Online? A Study of Smartphone Internet Availability

Denzil Ferreira
Center for Ubiquitous Computing
Oulu, Finland
denzil.ferreira@oulu.fi

Huber Flores
Center for Ubiquitous Computing
Oulu, Finland
huber.flores@oulu.fi

Karel Vanderbroucke
iMinds-MICT-Ghent University
Ghent, Belgium
karel.vanderbroucke@iminds.be

Aku Visuri
Center for Ubiquitous Computing
Oulu, Finland
aku.visuri@oulu.fi

ABSTRACT
An important facet of smartphone's usage is internet. Everything works flawlessly, as long as you have a good internet connection. A smartphone's functionality is immediately limited by the absence of internet: applications are not up-to-date; instant chat messages are not delivered when intended, or one is unable to get directions. Besides internet performance tuning, research has been scarce in leveraging users' internet access routines to improve smartphone's usage. By understanding smartphone internet availability, one may utilise this information to minimise data costs and improve users' experience while using internet-enabled applications. Our paper provides insight into when is it likely that an individual user is online, based on personal connectivity routines.

Author Keywords
Online; smartphone; context-aware; internet-of-things

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;

INTRODUCTION
Over the years, smartphones have become the *de facto* communication device, regardless of the country [11]. Mobile applications increasingly require internet access to sync and backup users' data and instant messaging and voice calls are connecting people across continents. Everything works flawlessly, as long as one has a good internet connection [13] and both parties are online. A smartphone's functionality is immediately limited at the absence of internet: applications cannot stay up-to-date; owners cannot do instant chat or check Facebook [1]. We focus on a user-centric understanding of smartphone internet access and availability. We investigate the following research questions:

- *How often are we connected online?*
- *Do we exhibit a preference to connect online?*

By understanding smartphone internet availability, we can utilise this information to improve users' experience while using applications by means of pre-emptive prefetching or informed scheduling, and minimise data costs by expecting WiFi availability at a specific time of the day. In practice, our analyses provide insight into when is it likely that a user is online, based on personal connectivity routines.

MUM '16, December 12-15, 2016, Rovaniemi, Finland
ACM 978-1-4503-4860-7/16/12.
http://dx.doi.org/10.1145/3012709.3016060

RELATED WORK
Multiple strategies can be used to measure mobile network performance. Internet performance is measured in terms of latency and it influences users' perception towards an application. To monitor and adapt the network constantly, requires a considerable computational effort for a smartphone. Consequently, opportunistic models for network connectivity have been explored in the literature to overcome these issues [6,7]. By modelling the different parameters that influence the effort of connecting to a remote service, it is possible to schedule data transfer at the most convenient moments for the mobile device, e.g., low energy rates.

To complement previous studies, our work focuses on understanding the network availability of a smartphone by considering user's usage behaviour. By modelling network connectivity as part of user's routine, it is possible to decide better the opportune moments that can be used by the mobile device to execute network operations and to fix inefficiencies in network mechanisms and communication protocols.

DATASET
To investigate smartphones' internet availability, we explore a dataset collected in our home country. This dataset contains the data of 66 participants of a 1-month and 15 days long, in-the-wild study, collected between February and March, 2016. This dataset' participants have diverse backgrounds (e.g., engineers, researchers, students) and was collected naturalistically: no encouragement to connect online is provided. The dataset is logged unobtrusively using AWARE [5] running on the background. Twelve participants were excluded (less than 7 days' worth of data), thus a final count of 54 participants. This dataset derived from an application investigating daily illness symptoms, and mood longitudinally. In total, on average, participants collected 33 days (SD=7.1) of internet data.

RESULTS
To account for potential outlier bias, we only consider participants with at least 7 days' worth of data. The dataset contains both WiFi and Network (i.e., operators' internet data plan) states (e.g., ON, OFF) and checks for internet availability (e.g., online, offline). Note that, even though the

WiFi or Network is ON, internet is not always available. Additionally, as we activate the WiFi or Network access i.e., switching from OFF to ON, there is a delay in acquiring a connection. Internet is available if the device can reach online content, regardless of the currently active internet access and it is appropriately managed by Android OS' Connectivity Manager API [3].

Participants are online intermittently throughout the day, losing internet connectivity on several occasions. On a daily basis, on average, participants are online for a total of 14 hours and 19 minutes (SD=9h 20m). A chi-squared analysis showed that there is a significant relationship between the day of the week ($\chi^2 = 557.7$, df = 6, $p < 0.001$) and frequency of internet access; and between the weekday/weekend ($\chi^2 = 3288$, df = 1, $p < 0.001$). Our participants were more frequently online on Mondays and during weekdays.

To investigate if there is a significant difference between internet availability at different times of the day, we divide the day in four segments: morning (6 AM-noon), afternoon (noon-6 PM), evening (6 PM-11 PM) and night (11 PM-6 AM). A chi-squared analysis showed that there is a significant relationship between the time of the day and frequency of internet availability ($\chi^2 = 370.9$, df = 3, $p < 0.001$). Our participants were more frequently online during the afternoon and evenings (29.8% and 27.3% of the time, respectively).

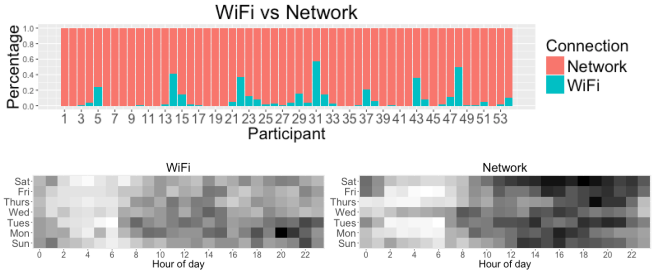

Figure 1. Participants' internet access ratios (top); daily and hourly usage routines (bottom).

As expected, participants connect online using WiFi or Network in different ratios (**Figure 1 - top**). The medians of WiFi and Network online sessions were 2h 57m and 8h 12m, respectively. A Wilcoxon signed-rank test shows that there is a significant effect of internet access (W=2, Z = -6.37, $p < 0.001$, r = 0.87). To access online, the participants preferred to use Network more than WiFi (**Figure 1- bottom**).

DISCUSSION

Mobile Internet Usage: Assumptions vs Observations

We had several assumptions from previous work, as follow:

1. We are always online, i.e., our device has internet [1,9]
2. We have an online routine [1,1,10]
   a. on weekends
   b. at the end of the day
3. We use WiFi more than phone Network [8,14]

For the majority of our participants, there are numerous timeslots, i.e., time when our participants are not connected online, thus indicating that 1) may not be a truthful assumption. A similar deduction is reported in [14] large-scale deployment, where the authors state "10% of [>16,000] participants have no network connection for at least 40% of the time, while half of our population spends less than 5% of their time without a connection." Price has been shown to affect how much time people spend online, where free access to internet may encourage excessive, problematic use [2]. Our dataset is from a country where unlimited high-speed (e.g., 4G, LTE) phone network is commonplace. So **one could expect "excessive" internet use. This was not the case for almost a 2-month observation**.

Overall, we found significant differences on the day of week and time of day for internet usage: Mondays ($\chi^2 = 557.7$, df = 6, $p < 0.001$) and during afternoon and evening hours ($\chi^2 = 370.9$, df = 3, $p < 0.001$), respectively. Thus 2) is partially a valid assumption. However, our assumption that weekends would be more an opportune time to be online is misplaced. In fact, participants connected online significantly more during the weekdays ($\chi^2 = 3288$, df = 1, $p < 0.001$). While previous work has reported that users to connect online using WiFi more frequently [14], assumption 3), we found the opposite (**Figure 1**) with a very significant effect (W=2, Z = -6.37, $p < 0.001$, r = 0.87).

We argue there are several reasons for a shift away from WiFi as means for internet access: high-speed mobile network is increasingly available in several countries throughout the world [12], and at less prohibitive prices. For the consumer, this means freedom to transit without losing internet connection, or sharing the network bandwidth. In addition, it has been shown that consumers trust more their Network connections, than when using an open WiFi network [4]. Evidently, there are exceptions. We saw a minority of participants using WiFi more frequently in the evening (8PM onwards) (**Figure 1 - bottom**). We can speculate them being at home and enjoying a high-speed internet connection using their home's WiFi, a routine also reported in [1].

CONCLUSION

Our empirical investigation indicates that we are not always online, contrary to what one may think with an unlimited phone network data plan. Throughout the day, our smartphones elude internet connectivity. Having a better understanding of personal internet connectivity routines offers an opportunity to make mobile applications more efficient, e.g., by a postponing pull/push to when it is more likely the user is connected, and improve users' experience when using an internet-enabled application offline.

ACKNOWLEDGMENTS

This work is partially funded by the Academy of Finland (Grants 276786-AWARE, 285062-iCYCLE, 286386-CPDSS, 285459-iSCIENCE), and the European Commission (Grants PCIG11-GA-2012-322138, 645706-GRAGE, and 6AIKA-A71143-AKAI).

REFERENCES

1. Joël Billieux, Pierre Philippot, Cécile Schmid, Pierre Maurage, Jan De Mol and Martial Van der Linden. 2014. Is Dysfunctional Use of the Mobile Phone a Behavioural Addiction? Confronting Symptom-Based Versus Process-Based Approaches. *Clinical Psychology & Psychotherapy* 22, 5: 460-468. http://dx.doi.org/10.1002/cpp.1910
2. Julie Broadbent and Michelle A. Dakki. 2015. How Much Is Too Much to Pay for Internet Access? A Behavioral Economic Analysis of Internet Use. *Cyberpsychology, Behavior, and Social Networking* 18, 8: 457-461. http://dx.doi.org/10.1089/cyber.2014.0367
3. ConnectivityManager | Android Developers. Retrieved 30/03/2016 from http://developer.android.com/reference/android/net/ConnectivityManager.html
4. Denzil Ferreira, Vassilis Kostakos, Alastair R. Beresford, Janne Lindqvist and Anind K. Dey. 2015. Securacy: An Empirical Investigation of Android Applications' Network Usage, Privacy and Security. In *Conference on Security and Privacy in Wireless and Mobile Networks*, ACM, 11:1-11:11. http://dx.doi.org/10.1145/2766498.2766506
5. Denzil Ferreira, Vassilis Kostakos and Anind K. Dey. 2015. AWARE: mobile context instrumentation framework. *Frontiers in ICT* 2, 6: 1-9. http://dx.doi.org/10.3389/fict.2015.00006
6. Huber Flores, Pan Hui, Sasu Tarkoma, Yong Li, Satish Srirama and Rajkumar Buyya. 2015. Mobile code offloading: from concept to practice and beyond. *Communications Magazine, IEEE* 53, 3: 80-88. http://dx.doi.org/10.1109/MCOM.2015.7060486
7. B Han, P Hui, V. S. A. Kumar, M. V. Marathe, J Shao and A Srinivasan. 2012. Mobile Data Offloading through Opportunistic Communications and Social Participation. *IEEE Transactions on Mobile Computing* 11, 5: 821-834. http://dx.doi.org/10.1109/TMC.2011.101
8. Kyunghan Lee, Joohyun Lee, Yung Yi, Injong Rhee and Song Chong. 2010. Mobile Data Offloading: How Much Can WiFi Deliver? In *Proceedings of the 6th International COnference*, ACM, 26:1-26:12. http://dx.doi.org/10.1145/1921168.1921203
9. Amanda Lenhart, Kristen Purcell, Aaron Smith and Kathryn Zickuhr. 2010. Social Media & Mobile Internet Use among Teens and Young Adults. Millennials. *Pew Internet & American Life Project*.
10. Antti Oulasvirta, Tye Rattenbury, Lingyi Ma and Eeva Raita. 2012. Habits make smartphone use more pervasive. *Personal and Ubiquitous Computing* 16, 1: 105-114. http://dx.doi.org/10.1007/s00779-011-0412-2
11. Smartphone Penetration by Country and Age Group (2011-2013). Retrieved 02/11/2015 from http://bit.ly/1GI0Ud6
12. Smartphone penetration Europe 2013. Retrieved 28/09/2015 from http://think.withgoogle.com/mobileplanet/en/graph/?country=at&country=be&country=dk&country=fi&country=fr&country=de&country=gr&country=nl&country=no&country=pt&country=es&country=se&country=uk&category=DETAILS&topic=Q00&stat=Q00_1&wave=2013&age=a4&age=a5&gender=all&chart_type=&active=age
13. Karel Van den Broucke, Denzil Ferreira, Jorge Goncalves, Vassilis Kostakos and Katrien De Moor. 2014. Mobile Cloud Storage: A Contextual Experience. In *International Conference on Human-Computer Interaction with Mobile Devices and Services*, ACM, 101-110. http://dx.doi.org/10.1145/2628363.2628386
14. Daniel T. Wagner, Andrew Rice and Alastair R. Beresford. 2013. *Device Analyzer: Understanding Smartphone Usage.* Springer International Publishing.