

On the Impact of 2G and 3G Network Usage for Mobile Phones' Battery Life

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Abstract—Over the last years mobile phones had a remarkable evolution. From a simple device for voice communication, it became a full blown multimedia device with multiple features and appealing services. In parallel with the introduction of novel services, mobile devices became more and more energy-hungry reducing the operational time for the user. To extend the battery life of mobile phones is one of the top priorities for mobile phones' manufacturers. This paper presents results of power and energy consumption measurements conducted on mobile phones for 2G and 3G networks. The services under investigation were text messaging, voice and data. The paper reports larger energy consumption in 3G networks for text messaging and voice services than energy consumption in 2G networks. On the other side the 3G networks become more energy friendly when large volumes of data have to be downloaded. The results imply that mobile phones should switch the network in dependency of the service used to save the maximum amount of energy. As this handover consumes energy, we include its analysis in our measurements.

I. INTRODUCTION

The evolution of mobile phones in the last decade has been remarkable. In less than ten years the mobile phones, starting with voice services and text messaging, became real multimedia devices. This evolution is based on Moore's Law. According to Moore's Law, the number of transistors that can be inexpensively placed on an integrated circuit is doubling every 18 months. Over the last years mobile phones have been provided with better hardware and are becoming more powerful day by day. Music and video players, in-built GPS receivers, high data rate for Internet connection, short range communication technology (WLAN, Bluetooth, Near Field Communication), high resolution cameras are just a few examples of what smart-phones can offer. Many services have been created using these technologies, for example multi player games, location based services (LBS), mobile social networks, mobile banking, mobile web browsing, mobile VoIP. Moreover several applications have been developed to access these services such as *Fring* (a mobile client for VoIP), *ebuddy* (a mobile web messenger to interact with MSN, Yahoo, Google Talk, MySpace and AIM communities), *aka-aki* (a social network application), *The journey* (a mobile location based game) and so on. All these applications and services are using the wireless air interfaces of the phone for communicating. In Figure 1 power consumption for different mobile services is shown. It is clear from the plot that all the capabilities that imply the use of a wireless air interfaces are power-hungry, thus significantly reducing the battery life of the phone.

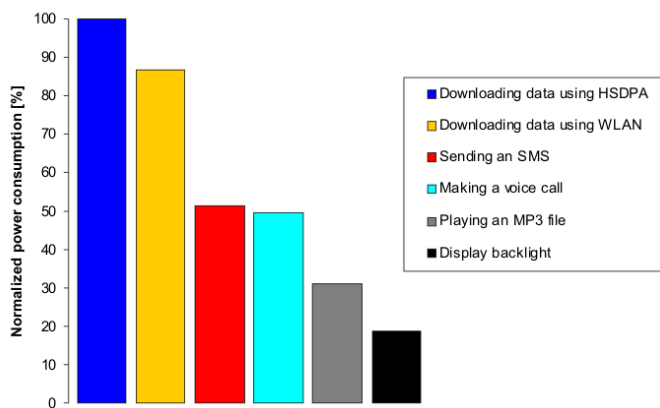


Fig. 1. Power consumption for different phone's services normalized to the power consumption needed for downloading data using HSDPA.

This is a problem that mobile phones' manufacturers have to face because unfortunately not all aspects of computing technology develop according to Moore's law, and one of these is the battery. Most mobile phones are powered by lithium-ion batteries. These batteries are popular because they can offer many times the energy of other types of batteries in a fraction of the space. In the current state of the art, chemists cannot sufficiently increase the amount of energy created by the chemical reactions. At the moment the only way to create more powerful batteries is to make them larger. However this does not well match with the evolution of the mobile terminals which tend to have less room available for the battery in order to accommodate additional components and technologies. Many attempts have been made to extend the battery life without renouncing to use the services that 3G phones offer. For example authors in [5] show the benefit of cooperation among mobile devices willing to share their wireless resources. Cooperation allows to reduce the energy consumption of mobile devices and at the same time to increase the quality of some services, such as file streaming or file downloading, as well as web browsing. Moreover authors in [8] describe another efficient way of saving energy in mobile VoIP. Instead of having a data connection open with WLAN when waiting for an incoming VoIP call, they suggest to use the GSM network as a wake-up signalling channel when the connection to the SIP server is needed.

To find the right strategy to save energy, knowledge of the amount of energy spent in every single action performed by the mobile phone is needed. We have made an energy measurement campaign on a commercial mobile phone, the Nokia N95. In this paper we present several results to show the impact of 2G and 3G networks on the energy consumption of the mobile device focusing on voice services, Short Message Service (SMS) and data connection. In Section II a motivation for this work is given. In Section III the testbed used for the measurements is described and the results of measurements for voice, SMS and data connection are presented and discussed in Section IV.

II. MOTIVATION

3G phones offer better services compared to 2G phones, especially regarding bit rate when downloading or uploading data. Moreover they can support data and voice traffic at the same time allowing video calls, for example. However, use of data services is only slowly becoming more widespread, and many costumers still use their phone mainly for voice and Short Message Service (SMS) and in a small portion for data services. Moreover, many areas still have limited 3G coverage and the phone continuously makes hand-offs from 2G to 3G network and viceversa as the mobile phones moves into and out of 3G coverage. Therefore being connected to a 3G network, especially when no data transmission is needed, has an high cost in terms of energy consumption. In this paper we present the results of the measurements made for the most widely used services, namely SMS, voice and data services. SMS is one of the most remarkable success stories in the world of data communication. Already in January 2007 the number of active users of SMS text messaging exceeded two billion. The first SMS typed on a GSM phone was sent in late 1993. The initial growth was slow, but it had an incredible boost over the years. GSM Association reported that in the first three months 2001 more than 50 billion SMS were sent over the world's GSM networks. In November 2007 Gartner [7] forecasted 2.3 trillion messages will be sent across major markets worldwide in 2008, a 19.6% increase from 2007. The SMS technology has facilitated the development of text messaging. The connection between the text messaging and the SMS technology is so strong that for many users SMS is used as a synonym for a text message. Given this huge number of text messages exchanged in the world, it is important to know the amount of energy spent to send them. In Section IV-A the results of the measurements for sending SMS of different size, and different received signal strength are presented.

The other very common service for mobile users is voice and one of the information that phone manufactures give in the specification of the device is the duration of the battery in standby and talking time. Actually this is one of the most important factors for people to choose a new phone.

As an example we cite the iPhone 3G. The battery life in talking time is shorter if the iPhone is connected to 3G networks (5 hours on 3G and 10 hours on 2G) as reported in the official website. Moreover, Apple suggests to its costumers some tips to save energy and make the battery last longer [1].

As shown in Figure 2, the first tip in the list reads: *"Using 3G cellular networks loads data faster, but may also decrease battery life, especially in areas with limited 3G coverage"*. In section IV-B we will show the results of the measurements

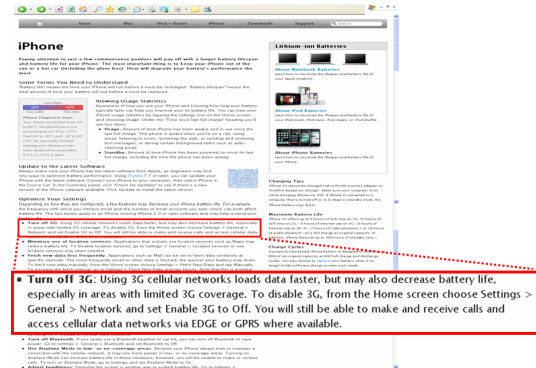


Fig. 2. Web page of the Apple iPhone 3G.

done for the voice service over both GSM and UMTS networks with the testbed described in Section III.

III. MEASUREMENTS TESTBED

The smartphone used for the measurements is a Nokia N95 [2] which is running Symbian OS as operating system. When making the measurements, we used scripts to control the phone. This allowed us to measure the consumption without interacting directly with the phone, avoiding to press keys and to have the backlight of the display turned on, which could lead to unprecise results. We used Python for S60 [10], [9] as programming language to develop the scripts for testing. We observe that there is no significant penalty in terms of energy and performance by using the Python environment compared to standard Symbian/C++ for the energy levels we deal with throughout this paper. The choice of the mentioned commercial device is due to several reasons. First of all it is a 3G phone and secondly it is able to run the in-built energy profiler [4] developed by Nokia. The Nokia Energy Profiler is an application running on the mobile device that allows to make measurements without any additional hardware. It provides the values for power, current, temperature, signal strength and CPU usage. To further check the correctness of the data measured by the energy profiler on the phone, the complete setup includes the AGILENT 66319D used as multimeter as shown in Figure 3. It is connected to a PC which is running the Agilent 14565B device characterization software, a tool designed for evaluation of portable battery powered device current profiles.

We have compared results obtained with the energy profiler with the ones obtained with the Agilent 66319D. Figure 4 shows that the two plots match almost perfectly with each other proving that data given by the Nokia Energy Profiler reliable.

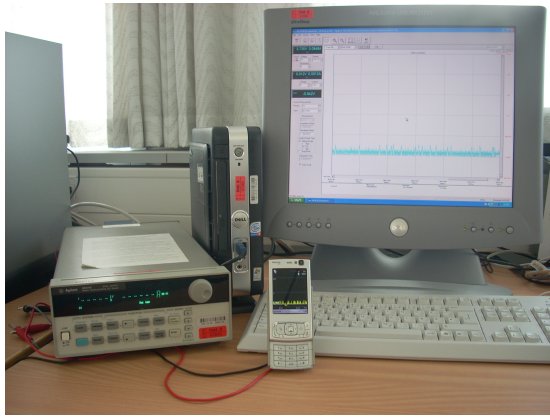


Fig. 3. Setup for the measurements. The Nokia N95 connected to the AGILENT 66319D equipment.

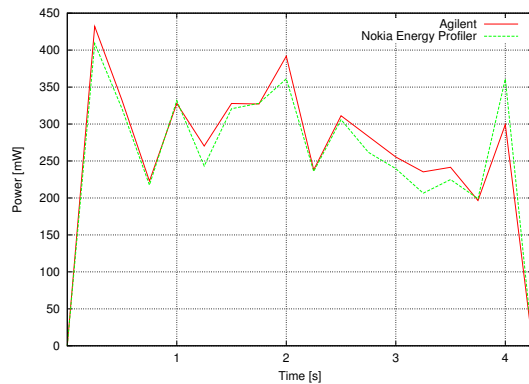


Fig. 4. Comparison of data obtained with the Nokia Energy Profiler and the Agilent 66319D while sending an SMS.

IV. RESULTS AND DISCUSSION

We now present the results of measurements for energy consumption made for SMS, voice and data services.

A. SMS

Text messages sent by using SMS can be encoded in different ways: the default GSM 7-bit alphabet, the 8-bit data alphabet, and the 16-bit UTF-16/UCS-2 alphabet. Depending on which alphabet the text is coded with, the maximum size per SMS is 160 7-bit characters, 140 8-bit characters, or 70 16-bit characters. It is possible to send longer texts by concatenating more messages with each other. Figure 5 shows the results of measurements done by sending messages of different sizes to evaluate how energy consumption is related to the length of the text. The messages were sent using both GSM and UMTS with a SIM card from TeliaSonera in Oulu, Finland.

We have sent 50 messages for each size and then plotted the average value of the energy spent. The phone was in the same position for all the measurements to have the smallest variation possible in the received signal strength. The plot clearly shows that the energy consumption increases linearly with the length of the message. The messages sent were 8-bit encoded, therefore it is possible to see some jumps up in the energy

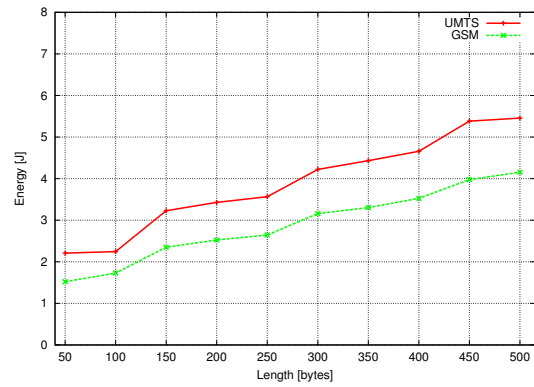


Fig. 5. Energy spent for sending text messages with different length.

consumption when two messages are concatenated, such as between 100-150, 250-300, and 400-450. It is interesting to notice that given a fixed length, sending an SMS using 3G is always more energy consuming than using GSM. The gap varies from 0.6 to 1.4 Joule. Another interesting relation exists between length of the messages and time needed for sending them. Figure 6 shows that the time increases with the growth of the size of the message and that the overall time needed is greater with GSM than with 3G. Moreover the gap between the two technologies increases linearly with the length of the text.

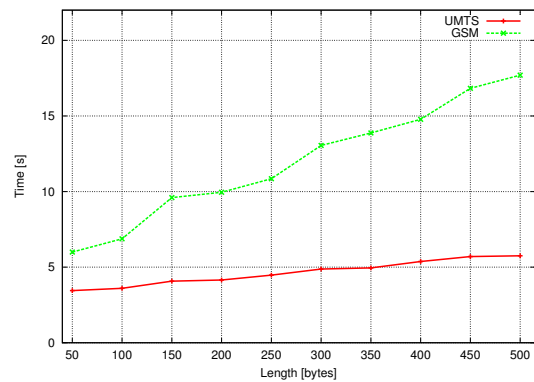


Fig. 6. Time spent for sending text messages with different length using both GSM and UMTS.

Authors in [6] have shown the benefit of using compression to save energy when sending short messages on mobile phones using SMS. The energy spent for compressing and decompressing messages is much less than the gain obtained by sending less data. Some software [3] is already available for downloading which is able to compress and decompress text messages. By using such a software, the energy for sending text messages can be reduced by up to 40%, depending on the compression level.

The plot in Figure 7 shows that the power level for GSM does not vary too much when the size of the text increases, whereas in the 3G case, it grows linearly with the length of the SMS.

Another factor which influences the power, the time, and therefore the energy, is the received signal strength. As shown

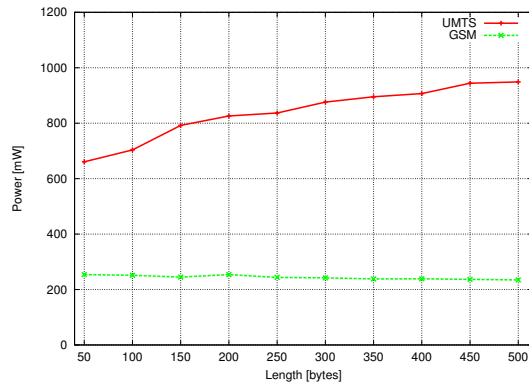


Fig. 7. Power values for sending SMS of different size using both GSM and UMTS.

in Figure 8 for both GSM and 3G, when the power of the received signal decreases, the time needed for sending the SMS increases.

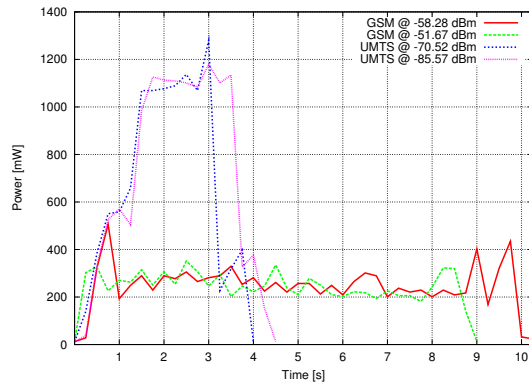


Fig. 8. Power traces for sending 200 bytes using UMTS and GSM networks. The plot shows two traces for each network with different received signal strength.

As shown in Figure 9 the power levels increase as well when the received signal strength decreases and therefore, more energy is needed when the signal is weaker.

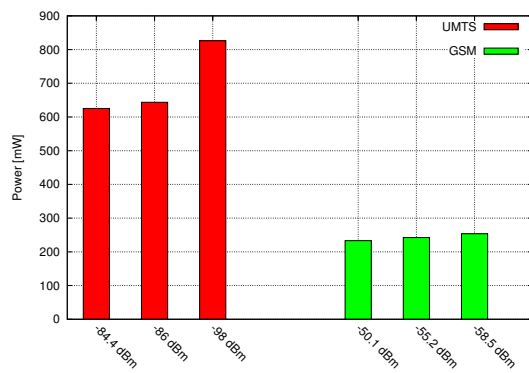


Fig. 9. Mean power level for sending 200 bytes using UMTS and GSM. The plot shows histograms for different values of received signal strength.

TABLE I
POWER CONSUMPTION FOR A NOKIA N95 IN DIFFERENT SCENARIOS OF VOICE SERVICE.

Scenario	GSM	UMTS
Receiving a voice call	612.7 mW	1224.3 mW
Making a voice call	683.6 mW	1265.7 mW
Idle mode	15.1 mW	25.3 mW

TABLE II
EXAMPLES OF ENERGY SAVINGS BY USING GSM INSTEAD OF UMTS FOR DIFFERENT SCENARIOS.

Scenario	Time [hour]	Energy saved [J]
Idle mode	8	220
Making voice calls	1	2095

B. Voice

As mentioned in Section II the battery duration of mobile phones highly depends whether they are connected to GSM or 3G networks. In Table I are shown the values for power consumption on a Nokia N95 for both GSM and UMTS using the voice service, carried out with the testbed described in Section III. The power values for the calls have been obtained by making and receiving a phone call of five minutes duration and calculating the average of the power levels. The power consumption during the idle time has been calculating averaging the power levels over eight hours of idle mode. All these tests have been performed using a SIM card from Sonofon in Aalborg, Denmark. The results show that making a call using GSM costs 46% less energy and receiving a call costs 50% less energy than using UMTS. Being idle while connected to a GSM network costs 41% less than UMTS. To give an idea of the amount of energy that can be saved by using GSM instead of UMTS for voice services, in Table II some examples are given. They show the substantial amount of energy that could be saved and used for other tasks. For example making a one hour voice call with GSM instead of UMTS, would allow to send more than 1000 text messages of 100 bytes.

C. Data connection

From a user perspective, it makes more sense to be all the time connected to the GSM network and switch to 3G only if data connection is needed. In fact the energy saved while using SMS or voice services can be used for other services offered by the 3G phones, such as Internet connection, VoIP, media and entertainment. On-demand use of 2G and 3G networks depending on the requested service, requires including this cost in the energy analysis. The results are shown in Table III and are obtained by averaging the values of 10 handoffs.

Figure 10 shows the plot of the mean values of energy per bit spent for downloading 500 KB of data for different data rates. When the phone is connected to the GSM network, the technology used for downloading is GPRS. In contrast, when connected to the UMTS network, HSDPA was used for downloading data. The plot shows clearly that the energy per bit decreases with the increase of the data rate for both data

TABLE III
DURATION, POWER AND ENERGY CONSUMPTION FOR MAKING HANDOFFS FROM GSM TO UMTS AND VICEVERSA USING A NOKIA N95.

Handoff	Power [mW]	Time [s]	Energy [J]
GSM → UMTS	1389.5	1,7	2,4
UMTS → GSM	591.9	4,2	2,5

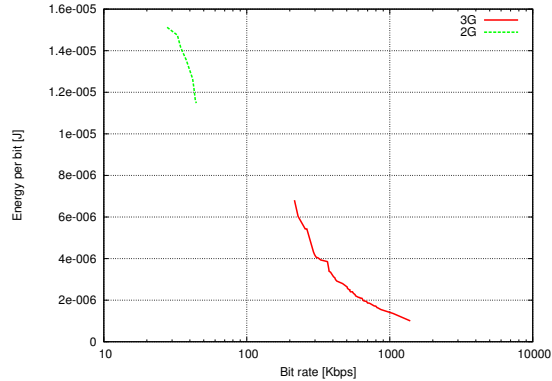


Fig. 10. Energy per bit spent for different data rates when downloading a file of 500 KB on both GSM (GPRS) and UMTS (HSDPA) networks.

connections. Furthermore, the amount of energy per bit spent for data download when connected to the UMTS network is significantly smaller than the one needed if using GPRS.

To give a better overview of the results presented, we give now an example of energy consumption for a monthly usage of mobile services. Let us consider a scenario where a user sends 50 SMS of 100 bytes, downloads 100 Mbytes of data, makes five hours of voice calls and 50 handoffs (only in case of the intelligent switching) per month. In Table IV we show the values for the energy consumed in that specific scenario by using 2G alone, 3G alone and the intelligent switching between the networks. The table provides a clear overview of the impact that different services have on the energy consumption. Furthermore it shows the significant reduction in terms of energy when using the intelligent switching.

V. CONCLUSIONS

Mobile phones have appealing services and features which unfortunately drain a lot of the energy stored in a capacity limited battery. It is a common problem among phones manufacturers to find a way to extend battery life of their devices and allow users to use mobile services for a longer time. Furthermore network operators are interested in longer

TABLE IV
ENERGY COMPARISON USING 2G ALONE, 3G ALONE AND THE INTELLIGENT SWITCHING BETWEEN THE NETWORKS.

Service	2G	3G	Switching
50 SMS of 100 bytes	90 J	110 J	90 J
100 Mbytes downloading	10006.2 J	3512.1 J	3512.1 J
5 hours of voice calls	12304.8 J	22782.6 J	12304.8 J
50 handoffs			245 J
TOTAL	22401.0 J	26404.7 J	16151.9 J

stand by times for the users as that may lead to higher use of their services. In this paper we presented the results of measurements conducted on a Nokia N95 to show the energy consumption for the most widely used services, namely SMS, voice and data using both GSM and UMTS.

For SMS, the results show that sending text messages using 3G is more energy consuming than using GSM. Moreover, we showed that the received signal strength has a high influence on the time needed for sending the message and therefore the energy.

Regarding voice services, we showed that being connected to the 3G network causes the phone to consume around 50% more energy. In fact, making a one hour call with GSM instead of UMTS, allows the phone save the amount of energy needed to send more than 1000 SMS of 100 bytes.

On the other hand, when a data connection is needed, 3G networks offer higher data rates with lower consumption in terms of energy per bit. Most users have the possibility to set the network they would like to use, which gives them the possibility to switch between networks depending on the actual used service. To simplify this method for energy conservation, it is possible to develop a middle-ware solution that handles the switching depending on the used applications in a automated fashion. From a network operator point of view the question whether to use 2G and 3G is not based on the energy consumption but on the capacity of the available networks. Nevertheless as pointed out before also network operators have an interest to increase the battery life of the users' phones.

VI. ACKNOWLEDGMENTS

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REFERENCES

- [1] www.apple.com/batteries/iphone.html.
- [2] www.forum.nokia.com/devices/n95.
- [3] www.smszipper.com.
- [4] G. Bosh and M. Kuulusa. *Mobile Phone Programming and its Application to Wireless Networking*, chapter Optimizing mobile software with built-in power profiling.
- [5] F. Fitzek and M. Katz, editors. *Cooperation in Wireless Networks: Principles and Applications – Real Egoistic Behavior is to Cooperate!* ISBN 1-4020-4710-X. Springer, April 2006.
- [6] F. Fitzek, S. Rein, M. Pedersen, G. Perrucci, T. Schneider, and C. Ghmann. Low complex and power efficient text compressor for cellular and sensor networks. In *IST Mobile Summit. Mykonos - Greece*, 2006.
- [7] N. Ingelbrecht, T. J. Hart, N. Mitsuyama, S. Baghdassarian, A. Gupta, M. Gupta, and S. Shen. Market trends: Mobile messaging, worldwide, 2006-2011, November 2007.
- [8] G. Perrucci, F. Fitzek, G. Sasso, and M. Katz. Energy saving strategies for mobile devices using wake-up signals. In *MobiMedia - 4th International Mobile Multimedia Communications Conference, Oulu - Finland*, 2008.
- [9] J. Scheible. *Mobile Phone Programming and its Application to Wireless Networking*, chapter Python for symbian phones. Springer, 2007.
- [10] J. Scheible and V. Tuulos. *Mobile Python: Rapid Prototyping of Applications on the Mobile Platform*. Wiley, ISBN: 978-0-470-51505-1, 2007.