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July 12, 2017

Via Electronic Submission

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

Re: Restoring Internet Freedom, GN Docket No. 17-108

Dear Ms. Dortch:

Measurement Lab ("M-Lab") submits this letter in order to reaffirm its support for the Federal Communications Commission's (the "Commission") efforts to promote public transparency on broadband access, as well as to support data-driven policy-making. M-Lab is a consortium of research, industry, and public interest partners dedicated to providing an ecosystem for the open, verifiable measurement of global network performance. In order to support partners, M-Lab provides measurement servers internationally within networks that host popular content and connect Internet service providers to each other ("transit ISPs"). Its infrastructure supports the SamKnows platform used in the Commission's "Measuring Broadband America" program and is relied on by an increasing number of regulators around the world for accurate and open data on their citizens' broadband access. In our February 19, 2015 submission to the Open Internet docket, we committed to research on the state of broadband and performance impact of interconnection in the United States, and submit this letter in line with that commitment.[1]

In October 2014, Measurement Lab released the report "ISP Interconnection and its Impact on Consumer Internet Performance" (the "Interconnection Study"), which was a first-of-its-kind, wide-scale study on the effects of interconnection disputes on consumer broadband in the United States.[2] This research was made possible by the volume of M-Lab's data collection, which contains over eight years of network measurements from a large population users across a diverse set of networks. M-Lab's focus on interconnection was initially inspired by our observation of relative underperformance in cities where the platform maintained multiple measurement sites. Using a straightforward research method and open data, M-Lab compared trends across the US to identify patterns of performance degradation that occurred between prominent access and transit ISPs. We defined "degradation" as a drop in download throughput, an increase in round trip time, or an increase in packet retransmission rate, relative to past performance of

[1] https://www.fcc.gov/ecfs/filing/60001018549
[2] https://www.measurementlab.net/publications/M-Lab_Interconnection_Study_US.pdf

that network and other networks in the same location. To avoid spurious reports, the incidents described were those where substantial degradation occurred, rather than minor disruptions. These episodes had clear fingerprints: observed degradation was nearly always diurnal, with significantly worse performance during peak use hours.[3] Degraded performance co-occurring with peak usage suggested that network load was causing congestion that lead to poor performance. These episodes of poor performance frequently continued every day for months without being fixed, which further pointed towards systemic network under-provisioning as a cause.

In the Interconnection Study, we found a consistent theme across multiple access ISPs and transit ISPs: the interconnection relationships between network operators has a significant impact on broadband performance.[4] Degraded performance between consumers and these transit ISPs can create barriers to accessing the services within these networks. In the most severe cases, degradation represented a substantial impediment to accessing certain content for several prominent access ISPs, lasting for months and leading to download throughput speeds well below the definition of broadband.[5] While the cases differed in end user impact, the trends were national and were observed on several different transit ISPs, rather than being one problematic network. M-Lab's interconnection research contributed to a stronger public discourse on the business relationships at the core of the Internet, and has been cited in filings to the Commission by a diverse set of parties.[6]

M-Lab has since invested resources to build up its presence in the United States to monitor more networks and to support further research on the state of interconnection. M-Lab has continued to expand its measurement infrastructure and data collection volume. The increase in the volume of tests paired with our expanded network presence has enabled M-Lab to make more assessments based on more diverse datasets. The platform now maintains fifty-six measurement sites in the United States, covering a number of transit ISPs in key peering locations across the country.[7] Additionally, M-Lab has launched new tools to monitor interconnection and analyze the dataset, without requiring time-consuming data processing or special technical expertise.[8] M-Lab's presence in diverse networks and geographies allows researchers and regulators using our data to differentiate between congestion as a symptom of interconnection agreements between ISPs, and network issues specific to a given local market. This perspective is

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[3] Defined by the Federal Communications Commission (FCC) as the hours between 7pm and 11pm local time.

[4] As we note in our publication: while we can infer that performance degradation is interconnection-related, we do not have the contractual details and histories of individual interconnection agreements and therefore cannot attribute business motivations for the congestion. We cannot tell whether any particular ISP between the user and a measurement point is "at fault," what the contractual agreement between ISPs did or did not dictate regarding interconnection, or what steps were taken to resolve any congestion.

[5] At that time, 4 Mbps.

[6] See: Letter of National Cable & Telecommunications Association in GN Docket No. 14-28. Page 3, January 21, 2015, http://apps.fcc.gov/ecfs/document/view?id=60001014982; Letter of COMPTEL, Level 3, Cogent and Netflix in
GN Docket No. 14-28. Page 3, January 13, 2015, http://apps.fcc.gov/ecfs/comment/view?id=60001008405

[7] For example, in Miami, M-Lab now maintains five sites (Level3, Cogent, Tata, GTT, and Zayo) and on Seattle, M-Lab offers similarly comprehensive coverage, with measurement points hosted in five transit networks (Cogent, Tata, GTT, Level 3, and XO).

[8] Mostly notably, M-Lab launched a new visualization platform that incorporates the functionality of the interconnection-focused Observatory and Telescope tools, and exposes more of the information contained within the global dataset, including raw data. https://www.measurementlab.net/blog/new-dataviz-site/#measurement-lab-launches-new-global-data-visualization-tools

necessary to identify nationwide trends in consumer Internet performance, and provides an opportunity for further review of past research.

As a platform committed to producing empirical data for the public, Measurement Lab has historically supplied the Commission with technical facts pertinent to its rule-making processes. In this filing, we review interconnection congestion episodes that appeared to had a negative impact on consumer broadband. Since the publication two years ago, the relationships between operators have changed, resulting in overall improvement in consumer performance and a notable remediation of congestion episodes covered in our initial reports. Often the improvements are sudden, reversing months long underperformance within days. The remediation of congestion parallels an overall improvement across networks in performance for broadband users, and in our analysis we do not find the same patterns of sustained degradation described in past reports. Additionally, a brief summary of the findings of the Interconnection Study is available as an appendix to this filing.

Since the Open Internet Order, Significant, Detectable Congestion Episodes Have Declined

Since the issuance of the Open Internet Order in February 2015, Measurement Lab has found a significant overall improvement in performance in broadband access in the United States and a subsidence of interconnection-related degradation. Based on review of the congestion episodes documented in the Interconnection Study and a new analysis of the M-Lab data, the problems identified in previous reports were often alleviated in the months after second quarter of 2015 and onward. Whereas we also noted cases of intermittent, medium-term congestion episodes in past publications, such as with XO and Comcast, the restoration of performance has been sustained.[9] Such issues are rarer now than in the past. A broad search of the dataset only identifies a small numbers of cases where interconnection relationships exhibit indications of congestion. M-Lab has also observed an overall improvement in the performance of broadband across all metrics. These finding demonstrate that since our original research the Internet in the United States has become more reliable and better performing, with interconnections less likely to be the bottleneck in consumers' access to content than in the past.

In order to automate analysis of the dataset, M-Lab developed a search tool to discover access and transit ISP pairs that demonstrated year-over-year performance drops similar to those documented in past interconnection research. The search tool re-discovered all the episodes from the Interconnection Study, and uncovered scattered instances of degradation from small networks, often universities or smaller ISPs. However, this automated analysis did not find, since 2015, widespread patterns similar to the performance degradation to the extent described in the Interconnection Study. We base our finding on this search process and manual inspection of the dataset.

The most significant degradation identified in our search was for Comcast users to M-Lab sites located in the transit ISPs Tata and GTT. The patterns of degradation match the diurnal trends of the Interconnection

[9] While there is often some level of diurnal variation, these patterns are commonly the product of statistical methods, and the variation exposed in the visualizations demonstrate that those relationships do not exhibit the same pattern of extremely lower results seen previously.

Study and suggest congestion between the networks. Both transit ISPs were networks included the interconnection-focused expansion of the platform and, as a result, M-Lab's observation of those networks began in September 2014. The underperformance appears from the outset of M-Lab hosting sites in GTT, therefore predating September 2014, while the degradation for Comcast customers across Tata appears later, beginning around September 2015. M-Lab had identified underperformance with Tata for multiple access ISPs in our June 2015 blogpost describing additional cases of congestion, however, those patterns were alleviated shortly after our research on the episode (notably with CenturyLink). Comcast is an exception: underperformance appears in the M-Lab data as a decrease of download throughput during peak hours that aligns with an increased packet loss at that time. As Figure 1 demonstrates, the degradation represents a substantial overall change in performance from Comcast to both transit ISPs, well beyond half of the performance compared to earlier in the day. During the same period, other access ISPs, such as AT&T or Verizon, no longer exhibit patterns of degradation to Tata and GTT. Likewise, Comcast users do not show the same underperformance to other sites, such as those on Cogent, Zayo, or Hurricane Electric.[11] A review of collected data related to Comcast and Tata from May and June 2017 shows less degradation, which tentatively suggests that remediative measures may have been taken recently to improve performance.[12]

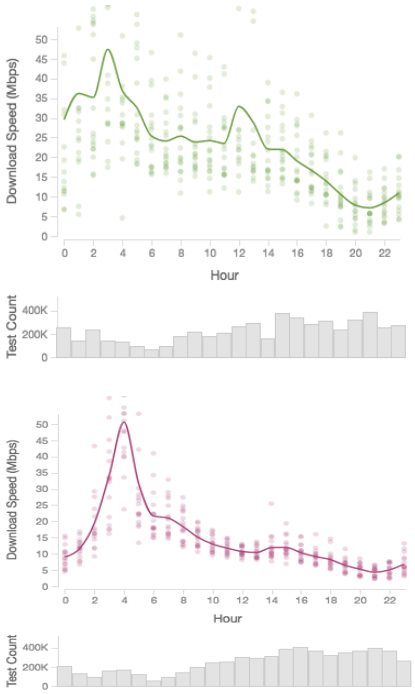

Figure 1: Comcast across Tata and GTT (respectively), January 2016 - April 2017, Diurnal Pattern, Download Throughput[10]

[10] http://viz.measurementlab.net/compare/location?aggr=month&end=2017-06-01&filter1=AS13367x&filter2=AS6453_AS3257_AS174&metric=download&selected=naus&start=2016-01-01

[11] http://viz.measurementlab.net/compare/location?aggr=month&end=2017-06-01&filter1=AS10774x_AS11486x_AS13367x&filter2=AS6453_AS3257_AS174_AS6461_AS6939&metric=download&selected=naus&start=2016-01-01

[12] At the time of filing, more recent data collected over the past two months do not appear in M-Lab's visualization platform or database due to mitigation to a new aggregation mechanism. This limitation should be resolved shortly, and M-Lab would be happy to assist any interested parties in accessing the data in the interim.

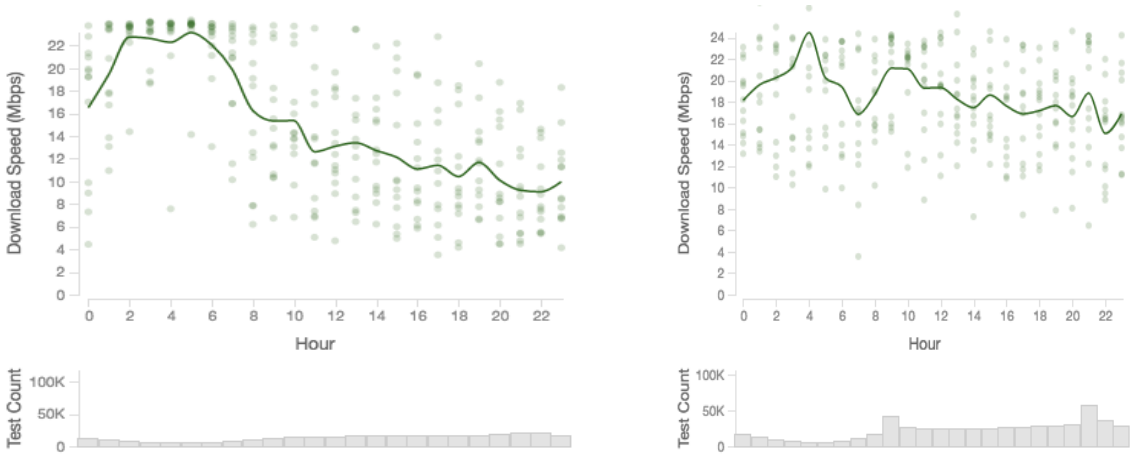

Figure 2: Verizon across Level 3, January 2014 - December 2014 and January 2015 - December 2015 (respectively), Diurnal Pattern, Download Throughput [13]

Overall, the M-Lab data shows a decline in the instances of interconnection-related underperformance and the remediation of previous congestion episodes. The improvement contrasts substantially with the situation described in previous interconnection research, where multiple access ISPs and transit ISPs showed sustained underperformance between each others' networks. In several of the episodes covered by M-Lab's research, the parties involved later published press releases announcing upgrades to interconnection capacity, which would have potentially addressed congestion due to under-provisioned capacity. The disclosures provide a point of comparison that was not previously available. In all cases, these announced upgrades result in demonstrable change in performance, alleviating previous issues. For example, in April 2015, Verizon and Level 3 announced a "long-term, bilateral interconnection agreement related to their public IP networks."[14] Verizon and Level 3 were identified in the original Interconnection Study as having a diurnal performance variation during 2014 that resulted in a more than 50% decrease in median download throughput during peak hours. As Figure 2 demonstrates, this underperformance changed within months of the announcement of the agreement, and performance between Verizon and Level 3 continues to improve since.

[13] http://viz.measurementlab.net/compare/location?end=2015-01-01&filter1=AS11486x&filter2=AS10753x&selected=naus&start=2014-01-01
http://viz.measurementlab.net/compare/location?end=2016-01-01&filter1=AS11486x&filter2=AS10753x&selected=naus&start=2015-01-01

[14] http://investors.level3.com/investor-relations/press-releases/press-release-details/2015/Level-3-and-Verizon-Enter-Into-Interconnection-Agreement/default.aspx
http://about.att.com/newsroom/level_3_and_att_enter_into_interconnection_agreement.html

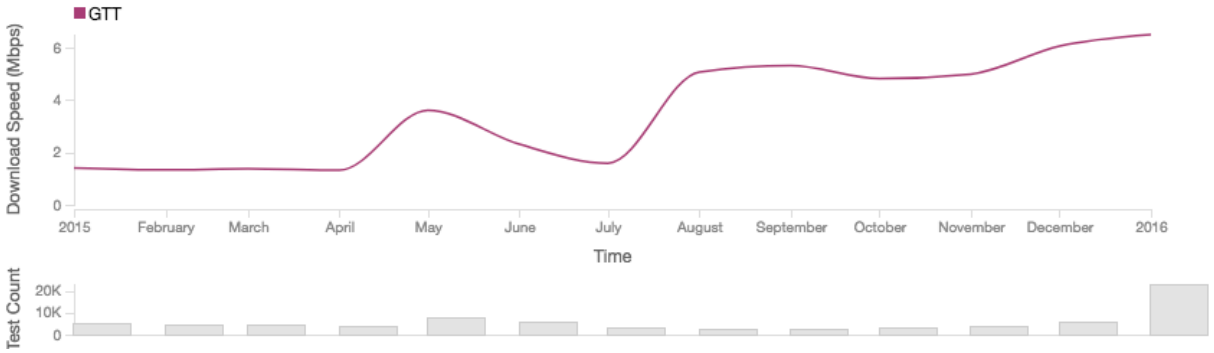

Figure 3: AT&T across GTT, January 2015 - January 2016, Download Throughput[15]

This is a repeated and common pattern for other access and transit ISPs over the latter half of 2015: the improvement of quality of service for customers of access ISPs that M-Lab had identified in potential congestion episodes in 2013-2014. In another example, in June 2015, GTT and AT&T announced a bilateral agreement to provide their clients with additional capacity.[16] Both networks were identified in a blogpost published by M-Lab that found that peak hour performance was frequently less than 0.1 Mbps. As with other cases, alternative access ISPs and transit ISPs did not display as substantial degradation to those same sites during the same period.[17] The announcement of added capacity is followed shortly by a dramatic improvement in measured performance between the two providers, leading to an increase in the median throughput result from 1.6 Mbps for July to 5.1 Mbps in the following month.[18] The improvement is sustained to present day, and performance has continued to increase overall. Over the following months, nearly all congestion issues identified within M-Lab's research on interconnection showed demonstrable improvements.

[15] http://viz.measurementlab.net/compare/location?aggr=month&breakdownBy=filter1&end=2016-01-01&filter1=AS10774x&filter2=AS3257&metric=download&selected=naus&start=2015-01-01

[16] https://www.gtt.net/press_release/gtt-att-enter-interconnection-agreement/

[17] https://www.measurementlab.net/blog/interconnection_and_measurement_update/

[18] Median statistics have their limits and are only used to convey information is an easy to comprehend manner. It is important to note that while M-Lab has partnered with a number of software and hardware manufacturers to increase the volume of consistent measurements from controlled testing measurements, the dataset is still derived from crowdsourced contributions. This will introduce sample populations that often skew simple statistic representations of the data. In one example, a new integration launched in February 2016 increased the number of high-throughput tests being conducted on a regular basis; as a result the median for several ISPs increases until July, when that number is offset by an even larger and perhaps more representative integration. Moreover, services tend to be multimodal, especially on diverse offerings – e.g. AT&T and Verizon with ADSL and Fiber – the median will change over time as a result of the prominence of measurements from one service over another.

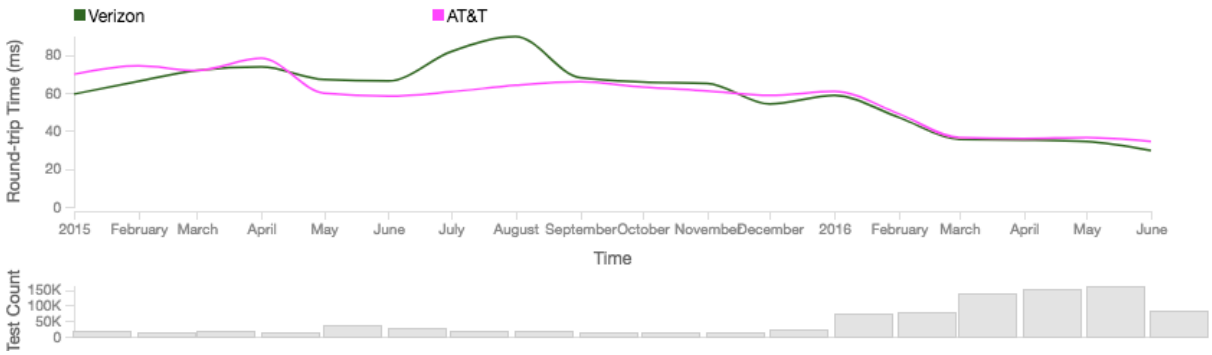

Figure 4: AT&T and Verizon across Level 3, January 2015 - June 2016, Latency[19]

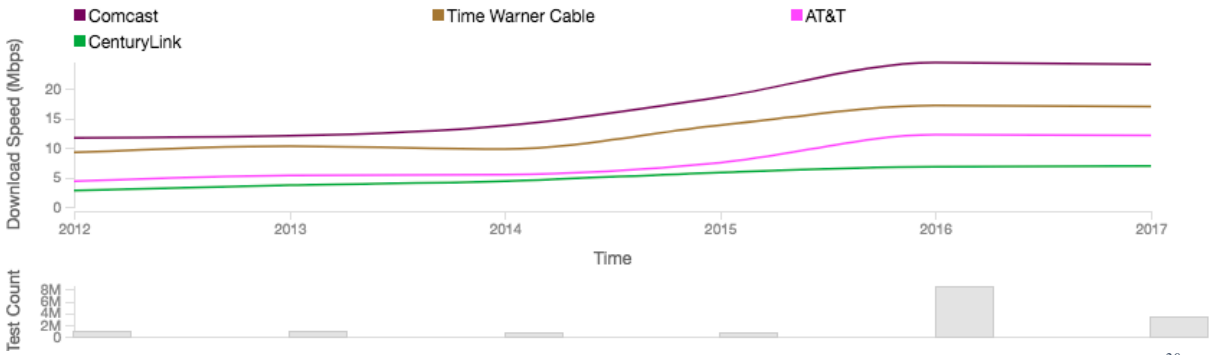

Figure 5: AT&T, CenturyLink, Comcast, and TWC across Level 3, January 2012 - January 2017, Download Throughput[20]

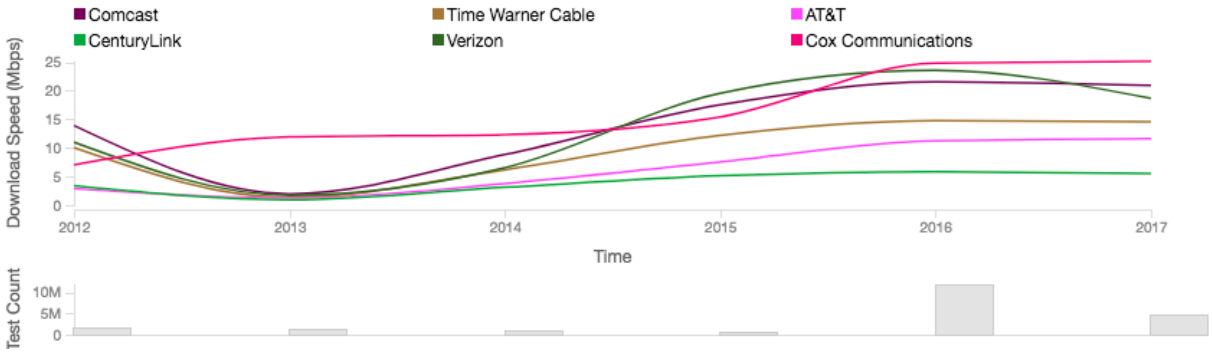

Figure 6: AT&T, CenturyLink, Comcast, Cox, TWC, and Verizon across Cogent, January 2012 - January 2017, Download Throughput[21]

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[19] http://viz.measurementlab.net/compare/location?aggr=month&breakdownBy=filter2&end=2016-06-01&filter1=AS11486x_AS10774x&filter2=AS10753x&metric=rtt&selected=naus&start=2015-01-01

[20] http://viz.measurementlab.net/compare/location?breakdownBy=filter2&end=2017-01-01&filter1=AS13367x_AS10796x_AS10774x_AS11398x_AS11486x&filter2=AS10753x&selected=naus&start=2012-01-01

[21] http://viz.measurementlab.net/compare/location?breakdownBy=filter2&end=2017-01-01&filter1=AS13367x_AS10796x_AS10774x_AS11398x_AS11486x_AS22773&filter2=AS174&selected=naus&start=2012-01-01

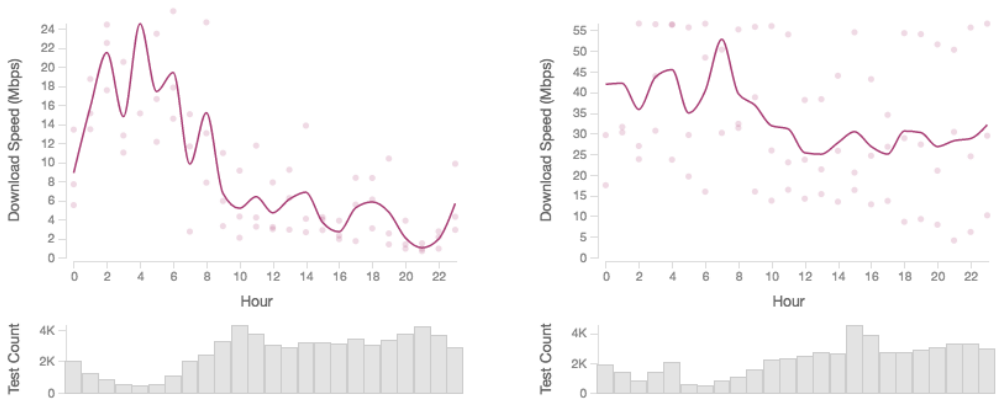

Figure 7: Verizon across GTT, June 2015 - August 2015 and August 2015 - October 2015 (respectively), Diurnal Pattern, Download Throughput[22]

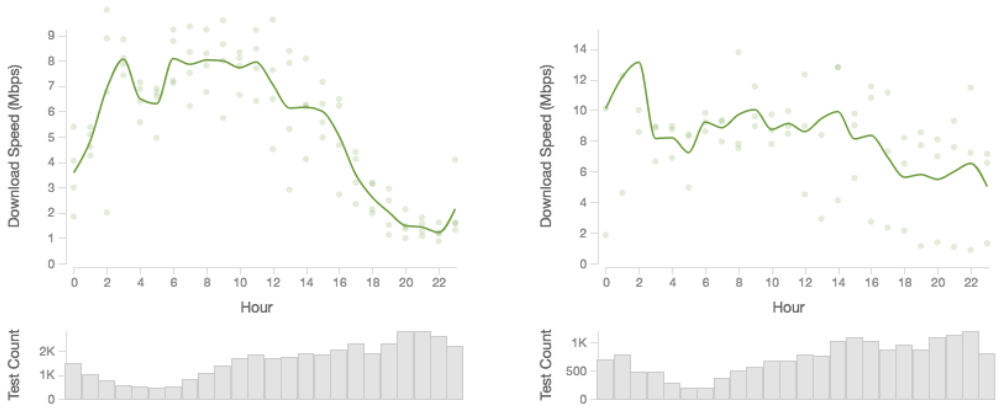

Figure 8: CenturyLink across Tata, October 2015 - January 2016 and January 2016 - March 2016 (respectively), Diurnal Pattern, Download Throughput[23]

Conclusion

A review of the M-Lab performance measurement dataset based on the parties and patterns identified in the Interconnection Study has shown that the widespread degradation experienced by American broadband users common in 2013-2014 has not recurred since the Open Internet Order was enacted. In several relationships where M-Lab had previously identified underperformance, press releases announcing upgrades to the interconnection between ISPs provided additional indication of changes in the relationship between networks and support our analysis of the dataset. These press releases were followed within days by substantial improvements to the performance of broadband consumers. No similar

[22] http://viz.measurementlab.net/compare/location?aggr=month&end=2015-08-01&filter1=AS11486x&filter2=AS3257&selected=naus&start=2015-06-01
http://viz.measurementlab.net/compare/location?aggr=month&end=2015-10-01&filter1=AS11486x&filter2=AS3257&selected=naus&start=2015-08-01

[23] http://viz.measurementlab.net/compare/location?aggr=month&breakdownBy=filter1&end=2016-01-01&filter1=AS11398x&filter2=AS6453&metric=download&selected=naus&start=2015-10-01
http://viz.measurementlab.net/compare/location?aggr=month&breakdownBy=filter1&end=2016-03-01&filter1=AS11398x&filter2=AS6453&metric=download&selected=naus&start=2016-01-01

degradation has occurred between the affected providers since, and few further degradations episodes have arisen since the Open Internet Order.

The Interconnection Study, and subsequent research, affirms that network management practices and congestion associated with interconnection relationships can be independently measured by an objective third party. Our research has demonstrated that interconnection congestion can have a sustained, deleterious impact on consumers. These incidents were not one-off events, and their resolution often appeared quickly when additional capacity was added to the interconnection points. The transparency provided by measurement is an important tool in understanding how interconnection will evolve in the United States. Through Measurement Lab, and other open performance measurement efforts, the Commission has the tools available to conduct continuous, independent assessment of interconnection health with objective methodologies and tested platforms. We believe that only through the transparency provided by open measurement will the Commission achieve its objectives to promote greater access for all Americans, and will continue to provide data on our findings as the Commission considers interconnection and the development of broadband in the United States.

Respectfully submitted,

Collin Anderson
Researcher, Measurement Lab

Appendix: Interconnection Study Findings (October 2014)

In the Interconnection Study, M-Lab observed sustained degradation experienced by customers of the most prominent American broadband access ISPs: AT&T, Comcast, CenturyLink, Time Warner Cable, and Verizon. The degradation documented in the publication occurred when traffic passed over interconnections with transit ISPs Cogent Communications (Cogent), Level 3 Communications (Level 3), and XO Communications (XO) – networks where M-Lab had hosted measurement endpoints. We observed similar patterns of performance degradation whenever and wherever specific pairs of access and transit ISPs interconnected. While the onset of congestion and end consumer impact differed between each access and transit provider relationship, the sustained episodes documented in the report typically began in early 2013, and continued into the following year.[24]

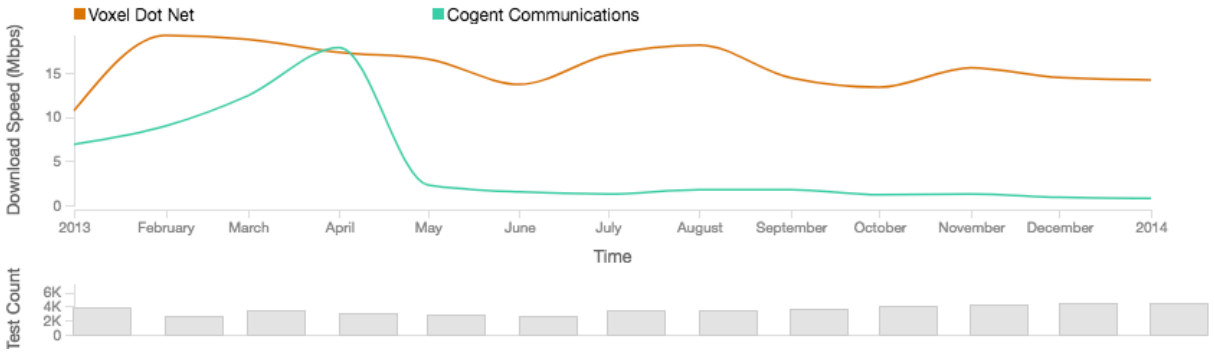

Figure 9: Verizon across Internap and Cogent in New York, January 2013 - January 2014, Download Throughput[25]

The degradation episodes were not simply the result of technical issues that were isolated to certain cities or for a limited amount of time. In our research, we became more confident in our findings of congestion when the pattern was repeated across multiple locations for the same access and transit ISPs pair during the same time period. The poor performance tracked the business relationship across geography. M-Lab has sought to maximize the diversity of the locations and networks where measurement servers are hosted. These trends occurred across locations that would be unlikely to share common infrastructure (e.g., Los Angeles and New York City), and for durations in which a purely technical issue should be resolved. As these qualities of duration and breadth compound, we can conclude that the business relationships between impacted access and transit ISP pairs is a likely factor in the repeated and unresolved patterns of performance degradation observed.

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[24] M-Lab does maintain sites on research networks or smaller transit providers, which could have incurred congestion as well. Additionally, the M-Lab data could describe further congestion episodes prior to 2013, as suggested in certain cases. The intent of the report was to demonstrate a technical method and provide public data, rather than describe all interconnection relationships possible. Thus, our initial research was more narrowly scoped, and we continue to build on this work to surface more trends in the data.

[25] http://viz.measurementlab.net/compare/location?end=2014-01-01&filter1=AS10796x_AS11486x_AS32953&filter2=AS29791_AS174&selected=nausny&start=2013-01-01

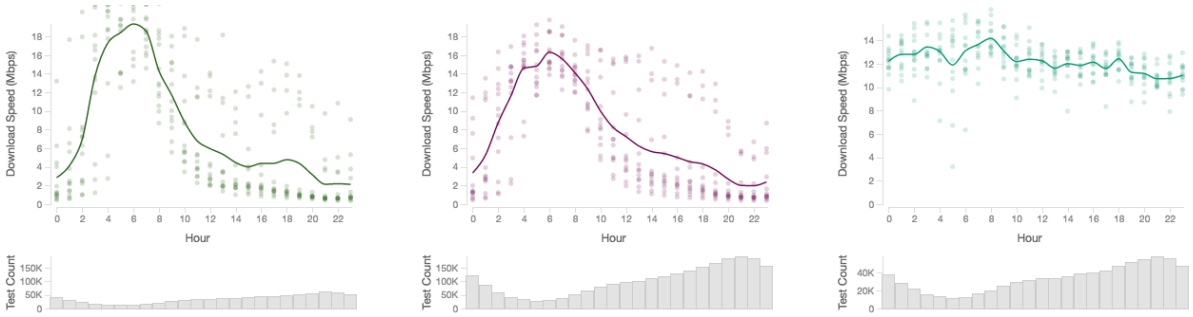

Figure 10: Verizon, Comcast and Cox across Cogent, January 2013 - January 2014, Diurnal Patterns, Download Throughput[26]

The patterns demonstrated with the large volume of measurements collected by M-Lab mirrored public reports of interconnection disputes and described the significant impact of congestion on consumer performance. The most dramatic degradation was between several prominent access ISPs and the transit provider Cogent.[27] Starting by April 2013 until late February 2014, we observed significant decreases in download throughput, increases in round trip time, and increases in packet retransmission rates that impacted customers of AT&T, Comcast, CenturyLink, Time Warner Cable, and Verizon. By January 2014, customers of these access ISPs were only able to achieve download throughput metric that met the FCC's definition of broadband at the time between 2:00 am and 1:00 pm. At its most extreme, the degradation led to download throughput of less than 1 Mbps for much of the day over several months. This degradation was observed across all of M-Lab sites hosted within Cogent's network.[28] It is very unlikely that the interconnections involved in these locations shared common physical infrastructure, pointing to a non-technical (business) issue at the root of the problems, and not a systemic technical failure in part of any network.

To rule out the possibility that performance issues were the product of failures isolated within an access or transit ISP's infrastructure, M-Lab used comparative baselines of performance with alternative networks. During the same period, customers of the Cablevision uniformly experienced good performance when connecting to the Cogent-hosted measurement point in New York (where Verizon and Time Warner encountered degradation). This indicates that Cogent had sufficient capacity within their network and began to rule out across-the-board problems with Cogent. During the same period, the same four access ISPs did not show the same patterns of degradation when testing against M-Lab's Internap host site hosted in New York City. This pattern is repeated for other locations elsewhere. M-Lab in most

[26] http://viz.measurementlab.net/compare/location?aggr=month&breakdownBy=filter1&end=2014-01-01&filter1=AS11486x_AS22773_AS13367x&filter2=AS174&metric=download&selected=naus&start=2013-01-01

[27] After publication, we discovered an interesting artifact of this sustained congestion. For the M-Lab results, extreme degradation was evident for measurements to Cogent-hosted sites over a year. In February 2014, this degradation was suddenly alleviated, without indication that interconnection capacity had been upgraded. Upon deeper inspection, we found that the change was due to the application of a prioritization regime within the Cogent, which created two tiers of performance. A representative of Cogent later elaborated on the measure taken to address continued impact to enterprise customers. This change limited our insight into the degradation after February 2014, but did not affect our prior findings.
https://groups.google.com/a/measurementlab.net/forum/#%21topic/discuss/vcQnaZJO6nQ

[28] Dallas, Los Angeles, New York City, and Seattle

cases identified alternative networks to serve as comparative baselines to demonstrate that issues seen were not isolated to the edge networks.

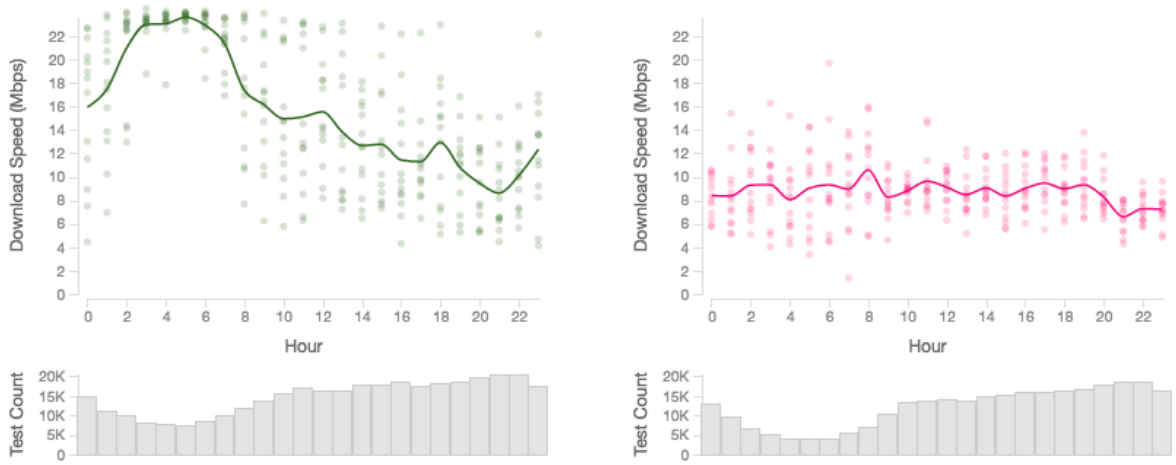

Figure 11: Level 3 across Verizon and Cox, January 2013 - January 2014, Download Throughput[29]

While the congestion observed to Cogent sites represented the most extreme case of degradation, the Interconnection Study was not limited to issues with interconnections to any particular network. Patterns demonstrating a similar, at times deleterious, relationship between interconnection and end-user performance were also present to measurement points on other transit ISPs, with similar diurnal underperformance during peak use hours. As with Cogent, the synchronized patterns of degradation across geographically disparate locations between the same access and transit ISP pairs points to a business relationship as the root of the problem, and not a technical failure.

In Atlanta and Chicago, where M-Lab hosts measurement points within the network of transit ISP Level 3, we found patterns of performance degradation for Comcast, Time Warner Cable, and Verizon customers. The degradation of performance was consistently observed across Level 3-connected locations. Verizon showed the clearest patterns of degraded performance. Starting in May 2011, Verizon customers in Atlanta and Chicago experienced persistent high round trip times that consistently exceeded 100 ms – well above the 60 ms average latency measured for transit networks. Beginning around June 2013, these symptoms were joined by degraded download throughput, particularly during peak use hours.

[29] http://viz.measurementlab.net/compare/location?breakdownBy=filter2&end=2014-01-01&filter1=AS10796x_AS11486x&filter2=AS10753x&metric=download&selected=naus&start=2013-01-01

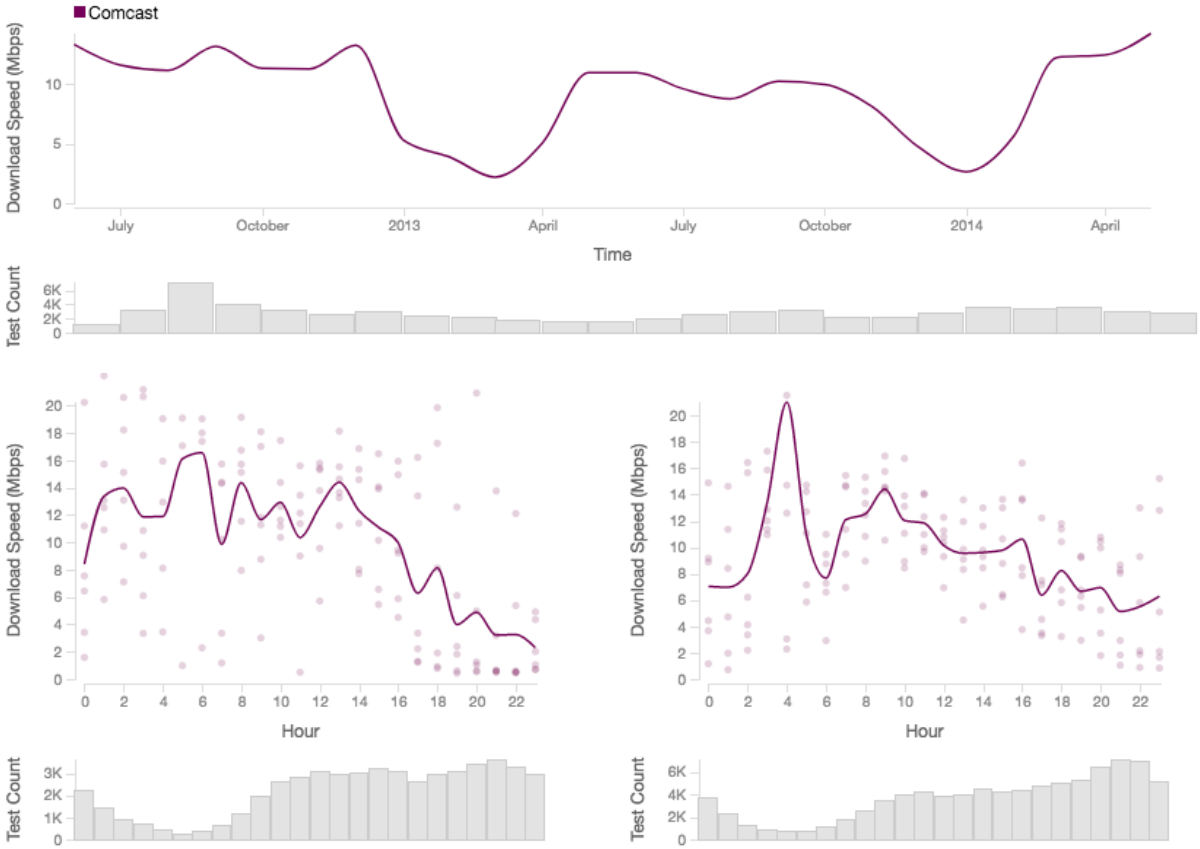

Figure 12: Comcast across XO in Washington, DC, December 2012 - May 2013 and October 2013 - March 2014, Diurnal Patterns, Download Throughput[30]

Lastly, the Interconnection Study also found sustained patterns of underperformance for customers of Comcast and Time Warner Cable connecting to the XO-hosted site in Washington, DC. While Time Warner Cable and Comcast do not share the same patterns and timing of decline, each experienced sustained periods of degradation, with the worst symptoms occurring during peak use hours.[31] Comcast customers connecting across the XO-hosted site experienced two periods of performance degradation resulting in decreased download throughput and increased packet retransmission rates (Figure 12). Time Warner Cable customers also experienced a substantial and consistent reduction in download throughput during peak use hours beginning around December 2012 and improving in the middle of 2014. Since these incidents were often episodic, and since M-Lab only maintained one XO-hosted site at the time, it was possible that these were more short-lived issues.

The Interconnection Study demonstrated that the performance of network relationships could be observed with the right infrastructure and data. One early lesson was that detecting this congestion required a sufficiently large amount of measurements from consumers to multiple sites. In order to be confident of

[30] http://viz.measurementlab.net/compare/location?aggr=month&breakdownBy=filter1&end=2014-05-01&filter1=AS13367x&filter2=AS2828&metric=download&selected=naus&start=2012-06-01

[31] Unlike Cogent and Level 3, M-Lab did not have another XO hosted site until January 2016. Thus, while we observe performance degradation, we could not determine whether this is linked to Access ISPs' interconnection relationships with XO, issues within edge networks, or some combination of both.

our findings, M-Lab was initially limited to the cities where it had long-existing infrastructure and a large sample of users from access ISPs. Our research did not assert that it covered the entirety of the interconnection ecosystem, only those prominent networks that M-Lab had presence in. Moreover, M-Lab focused on cases of sustained degradation that had significantly impacted broadband users, rather than brief periods that could have been the product of technical issues with little effect.

Following on from the Interconnection Study, in June 2015, M-Lab published the blogpost "New Opportunities for Test Deployment and Continued Analysis of Interconnection Performance" that documented more congestion episodes detected on additional transit networks.[32] In the months leading up to the first report, Measurement Lab expanded its infrastructure presence, covering new transit networks and diversifying the locations where it had sites in existing networks. This build out of infrastructure was paralleled with an emphasis on new partnerships and measurement tools to increase the amount of tests collected. After months of data collection from these new locations and networks, M-Lab found patterns of degradation that matched those of the Interconnection Report beyond the original transit ISPs.

Our updated findings showed persistent degradation experienced by customers of a number of major access ISPs across the United States during the first half of 2015. While the ISPs involved in each case differ, the symptoms and patterns of degradation are similar to those detailed in Interconnection Study: decreased download throughput, increased latency, and increased packet loss (compared to the performance through different access ISPs in the same region). In nearly all cases degradation was worse during peak use hours.

The congestion events included:

- AT&T, Comcast, Time Warner Cable, and Verizon with GTT Communications (GTT)
- CenturyLink with Tata Communications (Tata)

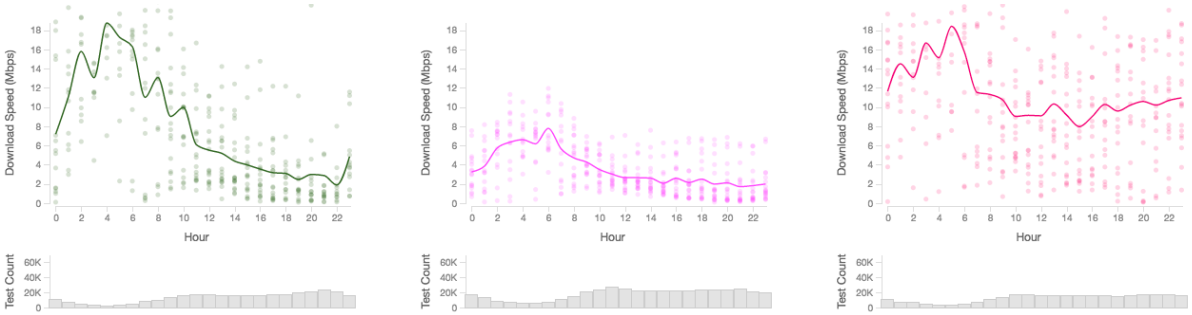

Figure 13: Verizon, AT&T, and Cox across GTT, January 2014 - June 2015, Download Throughput[33]

[32] https://www.measurementlab.net/blog/interconnection_and_measurement_update/

[33] http://viz.measurementlab.net/compare/location?breakdownBy=filter2&end=2015-06-01&filter1=AS11486x_AS10796x_AS13367x_AS11398x_AS10774x&filter2=AS3257&selected=naus&start=2014-01-01

M-Lab had established sites in Tata and GTT within the platform expansion, and from the outset, observed diurnal trends of underperformance for certain access providers that indicated congestion. Customers of Comcast, Time Warner Cable, and Verizon all saw degraded performance during peak use hours when connecting to Tata and GTT. These patterns were most dramatic for customers of Comcast and Verizon when connecting to GTT, with performance approaching 1 Mbps during peak hours in May. AT&T users experienced the most consistent patterns of congestion-related degradation on GTT with the most extreme with peak hour performance frequently less than 0.1 Mbps. In Seattle, CenturyLink users received consistent speeds across the day to Cogent-hosted measurement endpoints, while the peak hour performance to Tata was less than 1 Mbps. This congestion appeared at the start of collection of data, indicating that it pre-dates September 2014. None of these access providers experienced similar problems when connecting with other transit providers, such as Internap and Zayo, and Cablevision did not experience the same scale of problems on the transit ISPs.