Comparing Metro-Area Cellular and WiFi Performance

[Extended Abstract]

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ABSTRACT

Cellular and 802.11 WiFi offer two compelling connectivity options for mobile users. The goal of our work is to better understand performance characteristics of these technologies in diverse environments and conditions. To that end, we compare and contrast cellular and Wifi performance using crowd-sourced data from `speedtest.net`. We consider spatio-temporal performance aspects (e.g., upload and download throughput and latency) using over 3 million user-initiated tests initiated in 15 different metro areas, collected over 15 weeks. In these preliminary results, we find that WiFi performance generally exceeds cellular performance, and that observed characteristics are highly variable across different locations and times of day. We also observe diverse performance characteristics resulting from the rollout of new cell access technologies and service differences among local providers.

Categories and Subject Descriptors: C.2.1 [Network Architecture and Design]: Wireless communication; C.4 [Performance of Systems]: Performance attributes

General Terms: Experimentation, Measurement, Performance

Keywords: Cellular, WiFi, throughput, latency

1. INTRODUCTION

The past five years has witnessed an explosion in the capabilities of mobile devices that are both cellular- and 802.11 WiFi-capable. The combination of a short-range, high-speed capability, and a longer-range, lower-speed capability is compelling, and has driven the development of a wide-range of new mobile applications. Consequently, there is a large and growing demand for network bandwidth by mobile users.

A vexing problem for WiFi-enabled cell phone users, service providers, and application designers is seeking out and supporting the connectivity option that provides the best and most reliable performance. Over short time scales, issues that affect performance include local network service availability, handset characteristics, and interference, among others, while over long time scales, new technology and infrastructure deployments shape achievable performance. To help users make sense of the various connectivity options available to them, a number of performance testing applications have been developed and made available. In addition to assisting users to test their network performance, the data gathered by these applications offers the possibility to provide unique insights into mobile device performance.

SIGMETRICS '12, June 11–15, 2012, London, England, UK.
ACM 978-1-4503-1097-0/12/06.

In this work, we investigate mobile device performance using crowd-sourced data provided by `speedtest.net`, one of the most popular and widely deployed mobile bandwidth testers. The goal of our study is to understand the spatio-temporal characteristics of performance of WiFi-enabled cell phones in a selection of metro areas with different population densities and diverse geographic characteristics. A longer-term goal is to formulate conclusions about the spatio-temporal aspects of mobile device network performance that will lead to improvements in the relevant protocols, configurations, and infrastructure.

Our evaluation indicates a complex set of characteristics of spatio-temporal performance of mobile devices in a metro area. As expected, we find WiFi download and upload performance to be superior to cellular performance in most areas. We also find that WiFi latency measurements are at least a factor of two lower than cell latency in all areas. However, the latency difference tends to be smaller in larger metro areas, suggesting that greater efforts have been made to optimize those cellular deployments. In our ongoing work, we plan to drill down on the data in greater detail to further examine root causes for observed behaviors, and to examine user- and provider-specific performance characteristics.

2. DATA

`Speedtest.net` is a bandwidth/performance evaluation platform that is managed and maintained by Ookla, Inc.[1] The application can be run in a web browser, and native apps are available for both Apple iOS- and Android-based devices. Over 2B performance tests have been run since `speedtest` began in 2006, with global daily tests currently exceeding 125K per day. In this work, we only consider data collected from tests initiated from the iOS and Android apps.

Each `speedtest` is initiated by the client app. Upon invocation, a test request is directed to the geographically closest `speedtest` server; there are over 600 servers deployed worldwide. Each test consists of a latency test, followed by upload and download throughput tests. At the conclusion of a test, a rich log entry is stored at the local `speedtest` server that includes information such as a timestamp, client IP, device type and OS, device geographic coordinates, measured upload and download speeds (in kb/s), latency (in milliseconds), and access type (cellular or WiFi).

The data we consider were collected from `speedtest` servers located in 15 metro areas over a period of 15 weeks from February 21, 2011 through June 5, 2011. Selection of the 15 sites was based on attempting to amass a manageable dataset, yet one that provides a broad perspective on cellular vs. WiFi performance in metro areas that are diverse in their geographic, socio-economic and behavioral characteristics. We focus on five different metro area types:

[1] `http://www.ookla.com`

three in the US (Small: Lawrence, KS; Jackson, TN; Missoula, MT; Medium: Madison, WI; Syracuse, NY; Columbia, SC; and Large: New York, NY; Chicago, IL; Los Angeles, CA), one in Europe (Belgrade, Serbia; Brussels, Belgium; Manchester, UK), and one in Asia/Pacific (Ulaanbaatar, Mongolia; Almaty, Kazakhstan; Palembang, Indonesia).

3. RESULTS

Our preliminary results reveal a wide range of characteristics of cellular and WiFi performance. The raw comparison between the two technologies shows that WiFi provides superior download performance, with maximum WiFi performance varying widely. The difference in upload performance is much smaller, yet is also highly variable. Temporal analysis reveals that performance is sensitive to time of day in the largest metro areas, with performance decreasing for both cellular and WiFi during the hours of peak use. Comparisons between metro areas shows that larger markets provide a consistently higher level of performance for both technologies, suggesting greater engineering effort and resources deployed in more populous regions. However, analysis within more localized regions shows high variability in performance for both technologies in all markets.

As an example of our results, below, we analyze the temporal characteristics of download performance for cellular and WiFi. Figure 1 shows the hourly average download performance for each technology over an 8 day period for one metro area from each of the five area types (notice the different y-axis scales for cellular (top) and WiFi (bottom)). We observe that for cellular access, the performance for all but the largest metro area is fairly similar over time; performance for the New York, NY region clearly stands above the others. This trend is similar for other metro areas in the five area types. The latency profiles we observe in the data suggest suggest that the better engineered cellular infrastructure in large metro areas has a clear impact on throughput performance. We observe that for WiFi connections, while the smallest metro areas have generally lower throughputs, the differences are not as great among the metro areas for WiFi as they are for cellular connections.

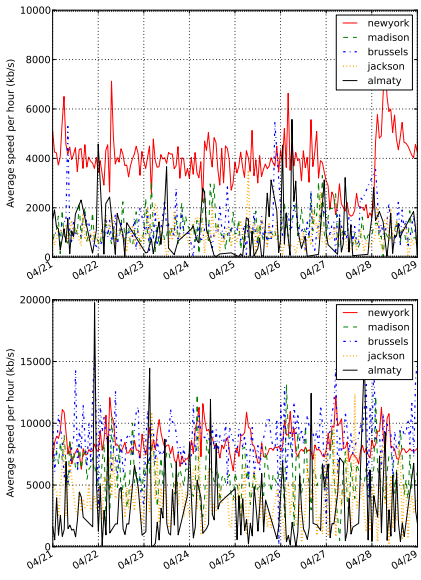

Figure 1: Average hourly performance for cellular downloads (top) and WiFi downloads (bottom) for exemplars in each of the metro areas during the week of April 21 to April 29, 2011.

4. RELATED WORK

There is a large and growing body of work that examines the behavior and characteristics of WiFi networks. Studies that are most closely related to ours have focused on analyzing mobile use characteristics in live deployments, *e.g.*, [2, 4, 5, 7]. Likewise, there is also a growing literature on empirical studies of cellular networks. Tan *et al.* describe one of the first empirical studies of 3G cellular networks in [9]; other empirical studies of behavior in cellular networks include [6, 8]. While these prior studies expand the body of knowledge on WiFi and cellular behavior individually, our work differs in objective, scope, measurement details, and the fact that we include analysis of both WiFi and cellular performance. Lastly, there are several studies that investigate both cellular and WiFi performance, primarily in vehicular settings [1,3]. Our results complement and expand this prior work by reporting client performance in diverse markets using a larger body of crowd-sourced data, and in more general (non-vehicular) settings.

5. CONCLUSIONS AND FUTURE WORK

Cellular and 802.11 WiFi are the *de facto* connectivity options for today's mobile users. The increasing availability of handsets and tablets that offer *both* connectivity options, coupled with the the explosion of applications that demand high performance means that users are sensitive to throughput performance for each technology. The objective of our study is to broadly compare and contrast the spatio-temporal aspects of performance of both technologies in 15 diverse metro areas using crowd-sourced data from `speedtest.net`.

In future work we intend to drill down on the data in greater detail in order to better understand user- and provider-specific performance, as well as variations in performance, *e.g.*, by considering related datasets such as weather conditions during test periods and cell tower/WiFi access point locations. Finally, we plan to conduct targeted, hypothesis-driven experiments in different markets using the `speedtest` application, again toward the goal of understanding the root causes of observed performance results.

Acknowledgements

The authors thank Ookla, Inc. and Andrew Bassett for generously making the `speedtest.net` data available for this study.

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