SMARTPHONE DATA TRAFFIC MEASUREMENT

Siniša Husnjak, Dragan Peraković, Ivan Cvitić
Faculty of Transport and Traffic Sciences
sinisa.husnjak@fpz.hr, dragan.perakovic@fpz.hr, ivan.cvitic@fpz.hr

Abstract

Smartphones are generating the increasing amount of data traffic and have a growing share in the total amount of data traffic. End users usually are not aware of the various factors which affect the amount of data traffic of a smartphone. Above mentioned shows the differences of the amounts of data traffic generated by the smartphone users. Insights into customer habits and needs can be obtained by measuring the amount of smartphone data traffic and this is the base for their prediction. Smartphone data traffic measurement by telecommunications operators and service providers has shortcomings in the form of inability to display the achieved data traffic outside of the mobile communications network (e.g., Wi-Fi data traffic). This paper will present possible ways of measuring achieved data traffic of a smartphone. Emphasis will be given on the possibilities of measuring data traffic by using the opportunities of smartphones and related applications.

Keywords
data traffic, smartphones, measurement, user's habits

INTRODUCTION

Mobile phones are developing into multimedia computers and laptops are getting smaller with cellular connectivity, increasing the amount of mobile Internet capable devices. [1] With technological convergence, integration of voice, texting, video, gaming, mobile internet and GPS and the increasing capacity of mobile networks, smartphones are able to provide advanced functionality to their users such as seamless communication, social networking, information, multimedia entertainment, m-commerce, personal productivity tools, and much more. [2]

The world is seeing a rapid technology migration to both higher speed mobile broadband networks and the increased adoption of smartphones and other connected devices. Smartphone adoption is already reaching critical mass in developed markets, with the devices now accounting for 60% of connections. It is the developing world (driven by the increased affordability of devices) that will produce most of the future growth, adding a further 2.9 billion smartphone connections by 2020. [3]

Smartphone traffic contributes a considerable amount to Internet traffic. The increasing popularity of smartphones in recent reports suggests that smartphone traffic has been growing 10 times faster than traffic generated from fixed networks. [4] Global mobile data traffic grew an estimated 74 percent in 2015. [5]

Many Internet users complain about charges they incurred for using more data than available under their monthly plan. In some cases, customers did not understand the amount of data they were using. In other cases, they did not believe they had used the amount of data for which they had been billed, and believed that the tool used by the service provider to capture the amount of data being used was inaccurate. [6]

The main objective of of this research is to describe the upgrade of existing (handset-based) methods for measuring data traffic of smartphones. These upgrades were made with the development of operating systems and applications of smartphones, but so far have not been analyzed in the scientific literature.

The research methodology includes a review of the current situation and the development of research methods which have been used in the measurement of smartphone data traffic, showing the advantages and disadvantages of various methods. Also, emphasis is placed on upgrading the existing methods of measuring data traffic on the device (handset-based), which in previous studies have not been studied.

PREVIOUS RESEARCH

The development of the monitoring software and the first test panels took place in 2003, while the first academic results utilizing the software were introduced in 2005. The handset-based mobile end-user research process was mutually developed by Nokia and Helsinki University of Technology, while the data acquisition platform was developed and owned by Nokia. [7]

There are not many of the studies on the regional and global level which show the possibilities and research methods for measuring mobile device data traffic usage. Some of these studies simply refer to existing methods for measuring data traffic of mobile devices and eventually show comparative characteristics of selected methods.

Research [8] studied different approaches of mobile data traffic measurement, each with specific strengths and weaknesses. It defined objective and subjective methods and submethods, with their characteristics. Research [9] represented detailed overview of research methods, their advantages and disadvantages, and the applicability of a particular method on the research objectives, measurement points, and future outlook for measuring mobile user behavior and service usage. It also studies differences regarding research scope and characteristics of collectable data. Moreover, privacy issues and other limitations also are considered. Use of multiple data collection methods and measurement points are studied in research. [10] In their measurements data were collected by capturing the IP traffic from mobile operator's central network nodes, by utilizing the usage accounting systems of mobile operators and by monitoring end-users' mobile handsets. Furthermore, the handset-based measurements were complemented with questionnaires filled by the participating users. Research [1]

focused on mobile network traffic measurements and studies their applicability for providing market understanding for the different stakeholders. Measurements from operational mobile networks are analyzed to provide factual statistics on the usage patterns. In research [11], mobile Internet usage was measured using three fundamentally different methods: data collection with operator reporting systems, packet data traffic measurement in mobile networks and usage measurements on individual handsets.

Some of the researches studied mobile device data traffic usage from a network perspective.

So research [12] studied mobile hand-held device usage from a network perspective and studied more than 20,000 residential DSL customers.They collected manual traces using tcpdump for all device types except BlackBerrys. With each device we performed the following set of actions using a wireless access point for data collection: connecting to the access-point, accessing several Web sites, watching videos on YouTube, using other mobile applications, checking and sending emails, using Facebook, and updating/installing mobile applications on the mobile hand-held device. Research [13] propose a platform for conducting mobile network measurement experiments through measurement isolation for applications, efficiently manages measurement experiments and enables a new class of experiments for the mobile environment, while research [14] addressed the measurement and modeling of GPRS user traffic.

Most of the researches used some form of mobile device monitoring application or software to capture data traffic usage. Studies with this measurement approach regularly focus on certain handset or OS types (e.g., Nokia or Android smartphones). [8]

So research [15] presented and evaluated the outcomes of a measurement study amongst Android mobile device users, who volunteered their device-level network activity data through a developed mobile application. Research [16] presented an Android application for network and device measurements through active probes that measure network parameters like latency, speed and loss rates and passive measurements that measure the applications installed on the users device and the network usage in bytes of each of the applications. The research [4] analyzed traffic characteristics and explored some important issues related to smartphone traffic. An application on the Android platform was developed to capture network traffic. The collected data was analyzed to understand the workload characteristics of smartphone traffic and study the relationship between participant contexts and smartphone usage. The amount of traffic generated at different times of the day and different days of the week, along with protocols used and content types generated has been explored.

Research [17] used the handset based measurement to collect the information regarding the mobile phone usage session. The data were collected from a set of test users, which have traffic monitoring software preinstalled. The data were utilized to characterize the context of usage. These different context of usage helps in understanding the user behavior. Research [7] defined a handset-based method for analyzing mobile service usage. The method combined collected handset-based usage data with survey data. Handset-based method is based on server-side infrastructure that communicates with monitoring software developed for Nokia S60 smartphones. Research [18] compares LTE and WiFi for transfers of different sizes along both directions (i.e. the uplink and the downlink) using a crowdsourced mobile application run by 750 users over 180 days in 16 different countries. Mobile application measured end-to-end WiFi and cellular network performance and uses these measurements to tell smartphone users if they should be using the cellular network or WiFi at the current time and location. The app also serves as a crowd-sourced measurement tool by uploading detailed measurement data to server including packet-level traces.

Some of the researches are based on questionaries so research [19] used data collected from three diverse smartphone usage studies to replicate prior work on mobile application usage and understanding of mobile device behaviors.

With regard to the development of hardware and software architecture of smart phones as well as their operating systems there are visible improvements in the field of measuring the volume of data traffic on the device.

In previous research there is a lack of research in the context of new possibilites and application upgrades for measurement of smartphone data traffic (on the device). Newly formed possibilities for measuring data traffic on the device will be shown in this study.

SMARTPHONE MOBILE AND WI-FI DATA TRAFFIC GROWTH

Smartphones provide a more data-intensive service to consumers than other handsets, with their ability to support Internet access via traditional applications such as web browsers and email clients, as well as a new category of mobile apps that enable a huge array of Internet services. [20]

By 2020 there will be 1.5 mobile devices per capita [5]. Smartphones accounted for close to 75 percent of all mobile phones sold in Q3 2015, compared to around 70 percent during Q3 2014. Today around 45 percent of all mobile phone subscriptions are associated with smartphones. The growth in data traffic is being driven both by increased smartphone subscriptions and a continued increase in average data volume per subscription. [21]

Smartphone mobile data traffic growth

Mobile data traffic is growing at an unprecedented rate. According to [5], the adoption of mobile devices, increased mobile coverage, and demand for mobile content are driving user growth two times faster than the global population over the next five years. This surge of mobile users, smart devices, mobile video and 4G networks will increase mobile data traffic eight-fold over the next five years.

Fuelled by the growing range of new services and applications, data traffic is expected to see an almost ten-fold increase by 2019. [3] Mobile data traffic is forecast to grow faster than mobile broadband connections, due to the significant increases projected for mobile data traffic per device. [20], [22]

Smartphone mobile data traffic growth and comparison of Cisco’s and Ericsson’s predictions are seen in figure 1.

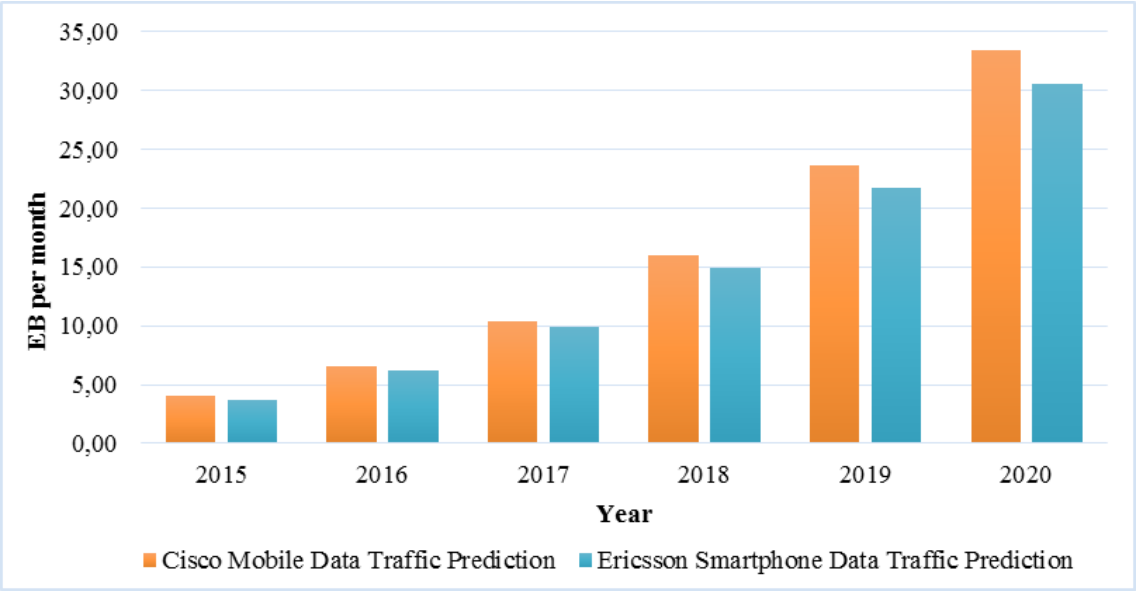

Figure 1: Comparison of prediction of smartphone mobile data traffic growth by Cisco and Ericsson, [5], [23]

The average smartphone will generate 4.4 GB of traffic per month by 2020, nearly a fivefold increase over the 2015 average of 929 MB per month. By 2020, aggregate smartphone traffic will be 8.8 times greater than it is today, with a CAGR of 54 percent. [5] According to [21], around 90% of mobile data traffic will be from smartphones by the end of 2021.

Smartphone Wi-Fi data traffic growth

Internet connectivity in smartphones is available through Wi-Fi and mobile networks. [4] Wi-Fi provides an invaluable complement to cellular in the delivery of high quality broadband services to smartphone users, particularly indoors. Cellular offers high performance, wide area blanket coverage but does not always cover indoor locations well. Wi-Fi fills these gaps at venues where local owners and users need improved coverage and access speed. [24] Wi-Fi plays as the dominant bearer of data traffic on cellular devices. [25] Monthly Wi-Fi data usage is much greater than cellular usage on 3G and 4G smartphones, and is growing much faster. Wi-Fi is also dominant partly because it is often free or at least perceived as free, particularly in homes and businesses, where the majority of smartphone Wi-Fi usage takes place. [26]

A way to address the increase in traffic is to 'offload' the traffic to Wi-Fi, where it can be carried over a fixed-wired or wireless network. This trend is increasing globally. By 2018, the proportion of Internet traffic generated from mobile devices and carried over mobile networks is forecast to fall to just 20% of total mobile traffic from its 2013 level of around 38% (while the absolute level of traffic carried on mobile networks continues to rise). [20]

Mobile data on network-connected devices can be offloaded onto these services at the discretion of the operator, to preserve spectrum use where possible, or the consumer who can link their devices to their Wi-Fi hotspot, often to save on data charges. [22] Global data for Android smartphone users highlights a more complementary relationship between cellular and Wi-Fi data usage, with both dramatically higher on 4G devices compared to 3G devices in the same period. [25]

Much mobile data activity takes place within users' homes. For users with fixed broadband and Wi-Fi access points at home, a sizable proportion of traffic generated by mobile and portable devices is offloaded from the mobile network onto the fixed network. In 2015, monthly Wi-Fi offload traffic (3.9 exabytes) exceeded monthly mobile/cellular traffic (3.7 exabytes) for the first time. Wi-Fi traffic from both mobile devices and Wi-Fi-only devices together will account for more than half (53 percent) of total IP traffic by 2019, up from 41 percent in 2014. [5]

RESEARCH METHODS FOR MEASURING SMARTPHONE DATA TRAFFIC USAGE

With regard to capturing mobile data traffic usage intensity the studies take very different approaches, each with specific strengths and weaknesses. As a consequence, it is pivotal to provide an understanding regarding the peculiarities of the principal methods chosen for measuring mobile data traffic usage as well as regarding their dissemination among the contributions in order to position research results in the correct context. [8]

The Internet traffic measurement is necessary for the network operators to have a constant insight at their traffic and other network parameters. It is virtually possible to measure the Internet traffic at any point on the Internet stream. The selection of measurement point depends on the purpose of the Internet traffic measurement. [27]

Various authors from different perspectives indicate different methods for measuring data traffic of mobile devices. According to [8], mobile data traffic usage intensity can be measured by objective and subjective methods.

Subjective methods (described in table 1) are self-estimates of personal usage amounts, collected in a one-shot survey or, infrequently, via a longitudinal panel. Self-reports require from the participants to remember detailed facets of past mobile data traffic usage. Since investigators mostly do not support mobile data traffic end-users with tools to recall and estimate the duration, frequency, data volume or the number of covered different services/applications, subjective mobile data traffic usage measurements are likely to be

limited in accuracy and level of granularity. However, surveys are the only approach providing the opportunity to include user motives, service perceptions and satisfaction, i.e., explanatory variables which are not readily observable. [8]

Table 1: Characteristics of subjective research methods for measuring smartphone data traffic usage, [8], [9], [28]

	Questionnaries	Interviews
Detail of accouracy	Poor	Poor
Type of data	Qualitative + quantitative	Qualitative
Access to data	Anybody	Anybody
External validity	Moderate	Moderate
Internal validity	Poor	Poor
Pros	Cost-efficient, good coverage	Flexible, interactive
Cons	Inflexible, rigid	Costly and slow

Objective methods (described in table 2) rely on "system-captured" mobile data traffic metrics. Depending on the measurement point in the system, these methods can be classified into four groups: handset-based measurement, traffic measurement, usage billing and log collection from servers. [7], [8], [9], [10]

Table 2: Characteristics of objective research methods for measuring smartphone data traffic usage, [8], [9], [28]

	Laboratory tests	Wireless networks		Server measurements	Handset-based measurements
		Traffic measurements	Charging records		
Detail of accouracy	Good	Very good	Good	Very good	Very good
Type of data	Qualitative + quantitative	Qualitative	Qualitative	Qualitative	Qualitative + quantitative
Access to data	Anybody	Wireless access operators	Wireless access/ service operators	Service providers (mobile operators, 3rd party providers...)	Those with monitoring client and ability to recruit the sample
External validity	Moderate	Good	Good	Good	Poor
Internal validity	Moderate	Good	Moderate	Good	Good
Pros	Coordinated research settings	Good coverage, data mining automation	Good coverage, data mining automation	Good coverage, data mining automation	Wide scope of research questions, point of convergence
Cons	Not a natural usage context, costly	Access to network gateways needed, only network services included	Access to charging records needed, only services generating charging data included	Access to network gateways needed, only client-server services included	Early-adopter needed, complicated process of data acquisition

The selection of a usage data collection method depends very much on its availability, i.e. on the researcher's access to data. The selected research method dictates the scope and size of the studied sample. [9]

In order to empirically analyze mobile data traffic usage and according to [7], several data collection methods and research approaches can be applied and they are here divided into seven main categories, seen in figure 2: questionnaires, interviews, laboratory tests, wireless networks traffic measurements, wireless networks charging records, server-side measurements and handset-based (e.g. user-centric) measurement platforms.

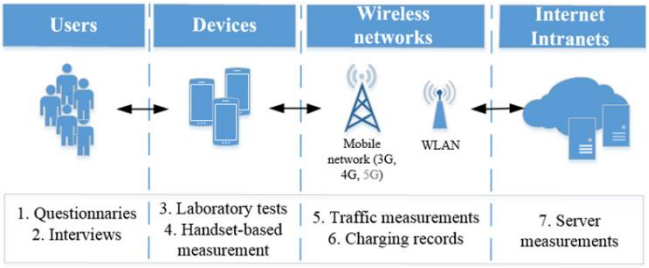

Figure 2: Sources for information and classification of research methods for data traffic measurement, [1], [9], [28]

Collection of usage data also raises many privacy concerns. At the level of an individual, users might change their behavior when aware of being studied. This is particularly relevant in participative methods such as surveys and handset monitoring studies. On the other hand, the "big brother" effect referring to pervasive surveillance and the reduction of personal privacy takes place when users are not certain what data is collected on them and by whom. [9]

Questionnaires

Questionnaires (surveys) are a commonly used data collection method for studying mobile user behaviour and service usage. Surveys are conducted on samples of real end-users, and can be implemented using various methods. [10]

Questionnaires are a flexible method to end-users. Questionnaires can include many kinds of questions. On the other hand questionnaires are subjective. The interpretations of both questions and answers pose challenges. [7] The main difference between surveys and different automated data collection methods is that surveys provide subjective data on usage as perceived by the respondents, whereas measurements generally provide more objective data. Survey studies can include any background variable (e.g. gender, handset type, pricing scheme) or other more abstract

explanatory variable (e.g. respondent attitude and values) the respondent is capable of providing. [9]

Interviews

Interviews are an interactive method of end-user research, where an interviewer asks questions directly from respondents. The interviewers can guide the discussion based on their own research interests. This is both a challenge and an advantage. [7]

Laboratory tests

Laboratory tests refer to preplanned tests taking place in a fixed context, such as in a laboratory. Services are provided to end-users in controlled environments, and during the experiment observations are done regarding end-user behavior. In some tests questions are also asked from end-users to complement usage-level observations. [7]

Wireless networks traffic measurements

In radio access or mobile network operator backbone infrastructures, mobile data traffic usage data can be gathered directly at intermediary network nodes via traffic measurement. However, individual users or specific user interactions can hardly be differentiated from each other without complementary measurements. [8] Traffic measurements take place in network gateways. The access to the operator's network is a challenge for external researchers. Also legal problems exist. [7] In wireless access network TCP/IP traffic measurement individual users cannot be separated from each other without complementary measurements. [9]

Server-side measurements

Servers are application specific, and not all mobile applications require servers at all. By doing measurements at servers, specific data points can be collected that reflect the server's functionality in the network. [7] The server side measurements are processed to generate the session level log. The server side measurements provide information regarding the traffic to that specific server only. [27] Server logs from content providers can provide several insights into the trends of Internet traffic. Such data are considered proprietary and are not shared outside the enterprise.

Server measurements just cover server specific services, the rest of mobile data traffic usage handled elsewhere is out of sight. Log file data are less detailed and the level of independent explanatory information on the individual user is constrained to e.g., device type or (approximate) geographic location if the service does not require a previous registration. [8]

Measurements done at network servers provide accurate information about the devices and applications used to access the content on those particular servers. Unfortunately, single server based measurements cannot give a holistic view on the usage of mobile services as the usage is typically fragmented over many servers. Even the most central servers, such as Google's search engine or operators' portals, can capture only a portion of the mobile service usage. [10]

Wireless networks charging records

According to [11], for subscriber charging and billing to work properly, appropriate charging information needs to be generated and collected by the network elements of the mobile network and forwarded to appropriate charging and billing systems. Charging data is also used as evidence of customer actions and for statistical analysis of service usage. CDR (Charging Data Record, formerly Call Detail Record) is a formatted collection of information about a chargeable event (e.g. time of call set-up, duration of the call, amount of data transferred, user identity, terminal identity…) used in billing and accounting. [9] CDR files are generated by the network, and are then transferred to the network operator's billing domain for the purpose of subscriber billing, inter-operator accounting, and/or other applications (e.g. statistics). [11] CDR based approach also provides the opportunity to combine the information from the CDRs to measurement results obtained from the other points in the network. [27] Legal problems are a major challenge for the utilization of charging record based studies in the academic domain. Charging records reveal private information on end-users. [7]

The accounting systems that register the usage of chargeable services by individual users are natural sources of information for any service provider. In GSM/UMTS/LTE networks, this function is typically called charging and billing, whereas for an IP network access provider, the accounting function is a part of the AAA (Authentication, Authorization, and Accounting) system. More specific TCP/IP traffic measurements (a.k.a. ''network sniffing'' or ''packet sniffing'') can be also conducted at various intermediary network nodes between terminals and servers. [10]

Billing data can be matched with supplementary information derived from the contracting party's master data file, but one cannot be sure that the actual user is always identical with the individual recorded as contract holder. [8]

Measurements at network nodes provide accurate and fine-grained data on the usage of the networks, and the devices used within those networks are accurately identifiable. However, all usage out of the scope of the operator's usage accounting system or the central network point selected for traffic measurements can not be observed with these methods, ignoring, e.g. WLAN and offline use. Typically, applications and content, especially those that are not controlled by the operator, are not easily identified by the accounting systems. [10]

Handset-based measurements

Handset-based software collects data at the ultimate point of convergence – the handset. Data that is extracted from the handset is of a wide scope. This data is also objective, as end-users cannot subjectively manipulate the data points that are collected. Usage data collected from handsets should, therefore, reflect actual usage pretty well. Given that handset-based usage data can be outputted in a standardized form, some automation of data mining can be developed. [7]

Handset-based measurement methods of modern smartphones are presented in the next chapter of this research.

Based on the discussion above all research methods have some pros and cons. However, the older manual research methods in particular are inadequate for larger studies due to higher costs. On the other hand, computerized research methods deployed earlier mostly rely on network or server-side measurements (narrow scope). These research methods inadequately study end-user behavior in the world of more complex mobile services. [7]

HANDSET-BASED SMARTPHONE DATA TRAFFIC MEASUREMENT UPGRADES

The evolution of mobile phones towards computer-like devices has made it possible to conduct device monitoring also at mobile handsets, regardless of whether any traffic is generated in the mobile networks. In mobile handset monitoring, a software agent in a monitored device records what the user does with the device, and sends that information further. [10]

Usage monitoring systems provide accurate, factual information about the used applications and consumed content. Different networks accessed by the monitored devices can be identified, as well as those use cases where no network connections need to be established. Granularity of the collected data is typically good across all the service components. Usage monitoring systems are, however, typically applicable only to one or few of the devices possessed by the end-user, therefore neglecting all the usage that takes place with other devices. For example, by installing monitoring software to a mobile handset, it is not possible to know how the user might be utilizing mobile networks with their laptops or MP3 players. [10]

The benefits of handset-based research methods include the accuracy of data, position at the point of mobile convergence (handset), and technical possibilities to study future mobile services and end-user behavior with both usage and questionnaire data. Today the handset technologies have advanced and particularly the emergence of programmable smartphone platforms provide a possibility to develop suitable handsetbased software for end-user research. A tailored handset-based end-user research process can contribute to solving research problems that have not been possible to address earlier. [7]

In case of the handset, a monitoring software can be installed which files usage intensities of either all device features and applications or single services, i.e., in-app tracking. Therefore, depending on the tracking design it is possible to either collect the entire usage or to focus on specific user initiated traffic. The software is also capable of recording supplementary information, such as time, location, network connectivity and battery status. [8] Device monitoring is typically conducted as panel studies, where the manual registering of usage events is replaced with the logging functionality of monitoring software or hardware installed in the device. [10]

During the research [4] for example, applications suitable for capturing and analyzing smartphone data traffic for research work were not publicly available. Nowadays, there are two main options for capturing and analyzing smartphone data traffic presented in this research: integrated (native) data traffic monitor application and third-party data traffic monitor applications. Classification and some of the examples for smartphone data traffic monitoring applications are shown in figure 3.

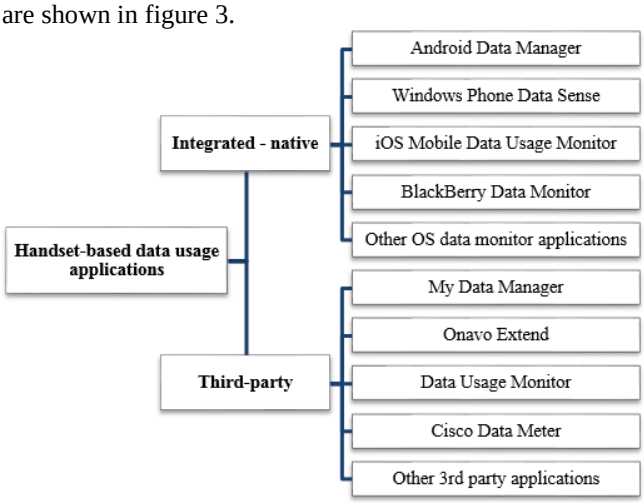

Figure 3: Classification and examples of smartphone data traffic monitoring applications

All mentioned applications (no matter native or third-party) may monitor network data usage for the data session. Applications may store and/or retrieve statistics for the network data usage associated with the particular application, and may further retrieve subscription plan information, for the network, associated with the user device. Smartphone application (no matter native or third-party), on a display, may provide the statistics for the network data usage associated with the particular application and in relation to the subscription plan information associated with the smartphone.

Integrated (native) data traffic monitor application

Many smartphones have built-in applications to help user keep track and manage data traffic usage in real-time. These applications measure the flow of data to and from device, and often provide useful statistics on how data traffic is being generated.

Integrated (native) data traffic usage monitor application is a built-in feature which lets user to track his data traffic usage and which apps are using it. Usage management options depend on the smartphone operating system version, and typical usage management options include [29]:

- tracking how much data traffic smartphone generates within a time frame
- monitoring data usage on mobile networks and over Wi-Fi networks
- notifications warnings for reaching certain usage amounts
- data restrictions to help prevent going over data traffic allowance
- seeing which applications and programs are generating data, and how much
- enabling and disabling mobile data usage
- restricting the background data traffic usage that some apps use
- turning roaming data on and off

There are differences in applications and their characterstics. Also, native applications for data traffic monitoring are connected with the smartphone operating system and its version and cannot be modified by user or developer.

Third-party data traffic monitor application

There are also many third-party applications available to consumers to monitor their data usage. For customers using mobile devices to access the Internet, monitoring tools are often available as applications that can be downloaded directly on the device. [6] Existing data usage monitors on smartphones can derive data usage information. Some third-party data monitoring applications like MyData Manager can record the detailed data usage history for each app. [30]

Many commercial mobile applications have been developed to help users keep track of their mobile data usage. Some examples include 3GWatchdog Pro (Android), DataWiz (iOS and Android), MyDataManager (Android), and Onavo Count (Android and iOS). To remain within monthly data caps, consumers are increasingly relying on those usage-tracking and data compression third-party apps that help to avoid overage fees. [31]

A few third party data management applications such as Onavo and My Data Manager allow users to input their monthly billing cycle information to gain greater insights into usage but require users to be familiar with how their data plan is billed. This process can be especially difficult for users on prepaid plans where there is no notion of a monthly billing cycle. Even for users on contract plans, if data is billed at different rates depending on whether a usage cap has been exceeded or not, the information may not be accurate. In some cases, these applications also make it necessary for a user to sacrifice privacy concerns to optimize data usage. [32]

CONCLUSION

A considerable amount of Internet traffic is generated by smartphone users and a little is known about measuring of smartphone data traffic. Many users have a limited understanding of how their devices use data traffic and many smartphone users globally are buying larger monthly data plans than they need. Also, many users are plagued with phantom data usage, which refers to the unexpected mobile data usage that does not accord with user perception.

Most people do not have a concrete idea of how much data traffic they consume each month. Moreover, an individual's data traffic usage can vary greatly from day to day, as relatively casual actions such as streaming a video can have a large impact on total data consumption. End users usually are not aware of the various factors which affect the amount of mobile and Wi-Fi data traffic of a smartphone.

There are many things that customers can do to both monitor the amount of data typically used by various kinds of Internet usage. Most participating service providers have tools that allow customers to monitor their data usage.

Smartphone data traffic can be measured from different locations using different methods. The growing number of smartphones and other advanced devices (e.g. tablets) are increasing the use of data-intensive applications, such as video streaming, on mobile networks. This research describe the upgrade of existing (handset-based) methods for measuring data traffic of smartphones.

In previous research there is a lack of research in the context of new possibilites and application upgrades for measurement of smartphone data traffic on the device. Newly formed possibilities using integrated (native) or third party applications for measuring data traffic on the smartphone are shown in this study.

REFERENCES

1. Riikonen, A., "Mobile Internet Usage - Network Traffic Measurements," Helsinki University of Technology, Helsinki, Finland, 2009.
2. Hamka, F., Bouwman, H., de Reuver, M. and Kroesen, M., "Mobile customer segmentation based on smartphone measurement," *Telematics and Informatics*, Vol. 31, No. 2 (2014) pp. 220–227.
3. Gsma, "The Mobile Economy 2015," London, England, 2015.
4. Kaisar, S., "Smartphone traffic characteristics and context dependencies," University of Saskatchewan, Saskatoon, Canada, 2012.
5. Cisco, "Cisco Visual Networking Index : Global Mobile Data Traffic Forecast Update, 2015–2020," 2016.
6. CCTS, "Understanding and Measuring Data Usage" 2011.
7. Verkasalo, H. T., "Handset-based Analysis of Mobile Service Usage," Doctoral Dissertation, Helsinki, Finland 2009.
8. Gerpott, T. J. and Thomas, S., "Empirical research on mobile Internet usage: A meta-analysis of the literature," *Telecommunications Policy*, Vol. 38, No. 3 (2014) pp. 291–310.
9. Kivi, A., "Measuring Mobile User Behavior and Service Usage: Methods, Measurement Points, and Future Outlook," *International Journal of Mobile Communications*, Vol. 7, No. 4 (2009) pp. 415–435.
10. Smura, T., Kivi, A. and Töyli, J. "A framework for analysing the usage of mobile services," *Info*, Vol. 11, No. 4 (2009) pp. 53–67.
11. Kivi, A., "Mobile Internet Usage Measurement - Case Finland," Helsinki University of Technology, Helsinki, Finland 2006.
12. Maier, G., Schneider F., Feldmann, A., "A First Look at Mobile Hand-Held Device Traffic," in *PAM'10 Proceedings of the 11th international conference on Passive and active measurement*, 2010, pp. 161–170.
13. Nikravesh, A., H. Yao, S. Xu, D. Choffnes, and Z. M. Mao, "Mobilyzer: An open platform for controllable mobile network measurements," *Proceedings of 13th Annuual International Conference of Mobile System Applications and Services*, (2015) pp. 389–404.
14. Kalden, R. A., "Mobile Internet Traffic Measurement and Modeling Based on Data From Commercial Gprs Networks," University of Twente, Enschede, Netherlands, 2004.
15. Lee, J. and Seeling, P., "An Overview of Mobile Device Network Traffic and Network Interface Usage Patterns," *Proceedings of the IEEE*

International Conference on Electro/Information Technology (EIT), (2013) pp. 0–4.

16. Muckaden, S. "Myspeedtest : Active and Passive Measurements of Cellular Data Networks Myspeedtest : Active and Passive," Georgia Institute of Technology, Georgia, Atlanta, 2013.
17. Soikkeli, T., "The Effect of Context on Smartphone Usage Sessions," Aalto University School of Science, Greater Helsinki, Finland 2011.
18. Deng, S., Netravali, R., Sivaraman, A. and Balakrishnan, H. "WiFi, LTE, or Both? Measuring Multi-Homed Wireless Internet Performance," *Imc*, (2014) pp. 181–194.
19. Church, K., Banovic, N., Ferreira, D. and Lyons, K., "Understanding the Challenges of Mobile Phone Usage Data," *In Proceedings of the 17th international conference on Human-computer interaction with mobile devices and services (MobileHCI '15)*, No. AUGUST (2015) pp. 504–514.
20. Society, I., "Internet Society Global Internet Report 2014," Geneva, Switzerland, 2014.
21. E. Inc., "Ericsson Mobility Report," 2015.
22. Society, I., "Internet Society Global Internet Report 2015," Geneva, Switzerland, 2015.
23. Ericsson, "Ericsson Traffic Exploration Tool," 2016. [Online]. Available: http://www.ericsson.com/TET/trafficView/loadBasicEditor.ericsson
24. GSMA, "Will Wi-Fi relieve congestion on cellular networks?" No. May, 2014.
25. Ovum, M., "Smartphone & tablet usage trends & insights 4G LTE and Wi-Fi powering data consumption", 2015.
26. Informa Telecoms & Media, "Smartphone use transforming with the rise of 4G and Wi-Fi," *White Paper*, 2014.
27. Din, F. U., "Mobile Internet Traffic Analysis : Session Level Approach," Aalto University, School of Electrical Engineering, Greater Helsinki, Finland, 2013.
28. Smura, T., Kivi, A. and Toyli, J., "Mobile data services in Finland: usage of networks, devices, applications and content," *International Journal of Electronic Business*, Vol. 9, No. ½ (2011) p. 138.
29. Hutchison, V. "Android data usage monitor," 2016. [Online]. Available: https://vodafone.intelliresponse.com/index.jsp?requestType=NormalRequest&id=2040&source=5&question=Android data usage monitor.
30. Jiang, S., Zhou, P. and Li, M., "Detecting Phantom Data Usage on Smartphones with Analysis of Contextual Information," Vol. 2015, 2015.
31. Sen, S., Joe-Wong, C., Ha, S. and Chiang, M., "Smart Data Pricing (SDP): Economic Solutions to Network Congestion," *Recent Advances in Networking*, (2013) pp. 221–274.
32. Mathur, A., Schlotfeldt, B. and Chetty, M. "A Mixed-Methods Study of Mobile Users' Data Usage Practices in South Africa" (2015) pp. 1209–1220.