Summary Review Documentation for

“Cell vs. WiFi: On the Performance of Metro Area Mobile Connections”

Authors: J. Sommers and P. Barford

Reviewer #1

Summary: The paper uses data collected by SpeedTest.net, a crowd-sourced mobile bandwidth testing site, to compare the performance of Cellular and WiFi networks. The data set used in this paper is great, and it has data points across different OSes, different cellular providers, and for 15 metros of varying sizes. Many of the measurement results were either intuitive or is already known from previous studies.

Strengths: I liked the characterization and the data set. The paper validates earlier results using a large extensive data set

Weaknesses: I think the authors could have done much more from the data set than what was presented. For example, it is well known that (1) WiFi has better upload/download rates than 3G, but 3G latency is more stable than WiFi, (2) WiFi/3G throughput is lower than wired broadband and (3) 3G performance is poorer during peak hours, and (4) diurnal characteristics of WiFi/3G access. These are the major findings of this paper, but they are all known

Comments to authors: I wonder why the authors didn't do much more extensive analysis of the performance of EVDO vs 3G vs LTE etc? The only graph(s) are that of performance consistency across a few cell towers

It was unclear if the phones/users were indoors or outdoors during the experiments. This can be a big factor in the performance of WiFi vs 3G

“this is the first study that compares and contrast cellular and WiFi performance in diverse metro areas” is not true. see reference [10]

“Cellular are subject to mobile data plans that are increasingly offered with no restriction” is also not true. Most plans have restrictions on bandwidth usage.

While the writing was clear, it was too rambling. This makes it harder to read. For example, Section 3 can be severely reduced, and the rest of the paper can be made much more concise

Reviewer #2

Summary: The authors present an analysis of 15-weeks of Speedtest.net crowdsourced data of network performance for both 3/4G and WiFi networks in several major metros. They compare performance across providers and handsets, as well as over time and space.

Strengths: The paper presents a lot of very interesting data. The authors have done a good job conducting an analysis of a number

of aspects. I am not aware of any other published source of data at this scale.

Weaknesses: The results are not particularly surprising, and it's not at all clear how they can be used to useful effect. The most tempting aspect—comparing WiFi to 3G—is not possible with this dataset due to the way that the data was collected. Hence, it cannot be used to inform or enable individual user network selection. Instead, it serves only as a broad-brush overview of network performance.

Comments to authors: You've done a nice job with what you have; the paper will surely be cited frequently. Unfortunately, it falls short of being a really exciting paper since there isn't much here that surprises or provides insights that one could obviously leverage in a useful way. I did appreciate, however, your attempt to summarize take-aways through the main results paragraphs.

At a high level, the title of your paper “Cell vs. WiFi” is misleading. It is extremely tempting to try to do a head-to-head comparison, but the data you have simply cannot support such an analysis. While you did refrain from conducting any quantitative analysis of Cell vs. Wifi, your text and especially intro and conclusions are littered with broad-brush statements regarding their relative performance. As you well know, what may be true in aggregate need not hold for any particular user. I would have found it very useful if you had found some way (even in a small scale controlled fashion in a small subset of the major metros studied) to try and determine whether the WiFi and Cell performance at a given location for a given device at a particular point in time are in any way related. *That* is the sort of information required to know whether Cell or WiFi would be the right choice for a given user at any moment.

In Section 3 you often do not directly reference the tables and figures from the text (e.g., Table 5 and Figure 3) making it somewhat cumbersome to find the data you are discussing in the text.

Reviewer #3

Summary: This paper studies 15 weeks of Speedtest data with the aim to understand performance differences between WiFi and cellular for 15 different geographical regions. The authors are able to make a number of interesting observations. This paper could certainly help as an archival piece of work clearly characterizing throughput and latency performance of wireless access.

Strengths:

- very interesting data set that does not only report on upload/download throughput and latency, but also phone type and operating system, cellular network technology

- careful analysis and reporting of interesting observations

Weaknesses:

- the data set itself is limited in drilling farther down into the reasons behind the differences (not to blame the authors)
- would have loved to see something specifically on LTE vs. WiFi

Comments to authors: This is a very careful study of a tremendous data set. The authors are able to study the performance of wireless access (WiFi and cellular) across time, space, and device. It would actually be so cool if speedtest also recorded the signal strength of the device - then one could actually attempt to drill down into the performance differences. All in all, I think the authors have done a really good job. It is primarily the limitation of the data set that leaves me wanting a little more depth. I would love to have an idea of whether the outliers are the result of channel conditions or contention.

I also found a few results slightly unexpected for me.

1. Residential data plans in the US and around the world tend to be asymmetric. On the contrary, cellular upload/download speeds in theory should not exhibit a similar asymmetry. Your results, however, do hint towards that direction (Table 3,4) . It would be wonderful to check the definition of the data plans you are actually studying (you know the provider and the location) and see whether this is something one should expect. Actually, this kind of high upload speeds over WiFi (Fig. 3(b)) make me wonder if you are actually measuring enterprise networks.
2. It is well known that the majority of the latency in the cellular network is due to the radio network. However, your statement that the same provider offering cell and broadband in certain regions is able to deliver similar performance to the customer on both networks. This is just counterintuitive to me. I would not expect the backhaul part to actually contribute that much to the client latency on cellular (aside from LTE where latency is indeed small). It would be nice to perform some active experiments (if possible) to confirm this particular statement.

Finally, given the promise that LTE bears, I would have liked to see a section just for LTE as a replacement , say, of the broadband service. How does it fare? Right now, one needs to look for the LTE line in the figures to extract this information. For instance, Figure 4(a) does show that LTE latencies are close to the ones of WiFi.

All in all, I find that this paper would be of interest to the community. I would love to see the above issues addressed in the final version.

More detailed comments:

- I really liked your limitations section.
- motivate the way you normalize performance and discuss what would be the desirable behavior (Section 4.1.2)
- your figures are all over the place. there is no better way to place them so that one does not have to advance 2 pages to see the results discussed in a section?

- Figure 8 is difficult to read, especially if I am supposed to be able to pick out the busy hours. Come up with a metric for peak and non-peak hour and discuss those.

Reviewer #4

Summary: This paper analyzes data from speedtest.net, a crowd-sourced performance measurement tool. The paper focuses on cellular/wifi performance measurements to cast light on the relative performances these complementary technologies. Some of the paper's findings are obvious (i.e. WiFi offers lower RTTs and higher throughput than cellular networks), but some are not. An interesting insight is the performance of different cellular technologies (3G, EVDO, LTE, etc), with LTE being shown to offer throughput comparable to WiFi.

Strengths: The paper is well written and well executed; its main strength is this dataset. It would be great if this dataset was made publicly available. The paper is both timely and a perfect fit for IMC.

Weaknesses: It would be nice if the authors discussed a bit more how the results they found could be used in practice beyond informing other researchers. For instance, the performance maps should be a great diagnosis tool for ISPs. Using information from this dataset one can imagine datasets could "pick" the right interface to use in a certain environment, etc. Once this discussion is in place (hopefully up front, after the intro), the data may need more slicing and dicing to answer some of the less obvious questions one can come up with.

Some of the reasons given for the observed performance results seem shallow - a deeper analysis is needed. (see details below). In general the paper does not really try to understand "why" the effects happen, it is content with observing "what" happens. Adding a bit more depth to the "why" discussion would make the paper better.

Comments to authors: You mention that the reason for less consistent wifi latencies is over-buffering at access points. That sounds like a secondary cause at best - another explanation is the much higher contention in the WiFi frequency bands coupled with the "random" nature of wifi access control (backoffs, etc). In contrast, cellular networks make allocation decisions on longer time-frames.

"Local providers exhibit similar performance characteristics, ... suggesting they use the same backhaul infrastructure" - I am not convinced by this statement. Is the assumption here that the bottleneck is in the backhaul? Please explain better.

At the end of section 4.2 - the reason you give is so generic that it almost provides no useful information. Can you try and explain it a bit more?

Reviewer #5

Summary: The paper uses crowd-sourced measurement data to contrast cellular and WiFi performance along multiple dimensions. The paper does a good job of the analysis. But the results are not particularly exciting.

Strengths: Huge data set and thorough analysis

Weaknesses: Results not exciting (kind of known)

Comments to authors: Overall, the paper does a good job of evaluating the huge data set involving performance tests. Some specific comments are below.

In spite of motivating the applicability of the work, I found the arguments too vague. At the end, it wasn't clear how to make use of the presented results. The results were also not that particularly exciting in that most of these things are kind of known.

Other comments:

- In Figure 3, Why do you think it was service plan and not modulation that's responsible for the "tiered" performance of Wifi? And also why is that the upload bw stays the same with different downlink bandwidths i.e there are horizontal lines but not vertical lines?
- On section 4.1.2, the definition of consistency is not very clear. How many samples were there per user to calculate average and 95th percentile?
- Cellular latencies are more consistent, possibly because their averages are higher? Also it is mentioned that wireless consistency is lower than wired, but no quantification of the same is provided.
- Section 4.3, Is the IDW interpolation valid for this type of data?

Response from the Authors

We thank the reviewers for their comments and suggestions.

In response to the reviews, we have enhanced the figures in the text to improve readability, and have clarified the text in a number

of places, including the discussion on performance consistency and our hypothesis regarding provider backhaul infrastructure.

A common refrain in the reviews was that the results in our paper are not "surprising", or that the conclusions we draw are well known. First, it's simply not true that *all* the conclusions in our paper are known: indeed, reviewer 3 points out some specific areas of novelty in our work. Second, our data set is significantly different than data that have been used in other studies that examine cellular and WiFi performance. We argue that the fact that our work replicates some of these prior results using vastly different data should be seen as a key strength of our study. Interestingly, the historian of science Harry Collins wrote in his book "Changing Order" that although replication is revered as a hallmark of science, scientists rarely carry out such studies since science "reserves its highest honours for those who do things first." We think that the network measurement community should be more receptive to studies that replicate prior results using new and/or different data.

Two reviewers indicated that they would like to have seen a more detailed comparison of different access technologies, e.g., EVDO versus 3G versus LTE, and an analysis of the possibility of using LTE as a replacement for WiFi. These are excellent suggestions, which we had already been considering. We intend to analyze our data, and additional data as it is made available by Ookla, Inc., to examine these issues comprehensively in future work. We also intend to examine the predictability of spatio-temporal performance, another excellent suggestion.