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Effects of Network Performance on Smartphone User Behavior

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Abstract

This paper presents a study that explores the relation between how the choice and use of an app depends on the network performance. While the relation between smartphone user behavior and contextual factors has been explored in previous research, the mobile networks' influence on the smartphone user behavior is largely unknown. Through analysis of a data set collected from ~1500 users using Ericsson Apps, a logging tool for Android phones, the results show indeed that data demanding apps have a strong positive correlation between the relative usage and the network performance. For example, the results demonstrate that users are around 1.4 times more likely to use YouTube on LTE than on EDGE. This information, combined with an understanding of contextual factors, can be used to optimize networks by adapting the network performance to the user's requirements and real levels of consumption. Furthermore, it can be possible to tune services pro-actively and improve the Quality of Experience (QoE).

Index Terms: Quality of Experience, User behavior, network performance, app usage, data analysis.

1. Introduction

The onset and increasingly fast adoption of smartphones has transformed the usage and the users' view on mobile services. In 2015, smartphone subscriptions worldwide were approximately 3.2 billion and it is estimated that this number will grow to 6.23 billion by 2020 [1]. Cisco [2] estimates that the increasing use of smartphones and the popularity of over the top (OTT) services such as Skype, WhatsApp and YouTube will generate an explosion of data traffic, with volumes forecast to grow at a compound annual growth rate (CAGR) of 53% out to 2020. Demand for mobile services is increasing, while the competition is intense [3].

With growing pressure to keep competitive, reduce churn and increase revenues, "a paradigm shift could be observed for service providers to deliver services not with a high Quality of Service (QoS), but with a high Quality of Experience (QoE) to their customers", according to Möller et al. in [4]. This paradigm shift can also bring to the business scenario new revenue sources by offering customized services and integrating users' QoE in the service provision scheme. This new approach requires mobile operators to understand what affects usage of mobile apps and services in order to structure a future customization in the service provision. Knowledge on effects of network performance on smartphone user behavior can contribute to optimizing the usage of network infrastructure and improve mobile QoE.

Previous studies have explored the relation between smartphone user behavior and contextual factors (*i.e.,* Ericsson [5], Verkasalo [6], and Bohmer *et al.* [7]). However, the mobile networks' influence on the smartphone user behavior is less studied. We explore this problem with an empirical approach, by collecting an important amount of data directly from mobile users' phones, and then applying a statistical analysis to find correlations between network performance and the use of different applications.

For the analysis, we have used collected data from ~1500 users using Ericsson Apps to determine i) whether the choice of the app depends on the current network performance and ii) how the use of an app is adjusted by the current network performance. The result shows that network performance is found to be clearly factored into the users' app choices. With this study we aim to provide insights on how mobile operators can use app information to optimize networks and also tune services pro-actively and improve QoE.

2. Method

The data used in this study was collected by Ericsson Apps (EA), which is an app engine for Android smartphones. Its purpose is to identify apps that the user might be interested in based on previous app usage. This is done by looking at the user's previous app usage and compares that with all other users' app usage.

EA collects all kinds of app usage data, such as app name, category, session duration and data consumption from all apps that are used in the foreground, i.e., the apps the user has active on the screen. EA also collects a broad range of client-side network data, such as network type (EDGE, UMTS, HSPA, HSDPA, HSPAP, and LTE), uplink and downlink throughput, dropped packages, duration of timeouts and signal strength. The data used in this paper was collected between June 2014 and May 2015, from ∼1500 Swedish users, where the data is anonymized by MD5-hashing of the user identifier. It worth to mention that most users are located in Stockholm and that the user pool consists mostly of Ericsson employees, which might create an homogenous group of users. This work describes some of the results presented in [8].

3. Results

Basic statistics for the app usage parameters was calculated from EA's data for Sweden in order to identify what apps that the analysis should focus on, considering both the data consumption and the number of sessions identified in the

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samples, see table 1. The statistics that stands out the most shows that three apps, Facebook, YouTube and Chrome, stand for ≥ 55.1% of the total data consumption. This makes them interesting apps to include in the analysis. The traditional mobile services, Phone and Messaging are also key apps. Other interesting apps are Viber, WhatsApp, Email/Gmail and Spotify. Both Viber and WhatsApp offer texting over data while Viber also provides VoIP.

Table 1. *Basic App Usage Statistics.*

Time	%	Data	%
Chrome	9.97	Facebook	22.48
Facebook	8.61	YouTube	17.86
Phone	7.11	Chrome	14.74
Facebook	6.73	SVT Play	5.11
Mobile	5.94	Google Play Store	3.93
WhatsApp	2.98	Spotify	3.29
Messaging	2.93	Netflix	2.32
Contacts	2.65	Instagram	2.15
Viber	2.61	Internet	1.54
Gmail	1.89	Maps	1.38
YouTube	1.76		

3.1. Influence of Network Performance on App Choice

The first part of the analysis is to look at whether the choice of the app depends on the current network performance, i.e. the network type available before the app was started. By computing the probability (1) of using an app given a particular network type, we can compare these numbers across network types, i.e. $p(app \mid network)$ is the probability that given network the app is used.

$$p(app \mid network) = \frac{p(network \mid app)\, p(app)}{p(network)} \qquad (1)$$

In the analysis the sessions are classified according to the network type that was displayed when the sessions started. This categorization includes those sessions that change of network during the sampling time. The results are filtered such that network types with less than 40 sessions are not plotted due to insufficient data size.

Figures 1, 2 and 3 show the usage fraction for YouTube, Whatsapp and Viber. The tag value in these figures represents the number of uses of the app on the considered network, while the usage fraction corresponds to $p(app \mid network)$.

In Figure 1 the usage of YouTube is shown. This Figure indicates that the users are not equally likely to use YouTube on all networks. It is also apparent that users are not as likely to use YouTube on networks with insufficient performance such as EDGE or UMTS compared to HSPAP or LTE. Our data shows that users are ~1.4 and ~1.15 times more likely to use YouTube on LTE compared to EDGE and HSPAP.

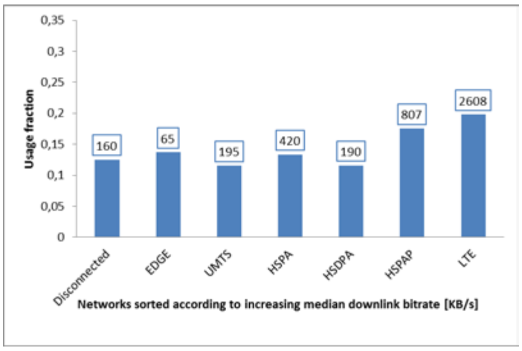

Figure 1: *Illustration of the relative usage of YouTube.*

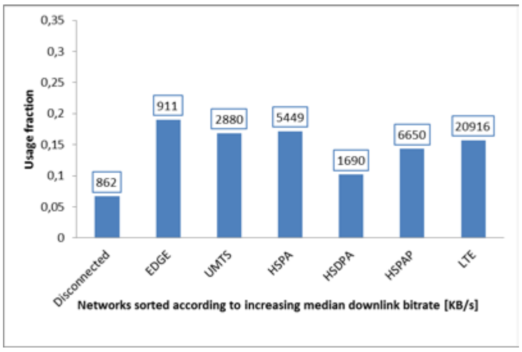

Figure 2: *Illustration of the relative usage of WhatsApp.*

In Figure 2 the usage for WhatsApp is shown, and it is evident that the dependency is negative, i.e., users are less likely to use WhatsApp on better networks. The maximum is for EDGE with a very sharp drop down to disconnected. For example, users are ~1.19 times more likely to use WhatsApp on EDGE than on LTE.

Figure 3 shows the usage for Viber. This application is similar to WhatsApp, it offers texting, which suggests that it should exhibit a similar behavior. However, Viber also offers VoIP and shows a radically different behavior compared to WhatsApp and users are ~5 times more likely to use Viber on LTE compared with EDGE.

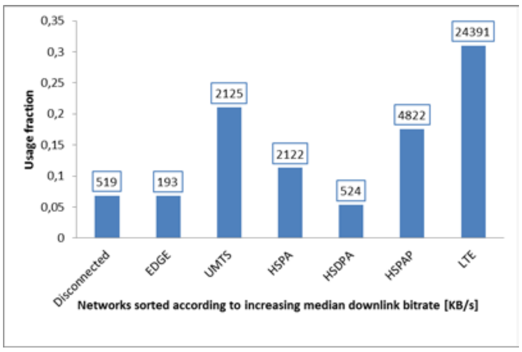

Figure 3: *Illustration of the relative usage of Viber.*

3.2. Influence of Network Performance on Apps' use

The second step in the analysis is to determine if and how the use of an app is adjusted by the current network performance.

The session duration and received data consumption for YouTube is illustrated in Figures 4 and 5, respectively. We can note that YouTube duration and data consumption increases sharply with increasing network performance.

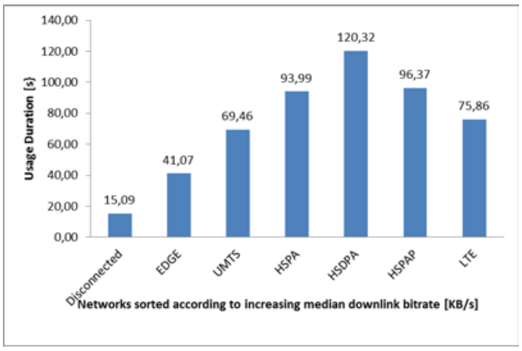

Figure 4: *Median session duration of YouTube.*

The average duration increases up until HSDPA where it reaches ~120 seconds, then decreasing to~76 seconds for LTE. A UMTS session consumes on average ~7.3 MB and lasts for ~69 seconds. It seems that UMTS is sufficient for YouTube to function, but the users are still restricted somewhat since the average session duration for UMTS is ~20 seconds less than for HSPA.

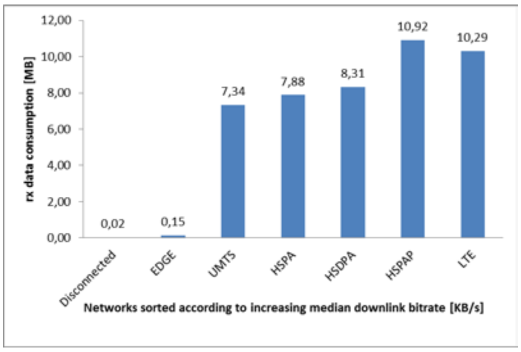

Figure 5: *Received data consumption of YouTube.*

WhatsApp session duration and received data consumption is shown in Figures 6 and 7, respectively. In this case, the average duration increases up until HSDPA where it reaches ~37 seconds. Then, the duration decreases down to HSPAP and LTE where it reaches ~29 seconds. It seems that users speed up their sessions when having access to a better network performance, or that the users are rather using some other app and therefore keep the WhatsApp sessions shorter.

According to Figure 7, WhatsApp is a low data consumption app, where received data consumption presents a stable behavior, with small differences among the different network types. It seems the average received data is not impacted by the increase in the network performance. The figure also shows a high data consumption when disconnected. This can be explained by the method used to classify sessions (i.e., according to the when the sessions started) and an unreliable connection (i.e., it turns on/off repeatedly). In this case, as the network may change during a session, it is still possible to send/receive text, and show data consumptions exceeding zero.

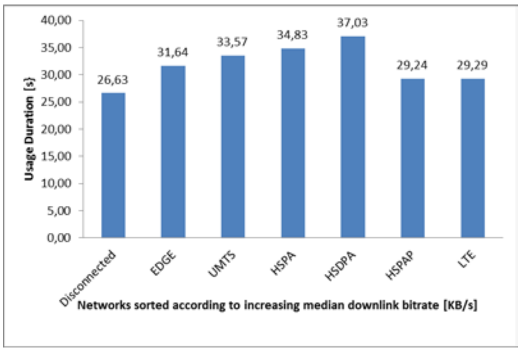

Figure 6: *Median session duration of WhatsApp.*

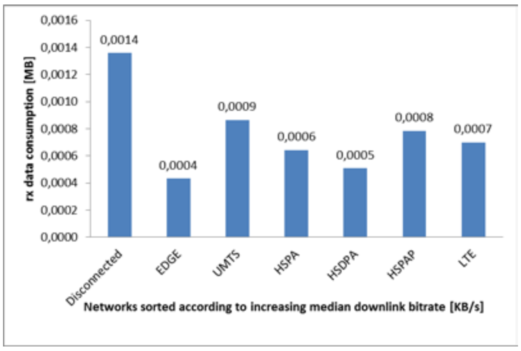

Figure 7: *Received data consumption of WhatsApp.*

The session duration and received data consumption for Viber is illustrated in Figures 8 and 9, respectively. The average session duration for Viber shows a decreasing behavior while network performance increases. Session duration decreases reaching the lowest level at ~14 seconds with HSPAP. LTE shows a slight increase on duration at ~16 seconds.

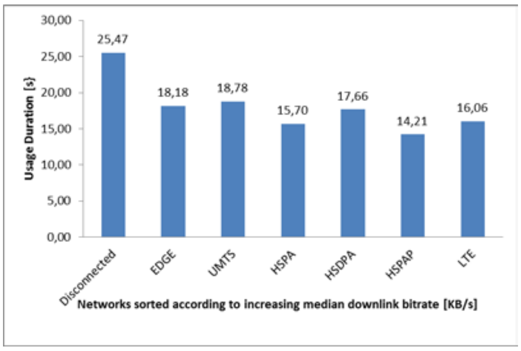

Figure 8: *Median session duration of Viber.*

From Figure 9, we can note that Viber is a low data consumption app, in which the data consumption increases sharply with the network performance, which can be connected to the VoIP feature offered by Viber. The average data consumption increases up until HSPAP where it reaches 0.002 MB where it decreases down to LTE at ~ 0.0015 MB. As in WhatsApp case, disconnect shows a high data consumption that can be explained by the classification method used in this analysis and the effect of an unreliable connection.

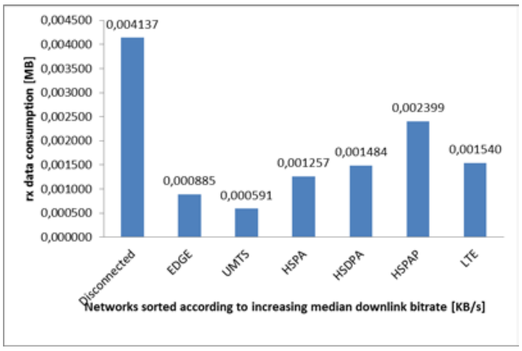

Figure 9: *Received data consumption of Viber.*

The investigation of the effects of network performance on smartphone user behavior has revealed that the users are incorporating information of the network performance in their choice of app and into how they are using the app. This information can be used to optimize networks, by adapting the network performance to the user's requirements and real levels of consumption. Furthermore, combined with an understanding of contextual factors, it can be possible to tune services pro-actively and improve the QoE.

In data-driven studies, it is of vital importance to accurately judge the validity and applicability of the produced results. Since this study is analyzing aggregated data, there are some possible statistical errors that can easily arise, i.e. user behavior found in some specific regions can't be assumed to hold for other countries as well. We have in this paper only focused on Swedish users. We also have data from other regions and countries and will include these in later analysis of the data.

4. Conclusions

The results from this study show that network performance is found to be clearly factored into the users' app choices. Data demanding apps have a strong positive correlation between the relative usage and the network performance. This is logical since for data demanding apps the network performance creates hard constraints, which means that at some network performance level the app is not functioning.

From the EA data, it is clear that the network performance affects the way the users are using their apps and that they are adapting their behavior to the current network performance. This study limits itself only to consider the relationship between network performance and app usage parameters and omits contextual parameters from the analysis but can be a starting point to a user behavior analysis, connected to QoE modelings.

Last, we would like to point toward some future work directions. (1) Contextual factors have been ignored in this study and incorporating these factors will most likely make the results of future studies more accurate. (2) To evaluate how users would be affected by changes in the network performance it can also be valuable to develop a user behavior model that can simulate how individual users act under different circumstances. (3) To extend the validity of the results it is necessary to demonstrate a heterogeneous group of users, and future studies can also include user profiling, even if that raises complex privacy challenges and was therefore omitted in this study.

5. Acknowledgements

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6. References

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