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AN OPEN SOURCE BASED TELECOM MEASUREMENT SETUP BASED ON COMMERCIALLY AVAILABLE MOBILE PHONES

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Abstract: This paper presents a mobile measurement setup, *VUBmeas*, which is based on open source software and commercially available mobile phones. The system design, both from a hardware and software point of view and the possibilities will be looked at. Two examples of applications are given to show its broad usability: one more in the field of positioning, the original field of research it was developed for.

Keywords: Mobile phones, cellular positioning, signal strength measurements.

1. INTRODUCTION

It's very hard to imagine a world without mobile communications. Strangely, the more frequent and widespread it is used, the less we know about it – due to its highly complicated nature. For understanding the main working principles, one can choose one of the many books on the topic (e.g. [5]), but there are few possibilities for capturing communication parameters, which could be interesting for lab sessions, or measuring the received signal strength (RSS) of an antenna.

The latter is especially interesting when verifying RSS-based positioning techniques, which is a research area that has gained recently interest, especially when applied within the field of Location Based Services (LBS). Besides the more-known satellite based techniques (GPS, Galileo), sensor based systems and especially mobile phone based positioning techniques are gaining momentum. Though, it is difficult to find a mobile measurement setup for the latter, since most of the existing monitoring programs and/or hardware [1, 2] focuses only on the communication aspects of the mobile phone network.

In spite of the LBS-hype, the situation for mobile phone based localization is not that developed yet. In the US the FCC E-911 regulations increased the availability of the technology (two networks opted for A-GPS, three for U-TDOA [ref]), but it's still waiting for the mass deployment of consumer applications. The European Commission decided to follow a market-demand driven approach. This makes that Cell-ID, a low-resolution method, is currently the only available technology in most of the European countries. Besides technologies that request extra hardware (U-TDOA, E-OTD, A-GPS), a lot of algorithms are proposed based on the currently available network parameters (e.g. RSS or Timing Advance (TA)). Most of these studies are only theoretical and lack an experimental verification, due to the difficulty to collect the needed measurements.

This paper presents a recently developed mobile measurement setup which is based on commercially available mobile phones and open source software. It is organized as follows: first the objectives are given and motivated (section 2), then the idea behind the object oriented design is explained (section 3), followed by an overview of how the setup can be used, including two examples (section 4). The work will be linked to our educational vision of sustainable development in a more philosophical treaty (section 5), after which short conclusions are presented (section 6).

2. OBJECTIVES

The need for a measurement setup originates from research in the field of localization techniques based on the received signal strength. However, when we started to develop the measurement setup, we were not interested in designing a use-once tool, so some key parameters were put forward: flexibility, ease of extension, price and broad usability. Each of them will be discussed shortly, after having motivated our choice for a mobile phone based system.

When it comes to measuring the received signal strength of a GSM antenna, either a mobile phone or a spectrum analyzer can be used. Measurements of the latter are much more precise, since a mobile phone only returns rounded values. Still, we decided to opt for the first since it is cheaper, easier to transport (a condition sine qua non for positioning) and thus to make real-time measurements. And since this is the aimed platform of the localization techniques under development, the loss in resolution is taken as acceptable. Additionally, it has the possibility of measuring communication parameters.

To measure the communication parameters, we

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could have opted as well for an integrated chipset [ref], to be mounted on a custom (to be designed) printed circuit board, or for a GSM modem. It is clear that the first would demand the most work, both on hardware and software levels. The latter is equivalent to a mobile phone based approach. Both need the development of software for making the interconnection with the device.

For the above mentioned reasons, we have decided that using mobile phones for building our measurement setup doesn't compromise on its functionality, which is taken a look at in the next paragraphs.

2.1. Flexibility

Most of the medium-precision localization techniques difference themselves by carefully selecting the order in which they connect to a base station (BTS), or by the smart processing of communication parameters (e.g. TA). With plain logging devices (e.g. Ericsson TEMS phones [1]) that output time stamped data, this is not possible – rendering them unusable for real-time tests.

The GSM network has four standard modes: no service (no connection between mobile and network), limited service (emergency calls only – no valid SIM card is needed), idle mode (the mobile is camped on a valid cell) and dedicated mode (the mobile is busy conducting a session – speech or data). *VUBmeas* supports all of them and adds a fifth mode where the mobile is not being controlled by the GSM network.

RSS measurements can be made in modes 2, 3 and 4. But to measure communication parameters, a valid SIM card is needed to operate in mode 4. In the fifth mode, the mobile is in full control and can decide which cell it will camp on (e.g. for making several TA parameter measurements), without interference of the network controlled mechanisms.

2.2. Ease of extension

The source code of *VUBmeas* is based on Gammu [3], which is an open source project, and has proven to be accessible, seen the rather large developers community. Anyone who is familiar with C++ will quickly find himself capable of making changes in order to achieve the needed degree of flexibility.

2.3. Price

The lower the price, the more accessible research becomes for a big group of people. Instead of a streamlined but costly solution like TEMS, our solution is built on freely available and rather inexpensive of-the-shelf components. The first is designed to be used by standard users, who are not necessarily technology experienced. *VUBmeas* does not offer a nice graphical interface which catches and treats all the possible errors, but this is largely compensated by the high flexibility. Evidently, when working towards a proof of concept or a prototype, this can be programmed easily.

2.4. Broad usability

Though originally being developed for localization purposes, it is possible to use the measurement setup for other purposes. The main advantage of a mobile phone based approach is that all the GSM parameters can be measured: the ones originating from the communication as well as parameters peculiar to the phone. Examples of the first are the TA parameter (very often used for localization algorithms), and the Bit Error Rate (can be used as a primitive estimate for the size of fast fading noise), an example of the latter is the remaining battery power.

3. DESIGN

The hardware consists of commercially available mobile phones, so our work was mainly situated in the software field. The developed libraries are based on Gammu, an open source project where applications are created for managing cellular phones functions (e.g. agenda, sending SMS's via a computer, etc.).

3.1. Hardware

The requirements for our measurement setup are as few as a laptop with free serial ports, a mobile phone and a cable to connect the mobile phone to the computer. Most mobile phones allow an external program to consult their parameters through the AT command set, though it is sometime very ill-documented on how to do so. We use Nokia phones, since on most devices a special mode, called Netmonitor, can be enabled. This software, originally developed for operator technicians to quickly check the setup parameters of a (newly placed) base station, makes it possible to reveal and thus measure the different GSM parameters.

3.2. Receiver accuracy

The communication parameters in a mobile phone are updated (and transmitted to or by the network) at approximately *2 Hz*. As a consequence, the received signal strength is only known at this same, rather slow, rate. Additionally, the signal strength is reported back to in rounded numbers, formulated as follows:

$$RSS(T) = \left[\frac{1}{\Delta T} \int_{t}^{t+\Delta T} rss(t)dt \right], \qquad (1)$$

where $rss(t) = 10\log\left(\frac{P_{received}(t)}{0.001}\right)$ is the received signal strength, expressed in dBm and $P_{received}(t)$ is the received power, expressed in Watt. Each signal strength sample is the integrated signal strength over a TDMA timeslot length (ΔT), approximately *0.6 ms*. How this integration and rounding is implemented by the telephone software, can differ from phone to phone. The square brackets in the notation of (1) stand for rounded average of a signal *x*: $[x] = \{ y \mid |x - y| \le 0.5 \}$.

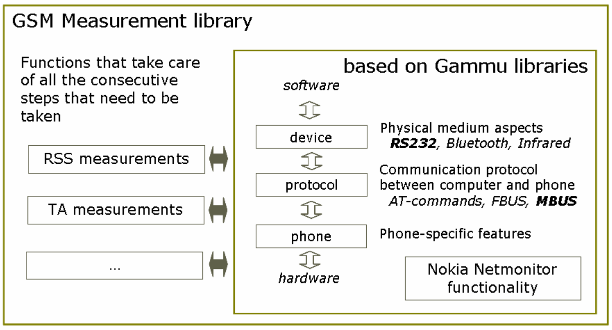

Fig. 1. The *GMSmeasurement* and *GSMphone* objects

The signal strength resolution is *1 dB* across the whole measurement range, which is -110 dBm to 40 dBm.

In the near future we plan to measure a channel simultaneously with a spectrum analyzer and the mobile measurement setup, to verify whether the reported values are unbiased and to get more information on the noise level, in other words to validate the phone used for measuring.

3.3. Software approach

In order to have an extendable base, the Gammu libraries were ported to an object oriented structure in C++. Figure 1 gives an overview of the architecture of the *GSMphone* object. It is important to notice that for the communication with a mobile phone a layered approach is being used. This is one of the main strengths of the measurement setup, since it allows a wide range of mobile phones to get connected.

- Phone: most mobile phones do not offer, though they have similar functionalities, a common instruction set. These differences are made transparent by this layer. Also phone specific functions can be added here (like the used *Nokia Netmonitor* functionalities).
- Protocol: this layer takes care of the protocol used for the communication between phone and computer. Either the generic AT command set is used, or more specific (often producer dependent) command sets like the FBUS/MBUS of Nokia.
- Device: deals with the physical medium aspects for the connection between computer and phone. The current possibilities are RS232, Bluetooth and infrared.

The *GSMmeasurement* object (Fig. 1), which is the core of the software, contains one or more (depending on the number of simultaneous measurements one wants to make) *GSMphone* objects. It is here that the actual routines for making the different measurements

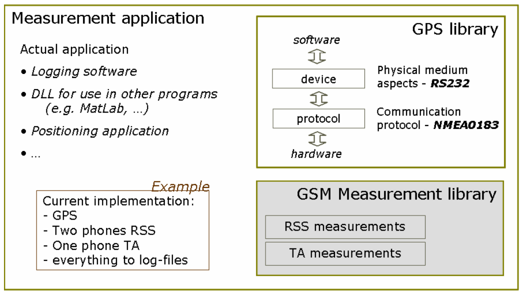

Fig. 2. The *GMSmeasurement* and *GPSmeasurement* objects and their integration into a measurement application

are coded.

At the same level, a *GPSmeasurement* object is created (Fig. 2). Since we plan to use the measurement setup to support research in the field of localization, our configuration setup needs the support of a GPS serving as a position reference. The used device is a JRC Differential GPS, the communication protocol is NMEA0183 (a mainly nautical standard, supported by most GPS devices).

4. APPLICATIONS

The developed setup supports currently two modes: data collection, logging, and real-time usage, either as a library (DLL) that can be used in another program or as a standalone (positioning) application.

4.1. Data collection

All the collected data is either time referenced or both time and position referenced. The latter allows the data to be geographically positioned in map views, providing a reference position. The first allows creating measurement campaign routes to be tested afterwards offline when experimenting with algorithms

The information of each device (mobile phones and/or GPS) can easily be combined in the data collection module. The result of a test drive or walk is a log file (one general one, or one per device) where every line contains the data of one measurement. An example is given in Table 1. Each line starts with a measurement number, followed by the time and position reference and is succeeded by the different measurements. In this example, the RSS, C1 and C2 parameters were measured for the 7 strongest available channels.

The collected data can then be used as a basic data set for the development of algorithms or later on as a reference set for comparing the efficiency of different algorithms. Refer to figure 3 for an example of how a

Table 1: Example of a log-file

Nr.	Timestamp	Position Reference	Measurement 1	Measurement 2	Measurement 3	Measurement 4	Measurement 5	Measurement 6	Measurement 7
7	04/18/06 12:26:00	152433.928183 168073.880516	**68** -73 32 32	**72** -76 29 29	**572** -79 7 -99	**572** -79 7 -99	**63** -83 22 22	**71** -84 21 21	**78** -84 21 21
8	04/18/06 12:26:00	152433.928355 168073.509705	**68** -73 32 32	**72** -76 29 29	**581** -76 10 -99	**572** -79 7 -99	**63** -83 22 22	**71** -84 21 21	**78** -84 21 21
9	04/18/06 12:26:01	152433.928528 168073.138895	**68** -73 32 32	**72** -76 29 29	**581** -76 10 -99	**572** -79 7 -99	**63** -83 22 22	**71** -84 21 21	**78** -84 21 21
10	04/18/06 12:26:01	152433.928528 168073.138895	**68** -75 30 30	**72** -76 29 29	**581** -76 10 -99	**572** -79 7 -99	**63** -83 22 22	**71** -84 21 21	**78** -84 21 21
11	04/18/06 12:26:02	152433.928528 168073.138895	**68** -75 30 30	**72** -76 29 29	**581** -76 10 -99	**572** -79 7 -99	**63** -83 22 22	**71** -84 21 21	**78** -84 21 21
12	04/18/06 12:26:02	152433.928700 168072.768084	**68** -77 28 28	**72** -76 29 29	**581** -76 10 -99	**572** -79 7 -99	**63** -83 22 22	**71** -84 21 21	**78** -84 21 21
13	04/18/06 12:26:03	152433.928700 168072.768084	**68** -77 28 28	**72** -76 29 29	**581** -76 10 -99	**572** -79 7 -99	**63** -83 22 22	**71** -84 21 21	**78** -84 21 21
14	04/18/06 12:26:03	152433.458773 168073.138676	**68** -77 28 28	**72** -76 29 29	**581** -76 10 -99	**572** -79 7 -99	**63** -83 22 22	**71** -84 21 21	**66** -86 19 19
15	04/18/06 12:26:04	152433.458773 168073.138676	**68** -77 28 28	**581** -74 12 -99	**72** -77 28 28	**572** -79 7 -99	**63** -84 21 21	**80** -85 20 20	**66** -86 19 19
16	04/18/06 12:26:04	152432.636444 168073.694510	**68** -77 28 28	**581** -74 12 -99	**72** -77 28 28	**572** -79 7 -99	**63** -84 21 21	**80** -85 20 20	**66** -86 19 19
17	04/18/06 12:26:05	152432.636444 168073.694510	**68** -75 30 30	**581** -74 12 -99	**72** -77 28 28	**572** -79 7 -99	**63** -84 21 21	**80** -85 20 20	**66** -86 19 19

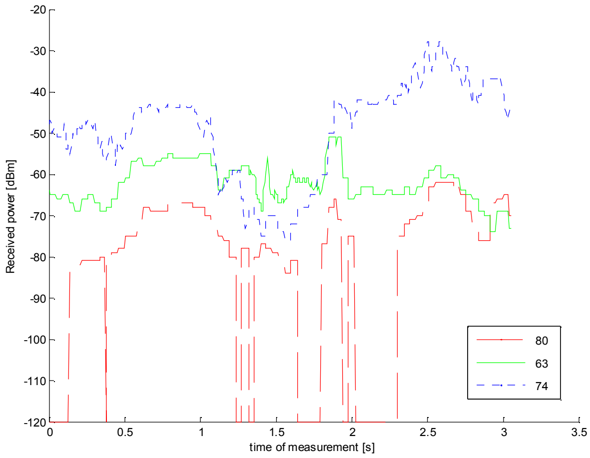

Fig. 3. Measured signal strength for 3 antennas (at the same BTS location, serving three different sectors).

log file can be visualized. For a positioning algorithm, we have filtered the signal of three antennas of interest out of the log file. Note that the signal drops to -120 dBm are due to the (temporary) loss of the signal, which happens very easily in a GSM network. Based on this data an angular positioning routine could be tested and validated.

4.2. Real-time usage - DLL

Once a positioning algorithm is developed, one will want to test it on large scale. Still, it can happen that certain parameters need to be optimized. In this case, it is useful and handy to have access to the measurement equipment from within the development software. This is possible by compiling *VUBmeas* as a DLL.

4.3. Real-time usage - application

Also a custom application can be built in order to perform a certain (repetitive) measurement action with some built-in alarms. It is, e.g. possible to write an application which measures and processes certain signals or parameters, processes them in order to notify a (technical or not) user that a certain action needs to be taken. This warning can also be sent by SMS to a distant location if needed. Another possibility is to have a prototype of a positioning application. Actually, the number of applications that can be thought of is numerous, both from the legislator, consumer and even operator point of view and is only limited by the imagination of the users.

5. SUSTAINABLE DEVELOPMENT?

According to the United Nations [4], sustainable development is a process of developing that "meets the needs of the present without compromising the ability of future generations to meet their own needs". Most commonly, this is referred to in the context of environment degradation and/or social equity and justice versus economical development.

We would like to stress the latter two and link them to (the ability to perform) research. The authors believe strongly that being able to experiment, at whichever level, will lead to the development of ideas and it their validation in economical terms. The effects can either be directly or indirectly visible, and be situated at a macro or micro scale.

This chance should be offered to all engineers and engineering students, since it is too often forgotten that engineers are supposed to interact with society and work on the improvement of an average person's life quality. With this measurement setup, we offer one more possibility to interact with society in a high-tech competency domain, and stimulate thereby both the safeguarding and development function of an engineer.

6. CONCLUSION

We were able to construct an easily extendable and cheap (less than € 100 for a basic setup) mobile measurement setup that has proven already its functionality in the research field of mobile phone positioning.

In the near future, we will develop an end-user application to get a rough location estimate (by using the Cell-ID and the Timing Advance (TA) parameter. Though rather a side goal, it will serve well as a development tool for companies interested in designing Location Based Services based on the currently available network technologies. At the moment there is interest of a Belgian LBS test lab.

Other future work involves the validation of the RSS measurements by coupling measuring simultaneously with a signal analyzer and the mobile phones (in lab conditions) and the translation of the current layers to newly available technologies (e.g. USB interconnection instead of the RS232 serial port).

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