A survey on 3G mobile network traffic performance and analysis in Ethiopia

Fanuel Melak Asmare¹*, Fekadu Mihret Geremew¹ and Lijaddis Getnet Ayalew¹

Abstract: Mobile phones have an impact on the economic development of a country as the technology develops through the provision of high-value 3G and 4G data services accessed via smartphones, tablets, and dongles that deliver mobile data services to businesses and consumers. To be able to fully utilize the resources and to focus on service provision and faster troubleshooting, traffic analysis for the optimization process is of paramount importance. High-quality traces obtained can further be exploited to predict the network load and the network configuration. This can intern be used in re-optimization and other engineering tasks for further improvement of the whole 3G network performance. In this work, 3G packet-switched network traffic had been analyzed based on selected performance indicators. The analysis had compared two 3G radio technologies with respect to cellular mode, time, and geographical locations.

Subjects: Communication Networks & Systems; Digital & Wireless Communication; Telecommunications

Keywords: throughput; delay; jitter; QoS; KPI; 3G; HSDPA; HSUPA

1. Introduction

3G represents one of the biggest opportunities the business world has ever seen, increasing the potential of mobile Internet and opening up new revenue streams. In 3G networks, mobile phones have become mobile devices combining a camera, video camera, computer, stereo, MP3 player,
and radio into one device. Rich-media information and entertainment are available at any time whenever there is a wireless network.

As the popularity of cellular networks grows explosively, it is increasingly important to develop an in-depth understanding of the characteristics of cellular traffic and performance. Thus, there must be a continuous task of analyzing 3G traffic and finding conditions to better optimize the existing deployed network to maintain the network system stability and availability.

The current cellular network in Ethiopia including 3G traffic experiences a lot of performance issues. Service interruptions are very frequent both in congested and rural areas, service unavailability is very common even in the middle of big cities, delays are sometimes too big, quality of service (QOS) issues are still a major concern in many parts of Ethiopia and so many other macro and micro factors are not very rare. Finding the major problems by analyzing and studying the network traffic to understand the important characteristics of the available network is of paramount value to solve the problems and optimize the whole network.

The importance of cellular network performance has attracted significant work. A considerable amount of work has been done on cellular traffic characterization and traffic performance in terms of traffic volume (Falaki et al., 2010), diversity (Falaki et al., 2010; Shepard et al., 2010), network performance (Kilpi & Lassila, 2006; Mattar et al., 2007; Romirer-Mairohofer et al., 2010; Shafiq et al., 2013), temporal and spatial variation (Paul et al., 2011; Shafiq et al., 2012). Similar studies have been undertaken in other countries and contribute solutions to the network under study. In China, for example, the analysis of 3G traffic performance shows important characteristics of the networks’ diversity (Hu et al., 2015), whereas in (Laiho et al., 2005) in-depth analysis of 3G traffic has been taken and advanced optimization methods have been proposed. There are quite a few numbers of similar papers published in different magazines and journals.

From the aforementioned descriptions, it is clear that a lot of significant work has been done. But, those detailed studies have been carried out in the US, Asia, and Europe, and they don’t have a direct impact on the Ethiopian scenario since traffic data vary from country to country. This work aims to bridge this gap and provide useful and detailed analysis on cellular traffic specifically on 3G networks. On this keynote, one-month (30 days) 3G traffic data were collected from major cities in Ethiopia such as Addis Ababa, Bahir Dar, Gondor Dessie, and Mekele. Since the current 3G architecture is designed based on all-IP concept following the traffic demand, which is inclined heavily towards data traffic, in this work much attention has been given to packet-switched (PS) networks.

2. Overview of performance indicators
For telecom operators, it is still a major challenge to identify the kind of data to monitor to improve both business profit and customer satisfaction. Service providers are trying to fine-tune these issues based on their key business objectives by predominately monitoring technical matters emphasizing financial issues. To quantify such matters, Key Performance Indicators (KPIs) evolved. According to the International Telecommunication Union (ITU-T) model (Wetmore et al., 2005), the KPI stems from broad key business objectives, which are mainly focused on cost reduction, profitability, and improving customer experience. These objectives constitute key performance objectives under it, which include technical objectives that can be quantifiably measured such as availability, reliability, QoS, network outage impact reduction, security, integrity, and so on as a second layer. The third layer in ITU-T’s quality model is KPIs which are detailed indicators measured in real-time that are measurable and support directly the key business objectives via key performance objectives (ITU-T E.800, 1988). In this survey, parameters that assess service/resource availability, service continuity, QoS and network performance indicators (Throughput, Call Setup Success Rate (CSSR), Dropped Call Rate (DCR), Soft Handover Success Rate (SHOSR), Latency (Delay) and Jitter) have been used for analysis (ITU-T E.800, 1988).
3. Service degradations in a mobile network
A certain degradation might be caused by different scenarios and thus it is difficult to link them to a specific cause. Hereafter are presented the degradations that can be encountered on a mobile network that is related to our interest (Donegan, 2013).

3.1. QoS problems linked to availability of the service
Degradations in this scenario include link failure, identification failure, and white call. If such failures occurred, the customer is not able to perform a successful call (Donegan, 2013).

3.2. QoS problems linked to service continuity
Call drop belongs to this group. There are several reasons for a call to be dropped, link failure: system failure, bad re-negotiation between two pieces of equipment of the network during a call and device bug, bad coverage area, handover failures due to cells neighborhood problem, etc. are to mention a few. In this scenario, the call is ended before any action from the customer or the service platform (Donegan, 2013).

3.3. QoS problem linked to network performance
Internet Protocol (IP)/Real-Time Protocol (RTP) packet loss and jitter due to congestion and buffer adoption problem; radio degradations due to interference, uncovered area due to obstacles, and bad optimization and handover latency are the sources of degradations in this group. These degradations, which are specific to the network mainly lead to audio degradation from the customer point of view: mainly chopped conversation, lack of interactivity, or distortion of speech (Donegan, 2013).

4. Results and discussion

4.1. Key performance indicators
The measurement results had been collected by inserting probes before the Radio Network Controllers (RNC) in the IUB interface as well as by taking stored results measured at the IU interface, an interface between RNC and media gateways and Serving GPRS Support Node (SGSN), using network management system’s operations system support (OSS) as shown in Fig. 1 below. Two radio technologies, High-Speed Downlink Packet Access (HSDPA) and High-speed Uplink Packet Access (HSUPA) were measured since these two are the ones that dominate Ethio-Telecom’s (ET) PS network.

The areas under analysis were Addis Ababa and four other major cities of Ethiopia such as Bahir Dar, Gondor, Dessie, and Mekele, and one-month data were collected from those cities since the aim is to evaluate the variability and dependency of the network performance on time and geographical locations for different 3G variants.

Figure 1. 3G network architecture.
The collected data were divided into two groups. One is the Addis Ababa region, which has almost as much data volume as other cities combined. This region is subdivided into five zones in order to see finely detailed results. These zones are SAAZ (south Addis Ababa zone), WAAZ (west Addis Ababa zone), CAAZ (central Addis Ababa zone), NAAZ (North Addis Ababa zone), and EAAZ (East Addis Ababa zone).

**Throughput:** Figures 2–5 show the results of the mean throughput of the test sites. It is observed that the overall throughput in all of the cities is very low.

Considering the peak achievable user data rates of HSDPA and HSUPA, which are greater than 1Mbps and 384Kbps respectively (Anwar & Li, 2008), only a few subscribers could surpass the measured throughput. This may be related to few number of PS network subscribers in Ethiopia. Figure 3 shows the proportionality of the HSDPA mean throughput recorded in cluster-1 areas. The highest HSDPA throughput was only an average of about 2Mbps in SAAZ followed closely by NAAZ and the lowest in this group is SAAZ, which is only about 1.6Mbps average. As it can be seen from Figure 2, HSDPA throughput recorded in cities outside of AA gets even worse. The throughput recorded in Gondar is the least with an average of 1.1Mbps while Bahir Dar with 1.4Mbps is the better throughput in the group.

The same trend is shown in Figures 4 and 5 for HSUPA traffic of cluster 1 and cluster 2, respectively. From cluster 1, the highest throughput was recorded by SAAZ, which is around 400Kbps and the lowest with 250Kbps is again in WAAZ. Whereas the throughput recorded in Gondar is the least with an average of 170Kbps and Mekelle with 200Kbps gets better throughput. It can be noticed that measurement in group 2 is far less when compared to group 1 even from the least, WAAZ. ET should work on promoting 3G services to its customers, and more work is needed in group 2.

There are a few possible solutions to increase throughput. Considering carriers, the number and used strategy could be modified to increase throughput. For example, we can have two carriers (F1 & F2) for all services. Or we could assign an F1 carrier for all services (voice, R99, HSDPA & HSUPA) and F2 for HSDPA & HSUPA only. These will in turn decrease handover between the carriers, which results in improving throughput. In Ethio-Telecom, the number of carriers used varies from two to five depending on the services areas and most of the carriers at this time are serving the R99. This may be the result of a high number of legacy mobile phone users. Promoting smartphone usage could be a potential solution. To further reduce the handover, decreasing inter-RAT (radio access technologies) neighbors is another measure we can take. This kind of neighbor uses CM (compression mode) therefore affecting the power. Handover reduction results in HSDPA/HSUPA throughput improvement.
A high number of mobile users in the overlap cell regions is also a potential problem since high handover is the characteristic of such areas.

Another possible cause is HSDPA/HSUPA scheduling algorithm. “Round robin” fashion, where each user is served no matter the RF conditions is the common option in the Ethiopian scenario. This might be good for users at the edge of the cell but it certainly affects cell throughput. “Proportional Fair” is a better option in this regard. In this scheduling algorithm, the RF
Conditions are evaluated, and users with better RF conditions are served more often—making cell throughput higher (compared to Round Robin).

**DCR:** The call drop ratio is also analyzed for separating HSDPA and HSUPA technologies, as we did for throughput. According to ET standard (adopted from 3rd Generation Partnership Project (3GPP)), the threshold for DCR is 2%. i.e. interruption is tolerable up to only a maximum of 2% of all the services. When we say service, we mean any kind of service including voice call, data, or multimedia. In this scenario, we can see from Figures 6–9 that DCR in every test site is within the threshold. Figures 6 and 7 shows that the maximum DCR in group 1 was 0.35% for both HSDPA and HSUPA, which is very much less than the threshold. As it can be seen from Figures 8 and 9, DCR records in group 2 are also less than the threshold value but when compared to group 1 much calls were dropped. It is evident from the plots that a maximum of 1.2% and 1.5% DCR have been observed from HSDPA and HSUPA, respectively, in Mekelle.

**CSSR:** The threshold for CSSR is 98% from ET standards. As it can be seen from Figures 10–11, except for EAAZ in the first week, all CSSR records are below the threshold. NAAZ shows the worst case in group 1 which goes as minimum as 93%. Even though Group 1 shows low results, it doesn’t
come close to any one of group 2. All of the cities in group 2 suffer from a lot of unsuccessful calls with the worst being Dessie, which recorded a CSSR of less than 84% except in one scenario where Mekelle scored the lowest of all, with about only a 75% success rate. This result matches with the original problem statement that too many calls have been dropped both during call time as well even before a successful call is established.

To improve CSSR, we have to check the following parameters. First of all, we have to make sure that there are no blocking resources, code, power, CE (channel element), and IUB (interface between RNC & node B). If there is any blocking in these resources, optimization process should be initiated. The next option is we have to make sure there are no hardware issues. Hardware issues or wrong installation can be impacted by low CSSR such as bad connector installation. This is a major problem in Ethiopia since power interruption is frequent and stays off for a long time, which decreases the battery life. Using solar power could help in this regard. We have to make sure that there is no such hardware problem to make our CSSR good. Next, we have to make sure that there is no overshooting coverage. We need to make sure that there is no overshooting or coverage overlap to get better CSSR.

**SHOSR:** Another important key performance indicator is the soft handover success rate. From the standards endorsed by ET, the threshold for SHOSR is 98%. It is clear from the results shown in

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Figure 8. HSDPA DCR recorded in group 2 including the worst from group 1, SAAZ.

Figure 9. HSUPA CDR recorded in group 2 including the worst from group 1, SAAZ.
Figure 10. Group 1 CSSR.

Figure 11. Group 2 CSSR including the worst-case from group 1, CAAZ.

Figure 12. Group 2 SHOSR including SAAZ from group 1.
Figures 12 and 13 that all of the test cases experience a good handover success rate, which is more than the threshold value.

5. Quality of service parameters
To get a better overview of this matter, we have sent more than 90000 “PING” messages through the network in Addis Ababa (Group 1). We have recorded parameters such as maximum delay, mean delay, maximum jitter and to test the general effectiveness of the network we also record the percentage of successful ping attempts.

**Delay:** Callers usually notice roundtrip voice delays of 150 ms or more. The human ear can detect about 250 ms latencies, 200 ms for sensitive people. If that threshold is not met, the communication returns annoying (Carvalho & Magedanz, 2009).

It is observed from the ping result of Figure 15 that the mean delay is less than 200 ms with a one peak maximum of 163 ms measured in EAAZ. But, when we consider the maximum delay, Figure 14 we have observed a few pings delayed up to around 4.8 seconds which is disrupting. We can also observe several instances where the maximum delay exceeded the threshold. These may be one of the reasons for service interruption. However, the overall delay scenario is considered safe since only a few pings experience such delays.

**Jitter:** Jitter between the starting and final point of the communication should be less than 100 ms. If the jitter value is smaller than 100 ms it can be solved using jitter buffers. If this is not the case, it must be reduced to an acceptable level.
We can observe from the result in Figure 16 that the jitter value is almost below the threshold except for a few instances. Those instances could be occurred due to line interruption at that moment. But when we assess the overall result, the jitter problem can be solved by putting a suitable amount of jitter buffer without sacrificing the network speed.

**Maximum PING Lost:** Finally, we have evaluated how many percentages of ping packets have been lost so that we could have a rough picture of the chance of voice and data packets’ successful arrival to their destination.

As it can be seen from Figure 17, in many of the tests less than 1% of the packets have been lost except in a few instances that we observe up to a maximum of 5%. This result may be tolerable for normal voice services, but for high data rates and high-resolution applications the outcome shows a seriously degraded quality of the service.

**6. Conclusion**

In this comprehensive survey, the 3G network traffic performance characteristics have been assessed. The performances of the standard High-Speed Downlink Packet Access (HSDPA) and High-speed Uplink Packet Access (HSUPA) have been analyzed for different scenarios of the user, time, and geographical locations. The data were collected and compiled from Ethio-Telecom. The results of the performance analyses have covered the basic expected operational conditions. Besides, the analysis has provided an understanding of the general performance parameters in comparison to the real outcomes.
The result has established a good starting point for further study of the performance of 3G network traffic. It has shown that the throughput is too low which indicates the number of users of 3G service is few and this should be dealt with considering the impact that data services alone could increase the gross domestic product (GDP) of one country, as separate studies had revealed. Even though the call drop rate and the soft handover success rate are in good condition, this might be connected to fewer subscribers. Increasing the number of 3G users might be the main issue for ET, but the current very low call setup success rate may be an obstacle. The CSSR is as low as 75% from the threshold value of 98% success rate, which results from an unacceptable amount of call trials for customers.

The result has also revealed that on certain conditions the delay experienced is huge, which makes VOIP services unintelligible, even though the number of instances with large delays is not frequent. When the number of subscribers increases, this might be a bottleneck for real-time applications.

Network load is higher in Addis Ababa compared to other cities under survey, which has contributed to better throughput. This is typical in developing countries where a majority of 3G subscribers reside. Thus, in such areas, increasing the bandwidth is a good option to increase throughput. Most importantly, hardware issues, which include power interruptions and fiber cuts reduce the CSSR as well as the whole network performance in general.

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