Different Perspectives of Interpreting Peak Utilization

Paper #0, 8 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 [6]) [1]), 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." [1]. The FCC accomplishes this role by following three major steps: (a) *defining a benchmark*[2] 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 [5]. 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][3]. 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 [8, 9], 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 **??** 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

[1] This issue is discussed in point 1, and point 12 of the Eleventh Broadband Progress Report, FCC No. 15-10A1, respectively [5]

[2] The FCC uses benchmark to a threshold, beyond which the access link will be considered broadband capable.

[3] 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 confilicting 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 and Characterization

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 that 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.

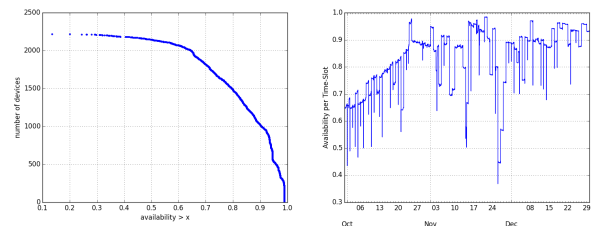
Field	**Description**
Device_number	Arbitrarily assigned CM device identifier
end_time	Fifteen minute sample period end time
cmts_inet	Cmts identifier (derived from ip address)
service_direction	1-downstream, 2-upstream
octets_passed	Byte count

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.



(a) *Heartbeat by device* **(b)** *Heartbeat by date*

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 [], as well as other researchers.

Granularity of 15 minutes: Broadband usage evaluated by commercial groups [], 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

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. We define usage as the actual traffic (bytes uploaded or downloaded) by the household being studied. Similarly, the average data rate is derived by calculating the usage in a 15 min time slot (in kbps). We also refer to this as utilization, and compare it to the access link capacity in our analysis.

3.1 Different Perspectives of Utilization

The FCC has the responsibility to increase the availability and deployment of broadband throughout the US (with the broadband threshold benchmark defined as 25 Mbps in downlink and 3 Mbps in uplink). Their progress report states that: given the option, users will adopt a higher tier bandwidth [], thereby meriting the high investment. However, a survey conducted by NCTA showed that the largest deterrent to broadband adoption is that users do not *need* broadband (the second largest is the cost). The conflicting view of the ISP is that the cost of deployment in an unchartered area is too high, unless a significant number of households *need* it. Thus, both parties are asking the same question: do people *need* a higher capacity, i.e., what is their *utilization* as compared to the capacity?

Previous research shows that the utilization will increase as the capacity of the access link increases [], and also that utilization[4] and capacity follow a law of diminishing returns [2]. However, such studies have been biased by studying users that actually required a higher capacity for their usage. It is inevitable that such a correlation would exist for such households, whose utilization is bottlenecked by the ISP.

In this work, we ask a more fundamental question: *how much does the user behavior change with increasing capacity*. Specifically, when the capacity is already very high and the user has not opted for an increase, does their utilization still vary with capacity? Both the FCC and the ISPs have a different perspective of the utilization:

The FCC perspective: *Utilization as adoption* of a higher capacity link when available (but not under the constraints of a much higher cost). The answer to this question is important to the FCC to encourage further deployment of high tier links throughout the US. Essentially, if *any* change is observed in link utilization due to the upgrade in our dataset, the FCC may interpret that as *adoption* to the higher available tier.

The ISP perspective: *Utilization as a capacity bottleneck*, i.e., if the ISP can show that the *maximum utilization* of a household does not vary with increasing capacity, it will prove there is not enough demand to offer a higher tier. The ISP needs the answer to this question for future capacity planning, and the cost-analysis for the investment of new technology in any area. For example, Google Fiber is now expanding to Salt Lake City, from where we received our dataset. The analysis of change in user behavior with capacity will estimate the number of users that actually *need* the higher capacity service offered by Google.

Thus there is a need to measure *utilization* at times when users *need* the Internet capacity the most: the peak usage.

[4] called demand in their work

3.2 Importance of Measuring Peak Usage

Internet usage throughout a day follows diurnal sleep-patterns, and researchers have shown that such patterns are in fact correlated with GDP, Internet allocations, as well as electrical consumption of a region [7]. This makes the study of usage behavior extremely relevant to the governmental bodies responsible for development, such as the FCC, when considering policy decisions.

Prime Time: The daily diurnal nature of usage patterns across many households naturally requires the provider to design networks capable of handling load at the peak times in a day. Such peak times are usually observed during evening hours, and the data transferred at this time is called peak usage. The FCC defines *Prime Time* as the local time from 7:00 PM to 11:00 PM [3], when many households heavily consume real-time entertainment traffic (video), seen as primarily responsible for high usage during these hours. Latency and performance are adversely affected during prime-time, causing bottlenecks at home, the last mile, in transit, or at the content server. For example, the Sandvine Global Internet Phenomena Report [5] showed that devices in the same household selected Netflix's own CDN (OpenConnect) during off-peak hours, and third party CDNs (with differing performance) during prime-time. This may happen because Netflix OpenConnect is over-utilized during prime time [8].

Prime Time Ratio: To measure the concentration of network usage during prime time, Sandvine defined the *Prime-Time ratio* as the "absolute levels of network traffic during an average peak period hour with an average off-peak hour". Based on the FCC definition of prime-time hours (7p-11p), we measure the daily prime-time ratio of set_{full} in section 4.2.

Peak Ratio: The Sandvine Reports show that although the mean usage has remained stable for the past few years, usage during peak-times has increased drastically [8]. To measure this growth, they introduce the concept of peak period, measured when the network is within 95% of its highest point. Although, these reports present a good view into aggregate usage patterns over a month, they neglect to analyze usage characteristics individually. Inspired by their definition, we measure the disparity between the 90 percentile of the peak and median usage of each household within a day, and call this the *Peak-Ratio*. In section 4.4 we show that the peak ratio can be used to divide users in the same tier based on their usage behavior.

In the next section, we analyze spacio-temporal network usage behavior: **Time Series Behavior (TS):** aggregating the usage (and utilization) per household over time (daily or weekly, per time slot). **Distribution Across Devices (CDF):** aggregating over time slots per day to measure utilization per device. We use the prime-time ratio and peak usage as criteria to evaluate usage behavior and interpret utilization.

[5]The Sandvine Reports [8, 9]are released bi-annually and contain a detailed analysis of aggregate Internet usage. They are also referred to in the FCC reports [3, 4, 5]

4 Results

We evaluate the usage behavior of the $test_{full}$[6] and the $control_{full}$[7] sets based on the criteria in table 2. We interpret the behavior of the datasets both separately as well as comparatively: (1) general inferences drawn from analyzing the dataset, and (2) comparative inferences drawn from observing changes in user behavior due to the upgrade in access link bandwidth (as explained in section 2.3)

First, we examine usage behavior and prime-time ratio as aggregates seen at the ISP. We use the total data usage per subscriber parameter to study these quantities. Next, we evaluate the utilization and peak time for each household in our dataset. We present the ISP perspective of utilization, and compare it to a users' perspective (FCC by proxy). We discuss a taxonomy of users based on their usage behavior and requirements.

Parameter	Definition	Agency
Prime $\text{Time}_{original}$	7:00 PM - 11:00 PM	FCC
Prime Time	8:00 PM - 12:00 AM	Authors
Prime Time Ratio	$\frac{\text{avg usage in peak (prime-time) hour}}{\text{avg usage in off-peak hour}}$	Sandvine
Peak Period	Time of network 95% of max	Sandvine
Peak Ratio	$\frac{\text{90\%-ile of max daily usage}}{\text{median of daily usage}}$	Authors
Usage per Subs.	$\frac{\text{aggregate data usage in time slot}}{\text{number of contributing subscribers}}$	Authors

Table 2: *Evaluation Criteria*

4.1 Usage Behavior

To characterize diurnal user behavior as observed at the ISP, we first calculate usage per subscriber (table 2), and then plot the median and 90%-ile of total usage over a week for both test and control sets (figure 2).

We observe that the rise to the peak prime time hour usage on weekdays is not plateaued like the pattern observed on weekends (and holidays). A generic (median) weekday aggregate usage consists of a rise in usage that starts early in the morning that builds up to the prime-time period, peaks, and then falls sharply. We do not observe a trough in mid afternoon (between 2:00 PM – 6:00 PM), as is usually the case for overall usage observed at US Fixed access providers [8].

Comparing the test and control sets, we observe that the median prime time and late night behavior is very similar (7:00 PM – 7:00 AM), but during off peak daytime (work) hours, the test set has a higher median than the control set. There was no change in prime time behavior in the evening, and an increased usage in off-peak daytime hours.

TODO: Concluding remark.. Conclusions for the FCC. Conclusions for the ISP

[6]household byte counters from (unknown) users with a 250 Mbps access link

[7]household byte counters from users with a 105 Mbps access link

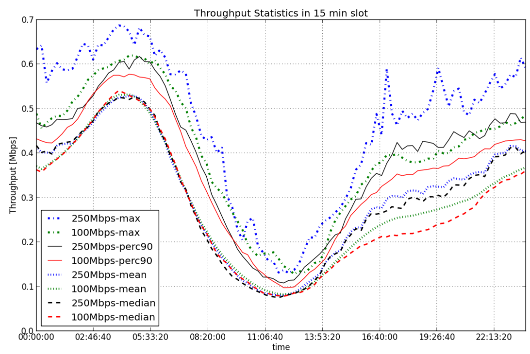


Figure 2: *agg (days) over means (devices): aggregate has no trough, peaks in the evening hours*

TODO: see todo.txt for analysis comments, explain, check

4.2 Prime Time Ratio

To characterize the prime-time ratio, as defined in 3, we calculate the aggregate data transferred at the ISP in an average prime-time hour, and divide it by the off-peak average.

Prompted by the monotonically increasing trend of usage behavior during daytime hours on weekdays (figure 2) we calculated the prime-time ratio for each four hour period throughout the day to find the evening hours with the largest ratio. In our dataset, the prime time ratio peaks at 8:00 PM – 12:00 AM, rather than FCC's definition of 7:00 PM – 11:00 PM. This discrepancy could be limited only to the high tier households in our dataset, but we deem that unlikely. Another reason could be that prime time is delayed globally with the rise in real time entertainment's contribution to traffic.

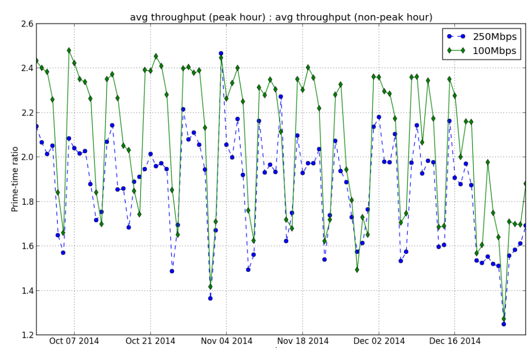


Figure 3: *Prime Time ratio showing weekly pattern + differences during holiday periods (Thanksgiving, Christmas)*

We use our updated definition of Prime Time (table 2) to calculate and plot the Prime Time ratio per day for the test and control sets in figure 3. A comparison shows that the test set's prime time ratio is 10% lesser, supporting the observation from section 4.1 that showed that the usage during prime time is similar across both sets, but the usage in off peak hours is higher in the test set.

TODO: see todo.txt for remaining analysis and concluding remarks

4.3 Interpreting Utilization

Utilization can be characterized in many ways, and each definition can answer a particular question. Furthermore, as stated in the previous section, multiple parties may interpret utilization differently, based on their aims and requirements.

Utilization as the average data rate for each device in each time slot portrays the overall spacio-temporal aspect of our dataset. We plot a distribution of the rate per device-time in figure 4. This shows that median utilization of household users is the same in both sets (50 kbps). A comparison between the test and control set shows that there is no affect on the overall adoption.

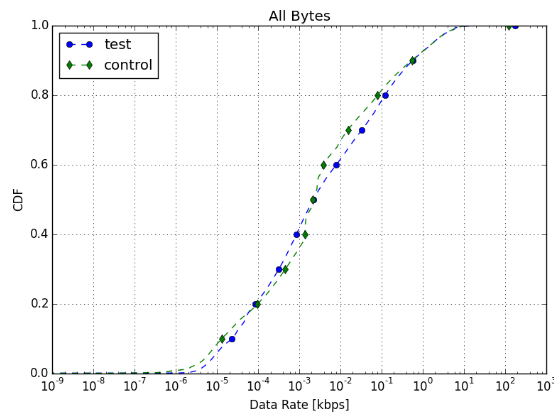


Figure 4: *CDF of data rate per time slot for all devices (agg view of data): Overall not much change due to capacity increase. Median data rate 2bps for 3 months x thousands of devices!*

Based on the measurement methodology, we study the highest utilization seen by a household both in its lifetime, and on each day. Our aim is to examine the peak usage per household, and study if the behavior changes due to an upgrade.

Figure 5a provides a distribution of the highest average data rate a household achieves. To avoid outliers, we also plot the 90%-ile of the max data rate achieved by households in both test and control sets. We see that a median household is expected to achieve the highest data rate of between 1 – 10 Mbps over its lifetime. This is much lower than the access link capacity, indicating that the median device has a utilization ratio (avg data rate:capacity) under 0.1 in our dataset. The number of households that increased their peak utilization beyond the control set's 105 Mbps capacity were negligible.

Surprisingly, we see that 30% of the households from the test set have a low peak utilization (under 0.1 Mbps), while 40% of the control set households are under 0.1 Mbps. Thus, the absolute peak utilization does not increase when compared to the access link capacity, but there is certainly an increase in peak utilization of devices that had a low requirement, due to the change in capacity.

To investigate this further, we also study the *peak utilization per device on a daily basis*. Figure 5b shows that for 30% of the devices, the maximum data rate in the test set is consistently higher than the control set, albeit no where near the actual access link capacity.

This is similar to the behavior observed in figure 2, showing that the peak usage during prime-time is unaffected, but lower utilization throughout the day is higher for the test set. We speculate that there could be two possible reasons for this increase in utilization: (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 short lived, or consistent, events due to a 15 minute time slot granularity and only looking at byte counters.

Different Perspectives of Utilization: We take this opportunity to reflect on the interpretation of the disparity of peak utilization per device, as shown in figure 5a. The ISP may interpret this as no change in peak usage, as the prime-time usage remained the same based on aggregated usage, even in prime-time. Thus, we believe that given the opportunity, the provider will not invest to offer a higher access link unless it in a region showing such low demand unless it is guaranteed profit, or is forced into deployment by an external agency.

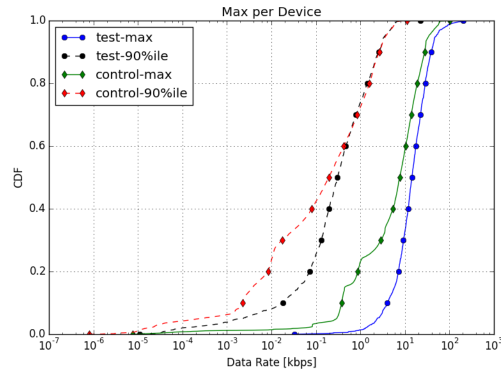
In contrast, the consumer (and therefore the FCC) might be convinced that individually the usage behavior of a household is affected by the increase in access link capacity, especially for households with a lower utilization. We believe that this is the perspective the FCC takes when considering deployment and adoption of broadband services.

TODO: needs work on conclusion Although our unbiased experiment still shows a certain correlation between utilization and capacity, it also contradicts the law of diminishing returns [2]. TODO: sanity check

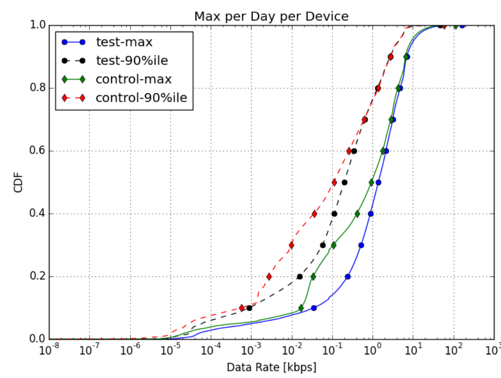
4.4 User Taxonomy based on Peak Ratio

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 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.

The median peak-ratio per device itself shows a large range, from 1 to 10e6 (figure 6), and the maximum peak-ratio per device was an order higher. Clearly there are some



(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.*

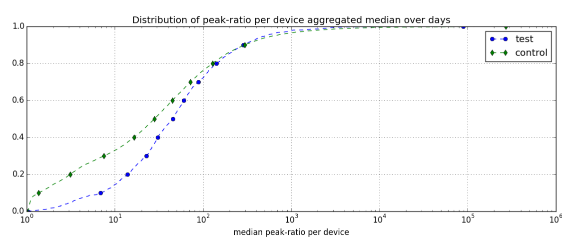


Figure 6: *Median peak ratio per device showing that test set has higher daily ratio (50 times by median). Thus ISPs should condition their networks to 50 times the median usage for each user added in the worst case scenario.*

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

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

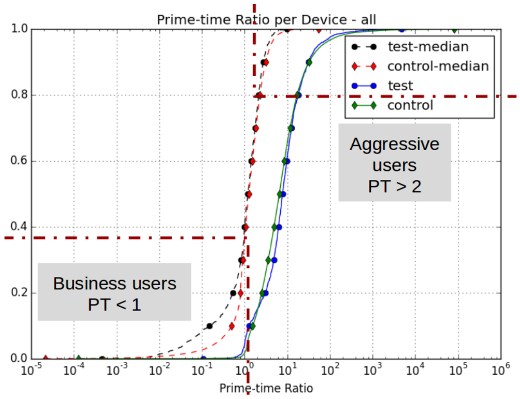


Figure 7: *(old) Prime Time ratio + usage can be used to divide users into four sets: aggressive all time + non aggressive all time, aggressive peak time, aggressive non-peak time (business hours). 30% PT $<$ 1: possibly businesses with normal work-hours . 20% PT $>$ 2: aggressive prime-time streamers*

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 transferred 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?
- multiple benchmarks of users segregated by usage
- fcc measures: availability to deployment to adoption, maybe go the other way
- survey sad adoption is low coz (1) user don't need bb and (2) its too expensive
- if we can estimate (1) as false, providers can be encouraged to build and automatically reduce (2)
- significant section of 100 Mbps set shows that they do not cap usage per day in 15 min
- this means low investment for next tier
- but a set like 25 or 50 might show otherwise [need data]
- other metrics: latency, etc considered by fcc

References

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