Composition of GPRS/UMTS traffic: snapshots from a live network

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Abstract. This paper focuses on the traffic composition in a real GPRS/UMTS network. We present results from two datasets covering two one-week measurement periods, in December 2004 and November 2005. We show how users and traffic split between access technologies (GPRS and UMTS) and services, and present an analysis of the per-user activity at the PDP-context level.
The results reported here provide an up-to-date view of the traffic and user activity in an operational 3G network. It should help those researchers interested in reproducing synthetic network scenarios to gain a better understanding about the traffic environment in a real network. Moreover, we discuss several technicalities found in performing such measurements, which should be helpful to those researchers active in 3G monitoring.

1 Introduction

The growing popularity of 3G terminals and services has extended the coverage of wireless Internet access to the geographic area, and 3G networks are becoming key components of the global Internet in Europe. However the 3G penetration and service portfolio are still in an evolutionary phase.

The planning and operation of a real network, as well as the related research activities, are based on a set of assumptions about the traffic and the service access patterns. In such an evolutionary environment it is therefore of key importance to perform measurements campaigns, or better maintain a continuous measurement program, in order to extract such information and track the evolution of the network environment. This paper is meant to represent a contribution towards a better understanding of the global traffic composition in a real 3G network. This work results from extensive traffic monitoring on top of the operational 3G network of mobilkom austria AG & Co KG, the leading mobile operator in Austria, EU. We provide an insight into the high-level composition of the global traffic in the network under study, for both GPRS and UMTS, and at the same time discuss some technical issues related to traffic monitoring in 3G. The content of this paper should be of interest to those researchers working on 3G, and provide them with a better understanding of how the traffic environment in a real 3G network looks like. To the best of our knowledge this is the first paper reporting measurement results about traffic composition in UMTS.

The rest of the paper is organized as follows. Section 2 introduces the monitoring setup and describes the analysis process. Section 3 investigates on the distribution of users and traffic between GPRS and UMTS, and the traffic per user. In Section 4 we look at the traffic composition with respect to different services. In Section 5 we inspect the per-user activity at the level of PDP-contexts. In Section 6 we reference those few available previous papers presenting similar measurements for GPRS (no paper appeared so far for UMTS). Finally in Section 7 we conclude and suggest directions for further work.

2 Monitoring setting and analysis process

The monitoring system. The development of a large-scale passive monitoring system - including a parser for the whole protocol stack of the 3G Core Network - and its deployment in the operational network of mobilkom austria AG & Co KG were accomplished within the METAWIN project [1]. Packets are captured with DAG cards and recorded with GPS synchronized timestamps. For privacy requirements, the frames are completely anonymized on-the-fly before being stored on the hard-disk: all subscriber-related fields at any layer of the 3GPP protocol stack (e.g. IMSI, MSISDN, IMEI) are hashed with a secret non-invertible function, while the user payload at the application layer is stripped-off.

Tracking modules. The monitoring system covers both the user- and control-plane. On each interface an on-line stateful module tracks the current TIMSI (Temporary International Mobile Subscriber Identifier) for each Mobile Station (MS), so each packet can be associated to the originating MS [1]. Furthermore, the tracking module on Gb/IuPS links tracks the MS position (i.e. cell), while the tracking module on Gn maintains several PDP-context attributes (e.g. APN). Such tracking modules enable some forms of analysis and traffic slicing that would not be possible based only on stateless traces. For instance, the analysis of per-user traffic can not be based on the IP address which is assigned dynamically. Also, the analysis of traffic for a specific class of users, e.g. discriminated by means of the APN, would not be possible without maintaining state for each PDP-context. The tracking procedure is prone to some limitations, for instance "border effects" at the boundaries of the measurement window: PDP-contexts that were activated before the start of the measurement period will not be accounted in the final statistics, leading to a certain under-estimation and bias against long PDP-contexts. In our data we verified that the fraction of unassigned packets (i.e. packets that are found in the traces but can not be referred to any fully tracked PDP-context) is less than 2% of the total packets seen durign the first day.

[1] Note that each MS is distinguished by a local identifier obtained by hashing the real IMSI. This process protects the user identity, since the real IMSI is never recorded. Furthermore the hash function and its parameters are undisclosed to the research staff, thus preventing real-to-hashed IMSI mapping associations for specific MS. For sake of simplicity in this paper we will maintain the term "IMSI" to refer to the local MS identifier.

Capturing on Gn. While we passively monitor all core network interfaces (Gi, Gn, Gb, IuPS) the results presented in this work are based exclusively on traces captured on Gn, specifically on the links near the GGSNs. All Gn links attached to all GGSNs were monitored, covering 100% of GPRS and UMTS traffic from home subscribers, traffic from visiting roaming subscribers is not considered. The choice of Gn for this type of analysis was based on the following motivations. First, capturing on Gi links would not allow per-MS discrimination nor PDP-context analysis, since IMSIs and PDP activations are not present on Gi. Second, complete coverage of IuPS/Gb would require tapping more physical links. Since separate SGSNs are used for UMTS and GPRS, on Gn it is possible to discriminate GPRS and UMTS traffic based on the IP address of the SGSN which is found in the IP header below the GTP layer (for more details about the 3GPP protocol stack see e.g. [2, pp. 41]).

Analysis process. The analysis process works as follows. Our code parses the entire packet trace and extracts a set of attributes for each PDP-context and for each connection (a definition of *connection* for UDP is given below). The PDP-context attributes include IMSI, start time, duration, transferred volumes (separate values for user data and signaling and for uplink and downlink), etc. The connection attributes include PDP-context identifier, IP addresses and ports, start time, duration, volumes, etc.

Volumes and connections. A point of clarification is due regarding the usage of the term “volume” and “connections”. By total volume we refer to the cumulated number of bytes at the IP layer, i.e. the GTP payload. Lower layer overhead (e.g. GTP header and below) are not considered here. Unless differently specified the volume values given in this paper refer to the cumulated uplink and downlink traffic. Regarding the term “connection”, in case of TCP traffic it will refer to the plain TCP connection. For UDP traffic we define a connection as the union of all packets seen with the same quadruple (source / destination addresses and ports) and within the same PDP-context, with a maximum inter-packet spacing of T (we used T=10 min). This choice might be critical when comparing the two implementation of the same service adopting different transport protocols, e.g. WAP 1.x (over UDP) and WAP 2.0 (over TCP). We verified that the average number of WAP connections per-user is approximately the same for both implementations: 1.3 and 1.4 for WAP 1.x and WAP 2.0 respectively. This comforts our definition of “connection” for UDP.

Non-disclosure policy. For proprietary reasons we can not disclose several absolute quantitative values like traffic volumes, number of users, number of Gn links, etc. that are considered business critical by the operator. In other words we can not disclose the *size* of the user population and of the traffic aggregate but only their *composition*. To comply with such policy, we provide only relative values, i.e. fractions, or re-scaled values. In other cases we had to truncate graphs (e.g. for ranked distribution) to avoid revealing the absolute number of users.

Table 1. Fraction of users and volume in GPRS and UMTS

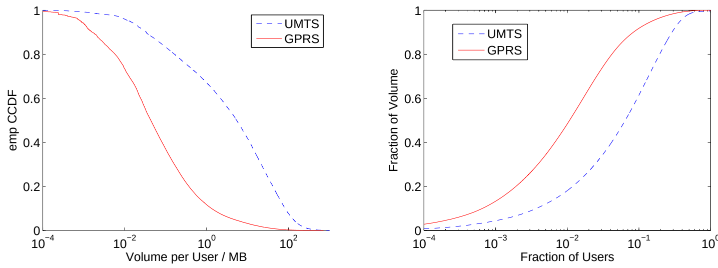
Dec04			**Nov05**		
RAN	Users	Volume	RAN	Users	Volume
GPRS	98.8%	58.3%	GPRS	90.7%	33.3%
UMTS	1.2%	41.7%	UMTS	9.3%	66.7%

3 Volumes and User Population in GPRS and UMTS

As a first step we show how the total traffic and user population are split between different services. We present results from two separate one-week periods in December 2004 and in November 2005, hereafter denoted respectively as Dec04 and Nov05 datasets. The comparison between the two provides an insight into the historical changes in the macroscopic traffic composition during almost one year. Attached to the 3G Core Network there are two different Radio Access Networks (RANs), namely GPRS and UMTS, delivering different link bandwidth (for further details see e.g. [3, pp. 23]). Since UMTS radio deployment is more recent, the UMTS coverage is smaller than GPRS and limited to urban and suburban areas. Note that EDGE was introduced in August 2005, therefore the dataset Nov05 includes data traffic from EDGE terminals, which we will account simply as "GPRS".

Table 1 shows the relative fractions of users and volumes found in the network for GPRS and UMTS. Users are identified by their IMSI (see note [1]). Note that only *active* users are accounted here, i.e. with at least one PDP-context activation in the measurement window. Attached but inactive users are not accounted. Note that in general UMTS capable terminals can also access GPRS radio outside the UMTS coverage. We label as "GPRS users" those seen exclusively on the GPRS section during the measurement period, while those that accessed the UMTS at least once are classified as "UMTS users". A caveat is due here since a "UMTS user" can also generate GPRS traffic: while this traffic is correctly accounted as GPRS, the GPRS user count in Table 1 only considers GPRS-only users. Therefore, the average per-user traffic can not be derived from Table 1. From Table 1 it can be seen that in Dec04 the number of active UMTS users was approximately two orders of magnitude less than GPRS, but the two groups generated comparable traffic volumes. In fact at that time a large fraction of UTMS mobile stations were 3G datacards mounted on laptops[2] coupled with flat-rate contracts, while UMTS hand-held devices were just starting to spread among subscribers. In Nov05 the fraction of UMTS users has increased, as the combined effect of additional UMTS subscribers plus legacy GPRS users upgraded to UMTS hand-held terminals. The fact that for UMTS the growth factor in the volume share is substantially less than for the user share suggests that most of the new additional terminals were hand-held devices rather than laptop datacards, under the assumption that the former ones generate less traffic than the latter due to a combination of differences in terminal capabilities and billing schemes. However laptop datacards are still an important subset in the UMTS terminal population. The rough comparison between the ratios of volume to user shares anticipates that the average per-user traffic is larger for UMTS than GPRS. This was expected,

[2] See e.g. `http://www.option.com/products/3g_edge.shtml`



(a) Volume per User (CDF)

(b) Fraction of volume cumulated by fraction of the top users

Fig. 1. Distribution of Volume per User in MB/week in Nov05. (The x axis is truncated to 10^{-4})

given that UMTS delivers a higher bandwidth and hence a better user experience than GPRS, despite they share the same billing tariffs.

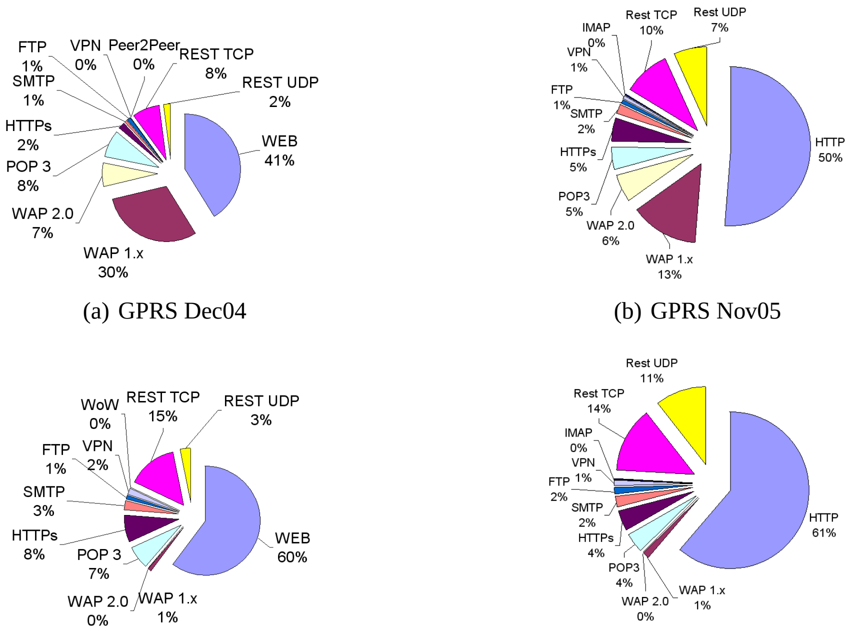
As a next step we evaluated directly the weekly volume generated by individual users. The per-user volume distributions for GPRS and UMTS in Nov05 are reported in Figure 1. All values are in MB/week. Note that in these figures a single MS producing both types of traffic (say v_u and v_g volumes respectively in UMTS and GPRS) will appear as two different MSs with distinct volumes in each class (i.e., v_u and v_g). Figure 1(a) reports the CCDF. It can be seen that the median is around 5.4 MB/week for UMTS and only 43 KB/week for GPRS. The distribution spans around five orders of magnitudes, denoting a large disparity in the user behavior. This can be seen well from Figure 1(b), where we plot the fraction of the top 1% users' traffic in a linlog plot. We obtain that the top 1% of UMTS users generated around 14% of total traffic, while the top 1% of GPRS users generated 52% of total traffic. For the 10% of top users, the cumulated fraction of volume jumps to 58% for UMTS and 92% for GPRS.

The GPRS figures reveal that the vast majority of users "seen" on GPRS are generating less than 1MB/week. At the other extreme of the range are the heavy-users, who transfer massive volumes of traffic. This suggests the possibility to classify the users into a small set of classes, so as to distinguish sporadic, heavy and intermediate users. In general such classification would be service-dependent, however as far as the total network load is concerned we can ignore service-specific metrics and just consider the total transferred volume in the measurement period. Hence we classified the users into four groups based on arbitrarily chosen threshold values on the weekly volume v: very low ($v \leq$ 10kB), low (10kB $< v \leq$ 1MB), medium (1 MB $< v <$ 100 MB) and high ($v \geq$ 100MB). We used the same boundary values for UMTS and GPRS. Table 2 shows the fraction of users and volume within each group for both datasets.

It can be seen that the vast majority of users (70-90%) in GPRS have less than 1MB per week (low and very low users), but they generate only a small fraction of the total traffic (≈3-6%). Note that the lowest group generate a negligible amount of traffic, despite (≈25-40%) of the users are found here. These are users that had a single or very few session (e.g. MMS via WAP), or perhaps activated a spurious PDP-context. We also note in GPRS an increase in the fraction of volume in the "high" group, from 7% to 24%: this is maybe an indication that more laptop datacards are being used on GPRS/EDGE. In UMTS, we see that the "low" and "very low" groups were almost

Table 2. Grouping per transferred volume (Values in fraction of total)

GPRS					UMTS				
Dec04	high	medium	low	very low	Dec04	high	medium	low	very low
Users	0.1%	29.3%	29.3%	41.3%	Users	13.0%	83.3%	3.5%	0.2%
Volume	7.0%	89.3%	3.7%	$< 0.01\%$	Volume	61.4%	38.6%	$< 0.1\%$	$< 0.01\%$
Nov05	high	medium	low	very low	Nov05	high	medium	low	very low
Users	0.2%	11.5%	61.7%	26.6%	Users	7.6%	59.4%	28.9%	4.1%
Volume	24.3%	69.5%	6.2%	$< 0.01\%$	Volume	51.2%	48.5%	0.3%	$< 0.01\%$



(a) GPRS Dec04 (b) GPRS Nov05

(c) UMTS Dec04 (d) UMTS Nov05

Fig. 2. Service Shares for UMTS and GPRS

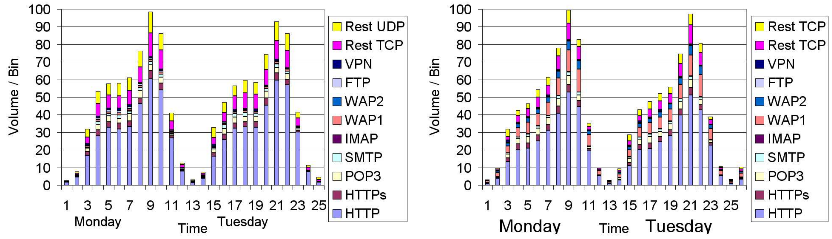
empty in Dec04 (less than 4% of users), while in Nov05 they raised to almost 33.0%. This is probably due to the introduction of a large number of hand-held devices, while in Dec04 the predominant terminal type was laptop datacard.

4 Service Mix

In a next step we analyzed the volume share per each service. The figures in this section do not include custom services implemented for specific customers, which where pre-filtered based on the APN. Also, we filtered traffic on ports tcp:135 and tcp:445, which is used by several scanning worms (see discussion in Section 4.3). The results are presented in Figure 2 for UMTS and GPRS separately and for both datasets. In all cases the largest volume share is on WEB. The biggest change occurred in GPRS, where the

Table 3. Daily service shares - GPRS / UMTS Nov05

	UMTS							GPRS						
Service	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun
HTTP	58.5	60.2	58.1	59.1	59.4	65.6	64.5	50.2	49.7	48.0	48.7	49.3	54.6	55.2
HTTPs	4.9	4.7	4.8	4.5	4.4	3.5	3.7	5.1	4.9	5.0	5.1	4.8	3.6	3.6
POP3	4.7	4.5	4.9	5.0	4.4	2.4	2.5	5.5	5.3	5.5	5.9	5.4	3.3	3.1
SMTP	2.1	2.6	2.5	2.2	2.0	1.1	1.5	2.1	2.2	2.3	2.2	2.0	1.4	1.9
WAP 1.x	1.5	1.4	1.4	1.6	1.5	1.4	1.2	13.9	13.4	13.4	13.6	14.3	14.4	13.1
WAP 2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	5.6	5.5	5.5	5.4	5.5	5.5
FTP	1.6	0.9	1.8	1.7	4.0	0.3	0.4	0.6	0.8	1.4	1.0	0.7	0.6	0.4
VPN	1.4	1.0	1.3	1.4	1.1	0.9	0.6	0.9	0.7	0.6	0.8	0.8	0.4	0.6
Rest TCP	12.7	12.5	13.2	13.6	13.1	15.0	15.1	9.0	9.3	11.1	9.9	10.3	9.9	9.6
Rest UDP	12.4	12.2	11.9	10.9	10.0	9.7	10.4	7.2	8.0	7.2	7.1	6.8	6.3	6.3



(a) UMTS Nov05 (b) GPRS Nov05

Fig. 3. Traffic composition across 2 days, 2h bins, Nov05 (Y-axis arbitrary rescaled).

WAP 1.0 share halved from 30% to 13%. Looking at the relative growth of volume for each service, we found that the WAP traffic in GPRS did increase in absolute volume (+80%), but less than other services (e.g. +339% for WEB). Email (POP3 + SMTP + IMAP) grew by +170% in GPRS and +160% in UMTS. The HTTPs service did also grow considerably on GPRS (+719%). Interestingly in Nov05 we found 0.8% of UMTS traffic was related to a popular online game (World of Warcraft).

4.1 Service Mix over time

Next we analyzed the stability of service shares on a day-by-day basis, limited to the top services. Table 3 shows the fraction of volume per service accumulated within each day. We can discriminate two different profiles for working days and for the weekend. The WEB traffic is always dominant and its relative share increases in the weekend - in UMTS 58-60% in working days and 65% in weekend. The share of email traffic (POP3 and SMTP) decreases in the weekend (in UMTS it roughly halves). We also notice a decrease of "Rest UDP" (which includes tunneled traffic, e.g. IPSEC) and VPN. The most likely explication is that this traffic is related to business people that tend not to use their mobile access on weekends. We observe that the WAP share in GPRS is relatively stable across all days.

Regarding the email volume we note that GPRS and UMTS display different levels of asymmetry: the ratio of email downloads (POP3+IMAP volume) to email sending (SMTP volume) is on average 2.8 for GPRS and 2.1 for UMTS. This can be accounted to the smaller uplink bandwidth in GPRS (21.4 kbit/s) and consequently relatively long transfer times which refrain the users from massive email sending.

Network engineers typically refer to the busy hour to dimension their networks. To answer the question if the weekly traffic share can also be used to adjust traffic shares in

Table 4. Grouping customers per used Services (Values in fraction of total)

GPRS				UMTS			
Usage:	WAP only	WAP and Email	Internet	Usage:	WAP only	WAP and Email	Internet
Dec04	89.3%	9.3%	1.4%	Dec04	0.1%	1.4%	98.5%
Nov05	82.5%	5.5%	12.0%	Nov05	25.0%	1.6%	73.4%

a busy hour simulation, we split the traffic further into bins of two hours. The results for two sample days are presented in Figure 3 (note that the y axis has been rescaled by an undisclosed factor in order not to disclose absolute volumes). The shape of the curves shows the busy hour between 7 p.m and 9 p.m. The inspection of the volume shares for each bin reveals that the traffic composition is relatively stable with the time-of-day in the range 10 am to 9 pm, with fluctuations within 5% (note that during the night the traffic level is very low and some service disappear completely). We conclude that the daily volume statistics are representative of the peak hour composition.

4.2 Grouping per Service

We now grouped the users according to the services they used. Following [4] we defined the following three groups: *WAP only*, *WAP and Email* and *Internet Services (no WAP)*. Table 4 shows the relative numbers of users in each of the three groups for GPRS and UMTS in Dec04 and Nov05. The first group represents the vast majority in GPRS, users who only use a mobile phone to browse WAP pages, download ring tones, send MMS via WAP and so on. In Nov05 [resp. Dec04] these are 80% of the GPRS users [resp. 90%], but only generate 20% [resp. 37%] of the total traffic. This group accounted for 0.1% of the UMTS users in Dec04, but in Nov05 they raised to one quarter of the total UMTS population (despite still the share of WAP in around 1% in UMTS). This is consistent with the fact that in Dec04 most users active on UMTS were laptop datacard users. The second group is browsing WAP, transferring emails but does not has WEB traffic. In the last group there is no WAP traffic and mainly WEB volumes. This is presumably dominated by laptop datacards. This group grew in GPRS (from 1.4% to 12%), bearing the whole WEB traffic (50% of total). Note that the GPRS numbers for Dec04 are consistent with the result presented in [4] for a different provider.

Notably, the combined growth of the “Internet” group in GPRS and “WAP only” in UMTS results in the two user populations being less distant now than one year ago. This is also confirmed from the reduced differences between UMTS and GPRS in the total service shares (Figure 2). It is possible to conjecture that the introduction of EDGE in GPRS and the ongoing replacement of handheld terminals towards UMTS-capable devices are probably the driving forces behind such convergence.

4.3 Filtering spurious connections

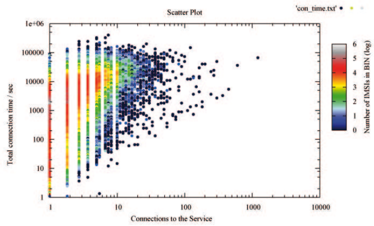
During the explorative analysis a large number of packets were directed to ports tcp:135 and tcp:445, mainly TCP SYN in the uplink direction. This is due to some self-propagating worms attached to some infected 3G terminals. The presence of such unwanted traffic should be expected since laptops with 3G datacards - often equipped with popular operating systems - coexist nowadays with handsets and smart-phones in the 3G network, and it is well-known that unwanted traffic is a steady component of the traffic in the wired networks since years (see for instance [5]). The detailed analysis of unwanted traffic and its impact on the 3G network will be covered in a following separate paper. Here is important that such traffic does not express user preference, and therefore we filtered it out before the analysis. The filtering rules were set heuristically as follows. For TCP we filtered out all connections with less than 2 packets in each directions (i.e., complete handshake plus one data packet). For UDP we filtered out all connections with less than 1 packet in each direction. The fraction of filtered packets was 3.4% (0.8%) in TCP and 2.1% (0.4%) in UDP in Dec04 (Nov05).

5 Analysis of the PDP-context activity

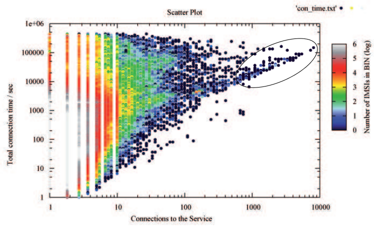
In this section we investigated the activity of each user at the level of PDP-contexts. The PDP-context in a GPRS/UMTS network is comparable to a dial-up process in wired networks: a user has to establish a PDP-context to transfer data via a mobile network (for more details see [6]). For this analysis we considered the Nov05 dataset.

5.1 Per-user activity

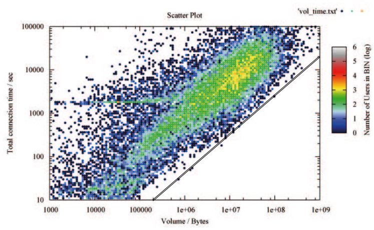
For each PDP-context j generated by MS i we extracted the total volume v_{ji} and the duration d_{ji}. For each MS i, we considered the following attributes: total number n_i of PDP-contexts, total transferred volume $s_i = \sum_{j=1}^{n_i} v_{ji}$ and total on-time $t_i = \sum_{j=1}^{n_i} d_{ji}$. Figure 4 shows scatter plots of these three attributes with logarithmic binning, separately for UMTS and GPRS. Each point represents the number of MS within each bin. In all plots there are boundaries due to admissible regions. The limit in Figures 4(a), 4(b) relates to the presence of a minimum value for the duration of a PDP-context, say d_{min}, which forces a user with n_i PDP-context to stay on-line for at least $s_i \geq n_i \times d_{min}$. In Figures 4(c), 4(d) the distribution is lower limited (marked by the line in the figures) by the maximum available bandwidth (cumulated uplink and downlink), which is 384 kbit/s and 85.6 kbit/s for UMTS and respectively for GPRS: the slope of the lower approaches these values, the difference being due to idle periods within each PDP-context. As expected the mass of the distribution for UMTS (Figure 4(c)) is shifted to the right compared to GPRS (Figure 4(d)) due to the higher bandwidth. The upper limit is due to the presence of a time-out for long inactive PDP-contexts.
In GPRS for $n_i > 200$ there is a linear cluster, with an average PDP-context duration around 12 sec (see circle). This is also visible in Figure 4(f) (see circle) indicating a constant size of the transferred volume within each PDP-context (around 1.7 kbytes). This is due to some automatic services, periodically activating short PDP-contexts (e.g every minute). Note that for UMTS only very few MS yield more than 200 PDP-contexts in the measurement window. Despite the MSs with $n_i > 200$ are a minor part of the total population (less than 0.1%), they generate a considerable fraction of all PDP-contexts (6.4% in UMTS and 33.6% in GPRS), accounting for ≈3% of the total volume. Interestingly 22.8% of the UMTS-users and 37.8% of the GPRS-users had only one PDP-context within the observation period.



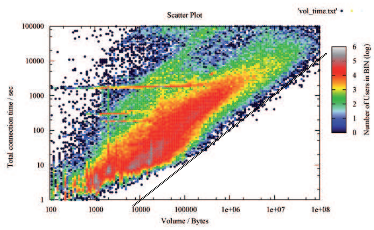
(a) t_i vs. n_i



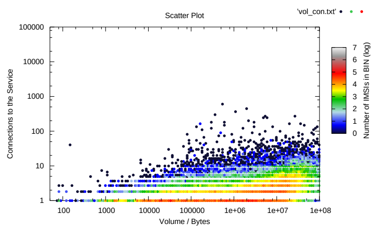
(b) t_i vs. n_i



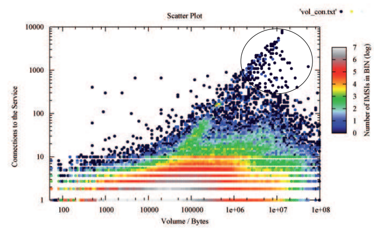
(c) t_i vs. s_i



(d) t_i vs. s_i



(e) n_i vs. s_i



(f) n_i vs. s_i

Fig. 4. Logaritmic Scatter Plots of per-MS activity attributes: Number of PDP-Contexts (n_i), Total ON-time (t_i) and Total Volume (s_i): UMTS (left), GPRS (right).

5.2 Distribution of PDP-context duration

Based on the high dispersion of n_i revealed by Figure 5, we know that a simple PDF of d_{ji} would be biased by those few users with a very high number of PDP-contexts. These are likely due to automatic periodic access to some custom service, with an intrinsically different behavior from other users. We therefore decided to classify the users into two main groups based on the total number of PDP-contexts and an arbitrary boundary value set to n_i =200. The CDF of the PDP-context duration for each group is shown in Figure 5. The curves for the group with $n_i \leq 200$ fit Weibull functions with parameters $(188.5; 0.37)$ for GPRS and $(936.0; 0.49)$ for UMTS. Note that the duration of PDP-contexts is larger in UMTS than in GPRS. For the group with n_i >200 the curves show strong discrete steps, which is consistent with the hypothesis of automatically generated procedures. In those applications where it is required to reproduce traffic patterns from this sub-population it might be useful to have a closed form representation of the empirical distribution. This can be approximated by a combination of discrete

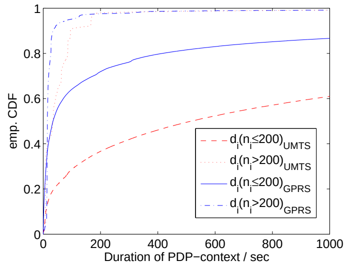


Fig. 5. Empirical CDF of PDP-context Duration

steps and a fitted curve of the residual PDP-contexts, with parameters extracted from the measurements. However we remark that such patterns are highly service-specific, and highly volatile due to the relative small number of involved MSs: for instance the introduction of a new service or simply a parameter change (e.g. a time-out) can have a major impact on the overall PDP-context pattern.

6 Related works

Regarding the service shares there are several papers showing results from measurements in mobile networks, but they are limited to GPRS. In [4] and [7] traffic on the Gn interface was recorded. The dataset was correlated with RADIUS messages to evaluate the service usage in the GPRS network at the PDP-context level. The observation periods were respectively 32 and 24 days recorded by a mobile operator in Hungary in beginning 2004. The results presented there show a smaller share of WEB traffic, likely due to the absence of laptop datacards at that time. In [8] more recent data is presented (end 2004). The recorded interface was Gb. The observation period was from 11 a.m to 4 p.m. on ten consecutive days. There are results for the fraction of volumes transferred with UDP and TCP, which match with our records, but no detailed information on the volume per service. There are also older publications covering certain specific services, mainly WAP (e.g. [9], [10]). The only other work presenting statistics about PDP-contexts in GPRS was the technical report [4]. To the best of our knowledge no previous paper so far has reported measurement results about the traffic composition in a real UMTS network.

7 Conclusions and Future Work

In this paper we have presented measurement results from an operational GPRS/UMTS network. We provided insight into aspects like traffic composition, per-user traffic distribution and per-user activity at the PDP-context level. We found that the global traffic composition is relatively stable on a daily basis, with some moderate differences between weekends and working days. We found a large variability in the weekly traffic per user, with distributions spanning five orders of magnitude and most of the volume concentrated on a small fraction of heavy-users. The inspection of the per-user activity at the PDP-context level held similar findings: the total user on-time spans several orders of magnitude. In GPRS most of the PDP-contexts are generated by a minor fraction of terminals, likely automated terminals with periodic PDP-context activations.

These aspects should be carefully considered when trying to reproduce synthetically the network-wide environment. More specifically, they challenge the practicality of adopting the concept of a representative "average user" in synthetic simulations.

In this work we have moved the first steps to wards the classification of separate user groups, based on the degree of activity and of the accessed services. In the continuation of this work we will try to zoom-in on the user behavior of some specific classes of users. For instance, based on our traces it would be interesting to directly compare the patterns of WEB traffic found in the 3G network with those found in the wired Internet (e.g. following the procedure developed in [11]).

The ongoing refinement of the monitoring system will soon make it possible the direct discrimination of the terminal type (laptop datacards, smart-phones, etc.) based on the the TAC code included in the IMEI identifier. This will allow the exact analysis of traffic based on terminal type.

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References

1. METAWIN Project. `http://www.ftw.at/ftw/research/projects/`. FTW.
2. Gunnar Heine. *GPRS - signaling & protocol analysis*. Inacon, 2002.
3. H. Holma and A. Toskala. Wcdma for umts, radio access for third generation mobile communications, third edition. *John Wiley & Sons, Ltd.*, 2004.
4. Kaldena, Varga, Woutersc, and Sandersd. Wireless service usage and traffic characteristics in gprs networks. Technical report, Technical Report Vodafone, 2004.
5. R. Pang et al. Characteristics of Internet Background Radiation. *Proc. of the International Measurements Conference (IMC'04), Taormina, Sicily, Italy.*, October 2004.
6. TS 23.060. *General Packet Radio Service (GPRS), Service description*. ETSI/3GPP.
7. T. Varga, H. Bert, and B. Sanders. Analysis and modelling of wap traffic in gprs networks. *ITCSS 04 Antwerpen*, pages 122–129, 2004.
8. H. Dahmouni, D. Rosse, B. Morin, and S. Vaton. Impact of traffic composition on gprs performance. *ITC 19th*, pages 1405–1409, 2005.
9. P. Stuckmann and H. Finck. A wap traffic model and its appliance for the performance analysis of wap over gprs. *Proceedings of the IEEE International Conference on Third Generation Wireless and Beyond*, pages 338–343, June 2001.
10. P. Stuckmann and C. Hoymann. Performance evaluation of wap-based applications over gprs. *Communications, 2002. ICC 2002. IEEE International Conference*, 5:3356–3360, 2002.
11. A. Bianco et al. Web user session characterization via clustering techniques. *IEEE GLOBECOM*, 2005.