Subscriber Group Behavioral Analysis for Data-Centric Service Consumption Beyond LTE-Advanced

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***Abstract*— In this paper we elaborate on the factors that have contributed the most to mobile data traffic growth witnessed in the past decade: mobile data subscriptions; mobile data enabled devices; mobile applications, always on and cloud services and standardization. From it a set of data-centric services and scenarios are derived: most expected by 2020. Based on them subscribers' universe was split into four user behavioral segments we introduce. All form the pillars of a traffic model, which is our main contribution, tested with real and estimated data from existing market studies. User segments' consistency and stability towards traffic generation, data consumption and service usage, as well as the probability of user segments shifting among services analysis can be performed. The effectiveness of the proposed model is demonstrated based on real world data, aiming to bring together technological, sociological and also economical perspectives into a single analytical framework.**

Keywords*— *LTE-A, data-centric services, capacity planning, subscriber segments, subscriber behavior, traffic

I. Introduction

Cellular telephone users' behavior has changed notably. Nowadays, users do not use cellular telephones solely for voice communications [1]–[6]. In fact, basic terminals are globally being replaced by smartphones [2][3], posing new challenges to mobile network operators (MNOs) [6]–[9]. But not only smartphones play an important role in mobile traffic generation nowadays [10]–[12]. Video streaming *via* tablet computing is increasingly popular, generating continuous streams of real time data [12]–[14]. Several market studies show that as networks become faster, video streaming usage greatly increases [5][7][13]–[19]. It is, therefore, crucial that MNOs prepare for increasingly bandwidth demand while delivering high performance and quality of service (QoS). With that in mind, we consider fundamental for MNOs to: profile subscribers into user segments according to service usage behavior; predict and score user segments' impact when deploying new technologies or increasing the availability of existing ones; adapt its service and value offers to increase their own and customers' benefit. Our contribution is a model framework considering those behavioral factors, reflected into traffic generation.

Section II focuses on historical and estimated evolution of data traffic generation and consumption. Section III characterizes mobile data over the last years and introduces new characteristics for 2020. The most prevalent user-centric services by 2020 are presented in Section IV, mirroring our expectations for next decade's data market. Section V introduces four user segments derived from subscribers' behavior towards data generation and consumption. The behavioral impact model is presented in Section VI. Results of evaluating it with real and estimated market data are presented in Section VII. Section VIII summarizes the whole work reporting the most significant conclusions.

II. Data Traffic Evolution

Sub-sections A to D focus on the factors that most contributed to increasing mobile traffic along the current decade.

A. Mobile data subscriptions

By the end of 2007 there were 300 million fixed broadband Internet subscribers in the world, reaching 620 million today. Estimations predict that by the end of 2014, it will rise to 940 million [1]. World universal mobile telecommunication system (UMTS) and high-speed packet access (HSPA) subscribers have doubled between 2008 and 2012. Predictions are that by the end of 2014, both technologies' subscribers sum up to 2.2 billion, surpassing fixed broadband [2]. Figure 1 shows the expected growth in HSPA subscriptions up to 2020. UMTS subscriptions are expected to stall from 2014 onwards, while HSPA subscriptions technologies will increase. Using data from market studies covering the 2010 to 2016 period, the corresponding trend was derived and expanded enabling expected HSPA subscriptions growth estimations up to 2020 [1][5-8][16-17]. Figure 1, depicts the results, translated as subscribers increase for both technologies, S_{HSPA} and S_{UMTS}, in a given current year Y_C, relative to a given start year, Y_S, can be written as

$$S_{HSPA} = [T_{HSPA} \cdot (Y_C - Y_S + 1)^{G_{HSPA}}] \cdot 10^6 \quad (1)$$

$$S_{UMTS} = \lceil \mathrm{T_{UMTS}} \cdot (\mathrm{Y_C} - \mathrm{Y_S} + 1)^{\mathrm{G_{UMTS}}} \rceil \cdot 10^6. \quad (2)$$

The above expressions consider growth indexes, G_{HSPA}, and G_{UMTS} as well as two growth factors, T_{HSPA} and T_{UMTS}. From Figure 1, $Y_S = 2010$, $G_{HSPA} = 1.35$, $G_{UMTS} = 0.16$, $T_{HSPA} = 282.5$ and $T_{UMTS} = 370.5$.

B. Mobile Internet enabled devices

Mobile Internet connected devices already surpassed fixed line connected computers [4]. In the 2010-2015 period worldwide share of smartphone in global mobile shipments is expected to rise from nearly 25 percent in 2010 to 56 percent in 2015[5]. We estimate that by 2020 smartphones will account for 72% of global handsets, as depicted in Figure 2.

In order to qualitatively measure the impact of advanced mobile devices, Figure 3 presents their traffic generation capabilities, compared to basic feature telephones[7].

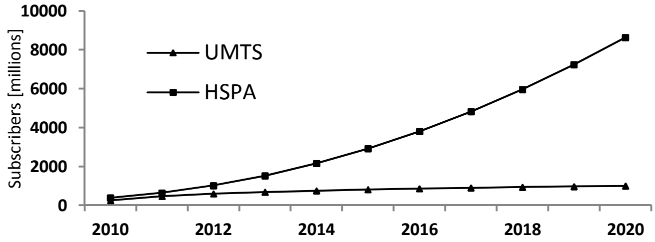

Fig.1. Estimated global subscribers' growth for UMTS and HSPA in 2010-2020 period.

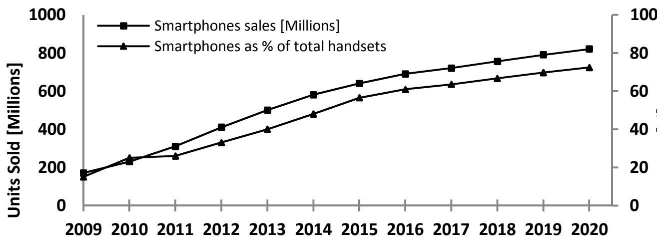

Fig.2. Smartphone sales.

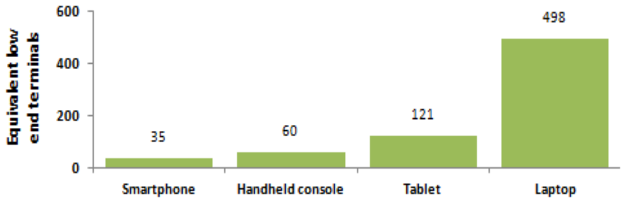

Fig. 3.Traffic generation capacity relative to low end telephones (adapted from [7]).

C. *Mobile applications, always-on services and Clouds*

High-end handheld devices drive the appearance of more complex and demanding services and applications. Nowadays existing subscriber communities generate, distribute and consume content, creating high amounts of traffic, whether in downlink (DL) or uplink (UL) directions. Figure 4 shows the estimated traffic share for the most popular services by 2016[7]. Video streaming is expected to account for 70% of all generated mobile data traffic, showing that mobile user's behavior is changing from non-real time to real time services usage. Mobile WEB/Data with 20% share by 2016 is strongly influenced by the advent of mobile applications. Application stores like Google's Play or Apple's App Store, *inter alia*, have changed the paradigm of application usage [12]. Both stores have already surpassed 15 billion application downloads, representing respectful traffic generation. Most recently, cloud technology is creating additional traffic, by enabling seamless solutions like software as a service (SaaS), desktop as a service (DaaS), infrastructure as a service (IaaS) and cloud gaming always relying on mobile connections to the Internet.

D. *Standardization*

Over the last decade standards releases evolved very rapidly enabling new radio resource optimization techniques and higher spectrum efficiency, resulting in increased global throughput and lower latency, as depicted in Figure 5. Figure 6 presents the evolution of UL and DL data rates and latency up to LTE-A and estimations up to 2020.We believe that at this rate, by 2015-2016 latency will drop below 1ms. Estimated latency decrease per year, L_{Year}, UL and DL data rates per year, ULr_{Year}, DLr_{Year}, may be derived from Figure 6.

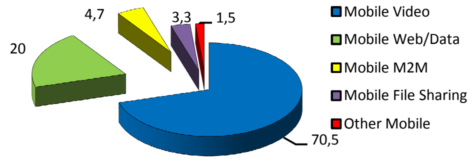

Fig.4. Expected traffic share per service [7].

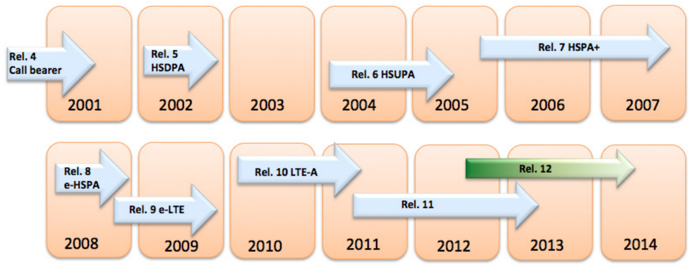

Fig. 5. 3GPP specifications timeline.

Considering a latency factor L_f, UL and DL factors UL_f, DL_f, an yearly latency decrease rate L_d and an yearly data rate increase UL and DL factors UL_i, DL_i, in a given current yearY_C, relative to a given start year, Y_S, we can write

$$L_{Year[\mathrm{ms}]} = L_f \cdot e^{-L_d \cdot (Y_C - Y_S + 1)}\,, \tag{3}$$

$$ULr_{Year[\mathrm{Mbps}]} = UL_f \cdot e^{-UL_i \cdot (Y_C - Y_S + 1)}, \tag{4}$$

$$DLr_{Year[\mathrm{Mbps}]} = DL_f \cdot e^{-DL_i \cdot (Y_C - Y_S + 1)}\,. \tag{5}$$

In this case and from Figure 6, we findL_f = 2579,6, L_d =-0,753, UL_f = 0,021, DL_f = 0,008 , UL_i =1,387, DL_i =1,121 and Y_S = 1998. We, therefore, believe that standard developments have been partially driven by worldwide mobile data traffic explosion as never before.

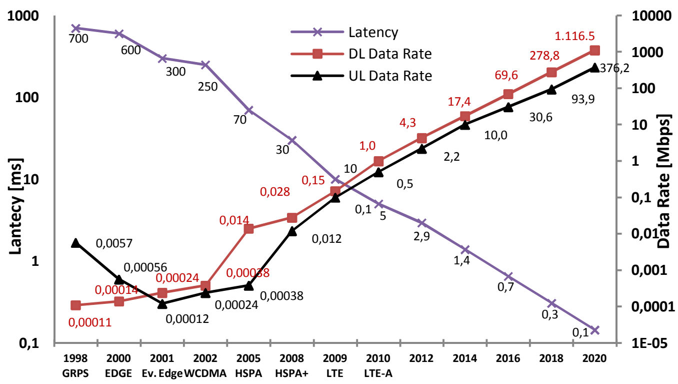

Fig. 6. Latency decrease forecast.

III. TRAFFIC CHARACTERIZATION

This section aims to characterize mobile traffic and data generation. Sub sections A and B present two different perspectives: data quantification and physical origin, respectively. Both play important roles enabling mobile operators to define new product strategies, new business models and also find what the best period to deploy network enhancements is.

A. *Mobile Traffic Quantification*

By 2015, mobile data traffic footprint of a single subscriber will be 450 times bigger compared to 2005 [5]. Forecasts state that by 2020, Asia will represent 43.9% of total world mobile traffic, Europe 28,2% and Americas 27,3%. Figure 7 presents the world mobile traffic evolution expected for the 2010-2020 decade.

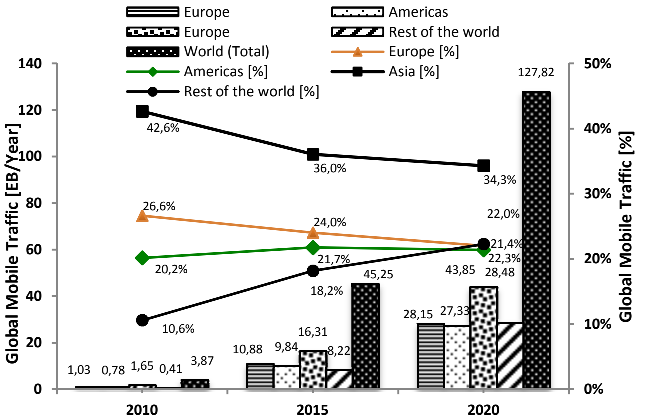

Fig. 7.Estimated traffic per World Region (adapted from [7]).

By 2015, wired connected devices are expected to account for 46%, whereas mobile devices will generate 54% of global IP traffic using cellular connections. Figure 8 presents the amount of traffic generated up to 2012 and the estimation for the future [5]. From Figure 8 monthly traffic per user, $U_{MT_{Year}}$, may be calculated considering a traffic factor T_f, and a monthly traffic increase rate T_i, in a given current year Y_C, relative to a given start year, Y_S, resulting in:

$$U_{MT_{Year}[\text{GB}]} = T_f \cdot (Y_C - Y_S + 1)^{T_i} \qquad (6)$$

In this case and from Figure 8, we find $T_f = 3{,}778$, $T_i = 1{,}4389$ and $Y_S = 2010$.

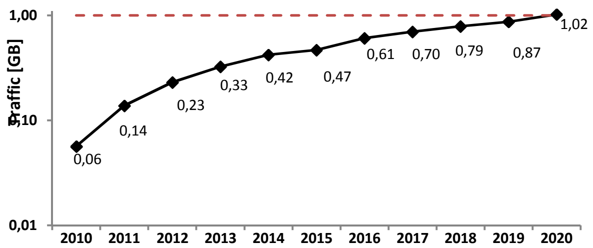

Fig. 8.World estimated monthly traffic per subscriber.

B. *Mobile Traffic Origin*

Over the last years the majority of traffic growth originates from indoors where cellular networks are not as efficient as outdoors [20]. To address indoor traffic demand and lack of efficiency, 3GPP introduced a heterogeneous mobile network environment, where outdoor macrocells coexist with indoor smaller cells, known as femtocells. Several femtocell architectures have been proposed [20]–[22], as well as use cases and services[23], focusing on challenges, advantages and disadvantages, all to address the indoor traffic demand. Several femtocell business models were developed aiming to maximize average return per user while minimizing capital (CapEx) and operational (OpEx) costs [24]–[28].With the deployment of femtocell technology, subscribers will experience increased indoor QoS as never before.

IV. Services and Assumptions

Sub-section A presents a set of services we believe most prevalent by 2020, while Sub-section B describes their respective assumptions. Both define a set of user behavioral segments presented in Section V. Data-Centric Services

The services presented below have high traffic generation capabilities and follow a data-centric behavior concept, adapted from [29]. The services considered to be the most prevalent in the 2016-2020 period are [8][30]–[32] Mobile Social Networking; Mobile Social Gaming (including cloud gaming); Video Streaming (including television broadcast); Voice over data; Peer-to-Peer communications (including video call); Mobile Web Browsing; Mobile commerce and banking; M2M communications[1]. Being 2020 the reference year, classical voice service is replaced by voice over Internet Protocol (VoIP), consistent with nowadays trending [11].

A. *Service and Technology Assumptions*

From last years' historical information, trending and technological predictions for the near future the following assumptions are made for 2020: Handheld devices and mobile Internet connections highly affordable; guaranteed data rates of 1Gbps/500Mbps DL/UL; mobile usage experience similar to fixed broadband; existence of cognitive radio techniques and wide adoption of femtocells; enhanced mobile data security; fixed to mobile convergence with single sign-on capabilities for all systems; mobile health monitoring and sensoring; decreased device usage complexity; massive M2M communications; increased online social interaction and user personalized services and applications; highly secure online payment services and wide adoption of cloud services.

V. User Behavioral Segments

Based on last section, we propose four consumer segments, with the possibility of defining others from particular geographic and demographic data: *Moklofs, Yupplots, Supmuts, Moplows.* The model supports any user segment set, which can be tailored accordingly to any specific demographic characteristics

A. *Moklofs*

Moklof stands for Mobile kid with lots of friends. Young individuals, early technology adopters. Strongly focused on mobile entertainment and messaging services, as well as online social communities. Online gaming, social networking, video and music streaming are very popular services as well as free cloud services. This segment generates high amounts of mobile data traffic, and is not sensible to data security needs.

B. *Yupplots*

Yupplot stands for young urban people/parents with lack of time. *Yupplots* prefer voice calls and telepresence applications. Mobile commerce and banking is treasured. Security, geographical and location awareness as well as remote surveillance are appreciated. *Yupplots* are not entirely Telecommuters, as they do not have nomadic life and behavior. *Yupplots* prefer automatically performed tasks

[1] We consider Consumer Telematics, Security, Vending/Kiosk/ATM, Digital Signage and mHealth the most used applications for the consumer behavioral segments identified in this work.

and automatically fed information. Machine to machine communications is highly valued by this segment, preferably at home.

C. Supmuts

Supmut stands for senior urban people with much time. As *Moklofs'* "grandfathers", they're technological aware and educated. *Supmuts* are very sensitive to social networking services, with particular interest in video calls. Travelling and online informational services are much appreciated. Remote video and audio communications are very important, with videoconferencing being predominant. Health services and applications and automatic body function sensoring are very treasured for this segment.

D. Moplows

Moplow stands for mobile professionals with lots of work. They are real Telecommuters with highly nomadic behavior world travelling. State of the art handhelds are used and demand high quality services from mobile networks. Mobility is key and *Moplows* need fast high throughput data connections to home and office, desirably in an automatic fashion, without human intervention. As they travel much, telepresence services are very important, usually by real time video conferencing over mobile Internet. Live continuous feed informational services are also important. Global network coverage, seamless communication, and high data rate services are essential for this segment.

VI. User Behavioral Model

In this section we introduce a model that quantitatively measures the impact of user segments' behavior regarding data traffic generation. This method considers the user segments defined in Section V as well as the data centric services from Section IV. Additionally, and to be as generic and close to reality as possible, the method allows integrating existing real world statistical information, that can be extracted from any source. We start by defining a probability distribution function for all services listed in Table III:

$$p_s(s) = \sum_{i=0}^{I} \delta(s-i) \qquad (7)$$

Where i is the service number and $\delta(s_s - i)$ is the usage probability of the i^{th} service, and I ithe total number of services.

TABLE III
Monthly Traffic Share [7][4].

Service Share [%]	Video	Data	M2M	File Sharing	Gaming	VoIP
2016	70.5	20	4.7	3.3	1.1	0.3
2020	72	17.5	7.0	2.2	1.0	0.3

Considering some services from Section IV-A might fit the same category from Table III, we define a generic probability distribution function given by:

$$p_{s_s}(s_s) = \sum_{k=0}^{K} \delta(s_s - k) \qquad (8)$$

where $\delta(s_s - k)$ is the usage probability of each of the K=2 services from Section IV-A. In our case, we consider services s_1, s_6 and s_7 to have the same probability of 33,(3)%. In order to associate services to user segments, we defined a probability distribution function per each segment for all services, where:

$$p_{u_s}(u_s) = \sum_{j=0}^{J} \delta(u_s - j) \qquad (9)$$

where J is the total number of services and $\delta(u_s - j)$ is the distribution associated to each j^{th} service. We further admit that the percentage of service usage per each user segment is split into N_l levels, given by:

$$N_l = \frac{100}{f_r} \qquad (10)$$

Where f_r is a resolution factor. For the current work, $f_r = 10$, meaning the percentage of service usage per user segment will be quantified in multiples of 10%. Per user segment a probability matrix per service usage is defined, representing the probability of using one of the services, where:

$$\sum_{u=0}^{J} P(u,s) = 1, \qquad s = 1, \dots I \qquad (11)$$

Finally we derive a traffic PDF:

$$T(u_s, s_s) = \sum_{j=1,k=1}^{J,K} \delta(u_s - j) \cdot \delta(s_s - k) \qquad (12)$$

VII. Results

The proposed model was tested with real data from [7]. Figure 9 shows the results for traffic per user segment by 2016, with Video Streaming, s_2, dominating traffic on all segments. *Moplows* and *Yupplots* are the segments that generate most traffic. Considering both segments have the highest penetration rates of higher traffic services, *i.e.*, Video Streaming and Peer-to-Peer communications consistency is obtained. *Moplows* have higher penetration rate of mobile social networking due to nomadic behavior, categorized as the second service with highest impact from [7]. *Moklofs'* and *Yupplots'* traffic impact are similar: *Moklofs* present higher usage levels of real time services and *Yupplots* higher M2M communications, mobile banking and commerce services. *Supmuts* are expected to have considerable impact due to their intrinsic technology awareness.

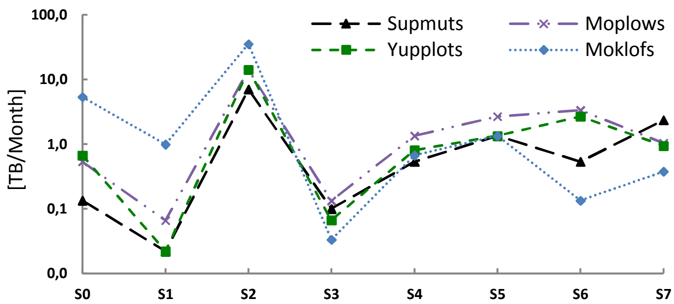

Fig. 9. Expected traffic per user segment by 2016 [TB/month].

Extending the analysis to 2020 estimations, in comparison to 2016, user segment's share on total traffic generation is presented in Figure 10. Traffic generation for all user segments follow the same tendency, with higher data volume, except for *Yupplots,* according to [7]. Concerning traffic spread and dispersion, Figure 11 shows *Moklofs* have the least spread, with high levels of and stability *circa* Video Streaming service. *Moplows* and *Yupplots* are the most uncertain, highly spreading traffic through all services.

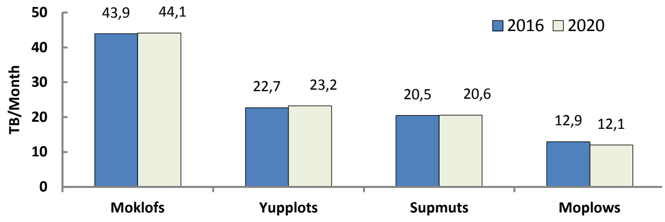

Fig. 10. User segments' share of global monthly traffic [TB/month].

The model can be used for spread or dispersion, as well as central tendency analytics. Integrating MNO data on user segment level allows for economics analytics. Customer driven and innovation CapEX are, *e.g.*, two indicators that can output from the model when feeding it with social-behavioral, technological and economical data.

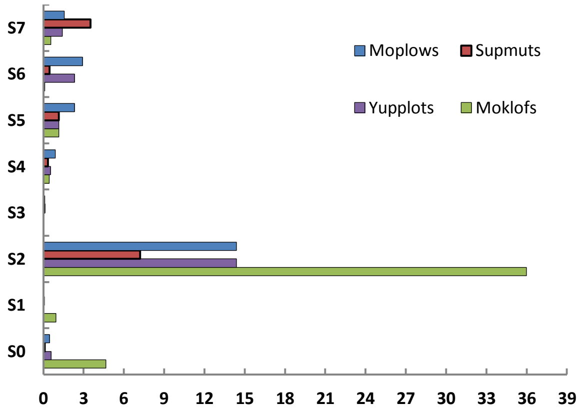

Fig. 11. Service traffic spread per user segment [%].

VIII. Conclusion

The main contribution of this work is a traffic model to quantify the impact of user behavior towards the generation of mobile data traffic over cellular networks. We started by presenting four factors contributing to unprecedented growth of mobile data traffic. A set of data centric services was identified as the most prevalent in 2016-2020 period and subscriber segments were introduced based on mobile traffic consumption patterns. Both permitted constructing the model to account for subscribers' data traffic generation behavior over a cellular network. Subscribers' traffic consumption patterns were accounted for. Applying existing market data statistics and estimations for 2016 and our own estimations by 2020 validated the model. The results show that traffic consumption patterns and user segments' have different impacts on overall network traffic and should be accounted for. Considering that user segment behavior when using data services can change and impact the overall network performance and capacity, user segment consistency and stability towards traffic generation was also analyzed. Churn rate is nowadays an important factor to be accounted per any MNO and this largely depends on user behavior. As so, the proposed model allows certainty and risk analytics, allowing MNOs to identify most stable segments to new or changes in services. Finally, we believe that the proposed model when integrated into a system simulator will provide additional dimensions of analysis, closer to MNO's subscribers, allowing capacity planning optimization and optimized technology introduction and change management.

Acknowledgment

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