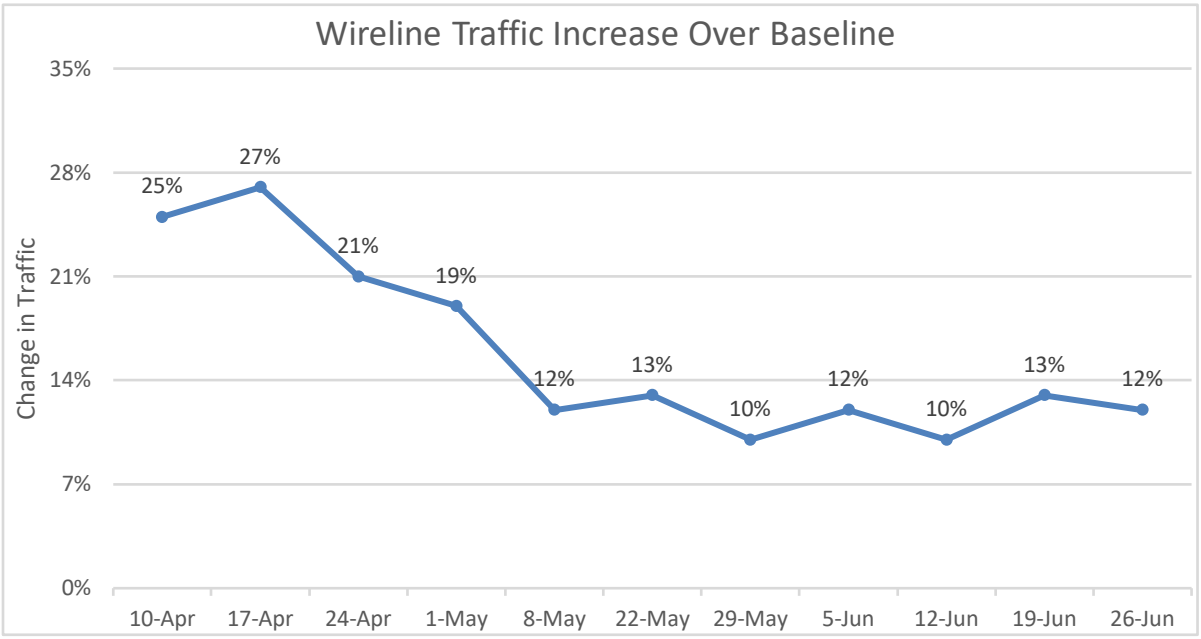



**Figure 6 - Wireline traffic change from baseline Adapted from USTelecom**

### 3.3. Small Cable Operators

ACA Connects, the trade association representing many of the smaller U.S. cable companies, reported that peak download usage was up 24% and peak upload usage was up 34% for its members (ACA Connects, 2020). Download consumption peaked at 44.7% (relative to February 1, 2020) on March 27, 2020, and the upload consumption peaked at 68.8% on March 24, 2020, as shown in Figure 7 and Figure 8.

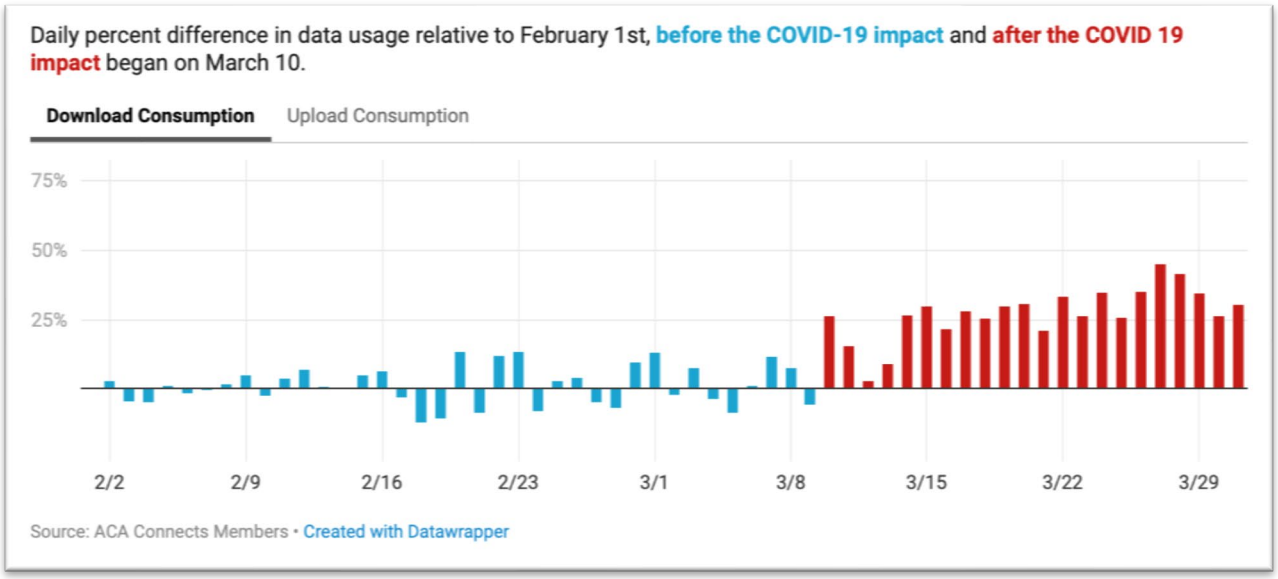



**Figure 7 - Download consumption. Source: ACA Connect**

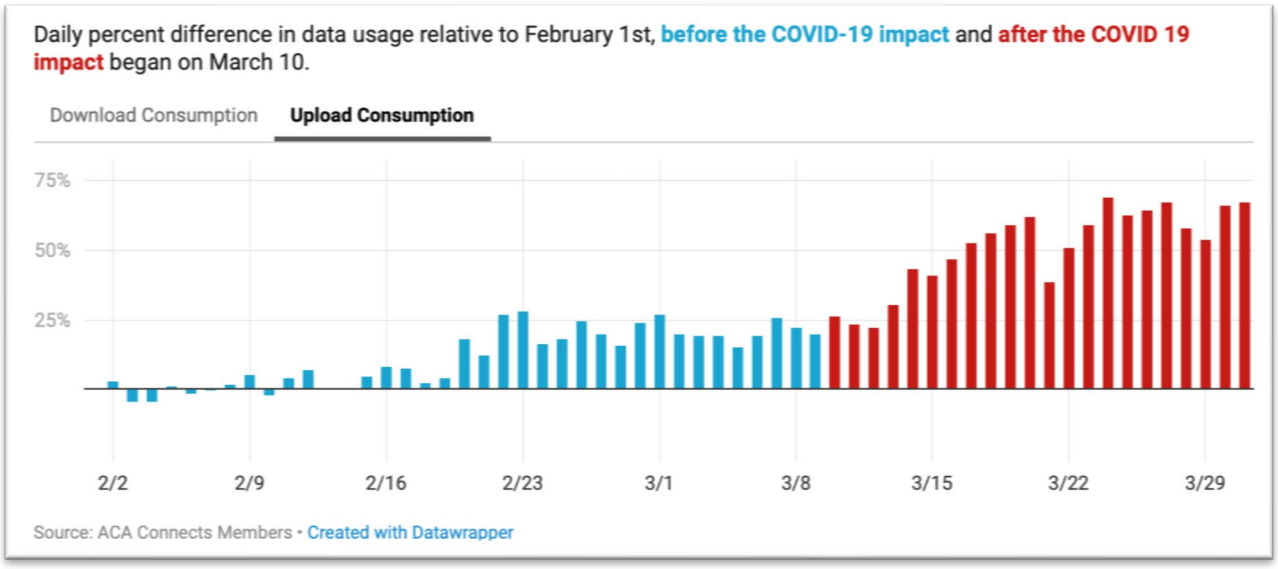



**Figure 8 - Upload consumption. Source: ACA Connect**

## 3.4. Global Internet

### *3.4.1. Nokia Deepfield*

At NANOG 79 (North American Network Operators' Group) in June 2020, Craig Labovitz of Nokia Deepfield gave a presentation on the impact of the pandemic on the internet on a global scale, in which he discussed impacts on networks both domestically and internationally (Labovitz, 2020). As shown in Figure 9, Labovitz reported that most networks typically have 40-50% traffic growth in one year, and many saw a 45% change during the first four weeks of the shutdown.

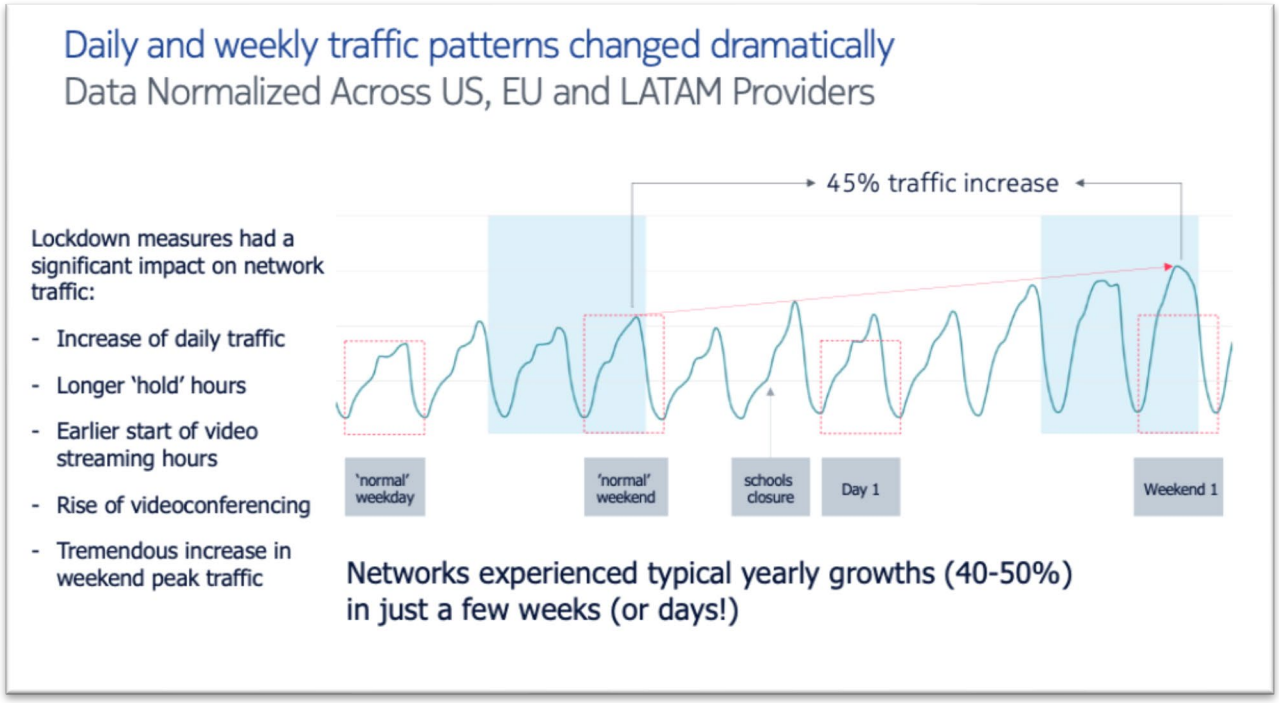



**Figure 9 - Reported change in traffic patterns. Source: Nokia Deepfield**

Labovitz also reported on the change in application usage as shown in Figure 10 after the first week of the shutdown, with the secure messaging app "WhatsApp" and videoconferencing apps in general showing the largest growth in usage. Figure 11 shows the growth in videoconferencing with Zoom usage growing as much as 700% on select networks. Figure 11 also shows how Zoom moved to a multi-CDN (content delivery network) strategy from a single CDN delivery strategy. Figure 12 illustrates how WebEx had somewhat consistent growth for each day of the week, while Zoom experienced its highest growth on Saturday and Sunday.

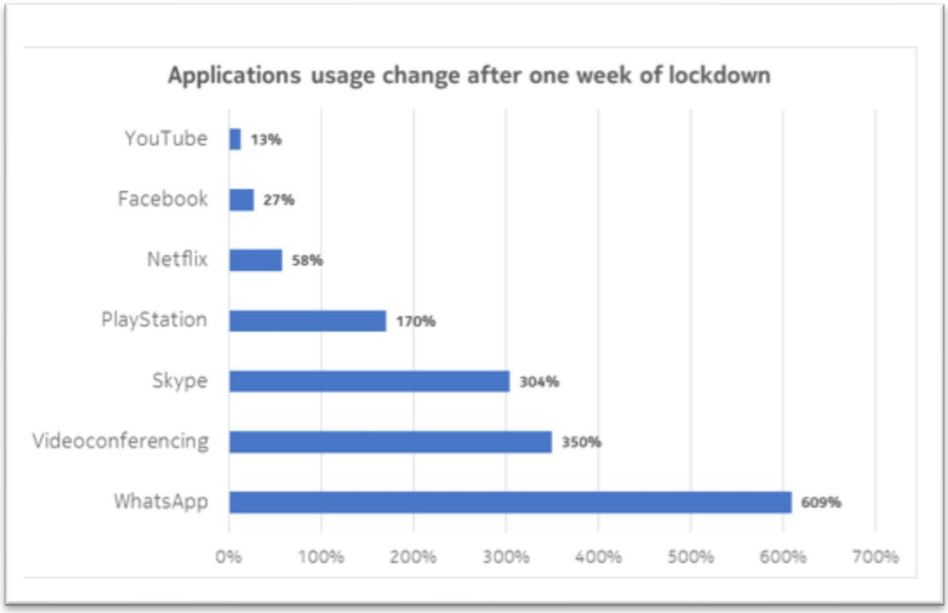



**Figure 10 - Change in application usage. Source: Nokia Deepfield**


**Figure 11 - Videoconferencing usage growth. Source: Nokia Deepfield**

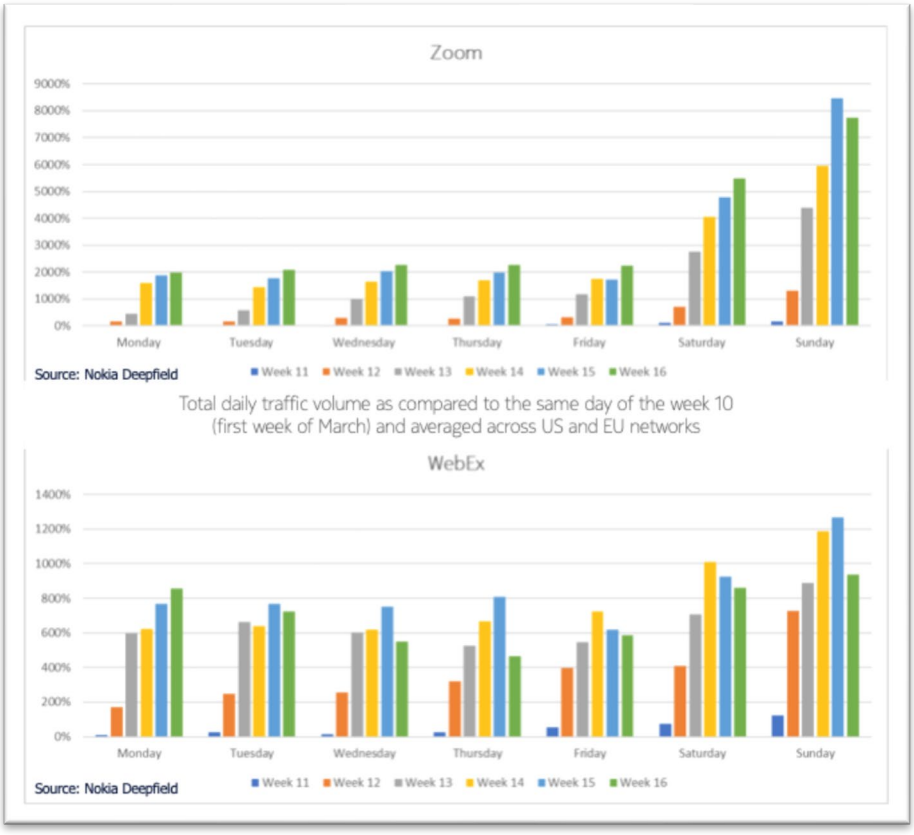



**Figure 12 - Change in Zoom and WebEx usage. Source Nokia Deepfield**

### *3.4.2. Sandvine*

Sandvine reported that Internet traffic grew almost 40% due to the shutdowns (Sandvine, 2020). In addition, Sandvine also reported on the total traffic by application category during the shutdown as shown in Figure 13, with video streaming having the largest share of the traffic at 57.6% and growing 2.2%.

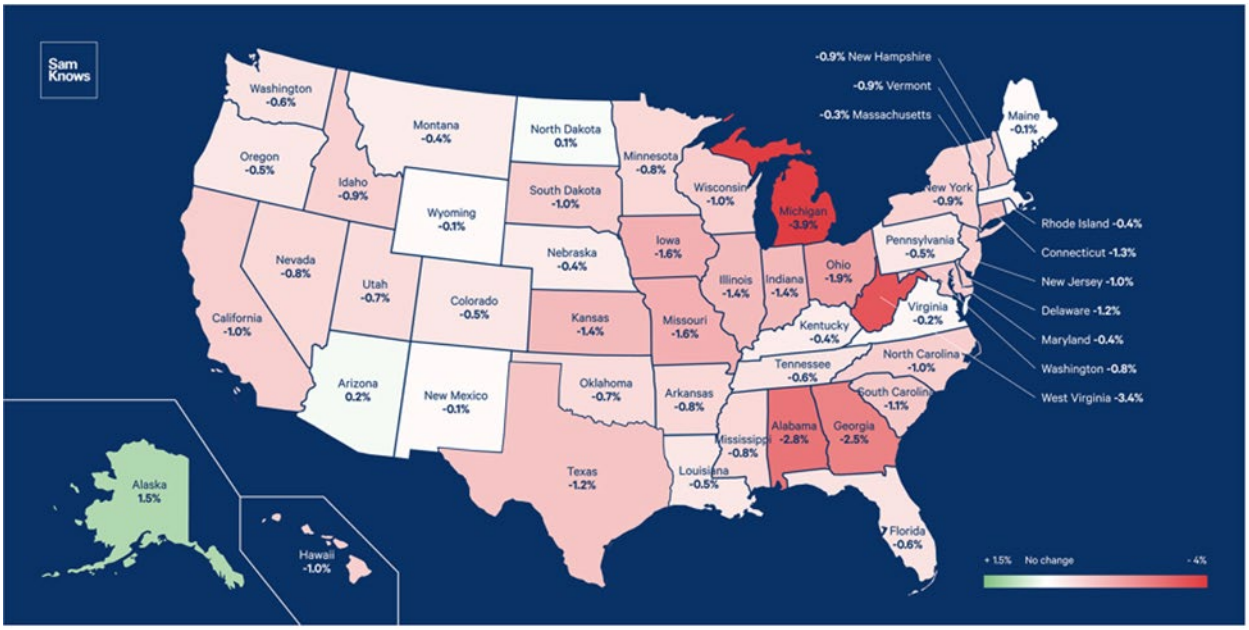
 


**Figure 13 - Sandvine global application category total traffic share Source: Sandvine.**

### *3.4.3. SamKnows*

SamKnows operates a large scale measurement platform that is used by ISPs, governments, academics and consumers. SamKnows gathered the test results from 500,000 homes that have a SamKnows-enabled router installed. These home routers run regularly scheduled speed tests to a major U.S.-based CDN every 10 seconds using multiple TCP (transmission control protocol) connections in parallel. SamKnows posted that most of the states only saw about a 1% decline in the download speeds as shown in Figure 14 (SamKnows, 2020). SamKnows did not provide any further explanation for what may have caused the 1% slowdown. Further it is unclear whether this reduction is within the margin of error or whether in fact the networks actually experienced a 1% decrease in downstream speed.




*Based upon a sample of more than 500k homes running automated download speed tests on a regular basis. Each speed test uses 16 concurrent TCP sessions and measures to a major US CDN. Measurements from 2020-03-12 were compared against measurements from 2020-03-24 to create this comparison.*

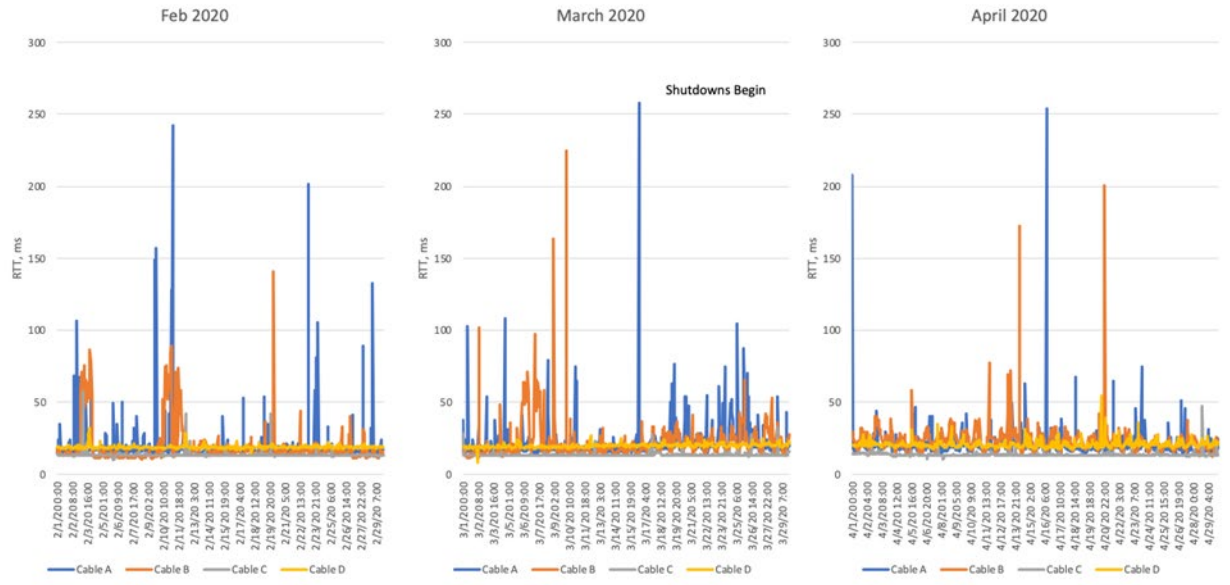
**Figure 14 - SamKnows measured change in download speed by U.S. state between March 12 and March 24 Source: SamKnows**

### *3.4.4. RIPE Atlas*

The RIPE Network Coordination Centre operates a large Internet measurement platform, RIPE Atlas, that employs a global network of probes that measure Internet connectivity and reachability. Each RIPE Atlas probe runs a set of built-in tests 24x7. One of the tests is for each RIPE Atlas probe to issue a set of pings every 15 minutes to each of the 13 root servers. The ping test results, in aggregate, can be used to monitor the latency on a network and as a proxy for detecting quality of service issues due to congestion or a change in routes.

To measure the impact of tele-everything, results were pulled from RIPE for the Atlas IPv4 ping test to the E-Root Server every 4 minutes for ten random Atlas probes on four of the largest U.S. cable networks for the period of February 1, 2020 to July 1, 2020. We grouped them by network operator to look at how the round-trip time changed from pre-shutdown to when the shutdown occurred. Figure 15 shows the round-trip times on an hourly basis for four of the major cable operators. For the most part, the round-trip time did not change very much between the pre-shutdown (February 2020) and when the shutdowns started (March 2020). During the first two weeks of the shutdown (March 15-30) we can see that there are periods when the round-trip times increase. Several of the spikes in the round-trip time occur during the early hours of the morning. Figure 16, shows the round-trip times for the last two weeks in March and we can see some spikes that could be correlated with a shift to tele-everything.




RIPE Atlas Probes Round Trip Time from Cable Networks to E.root-servers.net. E-root-servers.net uses IP Anycast to provider service from the closest location. All times shown are in GMT.

**Figure 15 - Round-trip time for major cable operators.**

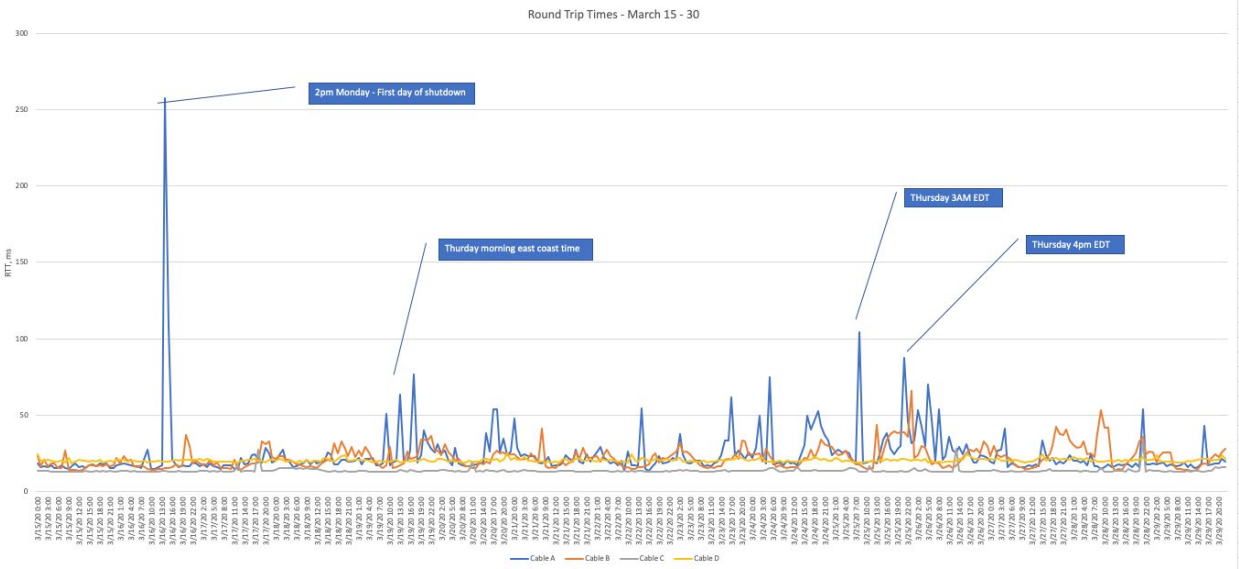



**Figure 16 - Round-trip times March 15-30.**

## 4. Observations

In addition to the published data above, we can glean some additional insights from other data that cable operators and others reported about network performance.

## 4.1. Traffic Growth

In general, overall broadband usage increased due to the shutdown. The NCTA Network Performance dashboard reported an increase in the peak utilization and others reported overall traffic growth between 20-50% ( (CTIA, 2020); (USTelecom, 2020); (ACA Connects, 2020); (Labovitz, 2020); (Sandvine, 2020)).

We can get an approximation of the magnitude of the traffic growth on the cable networks by comparing the forecasted growth of peak downstream and upstream bandwidth per subscriber with the observed growth in the peak utilization at the start of the shutdown. Ulm and Cloonan reported that in 2019 the downstream average bandwidth per subscriber during busy-hour (DS Tavg) was 1.97 megabit per second (Mbp/s) with a 5 year average CAGR (compound annual growth rate) of 37.8% and the upstream average bandwidth per subscriber (US Tavg) was 140 kbp/s with a 5 year average CAGR of 18.8% (Ulm & Cloonan, 2019). Using these numbers the DS Tavg is forecasted to grow about 3% each month and the US Tavg forecasted to grow about 1.5% per month on average. If we compare these with the observed change in the peak utilization on the cable networks of 20% in the downstream and 35% in the upstream, it becomes clear that traffic grew substantially as a result of the shutdown.

**Table 2 - Traffic engineering calculations for cable networks.**

| | Downstream | Upstream |
|---|---|---|
| **Tavg** | 1.97 Mbp/s | 140 kbp/s |
| **5-year CAGR** | 37.8% | 18.8% |
| **2020 forecasted monthly growth** | 3% | 1.5% |
| **2020 change in peak utilization** | 20% | 35% |

In addition to traffic growth, we can also infer that the shift to tele-everything resulted in cable networks experiencing about six months to a years' worth of traffic growth in a month and that this was consistent with what other ISPs around the globe experienced. We can also infer from the SamKnows download speed measurements that this growth did not have a measurable impact on the subscribers download or upload speeds. And finally, the shift to tele-everything caused a step-function in demand for bandwidth. It remains to be seen whether this is a temporary step function that will return to the pre-shutdown levels at some point, or if this is a permanent shift.

## 4.2. Service Delivery Infrastructure

ACA Connects posted peak transit network capacity utilized by day for its larger members as shown in Figure 17. We can see that the transit utilization did not change with the shift to tele-everything and we can infer from this that the service delivery infrastructure of content delivery networks, caches, and peering agreements with content partners worked well. This is consistent with a similar report by Labovitz, as shown in Figure 18 on the performance of the Netflix service delivery system where before the shutdowns Netflix had a 63% cache hit rate, and 46% cache hit rate once the shutdowns began (Labovitz, 2020).

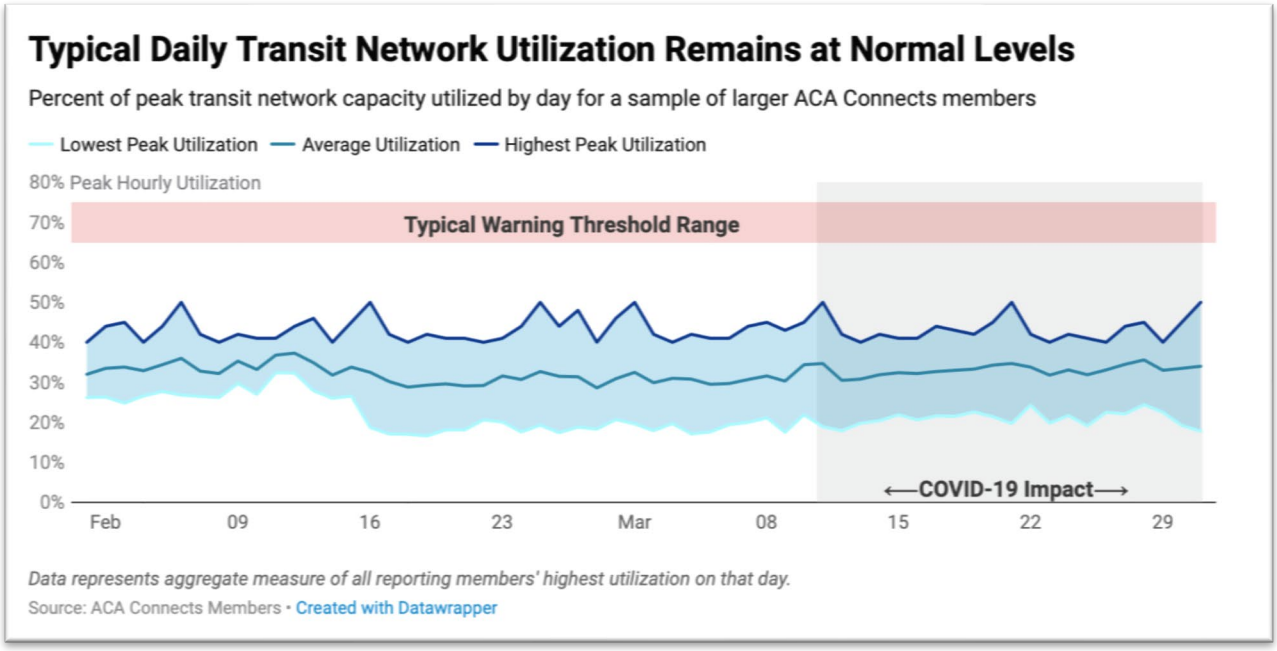



**Figure 17 - Small cable operator transit utilization.**

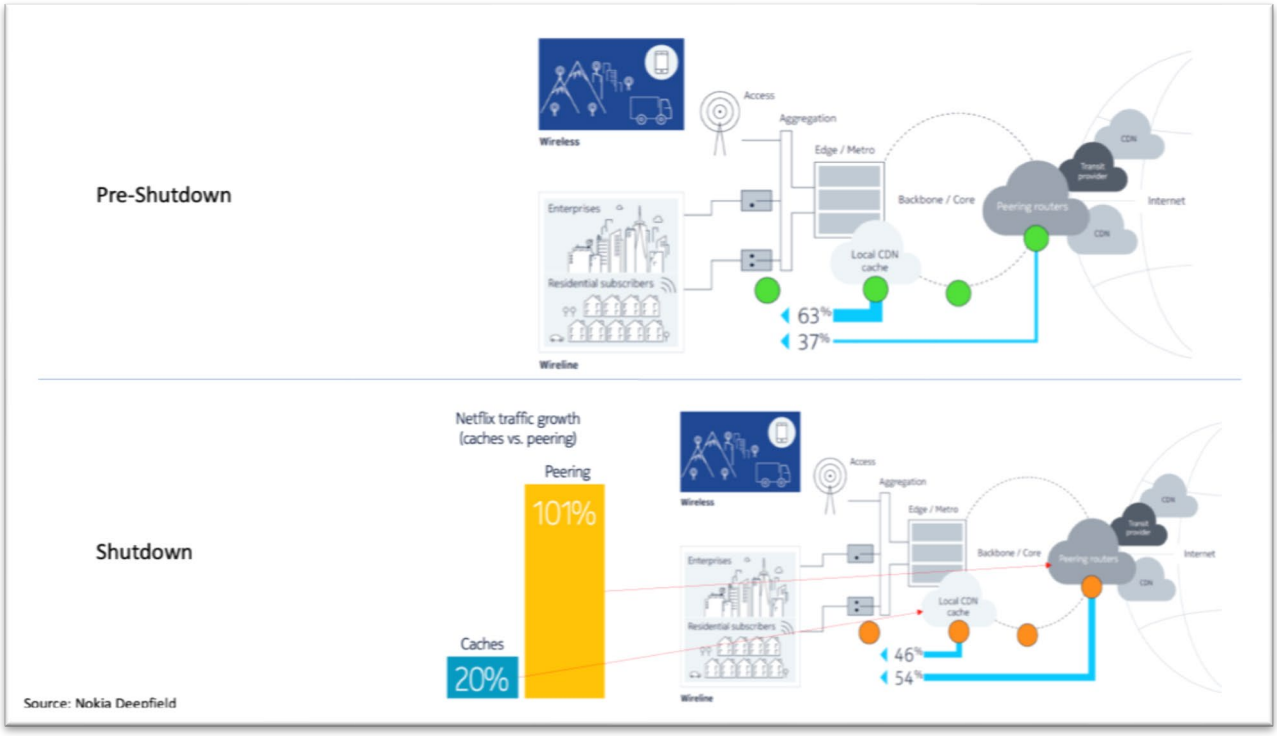



**Figure 18 - Netflix service delivery (CDN + off-net = via peering).**

### 4.3. Upstream Traffic and Telework

One of the big questions at the beginning of the shutdown was how would tele-everything impact the upstream traffic in the networks. We analyzed the data and attempted to correlate it with other data such as census data to see if geographic areas with high concentrations of occupations that can be done remotely might explain changes in upstream traffic. We cross-referenced service group utilization data with census data to generate the heat map shown in Figure 19. The heat map shows the states with the largest changes in upstream utilization combined with the largest percentage of the occupations that can be done remotely. The map was generated using data from March 1 and April 15, when most of the cases were still in the state of New York, and illustrates that there is some correlation between upstream utilization growth and tele-work. As much as there is high interest in such correlations, such conclusions are tentative at best. Time of year, weather, school and other factors can influence this. However, the heat map does seem to show some correlation.

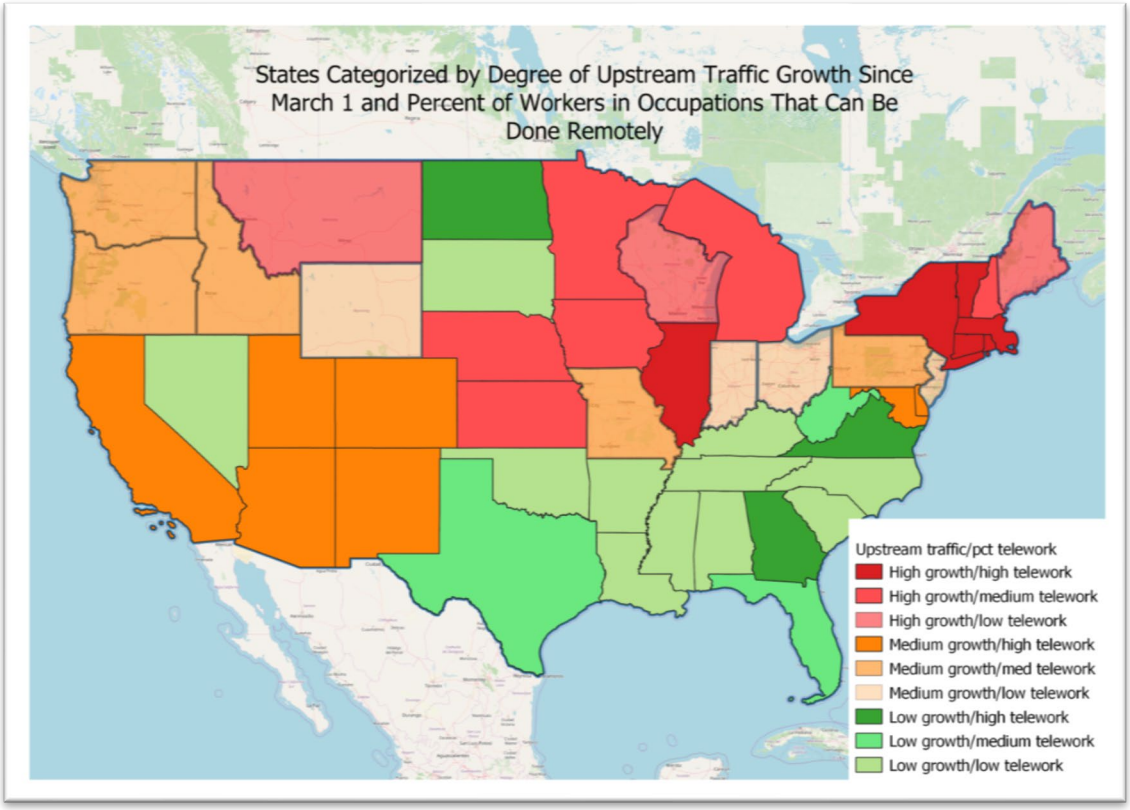



**Figure 19 - Upstream growth and telework by state combined for the period March 1, 2020 – April 15, 2020.**

### 4.4. Upstream and Vacation Homes

Similarly, we also looked to see if there was any potential correlation with areas experiencing large changes in upstream utilization due to subscribers migrating to their vacation homes to wait out the shutdown. Figure 20 shows utilization combined with vacation home data. The northern states with a large percentage of vacation homes experienced the largest increases in upstream peak utilization. This may be because many of the vacation homes in the north are three-season homes (spring, summer, and

fall) and therefore, what we may be observing is vacation homeowners moving to their homes earlier than normal as part of the shelter in place orders. Again, these types of correlation are suppositional.

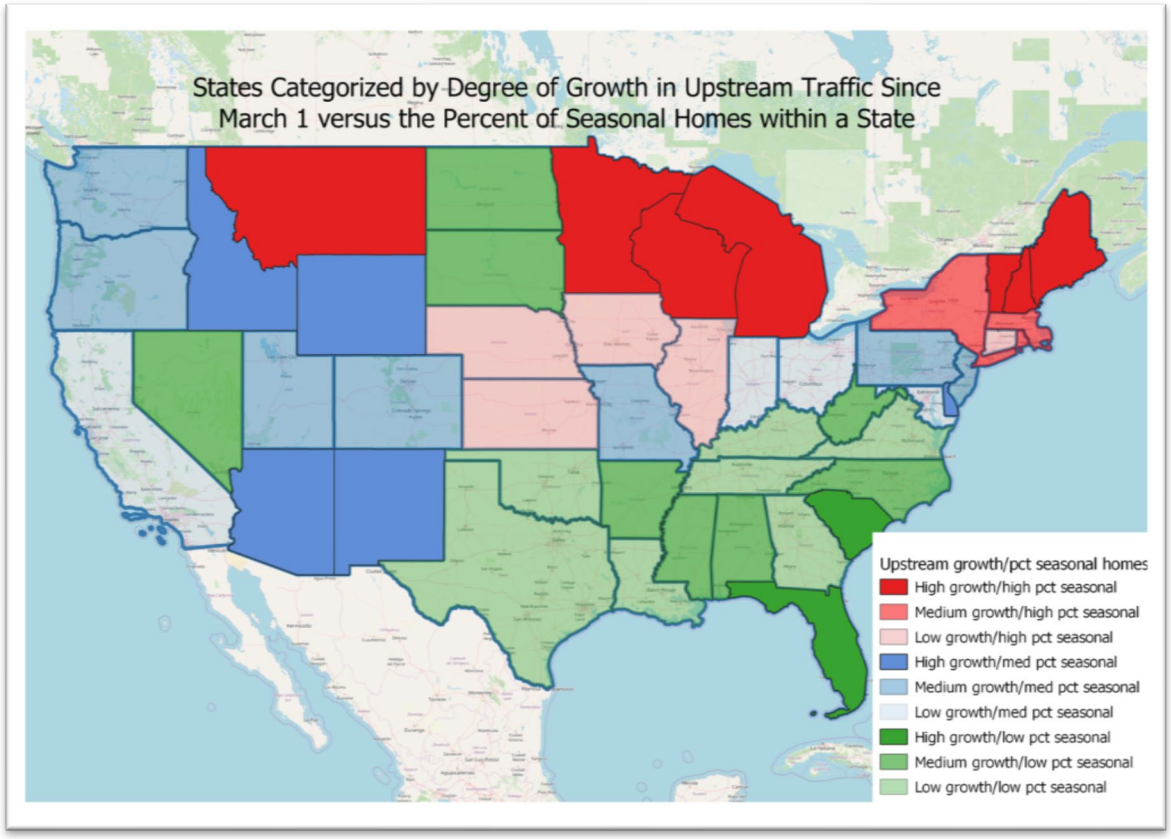



**Figure 20 - Seasonal homes and utilization combined for the period March 1, 2020 – April 15, 2020.**

## 4.5. Videoconferencing and Video Streaming

Another concern raised was the potential impact on upstream traffic with a high usage of videoconferencing for work, school, and entertainment. It was reported that videoconferencing applications such as Zoom, with symmetrical bandwidth requirements, experienced as much as a 700% growth with the largest growth occurring on weekends.

### *4.5.1. Average bandwidth per subscriber during busy-hour*

Using the average bandwidth per subscriber during busy-hour, Tavg, for the downstream and upstream from 2019 and the reported 5-year average CAGRs (Ulm & Cloonan, 2019), we can estimate the forecasted 2020 Tavg for the downstream and upstream around the time of the shutdown when consumers switched to tele-everything. In Table 3 we show the calculations for the forecasted Tavg and then extrapolate the change to Tavg as a result of tele-everything. We estimate that the downstream Tavg grew by 430 kbp/s, growing to 2,582 kbp/s, and the upstream Tavg grew by 51 kbp/s to 198 kbp/s.

**Table 3 - Average Subscriber Bandwidth During Peak Busy Hours.**

| | Description | Formula | Down | Up |
|---|---|---|---|---|
| **(A)** | 2019 average bandwidth/sub during busy hour (Tavg)[2], kbp/s | A[DOWN] / A[UP] | 1966 | 140 |
| | 2019 downstream-to-upstream traffic ratio | | 14 | |
| **(B)** | 2019 CAGR[3] | | 37.80 % | 18. 80 % |
| | | | | |
| **(C)** | Estimated monthly growth in Tavg | B/12 | 3.15% | 1.5 7% |
| **(D)** | Estimated growth in Tavg for Jan-Mar 2020, kbp/s | A*C*3 | 186 | 7 |
| **(E)** | Estimated Tavg at beginning of April 2020 | A+D | 2152 | 147 |
| **(F)** | Estimated DS:US traffic ratio for April 2020 | E[DOWN] / E[UP] | 15 | |
| | | | | |
| **(G)** | Change in peak due to shutdown[4] | | 20% | 35 % |
| **(H)** | Estimated growth in Tavg with shift to tele-everything, kbp/s | G*E | 430 | 51 |
| **(I)** | Estimated tele-everything Tavg , kbp/s | E+H | 2582 | 198 |
| **(J)** | Estimated tele-everything downstream-to-upstream traffic ratio | I[DOWN] / I[UP] | 13 | |

In relative terms the upstream's peak grew more than downstream. Converting the peak utilization to an absolute number allows us to take into account the asymmetrical nature of DOCSIS broadband connections and the fact that the upstream grew from a lower base. When we do this, we can see that in absolute terms that the downstream bandwidth usage grew ~9x the upstream.

Even though the usage of videoconferencing grew much more than the usage of video streaming, the fact that video streaming uses on average about five-times more bandwidth than videoconferencing, as shown in Table 4 and Table 5, contributed to the 9x growth in absolute bandwidth in the downstream.

**Table 4 - Videoconferencing bandwidth requirements.**

| | Upstream | Downstream | Average |
|---|---|---|---|
| **Zoom (Zoom, 2020)** | 600 kbp/s – 1.8 Mbp/s | 600 kbp/s – 1.8 Mbp/s | 1/1 Mbp/s |
| **WebEx (Cisco Webex, 2020)** | 500 kbp/s – 3.0 Mbp/s | 500 kbp/s – 3.0 Mbp/s | 1/1 Mbp/s |
| **MS Teams (Microsoft, 2020)** | 500 kbp/s – 1.5 Mbp/s | 500 kbp/s – 1.5 Mbp/s | 1/1 Mbp/s |

[2] J. Ulm and T. Cloonan, "The Broadband Network Evolution Continues - How Do We Get to Cable 10G?," p. 8-9
[3] Ibid, p. 8-9
[4] NCTA, "COVID-19: How Cable's Internet Networks are Performing,"

**Table 5 - Video bandwidth requirements.**

| Streaming Service | Downstream |
|---|---|
| Netflix | 5 Mbp/s |
| Hulu | 3 Mbp/s |
| Amazon Prime | 5 Mbp/s |
| YouTube | 7 Mbp/s |

### *4.5.2. Traffic Ratio*

The shift to tele-everything had minimal impact on the downstream-to-upstream traffic ratio. In 2019, the busy-hour downstream-to-upstream traffic ratio was 14:1. We estimate that it grew to 15:1 in 2020 prior to the shutdown and with the shift to tele-everything that it declined to 13:1. This is consistent with overall traffic ratio, as reported by OpenVault, which reported that it went from 20:1 down to 16:1 (OpenVault, 2020). The reduction in the overall traffic ratio can most likely be attributed to the increased use of videoconferencing during the daytime hours for tele-work and tele-school, while the smaller change during the peak busy hours is likely due to any increased upstream usage being offset by increased video streaming in the downstream.

## 5. Conclusion

The COVID-19 pandemic of 2020 caused a sudden shift to tele-everything that resulted in large changes in traffic patterns on the Internet and cable networks. In this paper, we looked at data collected and posted by the cable industry as well as data posted by other third parties on the performance of cable networks and the Internet in general with the shift to tele-everything. We observed that the shift to tele-everything caused internet traffic to grow 30-50% and that traffic on the cable networks grew 20-35%, with the traffic growth on cable networks somewhat independent of the size of the operator. We observed that the service delivery infrastructure of content delivery networks and caches worked well, with most of the traffic growth being observed in the access networks and not on the transit links. We also observed that even with the sudden growth in traffic, there was no measurable impact on the end user's quality of experience, as measured download speeds only declined about 1% and there was no measurable change in the round-trip time for the RIPE Atlas test probes.

We also looked at the impact of the shift to telework and the early opening of northern vacation homes on the upstream usage. We observed that there was a loose correlation between the two.

And finally, we looked at the impact of the growth in videoconferencing and video streaming on the network. We observed that even though the upstream in cable networks in relative terms grew more than the downstream, that the absolute bandwidth growth on the downstream was 9x the bandwidth growth in the upstream and that this is because video streaming uses about 5 Mbp/s per high-definition video stream compared the 1 Mbp/s in each direction used by the videoconferencing applications. The impact to the downstream-to-upstream traffic ratio was small as the growth of video streaming in the downstream was somewhat offset by the growth in video conferencing in the upstream.

Overall, U.S. cable networks have performed well during the pandemic.

# Abbreviations

| | |
|---|---|
| CAGR | compound annual growth rate |
| CDN | content delivery network |
| CMTS | cable modem termination system |
| COVID-19 | corona virus disease 2019 |
| DOCSIS | Data Over Cable System Interface Specification |
| DS | downstream |
| DSL | digital subscriber line |
| FTTH | fiber to the home |
| HFC | hybrid fiber coax |
| ISP | Internet service Provider |
| kbp/s | kilobit per second |
| MAC | medium access control |
| Mbp/s | megabit per second |
| NANOG | North American Network Operators' Group |
| SCTE | Society of Cable Telecommunications Engineers |
| Tavg | Average bandwidth consumed by a subscriber during the busy-hour |
| TCP | transmission control protocol |
| US | upstream |

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