

# Utilization as an FCC Broadband Benchmark

Paper #0, 7 Pages

## Abstract

The Federal Communications Commission (FCC) has recently taken major decisions in an attempt to regulate broadband in the US, creating disputes between itself and ISP providers. One such policy was the radical increase of broadband speed benchmark, that motivated both parties to investigate these regulations from different perspectives. This led to the Commission publically requesting comments on issues pertaining to “advanced telecommunication capabilities” to design future benchmarks based on metrics other than broadband speed.

In this work, we provide a much required input to the FCC’s open questions, supported by our analysis of usage patterns, rather than just the FCCs speed benchmarks. We analyse users with high tier access links and motivate the need of multiple benchmarks based on peak usage of different types of users. We also show that beyond a certain speed, user behavior is not significantly impacted by further increases in broadband capacity. Therefore, motivating the need to define benchmarks based on metrics other than broadband speed to truly offer “advanced” capabilities.

## 1 Introduction

The large impact of broadband Internet in our daily lives, and its rapid increase in providing services, requires regulation of all involved parties, such as all transit and content providers. The Federal Communications Commission (FCC) holds the important responsibility of overlooking public and private sector initiatives to ensure advanced broadband deployment throughout the US. As part of this responsibility (since the amendment to the Telecommunications Act of 1996 (section 706 [5])<sup>1</sup>), the FCC has been reporting results of its annual inquiry regarding the availability and timely deployment of “advanced telecommunications capability” to all Americans.

If the FCC determines that “*advanced telecommunications capability*” is not being deployed to all Americans in a reasonable and timely fashion, the Commission is required to “take immediate action to accelerate deployment of such capability by removing barriers to infrastructure investment and by promoting competition in the telecommunications market.”<sup>1</sup> The FCC accomplishes this role by following three major steps: (a) *defining a benchmark*<sup>2</sup> to evaluate

“advanced telecommunications capability”, (b) *auditing capabilities* of services offered by Internet Service Providers (ISPs), and (c) *spending the federal budget* to increase ISP capabilities, and accomplish their defined standards.

As independent researchers in the measurement community, it is our responsibility to ensure that the FCC defines broadband benchmarks and standards in a sensible manner. Efforts to define such benchmarks have always been based on aggregated data analysis by the FCC. The source of the FCC’s data are mixed across tiers and locations, and collected using different methodologies; particularly vantage points in the data were treated similarly without studying their actual usage requirements [4]. Based on such data, the FCC made a decision to aggressively increase the broadband benchmark threshold from 4 Mbps/1 Mbps to 25 Mbps/3 Mbps [1]<sup>3</sup>. This prompted a sharp response from ISPs offering technologies that suddenly did not qualify as broadband (such as DSL).

We support the move to a higher broadband standard based on the increasing share of high quality entertainment traffic in home broadband consumption [6, 7], as well as the possibility of offering advanced capability (such as telemedicine). But, we strongly motivate the Commission to revisit their evaluation criteria in reaching more meaningful standards. We also realize that the FCC requests comments on the issues of broadband benchmarking [section 6] in future. To this aim, we use a dataset collected purposefully to validate and improve the FCC policy on broadband benchmark.

Our study is based on Comcasts analytic data collected from home gateways for their customers in Salt Lake City, Utah. This data consists of byte transfers collected continuously every 15 minutes from two types of users; control: users that pay and use a high capacity access link (105 Mbps), and test: users that pay for 105 Mbps but are actually offered a much higher capacity access link (250Mbps) without their knowledge. This decision was specifically anticipated to enable researchers to investigate the question: does increase in bandwidth change usage behavior? Our analysis shows that not only are we capable of answering the above question, but we can also validate and improve more FCC policies on broadband benchmark.

Our contributions in this work are as follows:

- We reaffirm the importance of measuring performance during the prime-time hours, and urge the FCC to change and

<sup>1</sup>This issue is discussed in point 1, and point 12 of the Eleventh Broadband Progress Report, FCC No. 15-10A1, respectively [4]

<sup>2</sup>The FCC uses benchmark to a threshold, beyond which the access link will be considered broadband capable.

<sup>3</sup>4Mbps/1Mbps is defined as 4Mbps uplink, and 1Mbps downlink capacity.

standardize the measurement and interpretation of **prime-time ratio**. *Roya: should we use of “change” vs “revisit”*

- We shed light on the user’s and ISP’s conflicting perspectives of **capacity utilization**, and show that indeed, the user’s behavior does change when offered a higher capacity link even though the overall utilization stops increasing after a certain upper limit.
- We explore a user taxonomy based on **varying usage behavior** within the same tier, and suggest that the FCC adopt multiple benchmarks to better characterize broadband availability, deployment, and adoption in the US.

In this work, after offering details about our data and how it is sanitized in [section 2], we proceed by describing our methodology and evaluation criteria to study changes in broadband usage [section 3]. Next, we analyze spacio-temporal usage patterns as well as peak usage (during prime-time). Our analysis indicates that for high capacity access links, increasing capacity does not result in higher utilization, and motivates the need of multiple benchmarks based on varying usage within the same tier [section 4]. In the last section, we comment on the issues raised by FCC to investigate a better benchmarking solution for the US [section 5].

## 2 Data Source

Our dataset consists of network usage byte counters reported by Comcast gateways every 15 minutes from October 1, 2014 to December 29, 2014. There are two sets of broadband tiers that were used to collect this data: control set, consisting of households with a 105 Mbps access link, and the test set, consisting of households that were paying for a 105 Mbps access link, yet were receiving 250 Mbps instead. Users in the test set were selected randomly and were not told that their access bandwidth has been increased. There were more than 15000 gateway devices in the control set, with varying usage over the three months, and about 2200 gateway devices in the test set. *TODO: confirm - these were reported by Comcast gateways right?*

### 2.1 Data Description

The raw data sets provided by Comcast consisted of the test set, and 8 separate control sets consisting of more than 15k unique households, over different date ranges within the three months. Each dataset contains the following relevant fields: Device ID, sample period time, service class, service direction, IP address, and the bytes transferred in the 15 minute sample slot, as described in table 1.

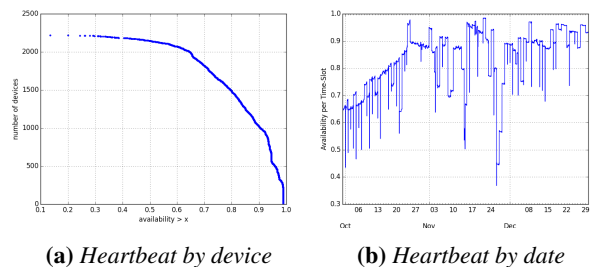
Field	Description
Device_number	Arbitrarily assigned CM device identifier
end_time	Fifteen minute sample period end time
cmts_inet	Cmts identifier (derived from ip address)
service_direction	1-downstream, 2-upstream
octets_passed	Byte count

**Table 1:** Field Descriptions for Comcast Dataset by Comcast

### 2.2 Data Sanitization

Our initial analysis of data transferred per time slot showed that certain gateway devices were responsive only for brief periods. We also noticed that certain time slots had a very low response rate throughout the dataset. *TODO: Why? asked comcast - waiting for response .*

We evaluate the fraction of responsiveness of a gateway throughout the dataset, as well as the fraction of responsiveness per time slot, and call this the **heartbeat**. Figure 1 shows how the number of devices decreases for a higher heartbeat requirement. Based on the common trend of this plot throughout the test and control datasets, we decided to only choose gateway devices with an heartbeat of at least 0.8.



**Figure 1:** Heartbeat, based on gateway device responsiveness. (Make common eps plot of heartbeat – 8 control sets (half filtered) + test sets vs availability.)

We sliced the sanitized test set based on the date range of each individual control set for comparison. We compared each of these tests individually to ensure that there are no outliers. We refer to the test and control sets in this case simply as datasets  $set_1 - set_8$ , where  $set$  is test or control. We also sliced and combined the sanitized data to give us control and test data for each month, referred to as  $set_{oct}$ ,  $set_{nov}$ ,  $set_{dec}$ . Finally, we combine all control sets to form a large concatenated dataset over the same date range as the complete test dataset, and we refer to this simply as  $set_{full}$ .

In the following analysis, we only present results for  $set_{full}$ , unless the behavior of an individual dataset varies significantly from the overall behavior and requires mention.

### 2.3 Relevance of the Data

In this section we describe how the Comcast database collected is both granular as well as unbiased. This database enables us to study usage behavior in a controlled setting. Beside, because of following properties, it is legitimized our use of it to compare and validate the FCC policy.

**Study Byte Counters:** The purpose of this work is to study the usage characteristics, irrespective of the application responsible for such usage. Limiting ourselves to just byte counters makes our analysis easily extendible to any ISP, and the FCC, interested in doing a similar study at a larger scale, without the risk of leaking PII. A study of applications

has already been performed extensively by Sandvine [1], as well as other researchers.

**Granularity of 15 minutes:** Broadband usage evaluated by commercial groups [2], or governmental survey bodies, usually employed by the FCC, tends to focus on aggregated usage statistics over months, long term trends, and applications. In our work we specifically focus on data transferred in 15 minutes, to avoid short term bursts that max out the capacity, but account for long term heavy flows (such as real time entertainment and voip calls) that will continuously max out the access link. This gives us a granularity fine grained enough to study major changes in usage characteristics (such as peak trends) while ignoring short term bursts of traffic (such as browsing)

Note that byte counter readings collected every 15 minutes from multiple households were synchronized for consistency in measurements.

**High Tier Measurements:** We limit ourselves to analyzing usage patterns in the high capacity access link tier only. The test dataset was collected by increasing the capacity from 105 Mbps to to 250 Mbps for 2200 randomly selected users, without their knowledge. This served a two-fold purpose in avoiding biases that studies on usage and capacity suffer from: (a) *Avoid behavioral change bias*: offering users with high capacity a further increase without their knowledge avoids the risk of behavioral changes that may occur when one purposefully buys a higher bandwidth connection; and (b) *Avoid frustrated user bias*: users already have a high capacity that gets upgraded, instead of opting for an upgrade because their previous capacity was insufficient for their usage. Studying datasets with these biases will always show a positive correlation between usage and capacity, and by examining a single high capacity tier, we avoid this.

**Single ISP, Same Location:** No bias between service plans, pricing model, and traffic treatment. Controlled setting. Paths + performance should be similar and unbiased by the ISP as data is from one city. Also avoids local behavioral biases (if any). This gives us a highly controlled setting to study usage behaviors in an unbiased manner across a very large set of users (15k control and 1500 test households). Thus we believe that are conclusions will be representative of broadband behavior in a general American urban city. We expect the baseline behavior of all users to be similar, and in fact, interpret any differences between the control and test set behavior as aggregate changes that occurred due to the an increase in access link capacity.

### 3 Methodology

We specify the evaluation criteria we use to compare usage patterns of the test and control sets.

In the following, we define capacity as the access link capacity offered by the ISP to the user. In the case of the Comcast dataset, capacity is 105 Mbps for the control set and 250 Mbps for the test set. Similarly, we define usage as the actual traffic (bytes uploaded or downloaded) by the

household being studied. We use usage across 15 min time slots to derive the average data rate and compare it to the capacity in our analysis.

[TODO: This section is not complete](#)

#### 3.1 Evaluation Criteria

We analyze based on three criteria:

- usage patterns
- peak utilization
- prime time ratio
- peak ratio
- traffic asymmetry

##### The Importance of Measuring Usage at Prime Time:

- Capacity planning is concerned about prime-time and peak behavior, i.e., max data rate per device is more important than the average rate of that device.
- Idle hour behavior is expected to stay the same, regardless of access link
- peak utilization definition

##### Prime-Time Ratio definition of prime time

- Sandvine defines Network Prime-Time ratio to measure the concentration of network usage during the prime-time evening hours.
- FCC says prime-time is 7-11 PM.
- Prime-Time ratio = absolute levels of network traffic during an average peak period hour with an average off-peak hour.
- Measure PT = avg data rate during a peak hour period : off-peak period.

Previous studies and reports [3] have indicated that peaks in prime-time occur mainly due to downlink video traffic, and may result in higher latency.

##### Peak Ratio

- define to measure imbalance in a day
- for each device, peak ratio = 90-%ile data rate per day / median data rate per day
- this metric can also be used to segregate users, based on who peaks at what time [section 5]

### 4 Results

[TODO: This is the results section](#)

We present a comparison between the usage characteristics of the control<sup>4</sup> and test<sup>5</sup>. We interpret the any variation between the results of both sets as a change in usage behavior due to increase in access link bandwidth.

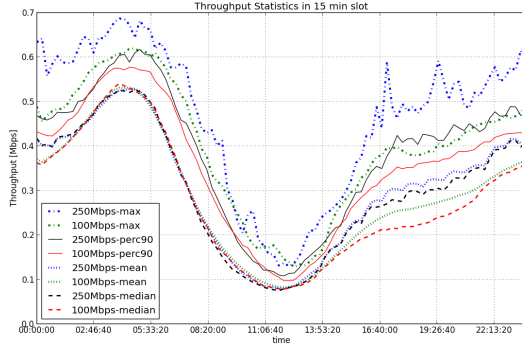
<sup>4</sup>household byte counters from users with a 105 Mbps access link

<sup>5</sup>household byte counters from users with a 105 Mbps access link

## 4.1 Usage Behavior

TODO: make two sub plots for (a) test and (b) control: (mean of day) (sum of device) bytes, include (perc90 of day) (sum of device) bytes and (median of day) (sum of device) bytes. Purpose is to show patterns individually, not compare differences. Patterns to show are (1) no troughs in usage, (2) prime-time hours shift (subsection 4.2), (3) difference between 90%-ile and median (subsection 4.4)

TODO: separate subplots for M-F and S/S/holidays – choose two interesting ones



**Figure 2:** *agg (days) over means (devices): aggregate has no trough, peaks in the evening hours*

We aggregate the the usage behavior of households both over space (i.e., distinct devices) and over time (i.e., over each day in the same time slot). We observe that the variance in daily network usage during weekdays is much higher as compared to weeknights and holidays. Thus, we divide our analysis based on day of the week in figure 2.

We find that the daily usage behavior on the weekend and holiday usage has four parts: (a) an initial sharp rise, (b) a flatter rise, (c) sharp rise to evening, (d) sharp decrease after 12 am. In contrast, weekdays clearly have two parts in a normal working day: (a) a rise in data usage from 7:00 AM that peaks in late evening around 8:00 PM, and (b) a sharp fall in usage from 12:00 PM to 6:00 AM in the morning. This pattern does not show any trough in the median network usage. This is in contrast to the aggregated usage patterns observed at ISPs that show a local small peak in network load in the morning (10AM), then dip in the afternoon, and then rise up again in the late evening hours. [6], TODO: confirm sandvine, check dasu shows this, check other studies.

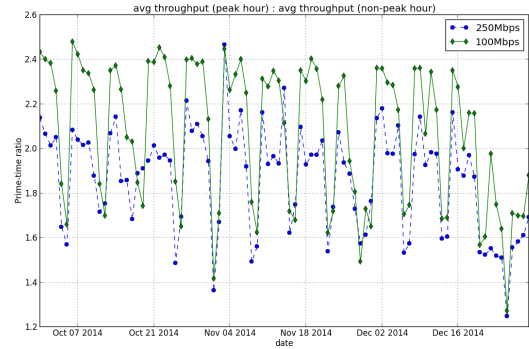
Figure 2 also shows that the peak hour behavior of both sets is very similar, but during the day, the median data rate of test set devices is slightly higher TODO: quantify than the control set.

TODO: Also, test set seems to have this small peak and a trough, but control doesn't. Why??. Test and control medians differ during office hours (10:00 AM to 6:00 PM) but are similar in peak hours...

## 4.2 Prime Time Ratio

In section 3, we established the importance of measuring behavior during prime time hours. To reiterate, the prime time hours as defined by the FCC is the period between 7:00 PM – 11:00 PM on weeknights when the network is under peak load [2]. TODO: The first occurrence of this definition was ... should this be in methodology??

Our analysis of the peak usage in figure 2 motivated us to revisit this definition. We observed that in our dataset the four hour period 8:00 PM – 12:00 AM is a much better indicator of prime-time hours than the FCC's original definition. This discrepancy could be limited to high tier households only, or it could imply that due to the flexibility of video-on-demand, consumers across the country are opting for a later time to watch real-time-entertainment.



**Figure 3:** *Prime Time ratio showing weekly pattern + differences during holiday periods (Thanksgiving, Christmas)*

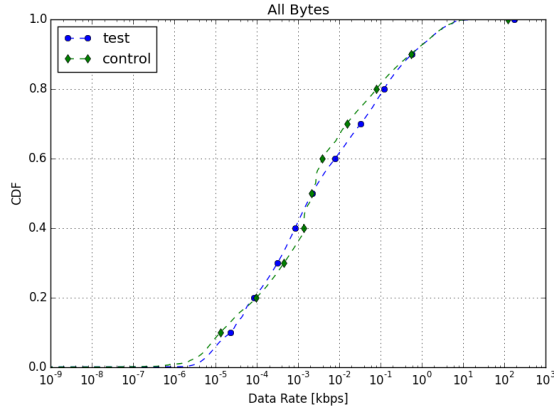
We use the updated definition of prime-time (as 8:00 PM – 12:00 AM) to examine the aggregate prime-time ratio each day for both test and control sets. Figure 3 shows that the prime-time ratio for the test set is 10% less than the control set, implying that the ratio of average data rates in peak (prime-time) hours and off-peak hours in a day reduces due to the capacity upgrade from 105 Mbps to 250 Mbps. The prime-time ratio can decrease only in two scenarios (1) the usage during prime time decreases, and off-peak remains the same, or (2) the usage during off-peak hours increased due to the upgrade.

We also noticed that multiple agencies define prime-time differently causing difficulty in comparing studies. We recommend that the FCC studies prime-time usage behavior and standardizes its definition. If supported by analysis, the FCC should update prime-time to a later hour.

## 4.3 Interpreting Utilization

The prime-time ratio showed that there is a possible change in behavior of the test due to an increase in capacity from 105 Mbps to 250 Mbps. Now, we try to answer the question: *Is there any change in user behavior due to the upgrade, and if so, where?*





**Figure 4:** CDF of data rate per time slot for all devices (agg view of data): Overall not much change due to capacity increase. Median data rate ~2bps for 3 months x thousands of devices!

We compare the distribution of the data transferred per time slot for all devices in the test and control sets. Figure 4 shows that the both sets have a very similar usage behavior distribution.

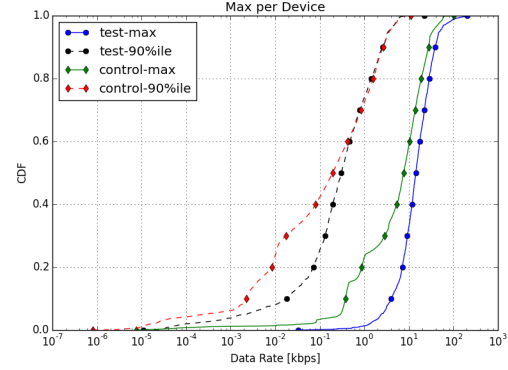
Next we investigate the distribution of maximum data rate achieved by each household (figure 5a) over the three month period. Our results show that although the high utilizing households ( $> 90\%$ -ile data rate) were similar throughout the set, showing no significant change in the maximum data rate, about 20%-ile of the test set devices saw a slight increase in the maximum data rate, which was much lower than link capacities.

To confirm this behavior over each day, we plot the maximum data rate achieved *daily* by each household (figure 5b). We observed that the maximum rate per device, for devices with overall low usage, was higher for the test set than the control set. We believe that this is an unbiased way to confirm the correlation between usage and capacity as the users were unaware of their increased capacity, nor did they require it.

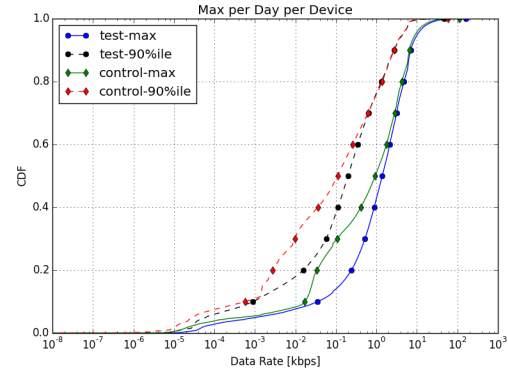
We explore the reasons for such a consistent behavioral change: Discounting the possibility of this being a baseline behavior (i.e., test set would show this even if it had the same capacity), we speculate that there could be two possible reasons for it: (1) short term downloads and/or web browsing achieves a slightly better data rate on a small time scale, or (2) real-time video quality is slightly higher, but not enough to completely saturate the access link capacity. Unfortunately, we miss these events due to a higher granularity of viewing data transferred only after 15 minutes.

**Different Perspectives of Utilization:** We take this opportunity to reflect on the issue of increasing broadband availability, deployment, and adoption being faced by the FCC [4]. The network usage increases slightly for low link utilization, without the user actively changing his/her behavior to saturate the link capacity.

The user, and therefore the FCC (representing the users' rights and demands), and the ISPs, are both correct, but



**(a)** CDF of max per device: test set has higher (max) average data rate below 10 kbps. 30% of devices in the control set have a max data rate of 2 kbps while 30% of test set has a max data rate of 10 kbps. (sanity check numbers, redo plot)



**(b)** CDF of max per device daily

**Figure 5:** Peak Utilization: The maximum data rate varies for test and control set for low data rates, and this variation is present daily.

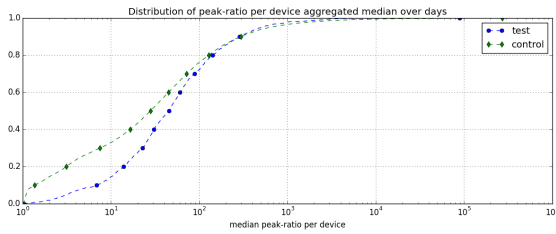
have a different perspective of broadband utilization and adoption; the slight change in behavior for low utilization could motivate a user to adopt a higher bandwidth tier. From the ISP perspective though, the users link capacity utilization does not show any change due to the upgrade in connectivity and is therefore a deterrent to offering the higher tier.

Vice versa, an ISP may tell the user that they need to upgrade their broadband access link to achieve higher data rate for low throughput periods too. And the user might not need it, as their link capacity is clearly not saturated. **TODO: ... doesn't make sense yet something missing ...**

We recommend that the FCC add multiple benchmarks, including **SG: ... what comes here?**

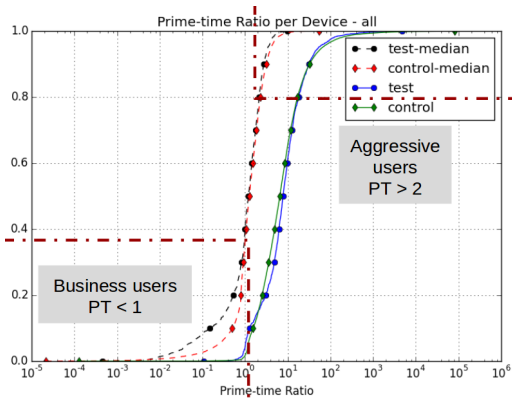
#### 4.4 User Taxonomy based on Peak Ratio

**Peak Ratio:** To further characterize and compare the deviation of data rate for the control and test set, we examine *peak-ratio* as defined in 3 Figure 6 shows that the median peak-ratio for each device in the test set is much larger than that of the control set. **TODO: replace much larger with the exact number or percentage . SG: Taken together with**



**Figure 6:** Median peak ratio per device showing that test set has higher daily ratio (50 times by median). Thus ISPs should condition their networks to 50 times the median usage for each user added in the worst case scenario.

our observations of a lower prime-time ratio of the test set (section 4.2) this implies that there are households in the test set that achieve a peak-ratio  $> 1$ , but not during the prime-time hour. We believe that these households might actually be small businesses or work-at-home users that peak during daytime hours instead of evening hours.



**Figure 7:** (old) Prime Time ratio + usage can be used to divide users into four sets: aggressive all time + non aggressive all time, aggressive peak time, aggressive non-peak time (business hours). 30%  $PT < 1$ : possibly businesses with normal work-hours. 20%  $PT > 2$ : aggressive prime-time streamers

The median peak-ratio per device itself shows a large range, from 1 to  $10^6$  (figure 6), and the maximum peak-ratio per device was an order higher. Clearly there are some households that have a very even usage throughout the day (low peak ratio), and others that are extremely aggressive only at certain times (high peak ratio). We plot this segregation in figure 7.

**TODO: EVERYTHING BELOW THIS IS TODO AND TODISCUSS**

**User Taxonomy:** The Sandvine reports present a taxonomy of users based on their contribution to real-time entertainment traffic. We incorporate a similar definition based on contribution to data traffic, along with our observations of utilization, to present a taxonomy of the users in our dataset. One category of users is the non-utilizers, i.e., non-aggressive low bandwidth users, that contribute less than SOME THRESHOLD PERCENTILE to the daily data trans-

ferred SG: these the ISP can ignore, also they probably don't need this tier as their utilization from the previous section must be super low. The second category is of users contributing most aggressively to the data at the ISP SG: these users will probably gobble up a higher capacity link if given a chance - they're the ones who effect all our graphs.. Need to check this claim. We further subdivide this high utilizing subcategory based on differing prime-time ratio and peak-ratios follows... **TODO: need to think and analyze this further: technical definition to do the analysis**

- Aggressive All-Time: Users having a low peak-ratio due to a lower variance. Is also expected to have a low prime-time ratio.
- Aggressive Prime-Time: The usual streamer with a high prime-time ratio and a high peak ratio.
- Aggressive Non-Prime-Time: Possibly a business user with a low prime-time ratio but a high peak ratio

**TODO: TO PLOT :**

- peak ratio cdf vs no of devices
- peak ratio cdf vs time of day where peak occurred
- no of devices cdf vs time of day where peak occurred

Based on differing usage profiles within the same high tier bandwidth, we suggest that the FCC adopt multiple benchmarks based on usage characteristics to better characterize broadband availability, deployment, and adoption in the US. Such multiple benchmarks can be the minimum broadband speed required per user based on the kind of traffic expected during a day. ISPs can also offer these users better plans based on hour-of-the-day or usage caps to encourage more off-peak usage. These users probably don't cause latency spikes in PT.

We recommend multiple standards...

## 5 Discussion

- results that are contradictory
- results that data suggests that is wrong
- a better way to measure and offer broadband based on utilization?

## References

- [1] Joshua Romero, IEEE Spectrum. FCC Redefines Broadband: Lack of Competition Now Obvious, January 2015. (Cited on page 1.)
- [2] Federal Communications Commission. Measuring Broadband America - 2014, April 2014. (Cited on page 4.)
- [3] Federal Communications Commission. Tenth Broadband Progress Report No 14-113, February 2014. (Cited on page 7.)
- [4] Federal Communications Commission. Eleventh Broadband Progress Report No 15-10A1, February 2015. (Cited on pages 1, 5 and 7.)
- [5] Federal Communications Commission. Telecommunications Act of 1996, February 2015. (Cited on page 1.)
- [6] Sandvine. Global Internet Phenomena Report - 1H, April 2014. (Cited on pages 1 and 4.)
- [7] Sandvine. Global Internet Phenomena Report - 2H, November 2014. (Cited on page 1.)

## 6 Appendix

In the FCC report No. 14-113, released on Aug 5, 2014 [3], the Commission asks some relevant questions about broadband usage, and requests comments from the community to improve its decision making process. We summarize their hypothesis and comments with regards to speed benchmarking as follows<sup>6</sup>

**Issue #13. Peak Time Usage.** Peak usage is defined as the average data consumed between 7:00 to 11:00 pm on weeknights. The

FCC asks if evaluating peak time usage is an efficient metric, or if average usage over a day should be considered instead.

**Issue #14. Broadband Speed Benchmarks.** Recently, the FCC defined the minimum broadband speed to be 25 Mbps for downlink, and 3 Mbps for uplink, anticipating future usage. The questions asked by the Commission are as follows: (1) What is the required broadband speed for moderate usage? (2) How should the Commission forecast future household broadband uses to justify such a benchmark?

**Issue #16. Adoption Based Benchmarks.** The FCC's previous experience suggests that broadband benchmarks should be based 70% adoption rate to encourage providers to increase broadband penetration. This would motivate a benchmark of 1 Mbps, however, the uplink speed benchmark has been set to 3 Mbps. Does this aggressive limit adequately anticipate the increasing use of symmetrical services, such as two-way video calling?

**Issue #19. Popular Speed Tier Benchmarks.** The FCC is considering setting future speed benchmarks based on the fastest speed tier with a substantial customer subscription. Does a higher speed tier suggest that service of that speed is necessary to enable users to originate and receive high-quality voice, data, graphics, and video telecommunications?

**Issue #22. Other Speed Benchmarks.** Broadband requirements are not uniform throughout the nation. Some users will have significantly greater needs. The FCC is interested to know whether it should opt for multiple benchmarks depending on user scenario, usage, occupation, etc.?

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<sup>6</sup>Note that the issue # corresponds to the point in the Eleventh Broadband Progress Report, FCC No. 15-10A1 [4]