Diversity and End User Context in Smartphone Usage Sessions

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Diversity and end user context in smartphone usage sessions

Tapio Soikkeli, Juuso Karikoski and Heikki Hämmäinen
Department of Communications and Networking
Aalto University
Espoo, Finland
{tapio.soikkeli, juuso.karikoski, heikki.hammainen}@aalto.fi

***Abstract*—Mobile end user context has gained increasing attention in the mobile services industry. Context information is seen as an important component in developing new, more personalized, mobile services and applications. This paper studies the effect of end user context on smartphone usage sessions. Smartphone usage sessions are used to depict user behavior and usage habits of smartphone users on a high level. We have detected end user contexts, and extracted smartphone usage session information from handset-based data of 140 smartphone users. We first examine and describe usage sessions as such, and then in different end user contexts. According to our usage session analysis, smartphone usage is highly diversified across users. For example, the average number of sessions per day ranges from 3 to 46. Characteristics of smartphone usage sessions differ in different end user contexts. For example, an average session is 37 % longer in the *Home*-context than in the *Office*-context, but *Office* has 56 % more sessions per time unit than *Home*. The results imply that mobile services and applications need to adapt to user behavior in order to be personalized enough, and that context awareness is indeed a worthwhile step towards this.**

Keywords—end user context; smartphone; usage session; diversity

I. INTRODUCTION

In the past few years the mobile device and mobile services markets have been affected by a strong emergence of smartphones. Smartphones are mobile phones that offer advanced computing abilities and connectivity options. Smartphones are programmable mobile devices, running complete operating systems in a manner similar to traditional computers. These features enable new kinds of mobile services that in turn shape the usage habits of smartphone users. As smartphones provide more and more applications for an increasingly wider range of usage situations, they become an increasingly integrated part of users' everyday life. The programmability of smartphones gives a possibility to turn the devices into data collection platforms providing detailed information on users' smartphone usage habits. The devices' strong integration into users' everyday lives gives a possibility to infer information also about the users' other, everyday, habits. We have used handset-based data collected directly from smartphones to detect the context of an end user, and extracted smartphone usage session information from the data.

The end user context is seen as important information when trying to develop more personalized mobile services. For example, Gartner [1] predicts that by 2015 context, particularly centered on location, presence, and social interactions, will be "*as influential to mobile consumer services and relationships as search engines are to the Web*". Detecting significant places (meaningful to a user) and contexts has gained more and more interest also in the academia [2], [3]. The potential value of context information lies in its possibilities to predict presumable differences in user behavior and usage habits related to the different contexts/situations of the user.

Smartphone usage sessions capture the user behavior and usage habits of a smartphone user on a high level. With the relatively comprehensive handset-based data which enables us to produce time-wise linked context and session information we can examine the effects of context on user behavior in the form of smartphone usage habits.

Our objectives are two-fold. First we aim to provide a high level overview of the smartphone usage habits of our handset-based data collection participants (i.e., panelists) by examining different smartphone usage session characteristics. Then we study the usage session characteristics in different end user contexts in order to answer the main research question: *Does the end user context have an effect on smartphone usage sessions?*

User context has been studied before, but inferring it from handset-based data is a relatively new approach. The same applies to handset usage studies. This is due to the fact that handset-based data collection could not exist before the capabilities of handsets were at an adequate level (i.e., smartphones were in use). Thus the body of previous research around mobile end user context and especially smartphone usage sessions is relatively slim. And finally, at least the authors are not aware of any previous studies combining the two subjects.

The paper is organized as follows. First, the terms smartphone usage session and end user context are defined and explained how they are understood in this work. Next, the methodology and data used are described. Then, the results concerning smartphone usage sessions, overall and in different end user contexts, are introduced and discussed. The final chapter concludes the paper.

II. SESSION AND CONTEXT

This paper is built around the terms *session* and *context*. Both of these terms are used quite differently in different situations and places. In order to have comparable results, the terms need to be defined as accurately as possible, and it needs to be explained how they are used in this work.

A. Smartphone Usage Session

In this work we are interested in non-voice smartphone usage sessions. By "non-voice" we mean smartphone usage including everything else except cellular voice calls. Smartphone usage sessions give an overview of the usage of smartphones. More fine-grained analysis by studying, e.g., individual applications is left for future work. A smartphone usage session is a time period which starts when a smartphone user starts interacting with his/her smartphone, and finishes when the interaction ends. Intuitively the usage session is quite straightforward to understand, but especially its technical aspects require defining. A couple of earlier smartphone usage studies, such as [4], [5] and [6], define a smartphone usage session as the time period the smartphone's screen is active. Due to the nature of our data, we have a slightly different approach.

Smartphone usage comes down to using the applications (including everything from camera to messaging and browsing etc.) the device has to offer. Thus, in our work, the basis for a smartphone usage session is a smartphone application session. An application session could be considered to begin when an application is launched, and end when the same application is closed. Unfortunately, even such simple actions as the launch or closure of an application can be somewhat ambiguous. Applications can run either in the foreground, or in the background of a device. When an application is running in the foreground, it is visible to the user, and the user is quite surely interacting with it. An application running in the background, however, is not visible to the user, although the user might have launched it and at some point will probably close it. In this work an application session is the time period an application is running in the device's foreground.

An individual application session consists of two parameters; a start time and an end time. A new application session can start right when the previous application session ends, or there can be idle time in between. A smartphone usage session can now be constructed of time-wise closely-spaced application sessions. A threshold value T is defined for the idle time between the application sessions. If the idle time is less or equal compared to T, the respective application sessions belong to the same smartphone usage session.

B. End User Context

Dey [7] provides examples of earlier, but in his opinion inadequate, definitions of context, categorizing them into two classes. The first one defines context by examples such as the following: context is location, the identities of nearby people and objects, and changes to those objects [8]. The other class of definitions provides just synonyms for context. Examples include Ward, et al. [9] referring to context mainly as the environment.

Dey himself is seeking for an operational definition of context, and provides the following: "*Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.*" In the case of examining mobile user behavior, using data collected from the users' mobile devices, the entities are the user and his/her mobile device. The entity of main interest is obviously the user. The mobile phone is used to gather information that can characterize the situation of the user. Somewhat problematic in this is the fact that the information collected from the mobile device can with absolute certainty characterize only the situation of the mobile device. For the situation of the user, some additional assumptions have to be made. We assume that the mobile device has only one user, and that the user has the mobile device always with her. With these assumptions it can be presumed that the information extracted from the mobile device can be used to characterize the situation of the user also. In our case the information includes the time and the place of the user.

By strictly following Dey's definition of context, time would be a context and place would be a context. We are, however, combining the time and place information in an attempt to put a meaning to a particular place. In this manner we get the following place-related end user contexts: (i) *Abroad*, (ii) *Home*, (iii) *Office*, (iv) *Other meaningful* and (v) *Elsewhere*. The first three contexts are self-explanatory. *Other meaningful* refers to a highly place-related context which does not have the characteristics of a *Home* or an *Office*, but still considerable amounts of time are spent there. In general, *Elsewhere* refers to something other than a meaningful place. A place is assigned *Elsewhere* if the time spent there is a lot less than in the meaningful places. *Elsewhere* includes on-the-move/traveling and possibly places like restaurants and other not so frequently visited places. As can be seen, the weight in this work is mostly on place-related contexts. Context is definitely much more than a place or a location, but, as reminded in [10], its other elements are still quite difficult to identify and measure.

III. METHODOLOGY AND DATA

The data in our use are acquired through handset-based measurements. The basic idea behind the data collection method is explained briefly below. Also the data, especially the parts related to our research, are described. For the context detection we use a special purpose algorithm. We discuss the main principles behind its functioning.

A. Handset-based Measurements and Data

The data used in this work were collected from a handset user panel, consisting mainly of students of Aalto University who have opted-in to participate in the data collection. The data collection period was from September 2009 to December 2010. Some panelists left and some new ones joined in during the period. The minimum time period for a panelist to be accepted into the analysis was three weeks. The number of panelists in the analysis is 140 and the smartphones in use

were Symbian S60 devices. The current dataset is biased towards Finnish male university students. However, the methodology described in this paper is applicable to wider datasets possibly obtained in the future. The data were collected by using a special purpose, on device, software platform provided by a third party developer, MobiTrack Innovations. The platform enables collection of a wide variety of handset usage data from individual users. The data include application usage, application installations, processes, battery levels and charging, Bluetooth and WLAN entries, phone calls, SMSs, MMSs, URL entries, network sessions, and uploads. The software preprocesses usage data and stores the data locally in the device, and then sends the data daily to a server for further use. The data collection is continuous and does not require additional participation of the user.

In this work we have used GSM/WCDMA cell id data and WLAN scan data to detect the end user contexts, and foreground application usage data to examine the smartphone usage sessions. A cell id data entry includes a timestamp, a cell id number and a mobile country code number. A WLAN scan data entry includes a timestamp, a WLAN access point's MAC address and signal strength of the access point. A foreground application data entry includes a timestamp, name of the application, application class [11] of the application, duration of the particular application session and an idle time before the next application session.

B. Context Detection Algorithm

A context detection algorithm utilizing only cell id data was developed in [12] to derive end user context information from handset-based data. The algorithm was developed further in [13] by adding more context categories and a possibility to utilize also WLAN scan data. Thus the improved algorithm consists of two parts; cell id-based context detection and WLAN scan-based context detection. The parts are designed to work separately because some of the users in the panel have not produced WLAN scan data. For those users who have produced WLAN scan data, the context information from the two parts is combined.

The cell id-based context detection uses cell id data as input. A mobile phone is nearly always connected to a cell tower. The cell id dataset is basically a timestamped sequence of the ids of all the cell towers the user has been connected to during the data collection period. The main idea behind the cell id-based context detection is to examine the user's time spending behavior under individual cells. In short, if the user has spent a lot of time under a cell, there most likely is a meaningful place for the user inside the particular cell's coverage area. A meaningful place translates into *Home*-context if the majority of night time is spent there. A meaningful place where the majority of normal office hours are spent translates into *Office*-context. If a meaningful place does not have the profile of a *Home* or an *Office* it is assigned the *Other meaningful*-context. The *Elsewhere*-context is assigned to places that are not seen as meaningful due to relatively low amount of time spent in these places. The *Abroad*-context is detected simply from the mobile country codes of the cell towers.

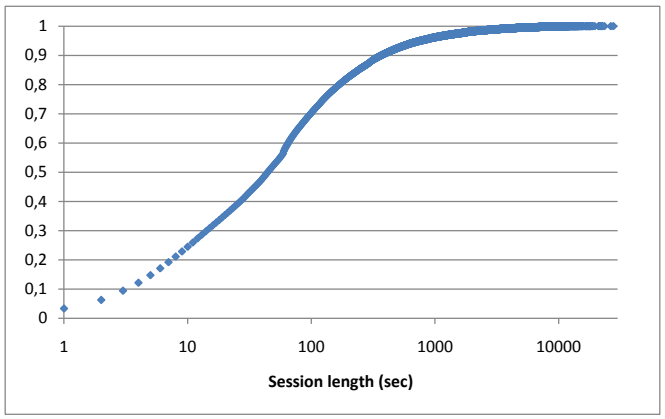

Figure 1 Cumulative distribution of usage session lengths

The WLAN scan-based context detection uses the same time-based heuristics in assigning the context labels to places. Different places are recognized from WLAN access points detected by the user's smartphone at a given point in time. These sets of access points are called WLAN fingerprints. An access point is depicted by its MAC address and signal strength. The WLAN scan-based context detection is used to support and give more accuracy to the relatively coarse grained cell id-based context detection. Places detected from the WLAN fingerprints can be pinpointed more accurately than the places derived from the cell ids. For example, context changes inside a cell can be detected with the WLAN scan based context detection. More detailed description of the context detection algorithm can be found in [13].

IV. Results and Discussion

In this chapter we present and discuss our results. First, we examine the smartphone usage sessions in general. The overarching theme is the diversity in the usage sessions. Then, we examine the usage sessions in the different contexts.

A. Diversity in Smartphone Usage Sessions

Smartphone usage session describes smartphone usage as a whole. By examining usage session characteristics such as session length and the number of sessions per time period, or interaction time with the smartphone, we can acquire some insight about the usage habits of the smartphone users. Based on our results, the main observation is that there is considerable diversity in the smartphone usage sessions. First, we noticed a wide variation in the session lengths. This is seen both on the level of an individual user, and on the level of the whole data collection panel. Second, the differences between users are great by any session characteristic measure. The following results are produced with the threshold value (introduced in Chapter II) $T = 0$ seconds.

Figure 1 shows the cumulative distribution of session lengths over the whole panel. Most of the sessions are short, but there are also few very long sessions. Mean session length is 207 seconds and the median is 45 seconds. The difference between the mean and the median is due to the few very long sessions. Figure 2 shows the mean and median session lengths of individual users. Most notable in the figure is the variation

between users. The highest mean session length in the panel is almost half an hour, whereas the lowest mean session length is just 50 seconds. The median session lengths of individual users tell essentially the same story. The average of the mean session lengths of individual users is 263 seconds and the average of the median session lengths is 57 seconds. These values are somewhat higher than the respective values calculated from the dataset as a whole. The values from the dataset as a whole are biased towards users with more sessions. In the latter values all users have the same weight.

Figure 3 shows the number of sessions per day and interaction time per day of individual users. Also both of these measures show diversity between users. Frequent users have a lot more interactions in a day with their smartphones than the more occasional users. The range of the number of sessions per day is from 3 sessions per day to 46 sessions per day. An average user has 20 sessions per day. The range of the daily interaction time is from little over nine minutes to more than four and a half hours per day. An average user interacts with her smartphone 73 minutes per day.

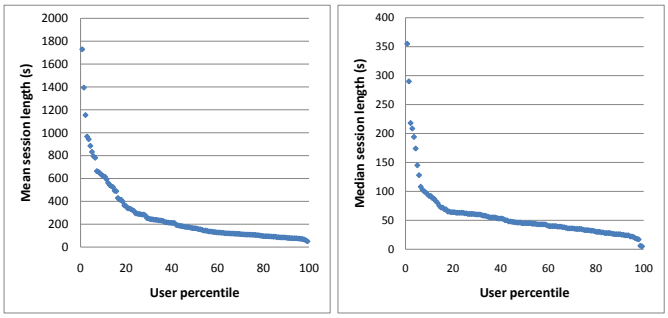

Figure 2 Mean and median session lengths of individual users

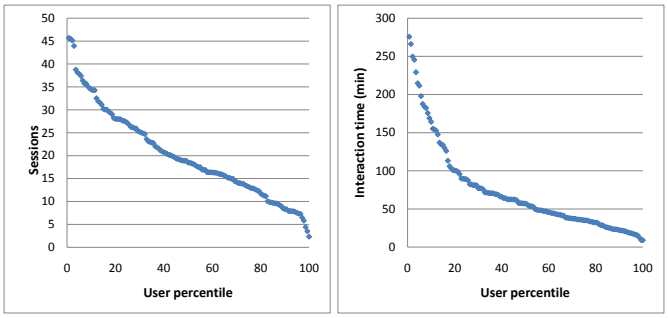

Figure 3 Number of sessions and interaction time per day

TABLE 1 SESSION CHARACTERISTICS IN DIFFERENT SMARTPHONE USAGE STUDIES

	Mean session length	Sessions per day	Interaction time per day	Usage session definition
Oliver [6]	1 min 8 sec	87	101 min	when the device's screen's backlight is on
Rahmati & Zhong [5]	6 min	10	72 min (estimate from a figure)	when the device's screen is on
Our study (T = 0)	4 min 23 sec	20	73 min	consecutive application sessions with 0 seconds in between
Our study (T = 30)	7 min 9 sec	13	74 min	consecutive application sessions with max 30 seconds in between
Falaki et al. [4]	10 sec - 4 min 10 sec	10 - 200	30 min - 500 min	when the device's the screen is on

The above examination of smartphone usage sessions shows that there are clear differences in the smartphone usage habits of different users. Variation across users is more than an order of magnitude by all of the measures used. Thus an average user does not represent very well the panel as a whole. The results obtained here are quite well in line with other smartphone usage studies. TABLE 1 shows a comparison of session characteristics and session definitions between different studies. We can see clear differences in the mean session lengths, and the number of sessions per day. However, shorter sessions are generally linked with a higher number of sessions and thus the overall interaction times are closer to each other. One reason for the differences might be the somewhat differing ways to extract usage sessions from data available for each of the studies. Other reasons could be the differences in user panels and mobile platforms used. In all of the studies diversity across users and across sessions was the main observation.

B. Usage sessions in different end user contexts

By combining the characteristics of smartphone usage sessions with context information, it is possible to examine the effect of end user context on the smartphone usage sessions. During a day a user can be in quite different situations, such as commuting, concentrating on work at the office or relaxing at home. The different situations or contexts pose their own limitations and liberties to potential activities, including smartphone usage. Knowing whether the end user context really affects smartphone usage helps, for example, to evaluate the importance of and need for context aware mobile services and smartphone applications.

Figure 4 shows the shares of total time spent, smartphone usage sessions and interaction time per context. The share of time spent at the *Home*-context is around two thirds, meaning 16 hours per day on average. The time share of the *Elsewhere*-context is slightly below one fifth. The *Office*-context has 8 % share and *Other meaningful* 7 % share. The *Abroad*-context has clearly the lowest time share with 2 %. The time share of the *Home*-context is very similar to time usage studies, such as [14]. The share of the *Office*-context, on the other hand, is clearly lower than the comparable categories in [14]. Our panelists are mainly university students and they do not necessarily have any clear regularly visited office-type place. Indeed, *Office* was detected only for 54 panelists with the cell id-based context detection. Using also the WLAN scan-based context detection, the number rises to 116. In the following examinations the *Abroad*-context is left for lesser attention because of its small share and because it is hard to really distinguish more specific usage contexts for it (business trip, holiday, etc.).

Almost half of the usage sessions have occurred in the *Home*-context. A little less than one third of the sessions have taken place in the *Elsewhere*-context. The *Office*-context has a 12 % share of the usage sessions, being slightly ahead of the 9 % of the *Other meaningful*-context. The *Abroad*-context has clearly the smallest share. The results for the interaction time are quite similar except for the rise of the *Home*-context and the decline of the *Elsewhere*-context.

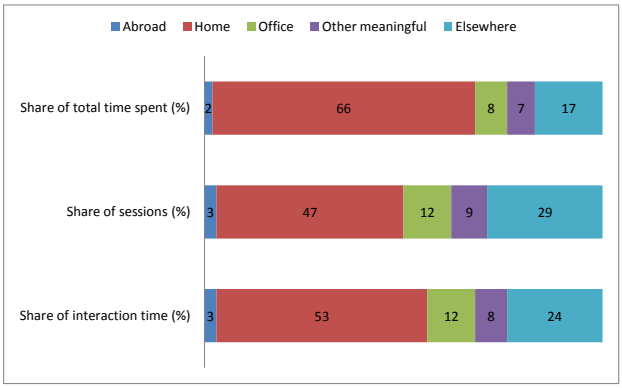

Figure 4 Shares per context

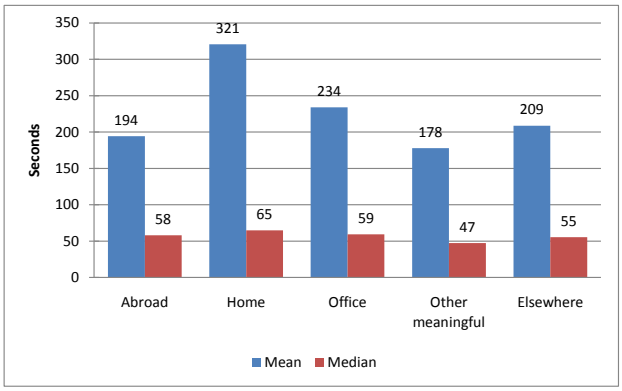

Figure 5 Mean and median session lengths per context

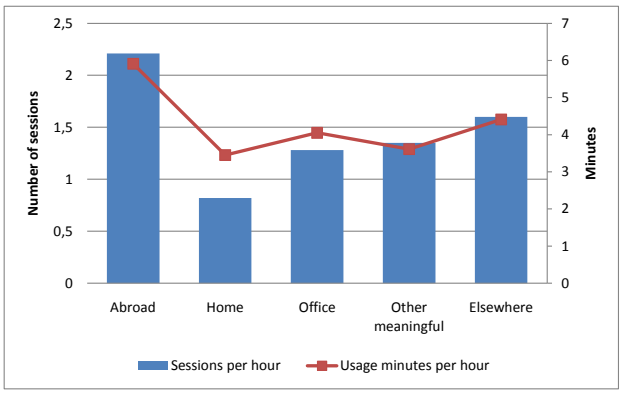

Figure 6 Intensity of usage (hours from 1 AM to 7 AM excluded)

The order of the contexts remains the same in all of the categories in Figure 4. However, the notable changes in the percentage shares indicate that there should be some differences in the characteristics of the sessions in different contexts. Figure 5 shows the mean and median usage session lengths per context. Based on these measures, the longest smartphone usage sessions occur in the *Home*-context. The other contexts (excluding *Abroad*) follow in order: *Office*, *Elsewhere* and *Other meaningful*.

The order of the mean and median session lengths seems quite reasonable. Home is the place where life probably is not too hectic and people can sit back and get acquainted with things. So, when using the smartphone at home the user can take the time and not be in a hurry. In the *Office*-context there might be clear differences in the usage situations between users, depending, e.g., on the type of work. Some people are able to use their smartphones along the workday, some people use the phone as a tool in the work, and some people just cannot use their phones while they are working (shop clerks etc.).The *Elsewhere*-context is quite close to the *Office*-context in terms of the session length. The *Elsewhere*-context includes usage situations in places where the user has not spent that much time, or is just on the move. In a context like this the user probably at times needs to concentrate on other things than just taking it easy with the smartphone. On the other hand, however, commuting in a bus or a train gives time to such activities as gaming or reading the news with the smartphone. The *Other meaningful*-context refers to situations in places where considerable amounts of time have been spent (maybe a friends' house or a place of some quite regular activity such as sports, for instance). The shorter session lengths could be explained with that the user might prioritize some other activities or socializing over smartphone usage, and does not have that much time to concentrate on individual sessions.

As seen above, most of the non-voice usage sessions occur in the *Home*-context, and the *Home*-context has also the greatest share of usage time. This is quite self-evident since the panelists spend most of their time in the *Home*-context. The shares of the number of sessions or the shares of interaction time, however, do not tell much about intensity of usage. For example, in the *Home*-context the shares of sessions and interaction time are considerably less than the share of total time spent. In the *Elsewhere*-context the situation is quite the contrary. Figure 6 shows the intensity of smartphone usage per context. The intensity of usage is measured here in number of sessions per hour and in usage minutes per hour. A problem with comparing the intensity between the contexts arises from the fact that most of the night time (i.e., sleeping time) is spent in the *Home*-context, while the other contexts appear mainly during the presumed awake hours. For the results shown in Figure 6 an approximated sleeping time from 1 AM to 7 AM was excluded. This is the time period when the usage, aggregated over the whole panel, is the lowest. Despite leaving out the night hours, the intensity of usage seems to be the lowest in the *Home*-context. Excluding the *Abroad*-context, the *Elsewhere*-context has the most sessions per hour and the most usage minutes per hour. *Office* and *Other meaningful* are quite close to each other.

In the *Home*-context the usage sessions are the longest, but the sessions occur least frequently. However, the longer session lengths do not fully compensate for the low frequency of sessions, i.e., also the relative interaction time is the lowest in the *Home*-context. This seems to indicate that in the *Home*-context the user has time to concentrate on smartphone usage once it is seen necessary, but overall the user does not see it necessary that often.

In the *Office*-context the usage sessions are the second longest, and the sessions occur clearly more often than in the *Home*-context. Session lengths and the frequency of their occurrence give the *Office*-context relatively high interaction

time per time unit. So, at least most of the panelists that have the *Office*-context seem to be able to use their smartphones during the supposed work time. In the *Other meaningful*-context the usage sessions are the shortest, but the sessions occur slightly more often than in the *Office*-context. Mainly due to the shorter sessions, the relative interaction time is somewhat lower than in the *Office*-context. The time spent in the *Other meaningful*-context is mostly outside working and night hours, but still in some quite regularly visited place. This certainly includes quite differing usage situations. In the *Elsewhere*-context the length of the usage sessions comes quite close to the session lengths of the *Office*-context. The usage intensity in the *Elsewhere*-context is relatively high with both of the measures. As already suggested earlier, in the *Elsewhere*-context the user might not have that much time to concentrate on individual usage sessions than, for example, in the *Home*-context, but there still seems to be a need to use the smartphone quite frequently.

V. CONCLUSION

This paper concentrated on studying smartphone usage sessions as such, and then in different end user contexts. In the beginning we defined smartphone usage session and provided an explanation how end user context is understood in this work. Later in the results the emphasis was on smartphone usage session characteristics, including usage session length, number of sessions per time unit, and interaction time per time unit. By examining these characteristics we observed that the smartphone usage is highly diversified across users, and thus an average user does not represent very well the panel as a whole. Smartphone applications and services need to somehow take into account the usage characteristics of individual users in order to be personalized enough. This calls for applications and services that are able to learn and adjust to user behavior.

The smartphone usage session information was combined with end user context information in order to examine the characteristics of the sessions in different end user contexts. The end user contexts are: (i) *Abroad*, (ii) *Home*, (iii) *Office*, (iv) *Other meaningful* and (v) *Elsewhere*. In absolute measures the *Home*-context was dominating. The *Home*-context had the longest sessions on average, the greatest number of sessions, and the longest interaction time with the smartphone. However, in the case of the two latter characteristics, the domination is due to the fact that most of the time is spent in the *Home*-context. To get a fuller picture, however, relative measures were used to compare these two characteristics in different contexts. The relative measures, number of sessions per hour and interaction time per hour, describe the intensity of smartphone usage, i.e., how frequent the usage is. The intensity of usage is the lowest in the *Home*-context and the highest in the *Elsewhere*-context.

The results imply that end user context indeed affects the characteristics of the smartphone usage sessions. In other words the users use their smartphones somewhat differently in different contexts. This in turn implies that smartphone applications and services should indeed recognize the user's context in order to adjust to the user behavior. And maybe some of the diversity between users is due to differences in their user contexts.

However, one needs to be careful not to draw too far-reaching conclusions from the aggregated level mean and median results. They certainly provide a good estimate about the situation, but diversity is present in all aspects of smartphone usage. Further research around the topic is definitely needed. For example, diving deeper into the usage sessions by analyzing individual applications is a logical next step.

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