Mobile Data Offloading: How Much Can WiFi Deliver? *

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ABSTRACT

This is a quantitative study on the performance of 3G mobile data offloading through WiFi networks. We recruited about 100 iPhone users from a metropolitan area and collected statistics on their WiFi connectivity during about a two and half week period in February 2010. We find that a user is in WiFi coverage for 70% of the time on average and the distributions of WiFi connection and disconnection times have a strong heavy-tail tendency with means around 2 hours and 40 minutes, respectively. Using the acquired traces, we run trace-driven simulation to measure offloading efficiency under diverse conditions e.g. traffic types, deadlines and WiFi deployment scenarios. The results indicate that if users can tolerate a two hour delay in data transfer (e.g, video and image uploads), the network can offload 70% of the total 3G data traffic on average. We also develop a theoretical framework that permits an analytical study of the average performance of offloading. This tool is useful for network providers to obtain a rough estimate on the average performance of offloading for a given input WiFi deployment condition.

Categories and Subject Descriptors

C.2.1 [**Network Architecture and Design**]: Wireless communication

General Terms

Experimentation, Measurement

Keywords

Mobile Data Offloading, Experimental Networks, Delayed Transmission

1. INTRODUCTION

Mobile data traffic is growing at an unprecedented rate well beyond the capacity of today's 3G network. Many researchers from networking and financial sectors forecast that by 2014, an average mobile user will consume 7GB of traffic per month which is 5.4 times more than today's average user consumes per month, and the total mobile data traffic throughout the world will reach about 3.6 exabytes per month, 39 times increase from 2009 at a compound annual rate of 108%. It is also predicted that about 66% of this traffic is mobile video data. The main drive behind this explosive growth is the increase in smart mobile devices that offer ubiquitous Internet access and diverse multimedia authoring and playback capabilities.

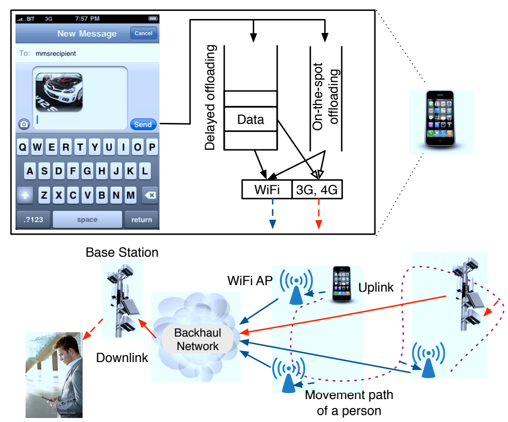

Figure 1: Sketch of mobile data offloading.

There are several solutions to this explosive traffic growth problem. The first is to scale the network capacity by building out more cell towers and base stations or upgrading the network to the next generation networks such as LTE (Long Term Evolution) and WiMax. However, this is not a winning strategy especially under a flat price structure where revenue is independent of data usage.

The second is to adopt a usage based price plan which limits heavy data usages. While price restructuring is rather inevitable, pure usage based plans are likely to backfire by singling out a particular sector of user groups, e.g., smart phone users, which have the highest potential for future revenue growth.

WiFi offloading seems the most viable solution at the moment. Building more WiFi hot spots is significantly cheaper than network upgrades and build-out. Many users are also installing their own WiFi APs at homes and work. If a majority of data traffic is redirected through WiFi networks, carriers can accommodate the traffic growth only at a far lower cost. Given that there are already a wide-spread deployment of WiFi networks, WiFi offloading addresses the "time-to-capacity" issue for the currently pressing need of additional network capacity.

There are two types of offloading: *on-the-spot* and *delayed*. On-the-spot offloading is only to use spontaneous connectivity to WiFi and transfer data on the spot. In delayed offloading, each data transfer is associated with a deadline and as users come in and out of WiFi coverage areas, it repeatedly resumes data transfer until the transfer is complete. If the data transfer does not finish within its deadline, cellular networks finally complete the transfer. Figure 1 illustrates a system with offloading.

*http://research.csc.ncsu.edu/netsrv/?q=content/wifioffloading

SIGCOMM'10, August 30–September 3, 2010, New Delhi, India.
ACM 978-1-4503-0201-2/10/08.

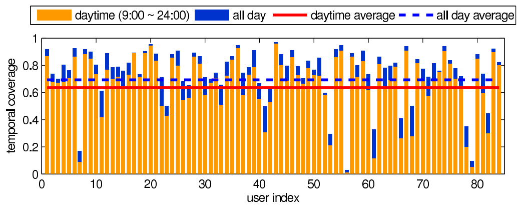

Figure 2: Temporal coverages of users.

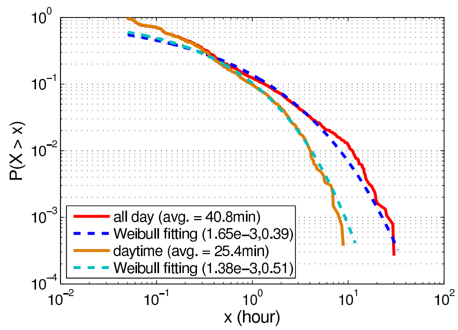

Figure 3: The CCDF of inter-connection times. The average is 41 minutes.

In this paper, we offer the first quantitative answers to how much offloading is beneficial by conducting an extensive measurement study in a metropolitan area. For our measurement study, we first designed and implemented an iPhone application that tracks WiFi connectivity. We recruited about 100 iPhone users who downloaded our application to their phones and used it for about a two and half week period in February 2010. The application is designed to connect to various WiFi networks as the users travel including its carrier's WiFi network. The application runs in the background to record the locations of WiFi stations to which each user connects, the connection times and durations, and the data transfer rates between WiFi stations and mobile phones, and then periodically upload the recorded data to our server. These data are used to carry out trace-driven simulation of offloading with diverse data traffic and WiFi deployment scenarios.

2. KEY OBSERVATIONS

From the measurement data, we focus on the statistics relevant to offloading: the total time duration of WiFi connectivity, the data rate during connections, the distributions of connection times and inter-connection times and the correlations of the total travel lengths with the data rate and time of WiFi connectivity time. Results which are not presented in this paper will be given in the poster.

The performance of offloading highly depends on the time duration that a user stays in a WiFi coverage area which is defined as *temporal coverage*. Note that the temporal coverage is much higher than spatial coverage in general. Figure 2 shows the daily average temporal coverage recorded by each participant. It also plots the coverage recorded during the daytime. The averages across all the users are 70% for all day and 63% for the daytime only. Difference between all day and day time averages arises because most participants are likely to have WiFi connectivity at home.

Figure 3 shows the CCDF (Complementary Cumulative Density Function) of *inter-connection times*, the time duration after a user leaves a coverage area, until it returns to a coverage area. The average is about 40 minutes for all day and 25 minutes for daytime.

Table 1: Input data to the experiment for Figure 4. We use the projection from [1] on the amount of mobile data traffic, their constituent types and proportion mobile data traffic in year 2014. We assign artificial deadlines to different types of data from short to long deadlines. The mean inter-arrival times are estimated from the estimated monthly volumes. DL : Deadline.

	Video	Data	P2P	Audio	Total
Ratio [1]	64.0 %	18.3 %	10.6 %	7.1 %	100 %
Data/month	4.48 GB	1.28 GB	740 MB	500 MB	7 GB
Avg. IAT	1 hour	2 hours	2 hours	1 hour	-
Traffic vol.	10 MB	5.7 MB	3.3 MB	1.1 MB	-
Traffic dist.	Weibull (k=0.5)	←	←	Exponential	-
On-the-spot	0 sec.	0 sec.	0 sec.	0 sec.	-
DL:short	10 min.	10 min.	5 min.	0 sec.	-
DL:medium	30 min.	2 hours	10 min.	0 sec.	-
DL:long	6 hours	6 hours	6 hours	0 sec.	-

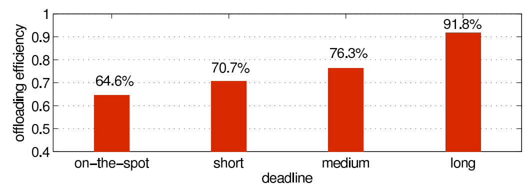

Figure 4: Offloading efficiency for mobile data compound at year 2014 predicted by CISCO for various delay tolerance.

Similarly to the inter-contact time distribution in human traces, the distribution is also heavy-tailed.

3. OFFLOADING EFFICIENCY

Since we have detailed records of user connectivity and data rates during the connectivity, they can be used to simulate the offloading of input traffic with diverse patterns including traffic volume, average interval and heavy-tail degree. We define *offloading efficiency* to be the total bytes transferred through WiFi divided by the total bytes generated.

To understand the impact of offloading in relieving the future traffic demands, we use the projection data shown in Table 1 released from CISCO [1] on the amount of mobile traffic demands by year 2014.

With on-the-spot offloading achieves about 60% offloading efficiency, short, medium and long delayed offloading achieve 71%, 76% and 92% efficiency, respectively. This result is highly encouraging as even with such a short deadline, we can have more than 70% offloading efficiency. Many more interesting results under different scenarios will be shown in the poster.

4. CONCLUSION

To the best of our knowledge, this paper is by far the first quantitative study on the offloading performance of mobile data traffic through WiFi networks. Through extensive evaluations of offloading efficiency under various traffic types, volumes, burstness and delay tolerance, we conclude that WiFi offloading is a simple, yet viable solution to the deluge of mobile data.

5. REFERENCES

[1] Cisco visual networking index: Global mobile data traffic forecast update, 2009-2014, February 2010. *http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html*.