Summary Review Documentation for

“Sharing the Cost of Backbone Networks: Cui Bono?”

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Reviewer #1

Summary: This paper considers the problem how to share the cost of a backbone network across customers. It considers various schemes and shows the discrepancies that can result, in terms of allocating costs on a per-link or network-wide level to individual customers. The discrepancies may arise due to the volume-based charging function (F-discrepancies), or metering schemes (M-discrepancies) or how customers are charged for triggering upgrades (L-discrepancies).

Strengths: This is the only paper I know of that considers this problem from an empirical standpoint at such scale. The topic is interesting and the analysis is broad and interesting too.

Weaknesses: It is not clear if the models considered have any practical ramifications. Several issues about the models used. Other than making many observations about discrepancies, the paper does not have any concrete suggestions for how tariffs should be structured or implemented.

Comments to authors: The paper describes a variety of models to associate costs with individual customers, e.g., volume-customer, peak-customer etc. In the intro you claim that these are cost sharing policies that are widely used by backbone providers. This is surprising to me and a revelation of sorts: As far as I understand, customers are charged either using fixed tariffs based on raw capacity purchased, or using percentile based tariffs. Are you saying that the cost models you propose somehow map onto these existing schemes? Or that there is a lot more than the naive view that people like me have about ISP charging? Or are you making suggestions for new ways to split costs, and showing us how to explore the design space and the issues therein?

The paper mentions OPEX in the beginning, but it is largely left out from the analysis. The focus seems to be predominantly on CAPEX. Also, no attempt is made at justifying the completeness of the costs considered, e.g., what about the costs of data centers or hosting centers or power supply? You may need to build out, or provision more power along with growing demand. Are these costs somehow taken into account. At the very least, the paper needs a disclaimer that the analysis is far from complete and represents a simplified starting point.

I’m not sure I completely agree with some of the arguments the paper makes about some of the schemes, e.g., volume-customer is considered to be more complex than 95th percentile or peak. What are you assuming about the network support needed here to come to this conclusion? E.g., I would assume that if you used the appropriate streaming algorithms you should be able to estimate 95th percentile and peak without too much complexity.

Your definition of the network-level costs does not make a whole lot of sense. E.g., Eq (7) makes sense for aggregate-peak-device, i.e., summing up individual link/device costs gives an estimate for network-wide cost. But it makes very little sense for volume-customer and peak-customer. E.g. what does it mean to sum up the customers’ peaks or 95th percentile on different links? This has a direct bearing on many of the analytical questions you outline.

Some more low level comments:

1. You use device and link interchangeably. I would think that each device has a cost that could monotonically increase with the number and capacity of links incident on it. Are you considering this aspect?

2. Is M-discrepancy only defined for network-level cost, as eq (9) seems to indicate?

3. How are device and network level L-discrepancies defined. For the latter, it is simply a sum of device discrepancies? As before, this would need proper justification as I am not sure such summing up makes sense in some cases. Similarly, TCO discrepancy is also confusing due to the lack of a precise definition.

4. Why do you say that Aggregate-Peak-Device is the absolute measure of fairness? Shouldn’t Shapley be more fair as it considers a more well rounded notion of the cost contribution.

5. The conclusion of Section 5.1.2 seems to contradict that of Section 5.1.1?

6. For most of section 5, the observations seemed obvious given the choices you made for the various cost sharing functions. What would have been more interesting is if you gave concrete suggestions for how to turn these observations into tariff schemes.

7. Section 5.6 was way too cursory to be useful. First, are you considering network-level cost here? Second, can you explain your observations a little, please? E.g., why is a large variability of cost within a single type of customer? Why are costs lower for EU/US ISPs? How do you come to the conclusions that “... a large fraction of their traffic crosses expensive inter-continental links”?

One the whole, I have many basic questions about the method used and the assumptions made. Yet, this may be a good paper to include in the program as it is fresh.
Reviewer #2

Summary: This paper presents an empirical exploration of different ways of charging customers for the traffic that they send over a network. They describe a range of policies along several dimensions (e.g., how the traffic volume is measured, where it is measured, etc.) and quantify the discrepancy that results in costs computed by different policies. The key finding is that the choice of policies matter, more so when considering the cost at the level of individual devices but less when considering the cost of the entire network.

Strengths: The paper represents a comprehensive exploration into how to best charge for traffic over a network. I found the paper to be thought-provoking and the results interesting.

Weaknesses: This might be a purely academic exploration. The authors do not discuss how one might go from the findings in the paper to a different charging model that reconciles the concerns of both ISPs and their customers. In fact, the interest of customers (e.g., in having a more predictable cost structure) and their selfish response to different policies is not even explored.

Comments to authors: I like this paper. It deals with a subject that is of increasing importance but still under-studied. The exploration is thought-provoking.

On the downside, I wanted more constructive suggestions from you on the implications of your findings. How should your findings be used by ISPs?

I also wished you had factored in the interest of customers whose priorities are different. For one, they like charging mechanisms that have predictability or at least those that they can control. It seems that with something like aggregate-peak-device their fate may be out of their hands, if the policy is literally implemented, as bursting by other customers can lead to increase in their bills.

Similarly, different charging policies create different incentives for customers. For instance, with volume-customer, they are incented to reduce their total demand (is that good?). With 95th-percentile and peak-customer, they are incented to reduce their burstiness (sound good, at least in theory). With aggregate-peak-device, they are incented to send less during peak hours (also sounds good). It seems that how customers will react is a key component of any charging policy.

The bit in Section 2 about why it is difficult to split cost amount customers struck me as rather weak. There you blame accounting complications and liability complications:

- First of all accounting complication is not a big deal if you have something like netflow/ipfix enabled on your ingress ports. Then, you don’t have to measure traffic at each router in the network. Just join netflow data (which contains source and destination addresses) from ingress ports with routing information to get the amount of traffic from a customer that flows over a network device. To my knowledge, most ISPs run netflow monitors at their ingress routers anyway (e.g., to detect DoS attacks or worm traffic patterns).

- The bit about liability is odd as well. Is anyone seriously ever proposing charging the last customer for the cost of upgrade? It seems that upgrade is a provisioning risk that all businesses (not just ISPs) take in some fashion.

Rather than the two things above being a challenge, I think the challenge for ISPs today is: there are many possible charging schemes, and it is unclear what the implications are of those schemes for them and for individual customers. This is the challenge that you really address in your work.

3.1: You claim that volume customer wins in terms of implementation simplicity. Perhaps. But it appears that larger points are, as I mention above, volume customer is controllable for a customer but aggregate-peak-device is not and the two policies create different incentive for customers.

3.3: You really need some justification for why you are studying L-discrepancies. See my point about liabilities above. Where are these policies coming from?

3.4: I found the bundling of differential equipment cost as a TCO-discrepancy somewhat odd (as in, out of sync with the other three discrepancies). It appears that you are saying that there are a few different ways of going from device cost to network cost, and those ways have implications. This seems different from the other factors. At least, I wouldn’t have called it a TCO discrepancy.

The experimental methodology of TCO-discrepancy was also unclear to me. What was held constant in those comparisons?

Finally, while I realize that data networks might be unique, but the paper made me wonder what is known about charging in other networks (e.g., cellular, telephony, transportation, etc.). Folks must have studied those in great detail. Do any of those lessons apply?

Reviewer #3

Summary: This paper analyzes the problem of sharing the cost of backbone networks. It defines a few very sensible metrics in which unfairness in cost distribution in clients can arise by using current pricing models, metering models, ways of charging for "updates" and cost differences across the network. They use traces from a tier-1 operator to see how much unfairness can arise in real life, and make interesting recommendations.

Strengths:

- very well written, clear paper
- the metrics make a lot of sense
- the experimental findings are interesting

Weaknesses: The paper assumes that traffic is inelastic and it will look the same even if the pricing method changes—it may change! The authors’ prior work on using the troughs in traffic to transfer big data for free is another example of customer adaptation to pricing.

Comments to authors: I really like your paper - it is well written, very easy to understand, and I believe it addresses an important and timely problem.

Two high level comments.

1. What is the pricing model used by the operator today? Is it possible that the traffic coming from customers is affected by the pricing model? Maybe the customers are shaping to reduce their cost? In this case, would it be possible to estimate what would happen if the pricing changed? It would be good if the paper touched on this issue.
Summary: This paper tries to create a rigorous framework to study different policies (pricing schemes) for recovering costs of backbone usage. They use ratios between candidate pricing policies and an "optimal" pricing scheme to determine how unfair proposed pricing schemes might be to individual customers.

Weaknesses: The paper oversimplifies in some parts and creates unnecessary complexity in other parts.

There is a heavy emphasis on formalism and equations as a substitute for clarity and insight. They typically give an expression for a term, such as a discrepancy, without explaining in English why they are describing it that way. This got very annoying quickly.

The authors use a lot of straw man candidate pricing proposals, such as having a new customer pay for an entire upgrade if he happened to consume the last unit of bit transport in the existing pipe. Silly.

There is no convincing argument that the Aggregate-Peak-Device pricing is the "absolutely fair" ground truth pricing mechanism, but the authors base the rest of the paper on this assumption?

There is too little emphasis and attempt to quantify the cost of proposed pricing mechanisms – both financial cost as well as cost in transparency to customers (counting every unit of bit transport on every link?) in addition to their "discrepancy" benefits.

Comments to authors: It is not clear that "individual discrepancies at the device level naturally cancel out as one sums up the costs of multiple devices." Is this true on many networks or did you get lucky?

"The cost of a specific device depends on the maximum amount of traffic that it has to carry during a certain time interval." – But is this the primary factor driving the cost of all devices?

"We assume that the backbone network operator fulfills its SLA by upgrading its links when utilization hits the 50% threshold" – is there a citation to support that this is still common practice?

"We consider these methods because backbone operators apply these policies in practice to determine the costs." Can you cite something here?

Comment on page 6 "(Fair in a way that it satisfies four intuitive fairness criteria [1,12,22])" – isn’t this too central a point to the paper to throw it away in some parenthetical references?

The 15 largest customers per network device cover 95% of the traffic on the devices? How many customers are on this network? It sounds not representative of a backbone.

"We stress that these are the prices of wholesale physical layer circuits and thus do not differ substantially from the actual cost of ownership" – That doesn’t sound right. Buying/leasing the circuit is not all it takes to maintain it.

You start talking about "joint effect" of two different discrepancies without motivating it.

"This implies that backbone operators should reconsider the pricing of IP transit services, which they currently price based on simpler policies such as the 95Percentile one." – reconsider pricing in what way? What about the other factors that go into selecting a pricing scheme, such as simplicity in understanding it, explaining it to customers, audit ability, cost of implementing?

Section 5.6 is not a very "deep dive" despite its introductory claim. Can you explain any of the observations you make about the figure? Is the inference in the last sentence (about content provider traffic crossing expensive int’l links) actually true? It contradicts what I understand about large content providers who carry most of such traffic. And it seems you have the data to confirm or refute that inference?
I know that ISPs have observed that the peak load on different parts of the network occur at different times, and that the peaks of different customers may not coincide with the total peak. This has come up in some regulatory filings, where the regulator wanted to use the peak of a customer as a measure of their load on the system, and the operator was arguing that the peak of one customer does not necessarily characterize the cost component of that customer. So one reason to look at models like this is that regulators may use models like this. Having data that shows how much picking one or another model can change cost allocation may be useful insight in the debates with regulators. (See discussion at bottom of Col 2, page 9.)

I think the advice that ISPs with highly divergent TCO for different parts of their networks may want to offer different prices to customers depending on their traffic patterns is valid, independent of the details of the models. On the other hand, one could argue that this point is obvious.

I thought the attention to triggered upgrades was not justified. In a large network, different components get upgraded at different times. Different customers trigger different bits of upgrade, and I think in practical terms it all sort of averages out.

Reponse from the Authors

To address the issues raised by the reviewers, we made the following changes in the revised version of our paper. First, we clarified the formal description of device and network level discrepancies as well as of M- and TCO-discrepancies. Moreover, we restructured the background section to increase comprehension. Second, we emphasize every time when it appears when the Aggregate-Peak-Device policy can be considered as the fair cost-sharing policy. Third, we point to tariffs schemes used in practice when we introduce the cost sharing policies we analyze. Fourth, we emphasize in the introduction that the focus of our work is the costs of the customers not how they should be charged. Our findings can influence backbone operators to revise their pricing strategies to avoid the issues identified by our study, however, we do not propose pricing strategies in this paper. In addition, we mention in the revised version that the analysis could be made on more detailed datasets that contain information of the costs of power supply, hosting, etc. We modified the descriptions of the examples of Section 3 and the results of Section 5.6 to improve clarity. Finally, we included several new research directions based on the reviewers’ comments (in Section 7), e.g., the impact of the applied metric on the behavior of the customers.