Master Thesis

“ The GeoSharing project: An Openmoko geoposition sharing system ”

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“ In theory, there is no difference between theory and practice;
In practice, there is. ”

– Chuck Reid

Nous remercions chaleureusement
le Professeur Marc Lobelle, notre promoteur
ainsi que Sébastien Combéfis et Xavier Carpent
pour leur guidance éclairée.

Abstract

Geo-positioning systems provide a way to locate objects or persons on Earth. Geo-positioning systems can be used in the scope of social networks allowing users to share their location at any time with their friends. They can also be used by rescue or military units. Because the GeoSharing project aims to provide a wireless real-time location system that can be deployed everywhere, independently of infrastructure and because nodes are susceptible to be in constant movement, the challenging part of this project is to maintain a consistent network topology in order to be able to reach each node at any time to share geographical positions. In order to fit more critical application fields, the system must also be secured.

The first version of GeoSharing is released for Openmoko Neo FreeRunner devices. It provides a secured way to share geographical positions over a wireless network. The network topology management is assured by a Linux dæmon implementing the Optimized Link State Routing (OLSR) protocol which is suitable for Mobile Ad Hoc NETwork (MANET). The graphical user interface of the GeoSharing application allows a real-time display of other nodes position on a map. A second version of the GeoSharing application can be developed including a dynamic allocation of IP addresses to nodes instead of manual configuration, a WPA2 security of the MANET instead of a WEP security combined with a Triple DES data encryption and a customized graphical user interface.

Contents

Acknowledgements

During the elaboration of this project, we had the chance to integrate a lot of open-source projects. We really want to thank people for their incredible work, motivation, reactivity and friendliness.

We thank *Erik Tromp* for his help in the understanding of the documentation related to the OLSRd BMF plugin, *Martin Jansa* for helping us to understand how to compile tangoGPS on Openmoko Neo FreeRunner devices, *Joshua Judson Rosen* for his help in the understanding of the GTK+ thread management involved in tangoGPS and all the members of the mailing lists related to the SHR-project.org, olsr.org and openmoko.org.

Introduction

The GeoSharing project is a system allowing users to share their geographical position with other users. The system makes it possible for every user to see the displacements of other users on a map. The system is deployed on Openmoko Neo FreeRunner devices which are open smartphones running an embedded version of the Linux operating system. Those devices are equipped with a GPS and a Wi-Fi module as it is today the case for many modern smartphones. In order to achieve the GeoSharing main goal which is to share geographical positions over a group of users and assuming that every user has an Neo FreeRunner with him, the GPS module is used to get the location of the device on Earth and the Wi-Fi module is used to spread the information between the devices.

There are many uses for location systems. Such systems can be used to track the positions of boyscout patrols for the organizers. But it can also have applications in more critical fields such as military and medical rescue situations. When soldiers are in operation, locating the different military units can indeed be crucial for tactical reasons. From a medical standpoint, it is really important to locate the injured soldiers as quickly as possible in order to rescue them. One can expand the application to a larger scale such as disaster relief units that need to be dispatched in an optimal way for rescuing victims. In these situations, it is crucial for medical units to have an effective location system with them in order to reach the right place as fast as possible and know where other rescue units are located.

This thesis details the analysis, design and development steps leading to a solution. The first chapter presents the Openmoko project and the Neo FreeRunner device specifications. The selection criteria which motivated the operating system choice is then presented in detail in Chapter 2. Chapter 3 introduces the interactions with the GPS module. Network protocols and the security of the application are addressed in Chapter 4. Chapter 5 is dedicated to the graphical interface. The last chapter presents the GeoSharing project and its limitations.

We hope you will enjoy your reading as we enjoyed to work on this project.

Chapter 1

Openmoko Neo FreeRunner

In the scope of this thesis, Openmoko Neo FreeRunner devices have been chosen to be the hardware platform to support the development and the tests of the GeoSharing application. The GeoSharing application is obviously generic and the concept can be ported to any mobile device.

The first section of this chapter introduces the Openmoko project. The next two sections present the Neo FreeRunner, its technical specifications and how to get started with it. The last section presents a brief analysis of how mobile applications can be compiled.

1.1 Openmoko project

> "*Openmoko is a project dedicated to delivering mobile phones with an open source software stack. Openmoko was earlier more directly associated with Openmoko Inc, but is nowadays a gathering of people with the shared goal of "Free Your Phone".*"
>
> – Offical Openmoko website: http://www.openmoko.org

Openmoko Inc. (Figure 1.1(a)) is a Taiwanese company founded in 2006 by Sean Moss-Pultz with the help of Timothy Chen. These two people were the originators of the Openmoko smartphone and other electronic mobile devices. Since 2010, this company has cancelled many future projects. This is the reason why the Openmoko project (Figure 1.1(b)) is now under the supervision of a world-wide community of developers which proposes new hardware updates for existing open smartphones such as the Openmoko Neo FreeRunner (also called GTA02). There exists now many local communities (english, french, german, etc.) taking care of the project. For example, the french speaking community was founded by Johann Suhm and his blog related to the Openmoko project is available at http://www.openmoko-fr.org.

(a) Openmoko Inc.

(b) Openmoko.org.

Figure 1.1: (a) Openmoko Inc. is a Taiwanese company founded in 2006. (b) Openmoko.org is under the supervision of a world-wide community.

1.2 Specifications of the Neo FreeRunner

The Neo FreeRunner (Figure 1.2) is the second phone designed by Openmoko Inc. to run Openmoko softwares. It is a Linux-based touchscreen smartphone whose production began in June 2008. Its predecessor was the Neo 1973 (GTA01) commercialized in Summer 2007.

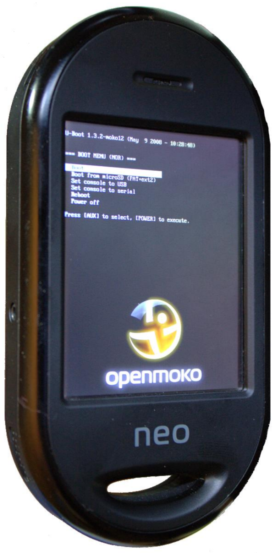


Figure 1.2: The Neo FreeRunner GTA02 is the second phone designed by the Openmoko Inc.

The Neo FreeRunner can run many Linux-based distributions. These distributions are adaptations of the Linux version for desktop computers to fit in mobile devices and are regrouped under the name of Embedded-Linux. Another important characteristic of this smartphone is that the hardware platform as well as the software platform are open.

The main specifications of the Neo FreeRunner are:

- a weight of about 184 grams
- a 400MhZ ARM processor
- 128 MB RAM memory
- 256 MB flash memory
- a micro SD card slot
- a 480x640 pixels touchscreen
- an internal GPS module
- 802.11 b/g Wi-Fi
- bluetooth
- two 3D accelerometers
- tri-band GSM and GPRS
- USB connector

Using such a device has advantages whose mains are:

1. the openness of all applications developed for it. This concept offers a large freedom in using and modifying already existing software installed on the device;
2. the integration of many communications means such as Wi-Fi, bluetooth, GPRS, etc.

The Openmoko FreeRunner can be bought from official FreeRunner distributors for about 250 €. The distributors list is available on the Openmoko Inc. website: http://www.openmoko.com.

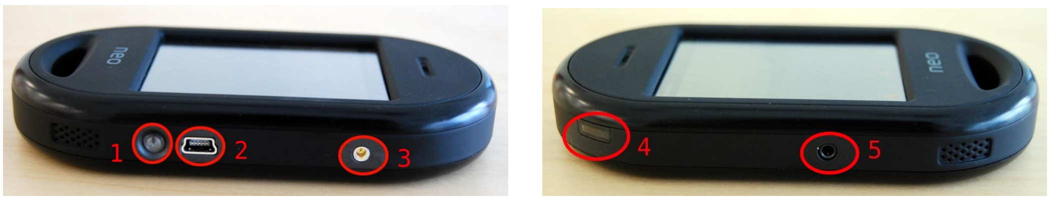
1.3 Getting started with the Neo FreeRunner

In order to have a better idea about how to get started with the Neo FreeRunner, this section presents a brief overview of the device itself and technical terms that are commonly used in the smartphones' domain. This section also explains different ways to get an internet connection on the Neo FreeRunner.

1.3.1 Buttons and connectors

The Neo FreeRunner has two external buttons and three connectors shown on Figure 1.3.

1. The **power** button is used to switch the device on or off. A brief press on the button powers on the device. A long press on the button shuts it down.
2. The **USB** connector is used for two purposes:
   - recharge the battery via a sector adapter connected to a power supply or via a classical USB cable connected to a computer;
   - exchange data with a computer.



(a) Right side of the GTA02 (b) Left side of the GTA02

Figure 1.3: (a) On the right side of the GTA02, the power button, an USB connector and an external GPS antenna connector. (b) On the left side of the GTA02, the 'aux' button and a 2.5mm phone jack connector. (Pictures from http://wiki.openmoko.org)

3. The **external GPS antenna** connector can be used to plug an external antenna in to improve the reception quality. Due to the smallness of the Neo FreeRunner (and its components such as the Wi-Fi and GPS antennas), the GPS accuracy is quite limited. The reception quality is thus improved when an external GPS antenna is plugged in.

4. The '**aux**' button is used in combination with the power button to access the boot menu and to browse the items of this menu.

5. The 2.5mm **phone jack** connector allows users to plug an headphone set in.

The actions associated to the interactions with the power and 'aux' buttons are often customized and generally depends on the operating system installed on the device. For example, the power button can be used to access the power management menu and the 'aux' button is used to lock and unlock the smartphone.

1.3.2 Memories and bootloader

There are two different flash memories inside the Neo FreeRunner: the NOR and the NAND memory.

- The NOR memory has a small capacity and can only be accessed in read-only mode. This memory only contains a fail-safe bootloader (Figure 1.4).

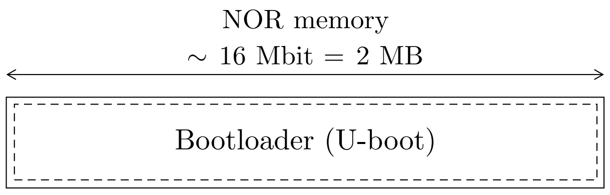


Figure 1.4: The NOR memory of the GTA02 only contains a fail-safe bootloader.

- The NAND memory has a bigger capacity than the NOR memory. The NAND memory is divided into three partitions (Figure 1.5): one for the bootloader, another for the kernel and the last one for the root filesystem. Those partitions are accessible in read and write modes and can be flashed separately.

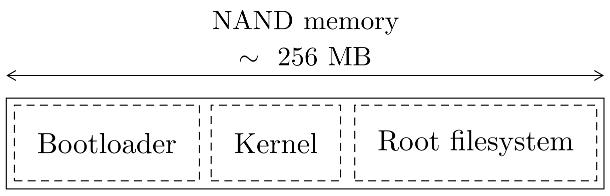


Figure 1.5: The NAND memory of the GTA02 is divided into three partitions respectively containing the bootloader, the kernel and the root filesystem.

Both memories contain a bootloader. The bootloader is a very small program needed to boot up an operating system. There exists two bootloaders for the Neo FreeRunner: Qi and U-boot. By default, the Neo FreeRunner is provided with U-boot as bootloader on the NOR memory. When the device is powered on, the NAND bootloader is launched. This latter loads the operating system if there is one installed on the NAND memory.

1.3.3 Operating systems

Since the commercialization of the Neo 1973 (GTA01) in 2007, many operating systems have been developed and updated to be compatible with the Neo FreeRunner (GTA02). Operating systems can be installed on the Neo FreeRunner using a computer connected to the smartphone with a USB cable.

It is for the flashing process[1] that the NOR memory is useful. In order to flash the entire or only a part of the NAND memory, the device must be powered up. For this purpose, the device must execute a program. But, this program cannot be on the memory to be flashed. Hence, the solution is to boot the device on the NOR memory (by pressing the 'aux' and power buttons) to execute the NOR bootloader.

Once the device is running the NOR bootloader, the NAND memory is ready to receive the new data. Tools such as `dfu-utils` and `neoTool` have been developed to make this process easier. The entire flashing process is detailed in Appendix A.1.2.

Flashing the device is not always required. It is also possible to update some operating systems via an internet connection instead of flashing a new version from a local computer.

[1] In this context, flashing means erasing the memory content by copying new data in the flashed memory.

1.3.4 Internet connection

There exists four different ways to get an internet connectivity on the Neo FreeRunner.

The first possibility is to use the GPRS modem of the device. When a valid SIM card is inserted in the phone and if the Access Point Name (APN) is correctly configured[2], a GPRS connection can be established via the mobile carrier. Unfortunately, this solution has a low bandwidth of about 40 kbit/s [GPR11].

The second solution is to use the built-in Wi-Fi module in order to connect the smartphone to any Wi-Fi network with several possible levels of security. In this situation, the theoretical bandwidth is defined according to the wireless network protocol: 11 Mbit/s for the 802.11b IEEE standard and 22 Mbit/s for the 802.11g IEEE standard [IEE11].

The last two possible solutions to get an internet connectivity on the Neo FreeRunner use a connection between the smartphone and a computer already connected to the internet. Preliminary configurations are needed for the computer to behave as a simple router. It must forward packets coming from the Neo FreeRunner to the internet and the other way around. The connection between the smartphone and the computer can be:

- a **bluetooth connection**. In this case, the Bluetooth Networking Encapsulation Protocol [BNE11] must be used.
- a **USB connection**. The details of this configuration are given in Appendix A.1.3.

1.4 Developing environment

Since the application developed in this thesis has to be run on the Neo FreeRunner, it is necessary to compile it for the specific architecture of those devices. There exists two ways to compile an application for low-cost hardware devices (i.e. low CPU and memory capabilities).

1. The first possibility is to natively compile source files on the device. This makes the assumption that there exists a compiler for the concerned programming language on the specific architecture. Obviously, the low capabilities of the device have an unfavourable impact on the compilation time. The output files of the compilation process are then certainly compliant with the architecture of the device.
2. The second possibility is to use a cross-compiler. Such a program allows to compile, on any computer, an application targeted for a specific architecture which is not necessarily the same as the one of the computer on which the code is compiled.

[2] For example, internet.proximus.be for the Belgian mobile carrier Proximus.

Hence, it is possible to take advantage of the computer CPU capabilities in order to compile faster than on the mobile device.

Both methods provide the same results. During the development of this work, the first solution has been used mainly for its easiness. The second solution requires extra configurations indeed, while the first one is straightforward.

Chapter 2

Choice of the operating system

When you get a mobile device on which you have to develop a new application, the choice of the operating system to work with is crucial. It has indeed to fit the application needs and some software and hardware criteria. Several variants of Linux have been ported to the Neo FreeRunner. This chapter presents the criteria which were chosen according to their relevance for the intended application to be developed. The choice of the operating system according to those criteria is then presented.

2.1 Choice criteria

In order to choose the most suitable operating system on which to develop and run the application, some requirements need to be defined and satisfied. These latter are related to the capabilities of the material and the needs of the application. For the GeoSharing project, a lightweight operating system is more than enough. The only features it has to support are a user interface, a GPS module and a Wi-Fi module. This section establishes a list of four criteria that must be satisfied by the operating system. Those criteria are to be evaluated and scored as objectively as possible on several operating systems.

1. **Stability**: the most important point is the stability offered by the operating system. This means that the system has to be reliable and robust and that it should not crash. In this work, the stability has been evaluated thanks to three major tests: the keyboard functionality, the native[1] applications usage and the use of the GPS and Wi-Fi modules. We will consider that the operating system is unstable if an application is able to crash it. If the operating system is well implemented, an application should not crash it. Such a behaviour will immediately discard the operating system.

[1] In this context, native means that the application is provided with the operating system package.

2. **Maintenance**: this criterion will evaluate if a system is still maintained by developers or not. Systems that are no more developed will be discarded in order to only keep up-to-date systems.

3. **Developers usage**: the fact that an operating system is widely used by developers community can be interpreted as a sign of trust. The most used system will indeed be susceptible to be the most satisfying one in terms of maintenance and stability. It may also be the system with the larger community working around.

4. **Energy consumption**: the energy consumption is not the most critical factor in our case but it can be interesting to use a system whose consumption is not excessive. The operating system will be tested with the Wi-Fi and the GPS activated without letting the system suspend in order to evaluate the longevity in the worst-case[2].

2.2 Potential choices

A general overview of the different operating systems usage is presented on Figure 2.1. This overview has been obtained through data collected on the official Openmoko wiki (based on statistics of March 2010 [Dis10]).

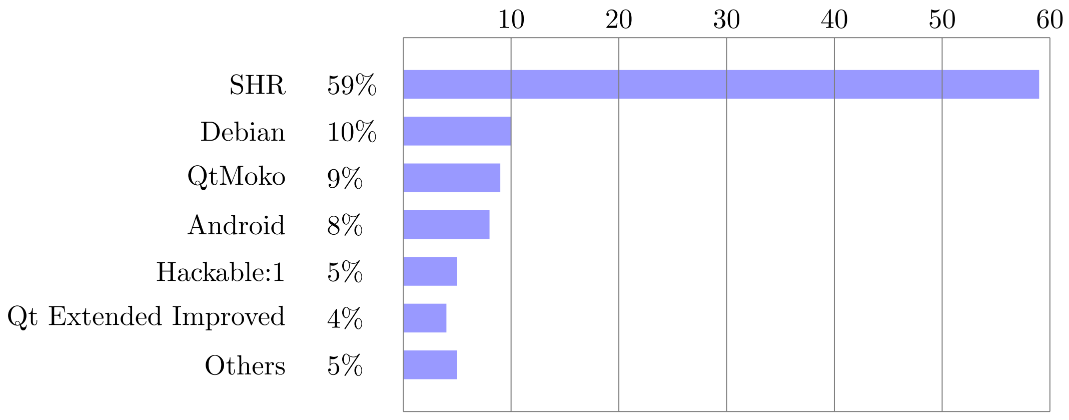


Figure 2.1: Percentage of operating systems usage among people registered on the official Openmoko wiki (http://wiki.openmoko.org).

Five candidates operating systems have been considered for this work: the four more used (SHR, Debian, QtMoko and Android) according to the official Openmoko wiki (Figure 2.1) and the Om Series as it is installed by default on the Neo FreeRunner.

[2] A functionality called *Wake-up from wireless* exists on the Neo FreeRunner. This functionality wakes up the operating system when this latter is in standby if the wireless module is triggered. Nevertheless, in the scope of the energy consumption evaluation test on the Neo FreeRunner, this *Wake-up from wireless* functionality is not used.

Here is an overview of every candidate operating system:

Stable Hybrid Release

Stable Hybrid Release (SHR) is based on Debian and provides an X server environment and Illume2 which is an enlightenment window manager module for small devices. SHR comes with a complete user manual and moves forward to a distribution for every day use.

Debian

Debian is a well known operating system generally used on computers. It can also be used on the Neo FreeRunner where it gives access to the numerous softwares packaged in the Debian repositories.

QtMoko

As well as SHR, QtMoko is a distribution based on Debian and is the most active distribution for the moment (one new version per month). The graphical interface is called Qt Extended Improved and has been developed with the Qt framework which is an open-source framework widely used.

Android

Android is an open-source operating system developed by a startup company with the same name which has been bought by Google Inc. Android is built on the Linux kernel and uses a custom virtual machine designed to optimize memory and hardware resources in mobile environments. This distribution is more and more used on new smartphones (HTC, Samsung, LG, etc.). The last version of Android has been provided by Google in December 2010. This release is the 2.3 (Gingerbread) and is installed on many recent smartphones, while the last stable version proposed for the Neo FreeRunner is the 1.5 (Cupcake) and the last unstable release is the 2.1 (Eclair).

Om Series

Om Series gathers the three first operating systems that have been developed when the Neo 1973 has been commercialized. It consists of Om 2007.2, Om 2008 and Om 2009. After June 2009, most of the developers have moved to SHR and abandoned the work on Om 2009 due to lack of resources.

2.3 Evaluation of the criteria

The set of criteria that has been defined in the previous section is the basis of the reflection leading to integer scores between 1 and 5 assigned to each distribution. The scores given below are not absolute scores but a relative ranking between the candidates.

1. **Stability**
   - **5 points** are assigned to SHR, Debian and QtMoko. Native operating system functionalities were tested and no major bugs has been encountered.
   - **3 points** are assigned to Android. Sometimes the operating system crashed when lots of tasks were running.
   - **1 point** is assigned to Om Series. Native functionalities such as the virtual keyboard were completely unstable (e.g. virtual keyboard appears when not needed and it is sometimes impossible to make it appear when needed).
2. **Maintenance**
   - **5 points** are assigned to QtMoko. QtMoko is the most maintained system thanks to a new version released every month.
   - **4 points** are assigned to SHR. SHR is also well maintained but less regularly than QtMoko.
   - **2 points** are assigned to Android and Debian. The development of those operating systems is still in progress but new versions for Neo FreeRunner devices are rare.
   - **1 point** is assigned to Om Series. The development of Om Series has been abandoned since 2009.
3. **Developers usage**

   Scores are given according to Figure 2.1: SHR gets **5**, Debian gets **4**, QtMoko gets **3**, Android gets **2** and finally Om Series gets **1**.
4. **Energy consumption**
   - **5 points** are assigned to Debian. Longevity tests showed that the autonomy of a Neo FreeRunner running Debian was really good. The battery was fully charged and the device last for about two days.
   - **3 points** are assigned to SHR, QtMoko, Om Series. Longevity tests showed that the autonomy of a Neo FreeRunner running those operating systems was quite good. The battery was fully charged and the device last for about one day.
   - **1 point** is assigned to Android. The same test was performed and the autonomy was really bad, less than an half-day.

Score summary

Table 2.1 summarizes the scores obtained by each candidate operating system for each criterion and gives the total score.

	Stability	Maintenance	Dev. usage	Energy cons.	Total
SHR	5	4	5	3	**17**
Debian	5	2	4	5	**16**
QtMoko	5	5	3	3	**16**
Android 1.5	3	2	2	1	**8**
Om Series	1	1	1	3	**6**

Table 2.1: This table summarizes the scores for each of the considered operating systems according to the criteria proposed in Section 2.1.

Figure 2.2 shows the same results graphically. For a given operating system, the more the delimited area is large, the more the operating system has a good total score.

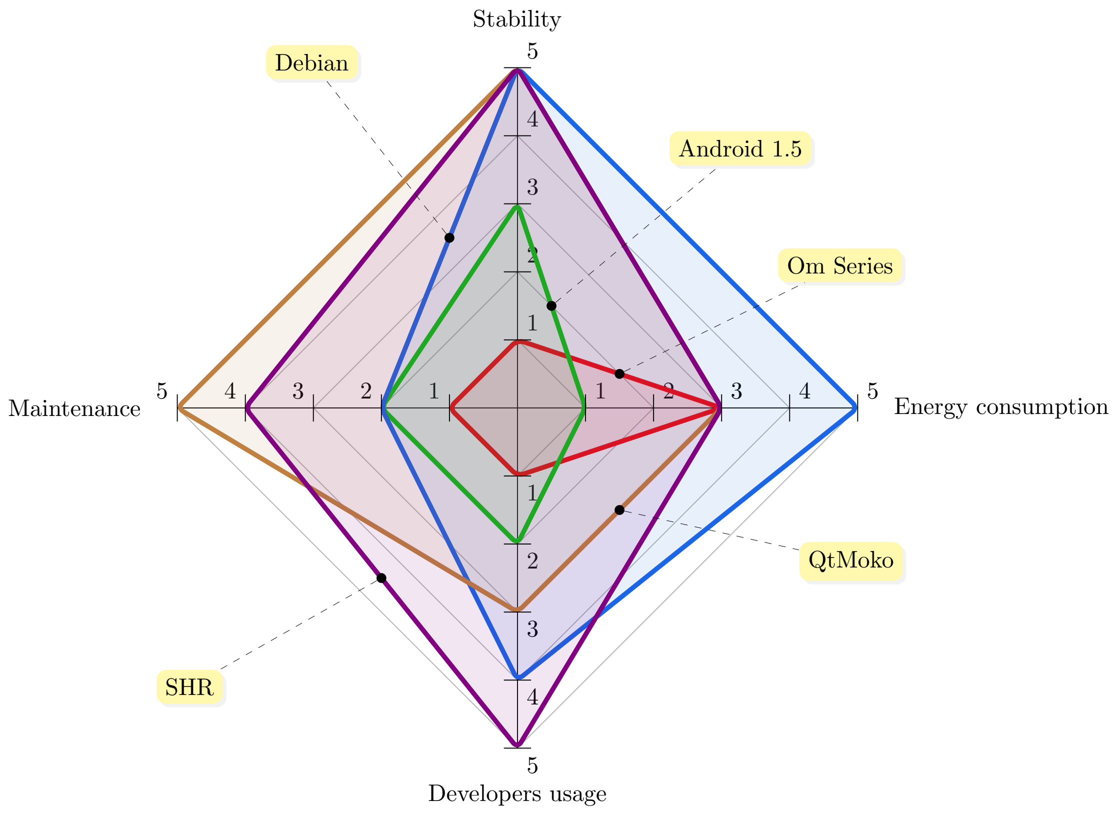


Figure 2.2: The spider is a graphical representation of the summarized scores.

The candidate operating system which gets the highest total score is SHR which has therefore been chosen to deploy the GeoSharing application on the Neo FreeRunner.

"*SHR is a GNU/Linux based operating system for smartphones and similar mobile devices. (...) SHR is based on OpenEmbedded and uses GNU/Linux at its core. It integrates the freesmartphone.org framework for telephony, networking, etc. (...) SHR is 100% community driven and based on Free and Open Source Software.*"

– Official SHR project website: http://www.shr-project.org

Chapter 3

Communication with the built-in GPS module

This chapter presents the first part of the GeoSharing project. The problem that is addressed is the interaction with the GPS module. Unlike the network part, described in the next chapter, the interactions with the GPS module have only to be done in one direction. The application must only be able to get information from the GPS module and has never to send information to it besides control message to switch it on and off.

The first section describes the architecture of the GPS module on the Neo FreeRunner. Then, the way the needed information are retrieved is explained. The last section presents a brief analysis of the preciseness of the data obtained through the GPS module.

3.1 GPS communication stacks

This section details the different layers between an end-user application and the hardware components involved when using the GPS module.

It is important to notice that there exists two main open-source GPS dæmons for smartphones. The way the communication with the GPS dæmon is done depends on the distribution installed on the phone.

These two dæmons are Gpsd and Ogpsd.

- **Gpsd** is used on some Om Series (2007 and 2008). Basically, this daemon is the link between the GPS receiver (hardware) and a simple interface to allow applications to retrieve position information. Gpsd communicates with upper layers via a TCP/IP connection opened on port 2947. Gpsd can handle simple requests on this socket and replies on the same socket.
- **Ogpsd** is used on Om Series built after 2008, and on Debian distributions. As previously mentioned, SHR is a Debian-based distribution hence the application

must deal with ogpsd in the scope of the GeoSharing project. Ogpsd differs from gpsd in its behaviour in the sense that it does not use a TCP/IP connection anymore but GPS data are retrieved through a D-Bus interface (Figure 3.1). D-Bus is a software message bus system behaving like a hardware bus and allowing applications to register on it to offer services to any other application such as in *service oriented architectures*. The GPS module is registered on the bus and can send GPS data on demand on this bus. Any application which wants to use this information can read it on the bus.

Unfortunately, many end-user applications have been developed on top of gpsd and have not been ported on ogpsd. To get rid of that problem, the FreeSmartphone.Org (FSO) community has implemented a backward compatibility module called fso-gpsd. This program runs on top of ogpsd in order to provide a TCP/IP interface to all applications looking for that kind of connection.

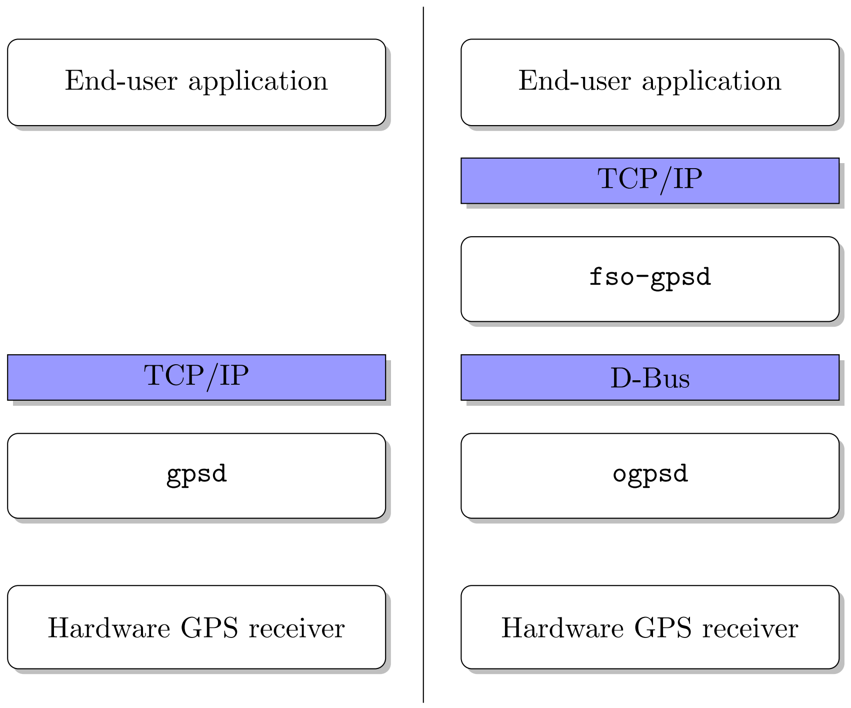


Figure 3.1: Gpsd and Ogpsd offer different connectivity modes.

3.2 Methods of geographical positions retrieval

This section presents different possibilities to get information about our position on Earth. The first possibility is to use directly the D-Bus. The second one is to use the TCP/IP connection opened on port 2947. Both solutions have been implemented in the

GeoSharing project. Advantages and drawbacks of each solution are given hereafter. When launching the GeoSharing application, it is possible to choose the method of geographical positions retrieval by specifying `dbus` or `tcp` as argument. By default, the D-Bus method is used. Details about launching GeoSharing are given in Appendix A.2.4.

3.2.1 D-Bus

The so-called D-Bus solution consists in accessing the D-Bus and reading for the data. Fortunately there exists a library (called DBusGLib [DBu07]) allowing end-user applications to read on the bus.

Once the connection with the bus is established, the interactions with it are done through function calls. There exists an API listing all the possible calls on the D-Bus [FSO11]. In the GeoSharing project, we only need one function call on the bus: **GetPosition()** which is used to retrieve a data structure containing information about the current GPS status such as the longitude, the latitude, the altitude, the number of visible satellites, etc.

One advantage of the so-called D-Bus technique is that it only requires a short piece of C code thanks to the already existing API's. Another advantage is the fact that the information is retrieved at a very low level of the architecture hence the number of modules involved in the process is smaller than if the TCP/IP connection over fso-gpsd is used. This smaller number thus reduces the probability of failures.

A drawback of the D-Bus technique is the fact that it is not generic (i.e all distributions do not implement de D-Bus interface).

3.2.2 TCP/IP on port 2947

The so-called TCP/IP solution is a little bit more complex to implement but is still easy to understand. The main idea is to open a local TCP connection on port 2947. After the connection establishment, no packets are exchanged until the application requests GPS data (Figure 3.2). Before sending the request, the application checks if the socket responsible for port 2947 is ready to accept a request. If yes, the application sends the request packet and waits for the reply. The same information are not sent twice to the application hence this latter might be waiting until fresh information are extracted from the GPS module.

One big advantage of this solution over the D-Bus one is the fact that it is more generic. As we can see on Figure 3.1, whatever the GPS dæmon used, the ability to establish a TCP/IP connection always exists. The TCP/IP connectivity can indeed be found on top of Gpsd in one solution, and on top of fso-gpsd in the other solution.

A drawback of the TCP/IP technique is that it is not always optimal (i.e. it is better to access a lower layer when possible).

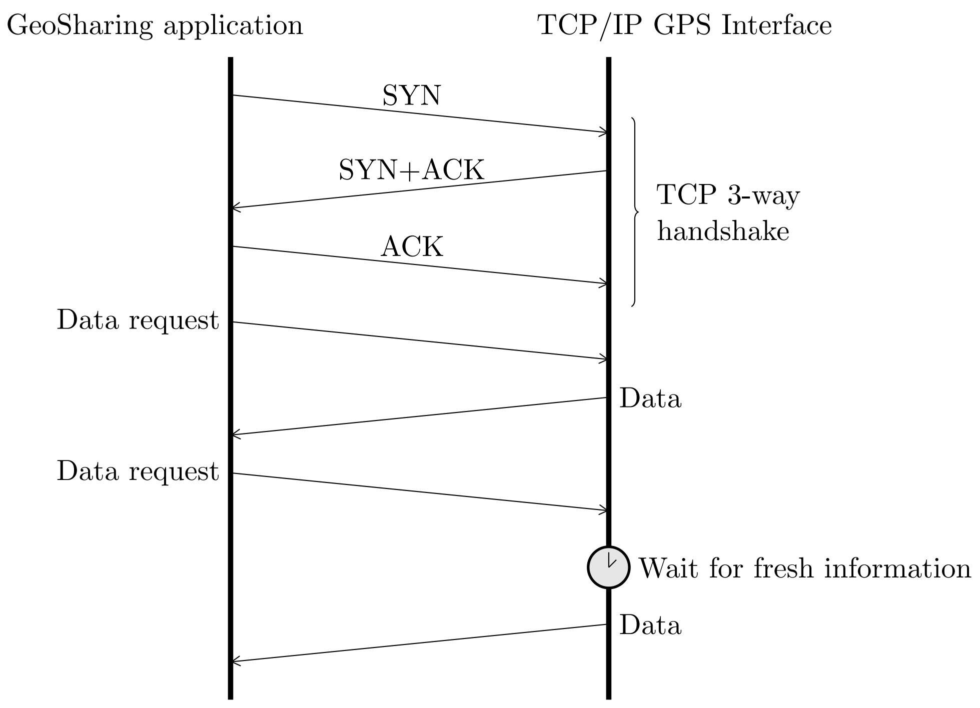


Figure 3.2: A scenario of a TCP connection establishment followed by a data request and reply is shown. Then, another request is done but the reply is only sent when fresh information become available.

To conclude, it is important to implement more than one solution for the GPS part of the GeoSharing application to avoid compatibility problems if the application is ported on other platforms.

3.3 Precision analysis

When developing an application based on geographical positions retrieved from a GPS module, one major point to analyse is the time needed by the GPS module to converge and its ability to provide an accurate position.

When the GPS application starts, it requires some time to get accurate location information. The more the current position is far from the last position registered before the last shut down of the GPS module, the more the converging time will be long. Figure 3.3 shows what happened at application start-up on three devices. Actually, two of the three Openmoko Neo FreeRunner involved in this test (A and B) had been shut down in the south of France a few days before the test. When the three devices were started exactly at the same place in Louvain-La-Neuve (Belgium), only the device which stayed in Louvain-La-Neuve (C) presented a correct geographical position.

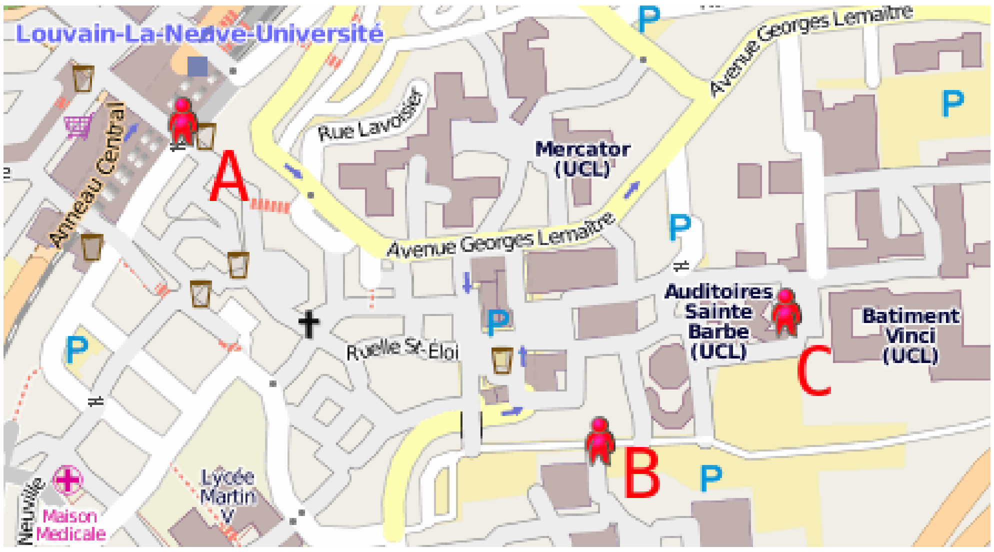


Figure 3.3: Before convergence, three different positions while the Openmoko Neo FreeRunner are at the same place.

Several minutes were needed for the two incorrect devices to converge and present a position close to the third one on the map. Even after this convergence time, devices did not present exactly the same coordinates. According to the datasheet of the Openmoko GPS receiver [Ant], the accuracy of this receiver is about 2.5 meters.

Unfortunately, nothing can be done to improve this convergence time because it is inherent to any GPS module. It is therefore essential to take this convergence time into account in the GeoSharing project. At start-up, the application using the GPS module requires a few minutes to be effective and reliable. On the Neo FreeRunner, an evaluation of the accuracy is provided by the GPS module. The evaluation of the accuracy is represented on a scale from 0 to 3. Geographical positions are then shared with the other users only if a certain accuracy threshold is reached: if the evaluation of the accuracy is greater or equal to 2.

Chapter 4

Network infrastructures and protocols

The previous chapter describes how to retrieve geographical coordinates through the GPS module in each Openmoko device. Since the ultimate goal of the GeoSharing project is that each mobile system knows the absolute position[1] of all the other mobile systems, there is a need for an underlying network allowing to share this information.

This chapter is dedicated to the presentation of the reasoning about the networking characteristics needed to spread the GPS coordinates between all the connected devices in a reliable and efficient way. The first section introduces the requirements that need to be satisfied by the Wi-Fi network on which the application relies. In the two next sections, several Wi-Fi modes and routing protocols are introduced and the choices that fit best the GeoSharing needs are selected, based on the pre-established requirements. Section 4.4 presents security aspects to take into account when sharing personal data on a network. The last section presents the implementation, in GeoSharing, of the theoretical solutions that have been chosen.

4.1 Network requirements

The system to be developed is required to be autonomous and robust to failures with a dynamic topology management. The system must indeed be deployable everywhere, independently of infrastructures. This means that the entire network must be self-managed by the Openmokos themselves. They have to be able to create the network and broadcast the Service Set Identifier (SSID) of the network in order to allow other devices to join it.

[1] The absolute position means the position on Earth which is not to be confused with the relative position which can be the distance between two people.

Once the network has been created and all the Openmokos are interconnected, coordinates of each system must be spread and made available to all the other systems. Therefore, each node in the network must act as a router for the others. The application that is to be developed is a real-time application, the position of each device belonging to the network has to be updated as quickly as possible so that the system reflects the reality as precisely as possible. In order to fulfil this requirement, an important required point is a low forwarding delay for (re)transmissions of coordinates. Another important point in order to build a real-time application is that the routing protocol should not overload the network with its update packets. The bandwidth should be reserved for data packets as much as possible.

The requirements can be summarized as follow.

1. **Autonomy**: the system should be deployable everywhere, independently of any infrastructure;
2. **Robustness** and **dynamism**: the system has to be failure resistant and able to self-manage the network topology;
3. **Low forwarding delays**: the system has to forward location data without introducing delays (e.g. delays related to the changing network topology) in order to follow the devices displacements as precisely as possible;
4. **Reasonable bandwidth consumption for topology updates**: the number of update packets sent by the routing protocol should be kept as low as possible in order to avoid losing data packets (containing location information) due to network overloading.

4.2 Wi-Fi modes overview

This section first presents an overview of the different Wi-Fi connectivity modes. The choice of the mode to be used in GeoSharing is presented and justified in the next parts.

4.2.1 Wi-Fi connectivity modes

There exists two well known possible connectivity modes to create a Wi-Fi network.

- The most commonly used is the wireless *infrastructure mode*. It requires a wireless access point operating as a router or a switch, to set this kind of network up. This centralized solution is generally used at home or in companies in order to provide an Internet connectivity to the users.
- The second mode is the wireless *ad hoc mode*. It allows multiple devices to be interconnected without the need of external support.

Both solutions have advantages and drawbacks. The infrastructure mode indeed provides a centralized solution which is easy to manage while the ad hoc mode is a distributed solution more complicated to manage. It is especially the case for the Dynamic Host Configuration Protocol (DHCP) which is responsible to distribute unique IP addresses to all the nodes of a network. DHCP has to be distributed to work with ad hoc networks. The security is also much more difficult to manage in a distributed system. This latter point is discussed in Section 4.4.

In ad hoc networks, each node is susceptible to leave the network at any time. This requires dynamic management of the topology for all nodes. Nodes can also join the network at any time which will increase the load at each individual device as the number of nodes increases. This is another limitation of this mode for small devices.

4.2.2 Wi-Fi mode choice

As just explained, both Wi-Fi connectivity modes present pros and cons. According to the needs of the application presented at the beginning of this chapter, the ad hoc mode is the more suitable. The infrastructure mode requires extra hardware to work but this requirement is prohibited by the autonomy criteria. Besides, it confines all devices within the radio range of the access point. Furthermore, the use of a centralized solution such as in infrastructure mode makes the network less robust: if the access point fails, the entire network will collapse. For those reasons, the ad hoc mode was chosen to be used by the GeoSharing network.

4.2.3 Ad hoc mode overview

As Andreas Tønnesen explains in his master thesis [Tø04] and according to the documentation found on Wikipedia, the free encyclopædia [Wir11], the wireless ad hoc mode consists in a decentralized wireless network. It is called ad hoc because it does not rely on any infrastructure such as router or access point. Basically, it allows two entities located within range of each other to communicate. The decentralized nature of ad hoc networks makes them more suitable for situations needing quick communication establishment without relying on additional infrastructures. If ad hoc networks are well suited for this kind of situations, they lack an important point. Ad hoc mode indeed allows two neighbours that are in radio range to communicate. But in order to spread the absolute location of each node through the network, a routing protocol whose aim is to set up and maintain traffic paths along which each node location will flow is still required. In the scope of this work, a protocol will be used to establish a self-configuring infrastructure-less network intended for position forwarding. The combination of the ad hoc network and its routing protocol is called *Mobile Ad hoc NETwork* (MANET).

Figure 4.1 illustrates the topology of such a network. Node A can communicate with node B via the intermediate nodes that act as routers to forward the traffic.

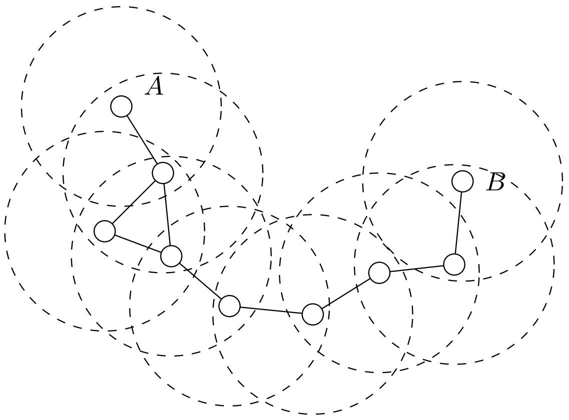


Figure 4.1: In this Mobile Ad hoc NETwork, node A can communicate with node B via the intermediate nodes.

DHCP in MANET

The DHCP issue in ad hoc networks (mentioned in Section 4.2.1) can be faced up in four different ways. MANET does indeed not provide any centralized mechanism to assign IP addresses to nodes joining the network. The four possible solutions to tackle this DHCP issue are:

1. **Manual IP address configuration.**
   Once a unique IP address has been attributed and set in the configuration files of each mobile device, it does not require any more configuration and it is ready to join the network at any time. Thanks to this manual configuration, it is possible to maintain a matching table with owner-IP relationships.

2. **Standard DHCP server on a centralized computer.**
   This solution consists in using a standard DHCP server on a centralized computer. In order to get an IP address, each device must be in the radio range of the centralized DHCP server. The DHCP lease time[2] must be set to a high value (e.g. more than one day). This long lease time ensures that, even if the DHCP server goes out of the devices radio range, the MANET can still run correctly.

3. **Standard DHCP server on an elected node.**
   This solution consists in using a standard DHCP server on one mobile device connected to the network. In a network, there must only be one active DHCP server at a time. Therefore, an election algorithm is used to determine which

[2] The DHCP lease time is used to define how long an IP address is valid in the network.

node will be the DHCP server. This algorithm must provide exactly one solution (i.e. the name or the reference of the elected node) whatever the network topology. An example of an election process can be a process where the chosen node is the one whose physical address of the interface connected to the network is the lowest. Another election process would be to select the node closest to the center of the network. Each node should therefore be able to act as a DHCP server since it is susceptible to be selected by the algorithm.

4. **Distributed algorithm.**
   This solution consists in using a distributed algorithm whose aim is to assign an IP address to a new node joining the network. Each already connected node in the network is asked to participate to the IP address choice. An example of such a distributed algorithm for dynamic host configuration for MANETS is MANETconf [NP02]. This algorithm is composed of two cases:

   - When the very first node wants to join the network, the algorithm initializes the MANET by assigning an IP address to this first node.
   - When a new address demand is coming from a new node, every node already connected to the network participate to the choice and the validation of the IP address.

The first solution is the simplest one but is not user-friendly in the sense that the change of the IP address of a device has to be performed by someone who knows where interfaces configuration files are located in a Linux-based operating system. Besides this drawback, this solution is fully effective. Furthermore, this solution does not require any control message exchange for IP assignment hence the network bandwidth can be dedicated to data packets instead of control packets. From a scalability standpoint, this solution presents good performances since no additional process needs to be achieved when the network is composed of thousands of nodes.

The second solution can be used only if the centralized DHCP server always remains accessible. It is indeed impossible for a totally new node to get an IP address if the DHCP server is out of range. It can especially be a problem in the military domain where soldiers must be able to set up the MANET anywhere, without relying on any external or centralized infrastructure.

The third solution is the less efficient one especially on small devices such as the Neo FreeRunner. The fact that, after the election, the IP address assignment process relies on a single device makes this solution less robust to failures (especially if the elected device fails or gets out of range of any other node of the network). Moreover, during the election phase, a part of the network bandwidth is used by control messages. Finally, the scalability of this solution depends on the scalability of the election algorithm. If the number of devices increases a lot, the amount of generated traffic for each election can indeed become hard to support to fit the network bandwidth.

The fourth solution is entirely distributed. According to [NP02], MANETconf, which is a distributed dynamic host configuration protocol, is reliable, message losses tolerant and scalable. But, the scalability analysis proposed in the paper is only based on the number of exchanged messages while the network state (that each node must maintain) must also be part of the analysis. The network state stored inside each node can indeed, as well as the number of exchanged packets, lead to scalability issues.

In the scope of the GeoSharing project, the first solution (i.e. the manual configuration) is used mainly for its easiness. Moreover, Neo FreeRunner devices used in this project have relatively small CPUs hence all not mandatory CPU usage is avoided. The implementation of one of the other possible choices can be the focus of further work.

4.3 Routing protocols overview

At this point, the general working concepts of the network have been defined. This section focuses on the routing protocol that will be used to set up and maintain traffic paths. The protocol choice is important because of the bandwidth limitation due to the wireless technology used in mobile devices.

Some of the most popular routing protocols available for an ad hoc wireless network are analysed in this section. But before going any further, *distance vector* and *link-state* routing concepts are introduced since they will be used in the remaining of this chapter.

4.3.1 Distance vector vs. link-state routing

There are two well known classes of distributed routing protocols which are distance vector and link-state routing. This section presents them since they introduce some technical background used in the following sections. Readers that are already familiar with those classes of routing protocols may safely skip this section and directly go to Section 4.3.2.

Distance vector routing

Distance vector routing is a very simple class of distributed routing protocols based on the advertisement of the distance from the originator towards each known destination. It uses a distributed algorithm to compute the shortest path towards each destination.

> "*Distance vector routing allows the routers to automatically discover the destinations that are reachable inside the network and the shortest path to reach each of these destinations. The shortest path is computed based on metrics or costs that are associated to each link. (...) Each router maintains*

a routing table. The routing table R can be modelled as a data structure that stores, for each known destination address d, the following attributes :

- *R[d].link is the outgoing link that the router uses to forward packets towards destination d*
- *R[d].cost is the sum of the metrics of the links that compose the shortest path to reach destination d*
- *R[d].time is the timestamp of the last distance vector containing destination d*

A router that uses distance vector routing regularly sends its distance vector over all its interfaces. The distance vector is a summary of the router's routing table that indicates the distance towards each known destination."

– Prof. Olivier Bonaventure [Bon11]

As it is explained in the book of Prof. Olivier Bonaventure [Bon11], the timestamp is used to detect link failures. Each entry of the routing table should be updated every N seconds, but in case of failure it is no more the case. Routers check every N seconds the timestamps of the routes stored in their routing table and remove those which are older than $3 \times N$ seconds. This class of protocols suffers from a problem that is known as the *count to infinity* problem in the networking literature. This means that nodes update their tables based on old information present in the network. Some solutions, such as split horizon with poison reverse, exist and reduce the bad behaviour introduced by this problem, but they do not solve it entirely.

Link-state routing

Another class of distributed routing protocols is the category of link state routing protocols. Unlike distance vector, every router belonging to the network learns the entire topology via message exchanges and the shortest path is computed locally thanks to the Dijkstra's shortest path algorithm.

"*For link-state routing, a network is modelled as a directed weighted graph. Each router is a node and the links between routers are the edges in the graph. A positive weight is associated to each directed edge and routers use the shortest path to reach each destination.*"

– Prof. Olivier Bonaventure [Bon11]

In this kind of routing, each router automatically discovers its neighbours by the use of HELLO packets that are sent every N seconds on all its interfaces. When receiving HELLO packets, a router knows to which neighbours it is connected. These HELLO packets are never forwarded and they can also be used to detect link failures.

> "*Once a router has discovered its neighbours, it must reliably distribute its local links to all routers in the network to allow them to compute their local view of the network topology. For this, each router builds a link-state packet (LSP) (...)*
> *As the LSPs are used to distribute the network topology that allows routers to compute their routing tables, routers cannot rely on their non-existing routing tables to distribute the LSPs. Flooding is used to efficiently distribute the LSPs of all routers. Each router that implements flooding maintains a link state database (LSDB) that contains the most recent LSP sent by each router. When a router receives a LSP, it first verifies whether this LSP is already stored inside its LSDB. If so, the router has already distributed the LSP earlier and it does not need to forward it. Otherwise, the router forwards the LSP on all links except the link over which the LSP was received.*"
>
> – Prof. Olivier Bonaventure [Bon11]

Distance vector and link-state routing protocols have been presented in a succinct way such that readers that are unfamiliar with these concepts can understand the next part of this section. These explanations are based on the document of Prof. Olivier Bonaventure. If you are interested in these protocols and want deeper details, you can read the original document [Bon11].

4.3.2 Underlying routing protocols

Now that the prerequisites have been introduced, the main routing protocols that can be deployed on ad hoc networks are presented. According S. Langkemper [Lan06], there exists two main types of routing protocols: *proactive* and *reactive routing.* This section is devoted to the presentation of routing protocols from those two main classes in order to choose the one that fits the most the needs of the application.

Proactive routing

Proactive routing protocols try to keep the routing table up-to-date on every node belonging to the network. The advantage of this kind of protocols is the fast forwarding times, because all the information for packet routing is available and up-to-date when a packet has to be sent. The main drawback is the continuous bandwidth consumption to spread routing information through the network, even when no data are exchanged between the nodes.

The main routing protocols from this class are: Distributed Bellman-Ford, Optimized Link State Routing, Global State Routing, Fisheye State Routing and Hazy Sighted Link State.

Distributed Bellman-Ford [Lan06] (DBF) belongs to the distance vector class, each node sends a routing table periodically to its neighbours. This routing table contains all the information known by the sender about the distance to reach each discovered in the network, at the time of sending. When a node receives a routing table, it updates its own routing table and only keeps the shortest path to reach each destination. Since this algorithm belongs to the distance vector routing class, it suffers from *count-to-infinity* problem. Ad hoc network topology is subject to frequent changes since nodes can move or fail. This routing protocol is therefore considered as unsuitable.

Optimized Link State Routing (OLSR) is an experimental protocol defined in RFC3626 [CJ03] which is similar to link-state routing. Each node selects some nodes in its neighbourhood which are called Multipoint Relays (MPRs). RFC3626 defines a mechanism to select the MPRs. These nodes will only forward messages from the node which have selected it as an MPR. Update messages are flooded over the entire network just as in link-state, but now only the MPRs relay the messages, decreasing the overall bandwidth consumption.

Global State Routing [Glo11] (GSR) is based on link-state routing. It does not flood link state packets through the entire network each time the topology changes but uses instead a periodic exchange of Link-State Packet (LSP) information, which reduces the control overhead. This packet contains a representation of the entire network topology and is only sent to neighbours. Each node can then compute the shortest paths (thanks to Dijkstra Shortest Path algorithm) using the information contained in the LSP. Since no global flooding is used, GSR greatly reduces the number of packets sent through the network when a node disconnects/reconnects. The fact that GSR depends on time for the update of the routing information, and is no more event-based, makes the update frequency a critical parameter that must be carefully chosen as discussed by Tsu-Wei Chen and Mario Gerla [CG98].

Fisheye State Routing (FSR) is an improvement of GSR described by G. Pei, M. Gerla and Tsu-Wei Chen in [PGC00]. With this protocol, nodes also only sends packets to direct neighbours. This protocol assumes that routes to nodes that are far are less important than routes to close nodes.

> "*In FSR, every update message doesn't contain information about all nodes in the network. Instead, information about closer nodes is exchanged more frequently than it is done about farther nodes, thus reducing the update message size. The center node has most up to date information about all nodes in the inner circle and the accuracy of information decreases as the distance from node increases.*"
>
> – SECAN-Lab (University of Luxembourg) [Fis11]

The routing table is accurate for close nodes but less precise for distant nodes. When a data packet is sent, since it goes from node to node, the route followed is reprecised at each node encountered along the path followed. Local changes are detected faster than distant changes according to the update period that has been defined.

Since both GSR and FSR only transmit information to their direct neighbours depending on the update period, it may take a long time before a topology change get communicated to the entire network.

Hazy Sighted Link State [SR03] (HSLS) also assumes that local changes of topology are more important than what is happening far away, as in FSR. While FSR is only based on an update period to delay the forwardings, Hazy Sighted Link State also has a *time-to-live* (TTL) to limit the spreading of LSPs through the network. This value is decreased by one in each packet which is forwarded and a packet with a zero value for the TTL is no more forwarded. Since this algorithm is also based on an update period, the neighbouring nodes will receive periodic updates (every N second(s)). This update messages will be forwarded at every update period, meaning that the next nodes will receive the update with an additional delay and a TTL value that has been decremented. Therefore, direct neighbours of the origin will receive update information every N second(s), next-hop will also receive these update information but, delayed of $2 \times N$ seconds, etc. So, close nodes will be aware of changes quickly while more distant nodes will receive update information less often. A long time can so be elapsed before a change is spread through the entire network.

Reactive routing

In opposition to proactive routing, reactive (or on-demand) routing protocols do not keep a routing table up-to-date but the path towards the destination is computed whenever a packet has to be sent. This technique reduces the bandwidth consumption since no update packets are sent, unless data are sent. It does not fit well mobile networks because flooding is used when a link fails, which happens frequently in mobile networks due to topology changes. So, flooding occurs very often and therefore reactive routing becomes close to link-state routing (where flooding is periodic). Furthermore, a delay is introduced when the first packet is sent to a host because of route computation.

This class of routing protocols is implemented by multiple routing protocols among which one can find: Ad hoc On-demand Distance Vector protocol and Dynamic Source Routing which are the two most common reactive protocols.

Ad hoc On-demand Distance Vector protocol (AODV) is an experimental protocol defined in RFC3561 [PBRD03]. It uses route request (RREQ) packets that are flooded throughout the entire network to discover the destination host. When a host receives a RREQ, it caches the route back to the originator in order to be able to unicast the route reply (RREP). As said previously, this category of protocols is not really efficient when used in dynamic networks. Indeed, when a RREQ is emitted, each node will get it. It is an expensive mechanism, especially if the requested destination does not exists. In ad hoc networks, topology changes are frequent. This implies that a significant part of the bandwidth will be devoted to route requests and not for application data transfer. Furthermore, all these requests introduce an additional delay, just to find a path to reach the destination.

Dynamic Source Routing (DSR) is an experimental protocol defined in RFC4728 [JHM07]. This protocol uses what is called *source routing*, meaning that each data packet that is sent contains the complete list of hops in the same order it passes through them. In order to find a path towards a certain node, the originator will broadcast a route discovery packet. Each neighbouring node will append its address to the list and broadcast the packet in turn. Once the destination node receives the route request packet, the list contains a path from the source to the destination. The destination node will then send the route request packet back to the source node via the reverse path contained in the packet. Source routing allows the source node to select the route it will use to send its data packets among the received ones and since the entire path is contained in the packet, it is easy to select a loop-free path. The main difference with AODV is that DSR does not cache the route towards which a node should send data back to the source node because everything is inside the packet. The advantage of DSR is that no control message packets are sent on the network periodically, reducing the network load.

4.3.3 Routing protocol choice

As presented previously, reactive routing protocols introduce more delays than proactive routing protocols. Since the third requirement (Section 4.1 on page 21) of the application is low forwarding delays, AODV and DSR are discarded. Even if more packets are used to keep each node of the network aware of the entire topology, proactive routing seems to be the best solution for the GeoSharing application. Because the wireless ad hoc network is made of small mobile devices, the bandwidth used for topology management should be minimized. Another point to take into account is that wireless technology of such devices is prone to lots of losses and so redundancy is required. There remains six different routing protocols belonging to the proactive routing class. As explained in Section 4.3.1, distance vector is subject to the *count-to-infinity* problem even with additional techniques such as *split horizon with poison reverse*. Therefore only link-state routing protocols are kept as possible choices.

Two more criteria are important for de developed application: forwarding delays and bandwidth consumption for topology updates. The following compares the three remaining possible choices.

GSR and FSR improve the bandwidth usage but introduce delays in the topology update by transmitting information to their direct neighbours depending on the update period. It may therefore take a while before the topology is updated in the entire network.

Hazy Sighted Link State also improves the bandwidth limitation but still has a problem very similar to GSR and FSR. Nodes that are quite far receive update messages after a relatively long period of time such that these nodes do not have recent information about whether a distant node is still present or not.

Optimized Link State Routing combines the advantages of proactive and reactive routing. That is to say, routing tables are always up-to-date thank to the global flooding technique and bandwidth consumption related to this flooding is reduced via the use of MPRs.

In light of the previous analysis, it appears that Optimized Link State Routing is the most suitable protocol for the GeoSharing application. It indeed keeps routing tables of every node up-to-date and reduces the number of update packets by the use of MPRs. Consequently, we choose this protocol as routing protocol in the GeoSharing MANET.

4.3.4 Optimized Link State Routing protocol in details

The Optimized Link State Routing protocol has been developed for MANETs. It is a proactive routing protocol as it has been explained in Section 4.3.2. Routing tables are therefore maintained up-to-date thanks to control traffic forwarding mechanism. The control messages are relayed by MPRs. This protocol suits very well for large and dense networks. The optimization achieved is better and better as the network becomes bigger and more dense (compared to a classical link-state protocol). OLSR fits very well the GeoSharing application because it has been designed to work in a distributed environment without relying on any centralized infrastructure.

Losses are frequent in wireless environment due to collision, electromagnetic interferences, etc. Nevertheless, OLSR does not require retransmission mechanism. A sequence number, which is incremented for each new message, is joined to every control message sent such that the receiver can check if the received message is the most recent or not and discards it if needed. OLSR relies on UDP on port 698 that has been assigned by the Internet Assigned Numbers Authority (IANA) to send packets. The protocol has been initially designed for IP version 4 (IPv4). But, it requires only a few modifications in the address lengths, in packet and message sizes to be IP version 6 (IPv6) compliant.

Another important feature of OLSR is its compatibility to extensions. Extensions (such as security and multicast-routing modules) can be used in combination with the standard OLSR protocol whose main purpose is to provide routing in a stand-alone MANET.

Multipoint Relays selection

Until this point, the assumption that MPRs are selected in an optimal way in order to establish connectivity between all nodes of the network was made. This paragraph briefly describes the way MPRs are chosen.

The optimal selection of the MPRs is an NP-complete problem. There exists heuristics to calculate a good-enough solution. In current OLSR implementation, *Simple Greedy MPR Heuristic* is used. Before starting any development, let's introduce the notions of *neighbourhood* (N), *2-neighbourhood* (N_2) and *degrees* (d^+ and d^-) of a node.

> "*For a node* u*, let* $N(u)$ *be the neighbourhood of* u*.* $N(u)$ *is the set of nodes which are in* u*'s range and share a bidirectional link with* u*. We denote by* $N_2(u)$ *the 2-neighbourhood of* u*, i.e, the set of nodes which are neighbours of at least one node of* $N(u)$ *but which do not belong to* $N(u)$*.*
> *(*$N_2(u) = \{v \text{ s.t. } \exists\ w \in N(u) | v \in N(w) \setminus \{u\} \ \cup \ N(u)\}$*).*
> *For a node* $v \in N(u)$*, let* $d_u^+(v)$ *be the number of nodes of* $N_2(u)$ *which are in* $N(v)$*:*
> $$d_u^+(v) = |N_2(u) \ \cap \ N(v)|$$
> *For a node* $v \in N_2(u)$*, let* $d_u^-(v)$ *be the number of nodes of* $N(u)$ *which are in* $N(v)$*:*
> $$d_u^-(v) = |N(u) \ \cap \ N(v)|$$
> *The node* u *selects in* $N(u)$*, a set of nodes which covers* $N_2(u)$*.*"
>
> – A. Busson, N. Mitton and E. Fleury [ABF05]

The selection heuristic (*Simple Greedy MPR Heuristic*) is composed of two steps. Given a node u:

1. The first step simply selects node(s) $v \in N(u)$ that cover(s) *isolated node(s)* of $N_2(u)$. A node w is defined as *isolated* if $d_u^-(w) = 1$.
2. The second step selects, among the remaining node(s) of $N(u)$, the one(s) covering most of the non-already-covered node(s) in $N_2(U)$.

The *Simple Greedy MPR Heuristic* is applied on the following topology:

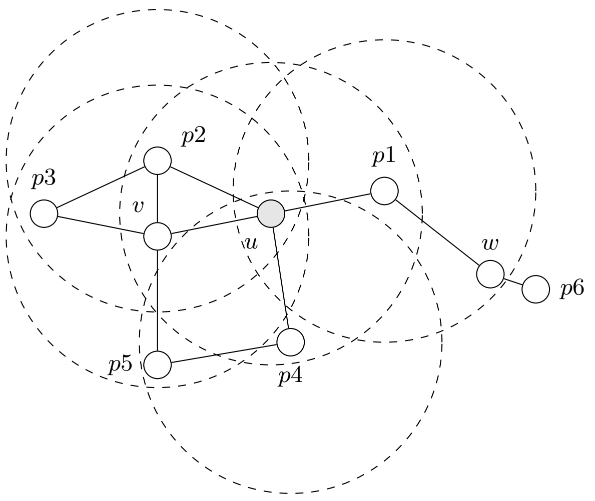


Figure 4.2: Radio ranges are represented by dashed circles. Radio ranges of nodes $p3$, $p5$, $p6$ and w are not shown for the sake of simplicity.

Initially, topology characteristics fore node u are:

- $N(u) = \{p1,\ p2,\ p4,\ v\}$
- $N_2(u) = \{p3,\ p5,\ w\}$

Let's apply the heuristic to node u:

1. node $p1$ is selected as MPR for node u because $d_u^-(w) = 1$ hence $p1$ is covering the isolated node w. There is no other isolated node on this topology.
2. node v is selected as second MPR for node u because it is connected with both $p3$ and $p5$ while $p2$ and $p4$ are connected with only one of them.

The resulting MPR selection for node u is represented on Figure 4.3.

The entire MPRs selection process can be formalized under the form of the pseudo-code presented on page 34 [ABF05].

Thanks to the MPRs, node u is able to communicate with its 1- and 2-neighborhood.

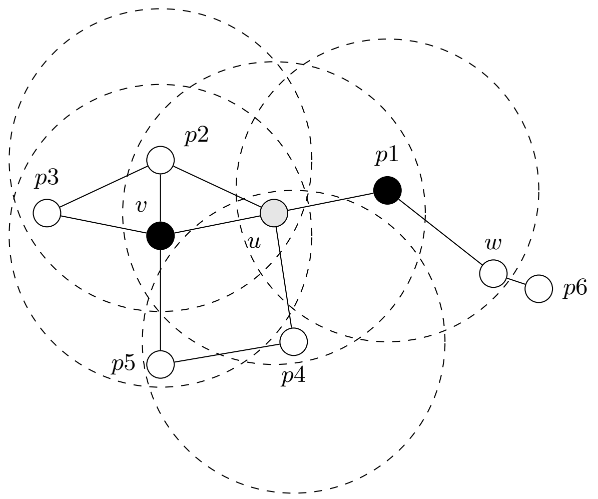


Figure 4.3: MPRs for node u are coloured in black.

Algorithm 1 : Simple Greedy MPR Heuristic (MPRs selection)

```
for all nodes $u \in V$ do
  for all nodes $v \in N(u)$ do
    if $(\exists w \in N(v) \cap N_2(u) | d_u^-(w) = 1)$ then
      Select $v$ as $MPR(u)$.
      ▷ Select as $MPR(u)$, nodes for which there is a node of $N_2(u)$ which has $v$ as single parent in $N(u)$.
      Remove $v$ from $N(u)$ and remove $N(v) \cap N_2(u)$ from $N_2(u)$.
    end if
  end for
  while $(N_2(u) \neq \emptyset)$ do
    for all nodes $v \in N(u)$ do
      if $(d_u^+(v) = max_{w \in N(u)} d_u^+(w))$ then
        Select $v$ as $MPR(u)$.
        ▷ Select as $MPR(u)$, the node $v$ which cover the maximal number of nodes in $N_2(u)$.
        Remove $v$ from $N(u)$ and remove $N(v) \cap N_2(u)$ from $N_2(u)$.
      end if
    end for
  end while
end for
```

4.4 Secured data transfer

Security is a core problem in network technologies, in particular in wireless network technologies. By nature, radio waves can be eavesdropped on by anyone who is in the radio range. Since the GeoSharing application is based on this wireless technology, some mechanisms should be added to prevent illegitimate persons to steal geo-location information or to send data over the network and potentially taking the control of it. For the GeoSharing application, the data packets flowing through the network contain the absolute positions of the devices on Earth. Since the application field could be sensitive, it is important to preserve the privacy of the users. The application is therefore designed so as to restrict the access to these sensitive data only to authorized persons.

The most common way to secure a Wi-Fi network is to use a security protocol as in many homes and companies Wi-Fi networks. These security protocols operate at the data link layer of the Open Systems Interconnection (OSI) model [Bon11] depicted on Figure 4.4.

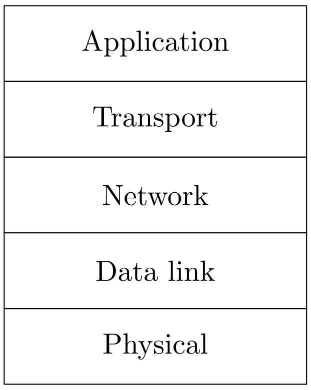


Figure 4.4: The five layers reference model was proposed by the International Organization for Standardization (ISO).

4.4.1 Data link-level security

The data link-level security prevents an unauthorized person to access the network. For this purpose, different solutions exist among which the most common are: WEP, WPA and WPA2.

WEP stands for Wired Equivalent Privacy and is a protocol used to secure Wi-Fi networks. Its security is based on pre-shared keys, meaning that the key used to secure the network must be provided to anyone wishing to connect to the network. WEP can be used with 64-bit, 128-bit or 256-bit keys. A 24-bit initialization vector (IV) is concatenated with a secret key of respectively 5, 13 or 29 ASCII characters. This protocol is broken since 2001 [FMS01] and today, it is possible to retrieve the key of a network protected with the WEP standard in a few seconds. Using WEP is generally better than letting the network *open* (i.e. without any security). If an attacker makes use of a packet stolen on a WEP-secured network, she implicitly admits having cracked the network in order to steal the packet. WEP is therefore nowadays more a mechanism to force attackers to do something illegal (i.e. wireless network cracking) when they want to steal information on a WEP-secured network.

WPA stands for Wi-Fi Protected Access. It is an improvement and a provisional solution to WEP. The main differences are the use of an initialization vector of 48 bits instead of 24 for WEP and the implementation of a layer on top of WEP called Temporal Key Integrity Protocol (TKIP). TKIP allows the system to dynamically change the key. This combination allows the protocol to be resistant to attacks developed against WEP. WPA is thus much stronger than WEP, although security breaches have been found in the TKIP algorithm used in WPA.

WPA has been designed to operate in two different modes. The first mode is called the *WPA-Personal* mode or *WPA-PSK* for Pre-Shared Key. It works exactly as the WEP encryption mode using a 256-bit key, but is more robust than WEP thanks to the TKIP mechanism and the longer IV. The other mode relies on a RADIUS server and is called the *WPA-Enterprise* mode. The user has to provide its credential to the RADIUS server and it receives a session key back. This mode is more complicated to set up in a MANET due to the centralised RADIUS server. Hence, the *WPA-Enterprise* mode is not considered in the scope of the GeoSharing project.

WPA2 is the successor to the provisional WPA protocol. WPA2 defines a certification that has to be satisfied by all new devices to be compliant with the Wi-Fi standard. It uses an even stronger encryption algorithm than WPA. WPA2 is believed to be only sensitive to brute force or dictionary attacks. Therefore, if a good password[3] is chosen, a WPA2-secured system can be considered to be secure.

In order to establish a WPA2-secured ad hoc network, the authentication process requires that each node acts as a client and a server for the other nodes. The WPA2 security scheme has not yet been deployed in the GeoSharing project. The deployment of this security scheme could be part of another study about security in MANET. Nevertheless, a reliable solution can be built based on WEP security (which is easier to achieve in ad hoc networks) combined with additional security mechanisms implemented in the application layer of the OSI model (Figure 4.4).

[3] A password is considered as good if made of a hard to guess combination of different types of characters such as upper and lower case letters, numbers and punctuation marks. It should not be found in any dictionary of any language.

In the GeoSharing project, the WEP security scheme is mainly used to force an attacker to do something illegal to join the GeoSharing MANET. The additional security mechanisms implemented in the application layer are used to ensure that, even if an attacker penetrates the network and steals packets, the content of each data packet remains unemployable.

4.4.2 Application-level security

As stated before, the WEP security scheme is weak and can easily be broken by an attacker. It is therefore crucial to ensure that the content of the packets, containing each node coordinates, flowing through the network are protected from unauthorized parties even if the channel is eavesdropped on. The GeoSharing application must guarantee the privacy and the integrity of the data exchanged on the MANET. The privacy ensures that data remain confidential even if a third party eavesdrops on the communication between legitimate parties while the integrity ensures that messages are not corrupted during their trip over the network. Two additional mechanisms must therefore be added in order to fulfil these two requirements. The first mechanism encrypts the content of the packets exchanged between legitimate parties in the MANET. The second mechanism computes a Message Authentication Code (MAC) used to ensure that the packet content has not been changed while flowing on the network. As we can see on Figure 4.5, if the message is encrypted at the data link level at which WEP operates, all the upper layers process the data in the clear. An attacker can therefore implement a malicious program to retrieve the data from these layers. To prevent this problem, the encryption and the integrity check should be performed at the application layer in order to prevent an attacker to exploit the intermediate layers between the application and the data link layers.

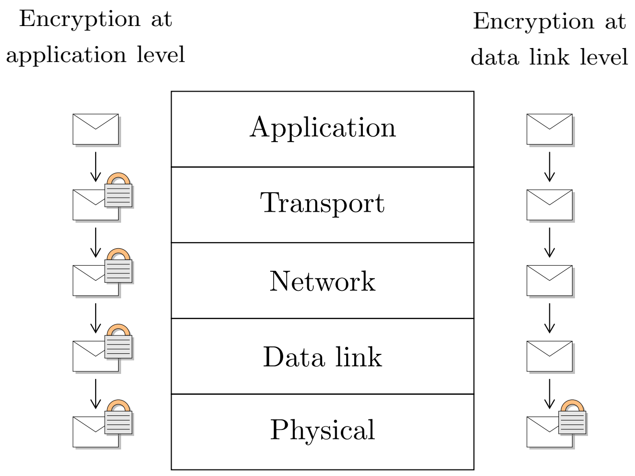

Encryption at application level
Encryption at data link level
Application
Transport
Network
Data link
Physical

Figure 4.5: If the message is not encrypted at the application level, it could be intercepted in intermediate layers by a malicious program running on the machine.

Encryption

The encryption of the content of the packets can be performed using a symmetric or asymmetric encryption algorithm. Asymmetric encryption algorithms are used to encrypt messages from one point to another and rely on a public/private key pair. The sender uses the public key of the destination in order to encrypt the message and the receiver decrypts the message using its private key. In the scope of the GeoSharing project, asymmetric encryption algorithms can not be employed mainly because messages are exchanged in multicast mode. Exactly the same packets are sent to all the nodes. It is therefore impossible to customize the packet for each destination. Customizing the packet means to encrypt the packets content with the personal public key of each node belonging to the network.

Symmetric encryption algorithms rely on keys that are shared between all the trusted parties. All the nodes therefore possess the same keys and can encrypt or decrypt messages thanks to these keys. In the GeoSharing project, a symmetric encryption algorithm is used.

The symmetric encryption algorithms that are the most commonly used are *Triple DES*[4] (3DES), *Blowfish* or *Advanced Encryption Standard* (AES). Nowadays, these three algorithms are still considered to be secure. The 3DES in Electronic Code Book (ECB) mode has been chosen to be used in the scope of the GeoSharing application but both AES and Blowfish could also be used. The ECB mode of 3DES is the most commonly used [Tri11] and the easiest to implement. 3DES is based on the simple DES algorithm which is performed three times. The data are firstly encrypted by application of DES, the resulting cipher is then decrypted by an application of DES^{-1} and finally re-encrypted by a last application of DES. The entire encryption process is equivalent to $E_{k_1}(E_{k_2}^{-1}(E_{k_3}(data)))$. This process requires at least two different keys, otherwise it becomes equivalent to a simple DES encryption since $E_k(E_k^{-1}(E_k(data))) = E_k(data)$.

In the scope of the GeoSharing project, three different keys are provided to the 3DES algorithm and are all 8-byte long. Since the ECB mode of 3DES encrypts the data by dividing it in blocks of 8 bytes, the encryption algorithm generates the same ciphertext if the same clear data are provided as input. It is therefore obvious that some information can be retrieved from such a scheme (i.e. the attacker knows that the clear data are the same if the ciphertext is the same). In order to tackle this problem, a 8-bit random value is added at the end of each 64-bit block of clear data to be encrypted. This process provides a high chance of getting different encrypted data as output of the 3DES algorithm as the 8-bit random value is different. The adding of the random byte aims to guarantee that no illegitimate party can deduce anything from the ciphertext.

[4] DES stands for Data Encryption Standard. Note that simple DES algorithm is broken but 3-DES is still considered as secure.

Two critical points have to be taken into account when dealing with this encryption algorithm.

1. In order for 3DES to provide a high security level, none of the three used keys must be the same as the one used for the WEP protocol. Since WEP is easily broken, it is possible to retrieve the key that is used and so one of the three keys used in 3DES is known.
2. Since the 3DES algorithm is based on shared keys, they have to be kept secret by all the users of the GeoSharing application. Otherwise, the entire security of the network is compromised.

The second point can be tackled by an additional mechanism such as a periodic re-authentication (e.g. every five minutes). The user is asked to re-enter a personal password in order to change the keys and be able to continue on using the application. This procedure limits the time during which an attacker can decrypt the encrypted data if she gets the keys used in the 3DES algorithm.

Message Authentication Code

At this stage, the data exchanged over the network are encrypted but changes on the packets' content can occur without the receivers detecting it. The aim of the MAC is to check the integrity of the packets' content. It allows any receiver to detect that a change occurred in the packets' content and discard the packet. Forged packets are therefore not forwarded any more on the MANET. Several different MAC schemes exist (HMAC, CBC-MAC, etc.) and can be used to compute the MAC of a packet's content. The MAC is a one way function[5] that accepts as inputs a secret key and an arbitrary length message and provides a MAC as output. The key used to perform the MAC computation has to be different from the other keys used (for the WEP protocol and the 3DES encryption).

To set the integrity check and the privacy together, several methods can be used and are listed just bellow in decreasing order of security levels [Avo11]:

1. $E_{k_e}(message)|MAC_{k_m}(E_{k_e}(message))$: the encrypted message is concatenated with the MAC of the encrypted message (Used in IPSec)
2. $E_{k_e}(message|MAC_{k_m}(message))$: the concatenation of the MAC of the message with the message is encrypted (Used in SSL)
3. $E_{k_e}(message)|MAC_{k_m}(message)$: the encrypted message and the MAC are concatenated (Used in SSH)

[5] One way functions have the property that it is extremely difficult to retrieve the original message based on the encoded message.

The first solution is therefore chosen to send the coordinates on the MANET. In order to check the authenticity and the integrity of a message, the receiver computes the MAC of the received encrypted message thanks to the shared MAC key and compares the MAC joined to the message to the obtained result as shown on Figure 4.6. If the MACs are equals, it means that the received message has most likely not been forged and the receiver can then decrypt the message to recover the data. Otherwise, it means that something unexpected happened and the message is discarded.

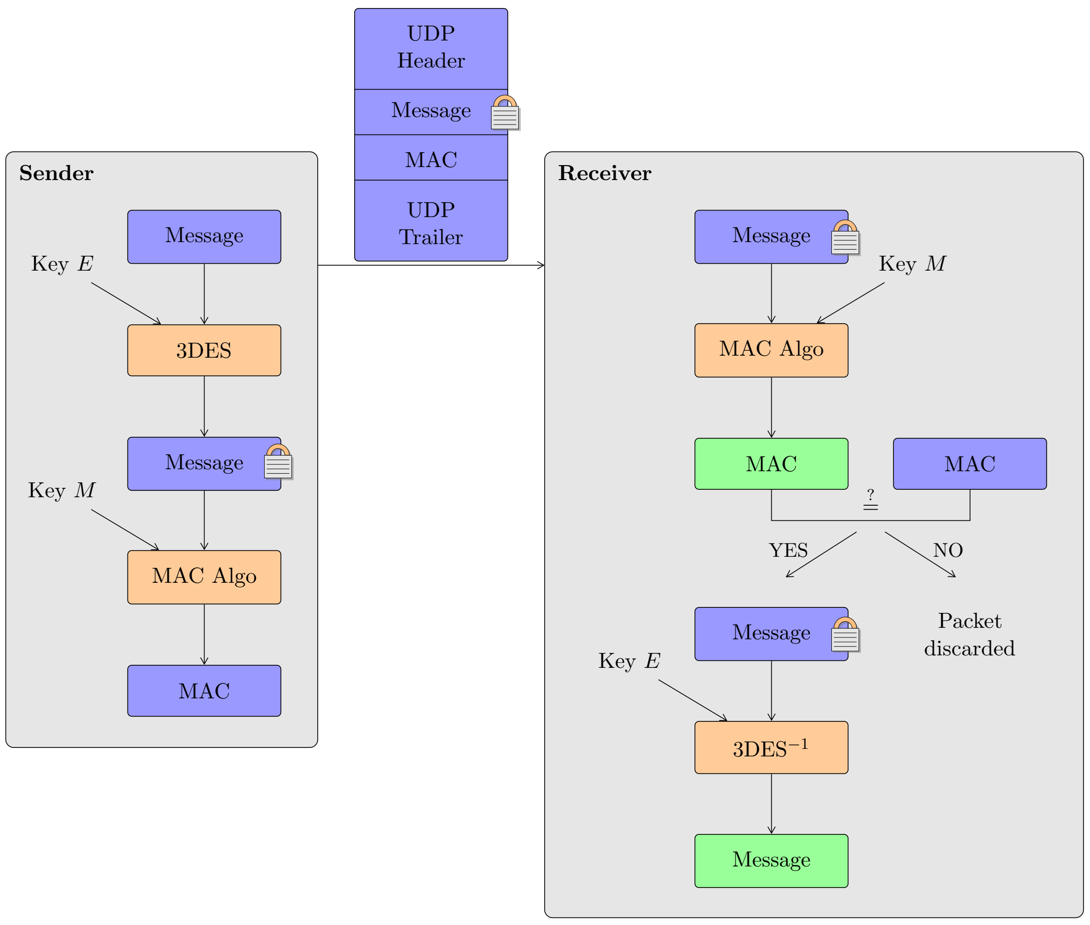


Figure 4.6: The receiver can check the integrity of the message and the authenticity of the source thanks to the MAC joined to the message.

In the current version of the GeoSharing project, the MAC mechanism has not been implemented yet and can be the focus of further work.

Vulnerabilities and further work

Some vulnerabilities have been identified and could be the subject of a further work. If some keys are used in multiple cryptographic algorithms, the entire security of the network could indeed be broken if only one algorithm is broken and the key is retrieved. The periodic re-authentication mechanism previously discussed could be implemented to face up this problem and restrict the time for the attacker to decrypt messages to only several minutes. Five different keys are needed to secure the whole application. A secure place has therefore to be found in order to store all these keys such that they can not be accessed easily (e.g. the Linux keyring).

Some attacks on the networks are still possible despite the encryption of the data and the integrity check via the MAC scheme. An attacker can indeed perform a replay attack on the network. This attack consists of replaying a packet previously captured on the network. The integrity of such packets is preserved, so the nodes trust the content and update the node's position accordingly. To tackle this attack, a sequence number has been added in the message such that the receivers only updates the position of a node if the sequence number contained in the packet is greater than the previously received one. This mechanism is detailed in Section 6.3.3.

Even if a sequence number is added in each packet, a Denial Of Service (DOS) attack is still possible. An attacker can indeed capture a message on the MANET and saturate a targeted node by sending this message many times with a short intermediate delay. The targeted node is obliged to process each received packet to discover the sequence number. If the number of packets received is really big, most of the resources of the device are dedicated to packet processing and no more to the sending. The node becomes inoperative. This attack can not be avoided if an attacker has penetrated the network.

The last vulnerability that has been identified is that an attacker can still deduce some information about the nodes position if she collects a lot of packets. The more packets she has, the more she can trust the deductions she made. Indeed, even if a random byte is added to each 7-byte block of clear text before encryption, the ECB mode used in the scope of this thesis does not provide a high enough level of security to ensure the privacy of the data. For example, if a node remains at the same position on Earth for a long time, it will send the same position many times. Since one random byte only guarantees 255 different values, if the same position is kept by the node, the same series of encrypted messages can be observed several times by the attacker. She can then have presumptions that a node is remaining at the same place but should not be able to deduce which node it is, neither where it is. The use of another mode (e.g. Cipher Block Chaining (CBC) mode) for the 3DES algorithm should tackle this problem.

4.5 Optimized Link State Routing in GeoSharing

An implementation of the Optimized Link-State Routing has been proposed by Andreas Tønnesen [Tø04] under the form of a Linux dæmon called OLSRd. This open-source implementation has been chosen to be part of the GeoSharing project in order to set up and maintain traffic paths. This dæmon is configured to establish point-to-point connectivity between all nodes of the MANET but, in GeoSharing, a multicast address is used to spread GPS coordinates over the network. For this purpose, a plugin is added to OLSRd.

4.5.1 Optimized Link State Routing Linux dæmon

The Optimized Link State Routing Linux dæmon has been implemented to be compliant with RFC3626 [CJ03] and can be found on the official web site: http://www.olsr.org.

Since OLSRd is the routing dæmon used in the GeoSharing MANET, it is relevant to evaluate the scalability of such a network. The author of this dæmon has run some tests [OLS07] showing that a very large network composed of thousands of nodes can run OLSRd without any scalability problem. The mobile devices used in those experiments were low-cost hardware with small CPU capabilities (200MHz) and 32MB of memory which is very similar to the devices used in the work of this thesis. The GeoSharing MANET should therefore not suffer from scalability issues.

4.5.2 Multicast in MANET

An important point to remember about OLSRd is that its goal is to maintain routing tables up-to-date. Thanks to these tables, a point-to-point connectivity is established between all nodes. The use of OLSRd permits thus to send data packets from one node to all other ones by specifying the unique IP address of each node.

In the scope of the GeoSharing project, the use of a multicast address to contact a group of nodes seems to be mandatory because of the potential high number of nodes in the network. Furthermore, this technique allows nodes to only receive packets from group of nodes to which they are attached.

In order to deal correctly with multicast addresses, the Basic Multicast Forwarding (BMF) plugin is used in addition to OLSRd. This plugin creates a virtual interface (`bmf0`) in order to send and receive multicast packets. In practice, only MPRs forward multicast packets reducing the amount of duplicates with relation to a multicast in a pure link-state routing protocol.

Section 6.1 presents the way OLSRd and its BMF plugin were installed on Neo FreeRunner devices used in the scope of this thesis.

Chapter 5

Graphical User Interface

From an end-user standpoint, the graphical user interface (GUI) is the most important component because it is the interface between the user and the application that allows the user to interact with it to perform the tasks he wants to execute on the application.

This chapter first introduces requirements that must be satisfied by the GUI of the GeoSharing application. It then describes different ways that can be used to build a graphical user interface along with the advantages and disadvantages for those different techniques that can be used. It finally explains the choices that were made for the GeoSharing application presented in this work.

5.1 Graphical requirements

Building a well designed and clear graphical user interface is always a challenge. The main purpose of the GUI is to show the geographical positions of other GeoSharing users on a map. In order to be fully effective, the GUI must satisfy three criteria:

1. **usability:** the user must feel comfortable with the GUI. Access to the program functionalities must be easy and intuitive. Each button or each picture in the GUI must be representative of the action related to them. This means that if a user sees a button on the interface, he can immediately knows what will happen if he clicks on it.
2. **high performances:** the GUI must be reactive and fluid.
3. **portability:** the interface must be easily ported from one operating system to another. Portability is close to adaptability in the sense that the GUI must fit as best as possible the screen resolution of the device running the application. Just rescaling the GUI to fit another screen resolution is not sufficient. Certain graphical components which are considered as less important should not appear on devices with smaller screens.

5.2 Potential architecture designs

Three possible architecture designs can be used in order to build a graphical user interface for the GeoSharing application.

1. **Stand-alone**: one solution to build a graphical user interface is to build it completely from scratch. Fortunately there exists some well implemented graphical libraries in C (such as GTK+) which are useful to create windows, buttons, menus, etc. But the GeoSharing application requires some more complicated features such as a map service (e.g. Google Maps), a zoom mechanism, a map caching mechanism for off-line use, etc. The main advantage of this solution is that since it is build from scratch, every part of the interface will have a role useful for the application. The main drawback is the cost to develop such an application regarding already existing libraries.

2. **Integrated solution inside an existing application**: the second possibility to develop the interface of the GeoSharing application is to integrate the GeoSharing functionality into an already developed open-source GPS application. The idea is to take one stable release of such a GPS application and to add new pieces of code into it. The advantage of this solution is the simplicity. As in many applications, the main loop of the program must be found and modified to add the GeoSharing functionality. One drawback is the backwards and forwards compatibility with other versions of the concerned GPS application. If the GeoSharing functionality is directly integrated in the application without anything designed for, users are obliged to keep this version of the application in which the GeoSharing GUI was built. Otherwise, GeoSharing updates should be done at the rhythm of the chosen GPS application which may involve a large maintenance cost.

3. **Plugin of an existing application**: the third possibility to develop the interface of the GeoSharing application is, as the second potential choice, to integrate the GeoSharing functionality into an already developed open-source GPS application. But the idea, here, is to first extend the GPS application to be plugin compliant and provide a simple interface for any plugin to interact with this GPS application. The next step is to develop one plugin for the GeoSharing functionality. The main advantage is the compatibility with any newer version of the concerned GPS application. If the core modifications in the GPS application (allowing people to add plugins) are as general as possible and are accepted by the developers community, these modifications will indeed remain on all new versions. In the same way, the GeoSharing specific plugin will remain compatible with the determined interface and the entire application will run correctly. One drawback is the weight of the final application. People who want to use GeoSharing must install this plugin compliant GPS application and the GeoSharing plugin.

5.3 Choice of the architecture design

As just explained, the three possible architecture designs present pros and cons. In a first time, the choice to discard the first solution (i.e. developing everything from scratch) was made to focus on the functionalities of the GeoSharing application and to have a usable user interface while minimizing the development cost. The developed interface could so be quickly used and could eventually be developed from scratch in future versions for efficiency, memory and CPU usage reasons.

Among the two remaining choices, the solution based on the plugin, proving the greatest modularity, is preferred. Adding the GeoSharing functionality into the core methods of an existing GPS application (i.e. solution number two) implies a decrease of the overall application *cohesion*[1] with an increase of its *coupling*[2] which is contrary to general rules of software engineering. That observation motivated the choice done for the GeoSharing application.

There are different possible choices for the application on which to develop the GeoSharing plugin. The default GPS application proposed with SHR (which is the operating system chosen to be part of the GeoSharing project) is tangoGPS. Another possible GPS application for Linux-based systems is Navit. The choice made in this work is to develop a GeoSharing plugin for tangoGPS. According to the criteria described in Section 5.1, it is obvious that tangoGPS is more suitable for the GeoSharing project. It indeed appears that Navit is more complicated to handle because menus are less intuitive and clear. The integration of a plugin menu in this existing menu is therefore complicated. The usability of Navit is thus worst than the usability of tangoGPS. Navit also offers lots of functionalities which are useless in the scope of the GeoSharing project such as car navigation instructions, shortest path computation, etc. From a performance standpoint, Navit and tangoGPS are equivalent. Since both applications provide a mobile and a desktop version, the portability criterion is, as well as the performance criterion, useless to choose between Navit and tangoGPS. Only the usability criterion leads to the choice in favour of tangoGPS.

5.4 TangoGPS plugin in details

It was necessary to adapt the standard tangoGPS version to be plugin compliant. For this purpose, a plugins interface has been developed and is presented in the first part of this section. The second part summarizes the requirements that need to be fulfilled in order to create a new plugin for tangoGPS.

[1] "*In computer programming, cohesion is a measure of how strongly-related the functionality expressed by the source code of a software module is*" [Coh11].

[2] "*In computer science, coupling or dependency is the degree to which each program module relies on each one of the other modules*" [Cou11].

5.4.1 TangoGPS plugins interface

The plugins interface aims at providing a clear and simple interface to allow people to develop and integrate plugins into tangoGPS. The interesting characteristic of working with plugins is that the host application (i.e. tangoGPS in the scope of the GeoSharing project) does not need to be compiled again when a plugin is added. At the application start up, the plugin interface of the host application is responsible for reading a configuration file containing information about the different plugins to integrate. It may also be possible to add a plugin dynamically, when the host application is already running. A communication API has to be defined in order to allow plugins to exchange messages with the host application when they are both running.

The general architecture of tangoGPS with the plugins interface and a few plugins is shown on Figure 5.1.

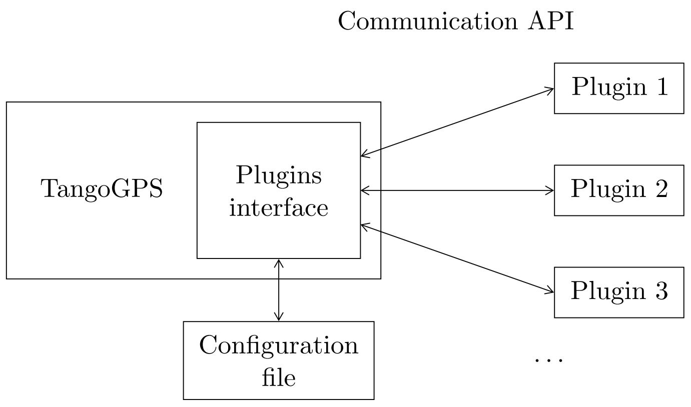


Figure 5.1: The plugin interface aims at providing a clear and simple interface to allow people to develop and integrate plugins into tangoGPS.

The version of tangoGPS on which the plugins interface has been developed is the version 0.99.4. The development of the interface is integrated into tangoGPS source files. It is developed in C and takes about 400 lines of code.

As we can see on Figure 5.1, a configuration file and different messages are involved in the process hence, before starting any development, the format of the configuration file and the messages has to be defined.

Configuration file

The configuration file is read when the host application is started. The file must be readable by any process and its location on the Linux filesystem of the device running tangoGPS must be `/etc/tangogps_plugins.conf`[3]. There must be one entry per

[3] This fixed location in the Linux filesystem is not a limitation since tangoGPS is a GPS application developed for Linux systems.

plugin and each entry must be composed of four different fields: `name`, `path`, `options` and `running`. An example of configuration file is shown hereafter.

```
# TangoGPS Plugins Interface

nbr_plugins = 2;

Plugin1 = {
    name        =   "PlugName";
    path        =   "./home/root/dev/plug_name/src/plug_name";
    options     =   "--server '127.0.0.1'";
    running     =   "/tmp/plugname.run";
};

Plugin2 = {
    name        =   "GeoSharing";
    path        =   "sh /home/root/dev/geo_sharing/run_geosharing.sh";
    options     =   "";
    running     =   "/tmp/geosharing.run";
};
```

- `name` contains the name of the plugin as it will appear in the menu of tangoGPS (Figure 5.2). The name must be unique among the plugins and the length of the plugin name is limited to ten characters.
- `path` is the path to the executable file that will be executed if the plugin is activated.
- `options` are the options to add if the executable file (specified in the `path` field) needs some.
- `running` is the path to a file indicating whether the plugin is already running or not. This file must be created by the plugin itself when it is running and removed when the plugin is stopped.

It is thus possible to develop a plugin for tangoGPS in a separate executable file and, thanks to the configuration file, tangoGPS is able to integrate and launch the plugin without recompiling any part of tangoGPS. In the scope of the GeoSharing project, the dynamic adding of plugin is not implemented but this feature can be the focus of further work.

Communication API

Since the plugin is ran in a separate executable file, there must be communication between the plugin and the host application. The communication is done via a Unix socket[4] opened at `/tmp/tangoPlugin.sock`. Each plugin can send messages on this

[4] Unix socket is a way to share information between processes of the same machine with the help of a shared file.

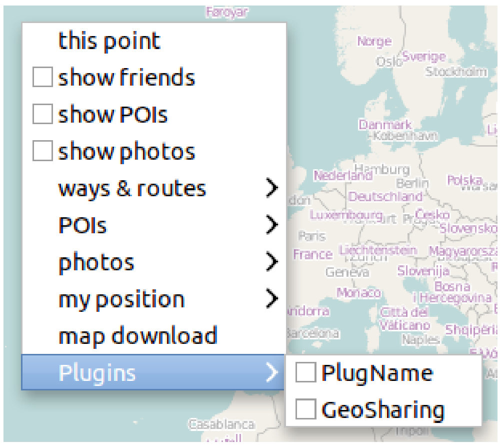


Figure 5.2: One entry per installed plugin is created on the tangoGPS menu after the configuration file has been read.

socket to interact with the host application. A communication API has been developed. The first version of the plugins interface proposed in the scope of this thesis can handle three different messages.

- A **display message** is used to ask tangoGPS to draw a picture on the map at precise coordinates. The message has the following format:

  ```
  disp # pluginName # identifier # latitude # longitude # img $
  ```

  where

  - `pluginName` is the name of the plugin sending the message. The plugin name must be the same as the name written in the configuration file.
  - `identifier` is a unique name describing what is represented by the point on the map. For example, if a plugin populates the map with different Points Of Interests, the identifier can be “Hotel Ritz”, “Parking” or “Irish Pub”. In the GeoSharing project, the identifier is used to differentiate users.
  - `latitude` and `longitude` are the coordinates on Earth (in degrees) where to draw the picture.
  - `img` is an integer value representing the picture to be drawn on the map. In the first version of the plugins interface, there are only two accepted values for `img`. The value 1 must be specified for the yellow figure (Figure 5.3(a)) and the value 2 must be specified for the yellow star (Figure 5.3(b)).

- A **delete message** is used to ask tangoGPS to delete a picture previously drawn on the map. The message has the following format:

  ```
  dele # PluginName # Identifier $
  ```

Figure 5.3: The value 1 must be specified for the yellow figure and the value 2 must be specified for the yellow star.

- A **redraw message** is used to ask tangoGPS to refresh the entire map. The message has the following format:

  ```
  redr $
  ```

Thanks to this communication API, any plugin can communicate with the host application and ask for different tasks such as displaying something on the map, deleting something from the map and refreshing the map.

When the host application is started, the plugins interface parses the configuration file to look for plugin details. For each plugin entry in the configuration file, the plugins interface creates a entry in the plugin menu of tangoGPS (Figure 5.2) and stores the information related to the plugin (e.g. `name`, `path`, etc.) in a linked list (called `plugin_list`). When the configuration file is totally parsed, the plugins interface can rely on this linked list where each node of the list represents a plugin and contains all the informations related to the plugin. The dynamic aspect of the linked list could permit the adding of plugins dynamically. A mechanism could indeed ask the user for information (e.g. `name`, `path`, etc.) about a plugin that he wants to add on-the-fly. Those information must be added to the linked list and a new entry must be created on the plugin menu. A second linked list (called `plugin_data_list`) is also created in order to contain up-to-date information about locations received from the plugins. Each node of this second linked list represents a location and contains the name, the latitude, the longitude and the picture of the location. Moreover, the node also contains the name of the plugin responsible for the node.

The activation of a plugin is done via the plugin menu (Figure 5.2). When a plugin is selected (the user clicked on it), two cases are possible. Either the plugin is activated or deactivated.

- If the plugin is **activated**, the plugins interface checks if the process related to the concerned plugin is already running or not. For this purpose, the plugins interface makes a call to `fopen()` on the file referenced in the `running` field of the configuration file to check if the file exists or not. If the file does not exist, the plugins interface launches the plugin process via a call to `execve()`. TangoGPS plugins interface is then ready to receive messages as it is described in the communication API.

- If the plugin is **deactivated**, every location for which the plugin is responsible has to be removed from the screen and from the `plugin_data_list`.

Upon reception of a message on the Unix socket of the plugins interface, the message must be processed. The plugins interface takes the first four characters of the message to extract the type of the message. It can be `disp`, `dele` or `redr`.

1. If it is `disp`, the plugins interface checks if the plugin which sent the message is active or. If it is the case, the plugins interface updates the `plugin_data_list` with the information contained in the message.
2. If it is `dele`, the plugins interface also checks if the plugin which sent the message is active or not. If it is the case, the plugins interface deletes the location specified in the message from the `plugin_data_list`.
3. If it is `redr`, the plugins interface calls `repaint_all()` which is an already implemented function of tangoGPS. The `repaint_all()` function is responsible for repainting the entire map including locations received from the plugins.

5.4.2 Plugin creation

The creation of a new plugin for tangoGPS is made easier with the plugins interface. Thanks to the configuration file, any plugin can be added to tangoGPS without the need of compiling again the whole application. The new plugin is developed independently of tangoGPS. There are only a very few requirements that must be satisfied by the new plugin.

1. The new plugin must be compiled and the binary file must be made available for tangoGPS.
2. The configuration file of tangoGPS plugins interface must be filled in correctly with all the information needed to launch the plugin.
3. All the messages sent to the plugins interface must respect the communication API.

Apart from that, the new plugin can implement any functionality while the format of the interactions with the plugins interface remains compliant with what is defined in Section 5.4.1.

The modifications made to tangoGPS in order to make it plugin compliant allow anyone to add new functionalities to tangoGPS with a small development cost. Many functionalities can now easily be ported to tangoGPS. For example, a new plugin can be developed to display to a car user all the radar systems whose locations are stored in a database.

Chapter 6

GeoSharing project

This chapter is dedicated to the practical steps which led to the GeoSharing application. The theoretical choices made during the elaboration of the GeoSharing project have been incrementally implemented and integrated to form a whole. The C language has been chosen to implement the different functionalities of GeoSharing mainly for its high performances that makes it suitable for application development running on low-cost hardware. Moreover, the C language is widespread in mobile application development hence a C compiler (e.g. gcc) is available for many architectures either directly in the operating system running on the device or as a cross-compiler.

The first section of this chapter presents how the Linux OLSR dæmon has been integrated to the GeoSharing project to serve the GeoSharing objectives in terms of network topology management. The second section explains the way all the different parts of the GeoSharing project run together. Section 6.3 details the core functionalities of the GeoSharing application and how those functionalities are implemented. Section 6.4 explains how to enjoy the GeoSharing application as an end-user. Finally, Section 6.5 presents future development work that can be done to improve the GeoSharing project and bring it further.

6.1 OLSRd and BMF set up on the Neo FreeRunner

As stated in Section 4.5, the OLSRd dæmon developed by Andreas Tønnesen [Tø04] was chosen to be part of the GeoSharing project. This dæmon provides efficient routing table management and low forwarding delays. In addition to this dæmon, the BMF plugin is used to allow multicast packet forwarding required in the scope of the GeoSharing application.

The source code of the 0.6.0 version of OLSRd is available on http://www.olsr.org, the official website of OLSRd dæmon. The sources must be compiled for the Openmoko specific architecture. This OLSR dæmon contains a syntactical analyser (for exchanged messages analysis purpose) whose source code must be generated before the dæmon compilation. For the source code generation of the syntactical analyser, `bison` and `flex` tools are needed but are unavailable on the operating system used in the scope of the GeoSharing project. The source code generation of the syntactical analyser can also be done on any architecture (e.g. on a standard i686 computer) since the outputs of `bison` and `flex` are non-compiled files only containing C code. Once this generation is done, only `gcc` is needed hence OLSRd code can be compiled on the Neo FreeRunner.

The BMF plugin is used in addition to the core functionalities of OLSRd to allow multicast message forwarding. This plugin must be compiled and installed. A configuration file must be modified to notify OLSRd that it must load the plugin at start up. The OLSRd and BMF plugin compilation and installation steps are detailed in Appendix A.2.1.

When OLSRd is running in combination with the BMF plugin, a virtual network interface called `bmf0` is created in order to manage multicast packet forwarding. Multicast packets are therefore sent/received via the `bmf0` interface. Upon reception of this kind of packets on node N, the `bmf0` interface forwards the packets to OLSRd. OLSRd pushes the packet to the application layer and retransmits the multicast packet if node N is a multi-point relay and if the packet has not yet been retransmitted. Point-to-point packets flowing through the network are directly managed by the non-virtual Wi-Fi interface (`eth0`) and are forwarded to OLSRd as well. An example of a multicast packet transmission is shown on Figure 6.1.

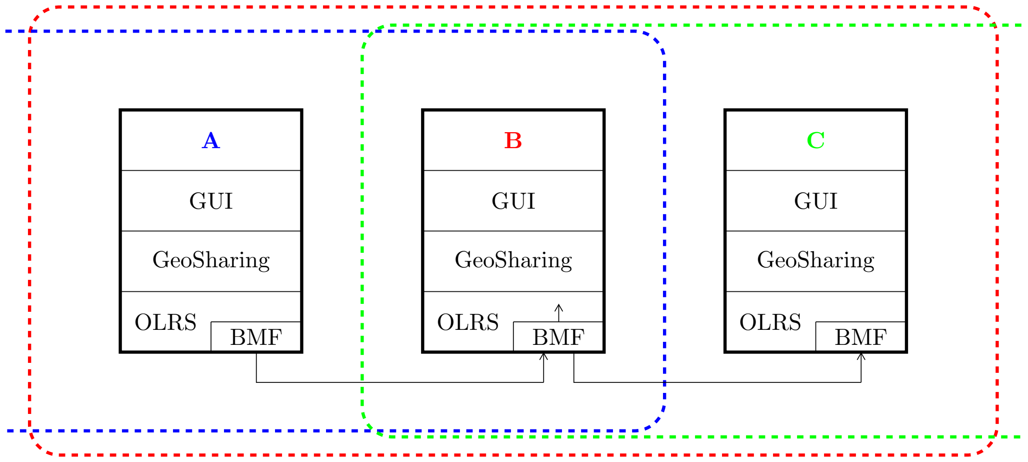


Figure 6.1: Node A sends a multicast packet. The only node in its range is node B which is an MPR. B therefore receives the packet on the bmf interface. A copy is pushed to the application and the multicast packet is forwarded to C which processes the packet in the same way. Radio ranges are represented with dashed coloured lines.

6.2 How GeoSharing runs

The GeoSharing project is composed of three different modules.

- **OLSRd** is used to serve the GeoSharing objectives in terms of network topology management.
- **GeoSharing** is the main application of the GeoSharing project. This module retrieves GPS data and shares them over the network via multicast encrypted messages through an internet socket. This module also send formatted messages to the plugins interface of tangoGPS through a Unix socket. More details about this module are provided in the next parts of this section.
- **TangoGPS** (via its **plugins interface**) receives formatted messages and display the locations contained in those messages on the map.

The interactions between those modules are represented on Figure 6.2. Details about the installation of OLSRd, the GeoSharing application and tangoGPS on a Neo FreeRunner are provided in Appendix A.2.4.

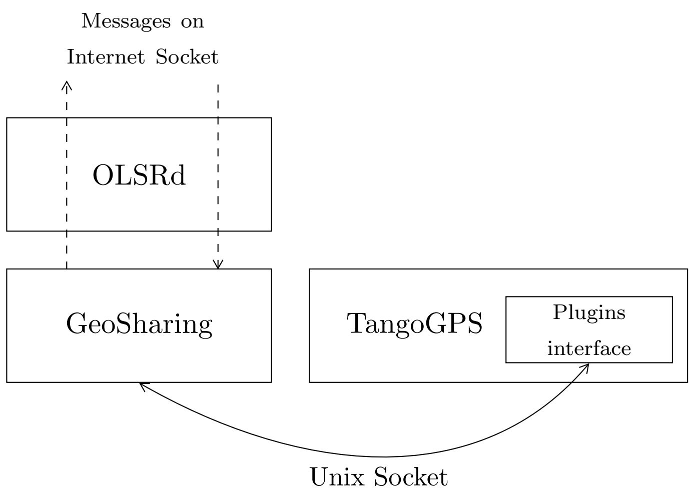


Figure 6.2: The interactions between the modules are done through sockets.

6.2.1 GeoSharing files organisation

The main application of the GeoSharing project has been implemented in C. For the sake of readability and maintainability, the application is split into four different pairs of files. Each pair consists in one file containing the code (`*.c`) and one file containing the headers (`*.h`). As we can see on Figure 6.3, the pairs are the following:

1. The **gps_dbus** pair contains the code related to the communication with the GPS module via the DBus interface. These files represent about 120 lines of code.
2. The **gps_tcp** pair contains the code related to the communication with the GPS module via the TCP connection opened on port 2947. These files represent about 180 lines of code.
3. The **network** pair contains the code related to the interactions with the sockets used to send information to the network in one hand, and to the plugins interface in the other hand. These files represent about 300 lines of code.
4. The **geo_sharing** pair is the entry point of the application and contains the backbone of the GeoSharing application. These files represent about 220 lines of code.

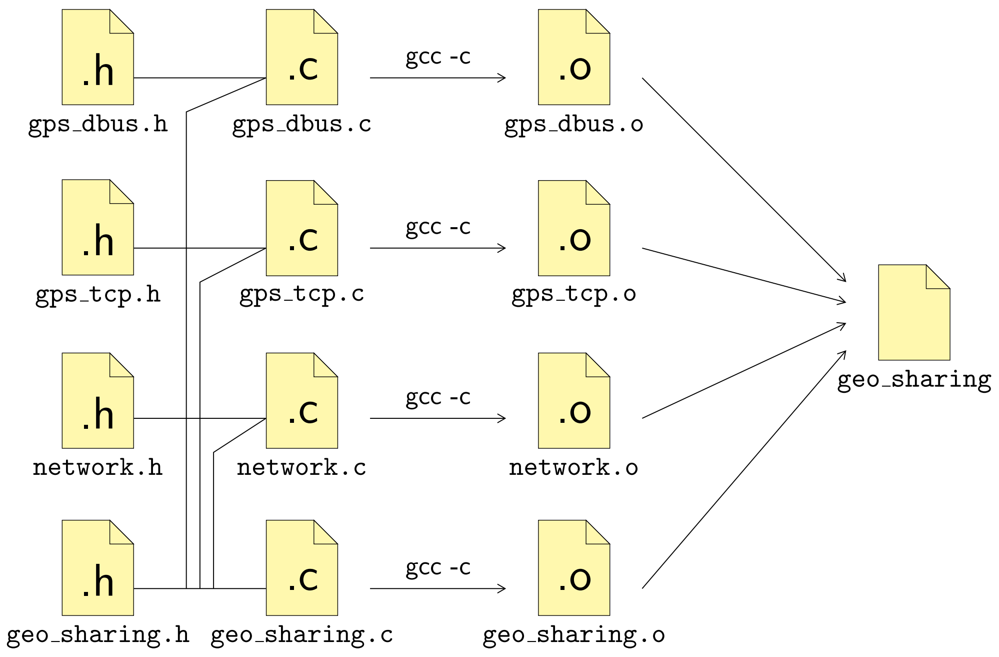


Figure 6.3: The GeoSharing application is split into four different pairs of files. Each `c` file includes its corresponding `h` file and the `geo_sharing.h` file. The compilation process is led by a Makefile provided with the GeoSharing application.

This file organisation aims to provide the weakest coupling and the strongest cohesion as possible. Each pair of file indeed provides specific functionalities which reflects a strong cohesion. The independence of each pair of files reflects a weak coupling between all the pairs. This independence also implies a high reusability. For example, the gps_dbus pair (as well as the gps_tcp pair) can be used independently of the GeoSharing application to communicate with the GPS module in any other application.

The GeoSharing application is provided with a Makefile which is responsible for the compilation of the GeoSharing application. The Makefile takes care of the dependencies between files (as shown on Figure 6.3). Each pair of files is preprocessed, compiled and assembled to create one object file (`*.o`). All the generated object files are linked together in a final step to create the executable file of the GeoSharing application.

6.2.2 GeoSharing processes overview

The GeoSharing application is divided into three parts as depicted on Figure 6.4. A process parallel to the main process is created when the application is launched. The parallel process that has just been created is itself divided into two threads.

1. The main process (called the **Sender** on Figure 6.4) is responsible for retrieving the GPS coordinates from the GPS module according to the method specified (`dbus` or `tcp`) when the application is launched. Technical details about how to specify the method of geographical positions retrieval are given in Appendix A.2.4. As explained in Section 3.3, an evaluation of the accuracy of the position retrieved is provided by the GPS module. This evaluation is represented on a scale from 0 to 3 and is called the fix. If this value is greater than 1, a message is composed with the retrieved coordinates. This message is then encrypted and send in multicast mode through the network. The process is repeated every two seconds.

2. The parallel process created when the application started consists in two threads.
    1. The main thread (called the **Receiver** on Figure 6.4) is responsible for the reception of packets coming from the network. The packets are decrypted and parsed to extract the information contained in them. A list containing the location of the nodes from which packets have been received is maintained up-to-date. The information contained in each packet are then formatted and forwarded to the plugins interface of tangoGPS in order to provide to the end-user an always up-to-date display of other nodes location.
    2. The other thread (called the **Garbage Collector** on Figure 6.4) is responsible for maintaining the list (containing the location of the nodes from which packets have been received) with only fresh information about nodes. For this purpose, every ten seconds, the garbage collector checks each element of the list and, if more than 30 seconds have elapsed since the last time it has been updated, a formatted message requiring the removal of the node from the graphical interface is sent to the plugins interface of tangoGPS. The element is then removed from the list.

From this brief overview, three core functionalities are extracted: the way GPS data are retrieved from the GPS module, the way the encryption and decryption mechanisms works and the way packets are exchanged through the network. These three functionalities are described in more details in the next section.

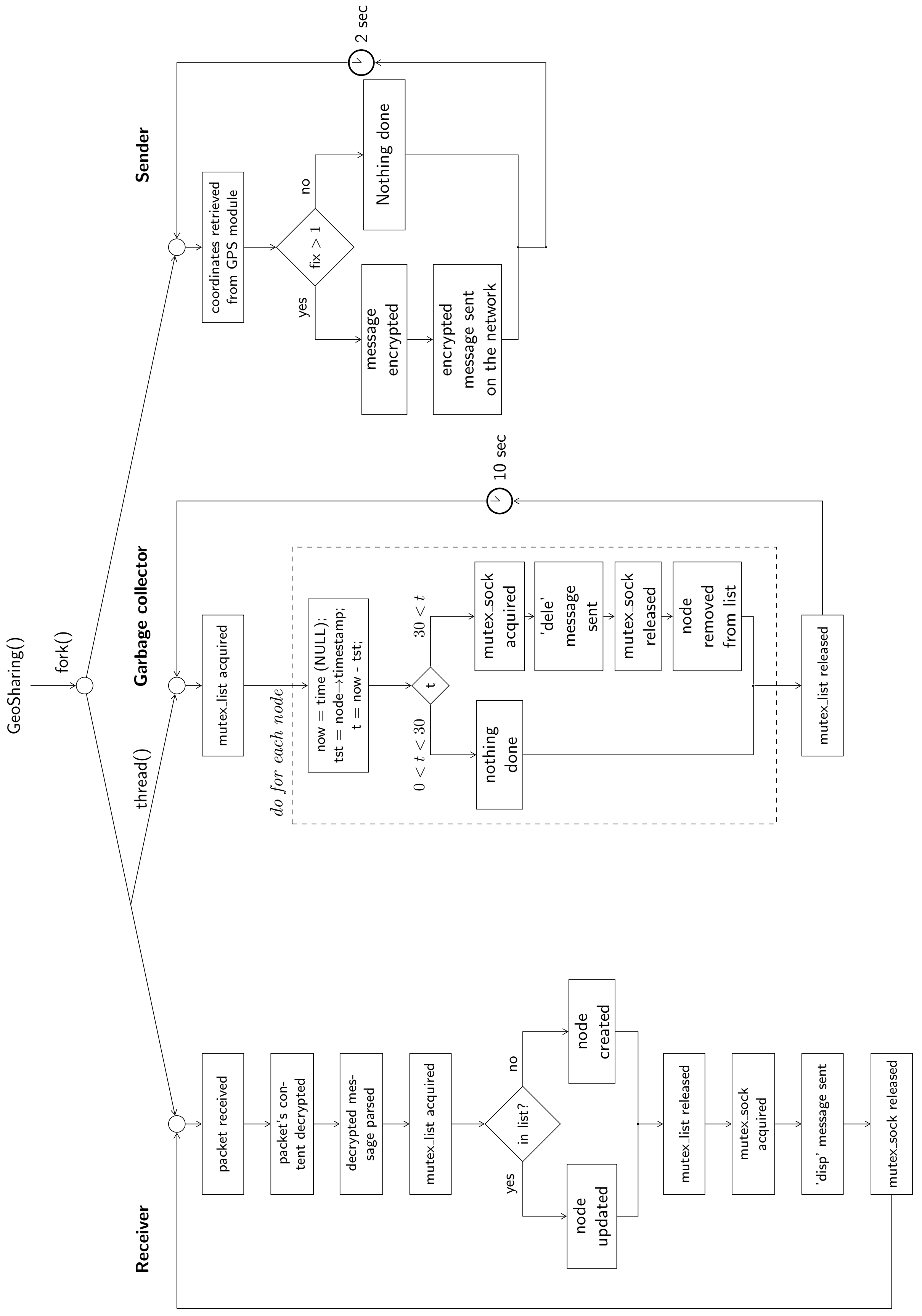


Figure 6.4: The GeoSharing application is divided into three parts.

6.3 GeoSharing core functionalities

The GeoSharing application consists in different core functionalities. Geographical coordinates must be retrieved from the GPS module. Once these coordinates are available, a secured data packet must be build to be sent through the network. Upon reception of a data packet from another node, the coordinates must be made available to the GUI.

6.3.1 Location data retrieval

In order to retrieve location data, a communication must be established between the GeoSharing application and the GPS module. As stated in Chapter 3, two different ways to communicate with the GPS module have been implemented in GeoSharing: D-Bus and TCP communication scheme. Both solutions are usable in GeoSharing (see Appendix A.2.4) but the D-Bus solution is used by default.

- **D-Bus**: The geo-position data retrieval consists in three steps. The first two steps initialise the D-Bus connection and the GPS module.

  1. The **connection on the bus** is made via a call to `dbus_g_bus_get()` of the DBusGLib library [DBu07]. The bus type towards which the connection should be done must be specified and the call returns a connection to this bus.

     ```
     DBusGConnection *connection = NULL;
     GError *error = NULL;
     connection = dbus_g_bus_get(DBUS_BUS_SYSTEM, &error);
     ```

     Listing 6.1: This piece of C code is taken from `gps_dbus.c`.

     where

     – `DBUS_BUS_SYSTEM` is a constant from the DBusGLib library specifying the bus on which the connection has to be established;

     – `error` is an address where an error can be returned.

  2. The **start of the GPS module** is made via a call to `dbus_g_proxy_call()`. This function takes a method name as argument. To start the GPS module, `"Start"` must be specified as method name. There is no returned value of this call.

```
dbus_g_proxy_call(device_proxy, "Start", &error,
                  G_TYPE_INVALID,
                  G_TYPE_INVALID);
```

Listing 6.2: This piece of C code is taken from `gps_dbus.c`.

where

- `device_proxy` is a pointer to the GPS Device interface [FSO11] accessible via the bus;
- the two `G_TYPE_INVALID` arguments delimit the output values. In this case, since there is no returned value of this call, the two `G_TYPE_INVALID` arguments are next to each other.

The third step can be executed as many times as needed to ask for location data.

3. The **location data retrieval** is made via a call to `dbus_g_proxy_call()`. To ask for location data, `"GetPosition"` must be specified as method name. As well as for hardware buses, the location where the call reply has to be written must be specified at call time. When the call is done, the data are available at the previously specified address.

```
dbus_g_proxy_call(position_proxy, "GetPosition", &error,
                  G_TYPE_INVALID,
                  G_TYPE_INT, &fields,
                  G_TYPE_INT, &timestamp,
                  G_TYPE_DOUBLE, &latitude,
                  G_TYPE_DOUBLE, &longitude,
                  G_TYPE_DOUBLE, &altitude,
                  G_TYPE_INVALID);
```

Listing 6.3: This piece of C code is taken from `gps_dbus.c`.

where

- `position_proxy` is a pointer to the GPS Position interface [FSO11] accessible via the bus;
- the two `G_TYPE_INVALID` arguments delimit the output values. In this case, five different information about the geographical location of the device are retrieved.

- **TCP**: The geo-position data retrieval consists in three steps.

1. The **connection to the GPS socket** is made via a call to `gps_open_r()`. The GPS module is automatically turned on (if it is not already the case) when a TCP connection is established.

```
int error = gps_open_r(SERVER_ADDR, DEFAULT_GPSD_PORT, gpsdata);
if(error < 0){
    perror("An error occurred with the GPS socket");
}
```

Listing 6.4: This piece of C code is taken from `gps_tcp.c`.

where

- `SERVER_ADDR` is the IP address of the device on which the GPS dæmon is running. If the dæmon runs localy, `localhost` can be used as IP address;
- `DEFAULT_GPSD_PORT` is the TCP port on which the TCP connection must be established. The port 2947 is used by default;
- `gpsdata` is a structure containing lots of fields among which the GPS socket descriptor that is filled at this step.

The second step can be executed as many times as needed to ask for location data.

2. The **location data retrieval** is made via a call to `gps_poll()`. The memory address of the `gpsdata` structure must be specified to `gps_poll()` to indicate where the geographical data have to be written. When the call is done, the data are available at the previously specified address.

```
int error = gps_poll(gpsdata);
if(error < 0){
    perror("An error occurred while retrieving data from the GPS
        socket");
}
```

Listing 6.5: This piece of C code is taken from `gps_tcp.c`.

3. The **closing of the socket** is made via a call to `gps_close()`.

```
(void)gps_close(gpsdata);
```

Listing 6.6: This piece of C code is taken from `gps_tcp.c`.

6.3.2 Security management

As explained in Section 4.4, security mechanisms are present at the data link layer and at the application layer.

Data link-level security

In the GeoSharing project, the choice was made to use a WEP-secured Wi-Fi network in ad hoc mode to connect all the nodes together. Configuring such a wireless network in a Linux environment can be done via the configuration file dedicated to the network interfaces of the device. This configuration file is located at `/etc/network/interfaces`.

On the Neo FreeRunner (the devices used in the scope of the GeoSharing project), the wireless interface is denoted as `eth0`. The following lines need to be added in the configuration file in order to set the wireless network in ad hoc mode with the WEP security enabled. As we can see in these lines, the WEP key (`F4C3DEB3BE`) is written in the clear.

```
auto eth0
iface eth0 inet static
    address 10.0.0.1
    netmask 255.0.0.0
    network 10.0.0.0
    wireless-mode ad-hoc
    wireless-essid GeoSharing
    wireless-key F4C3DEB3BE
```

Listing 6.7: This configuration lines are taken from `/etc/network/interfaces`.

Once the configuration file has been modified, the network interfaces have to be restarted. The simplest solutions are to restart the device or execute the following command in a terminal of the device: `/etc/init.d/networking restart`.

Application-level security

The encryption and the decryption of the data contained in the packet flowing through the network is performed thanks to a C library implementing the 3DES algorithm. This library has been written by Michael Roth [Lib98].

Before encrypting or decrypting any message, the algorithm requires three 8-byte keys in order to build the DES encryption context. This context contains information derived from the keys. Since three keys are used for the 3DES encryption algorithm, the context is build via a call to `gl_3des_set3keys()`.

```
const char TDES_KEY1[] = {'H','Y','k','p','9','(','e','S'};
const char TDES_KEY2[] = {'#','l','L','V','r','7','X','4'};
const char TDES_KEY3[] = {')','j','f','Q','Z','n','4','!'};

gl_3des_ctx context;
gl_3des_set3keys(&context, TDES_KEY1, TDES_KEY2, TDES_KEY3);
```

Listing 6.8: This piece of C code is taken from `network.c`.

where

- `context` is the address of the `gl_3des_ctx` structure.
- `TDES_KEY1`, `TDES_KEY2` and `TDES_KEY3` are arrays of characters representing the three keys.

The encryption and the decryption of the data are performed according to the mechanism depicted on Figure 6.5.

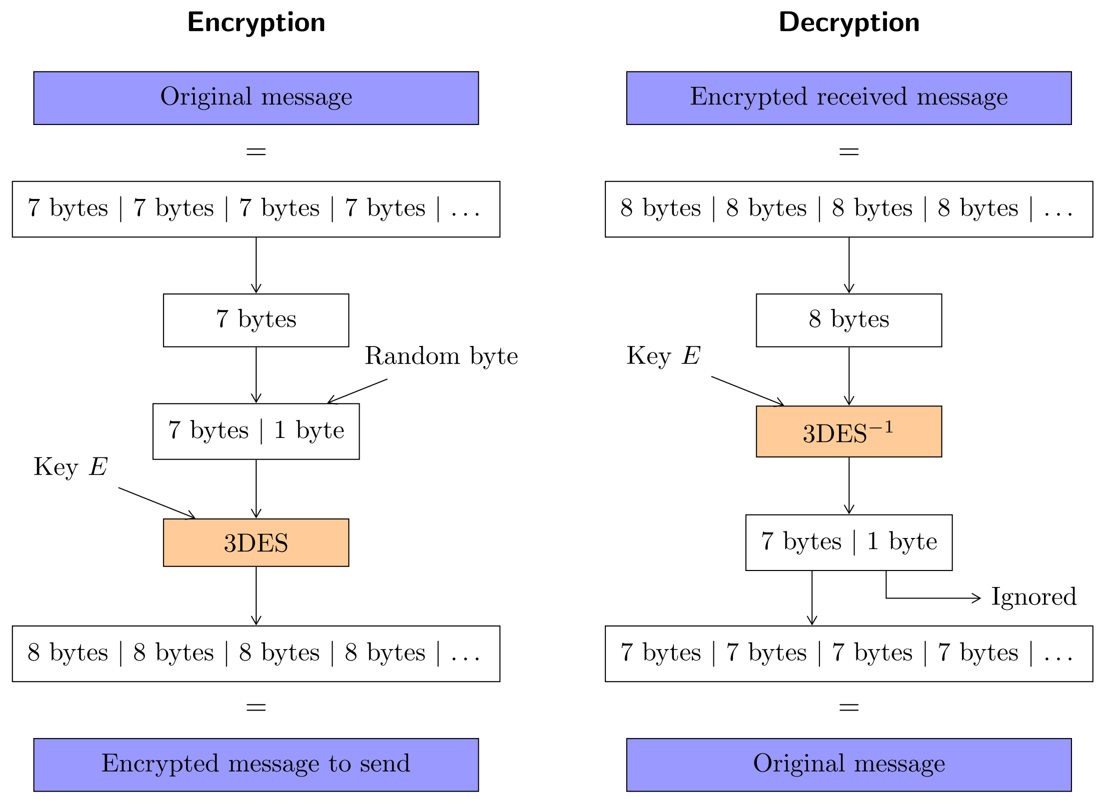

Encryption
Original message
=
7 bytes | 7 bytes | 7 bytes | 7 bytes | ...
7 bytes
Random byte
7 bytes | 1 byte
Key E
3DES
8 bytes | 8 bytes | 8 bytes | 8 bytes | ...
=
Encrypted message to send
Decryption
Encrypted received message
=
8 bytes | 8 bytes | 8 bytes | 8 bytes | ...
8 bytes
Key E
$3DES^{-1}$
7 bytes | 1 byte
Ignored
7 bytes | 7 bytes | 7 bytes | 7 bytes | ...
=
Original message

Figure 6.5: Each time the 3DES encryption algorithm is used, seven bytes of the plaintext concatenated with a 1-byte random character are encrypted. Each time the $3DES^{-1}$ decryption algorithm is used, the eighth byte of the retrieved plaintext is ignored.

- **Encryption**: As explained in Section 4.4.2, the 3DES algorithm encrypts 8 bytes at a time. These 8 bytes consist in 7 bytes from the plaintext and one random character of 1 byte. The 3DES encryption is performed via a call to `gl_3des_ecb_encrypt()`. A graphical representation of this mechanism is shown on the left side of Figure 6.5.

```
srand(time(NULL)); /* Initialisation of the random generator */
int t = MSG_LENGHT / 7;
if(MSG_LENGHT % 7 != 0){
    t++;
}
for(int i = 0; i < t; i++){
    strncpy(tmp, original_msg+(7*i), 7);
    tmp[7] = (char) rand() % 255; /* Insert a 1-byte random value */
    gl_3des_ecb_encrypt(&context, tmp, encrypted_msg_to_send+(8*i));
}
```

Listing 6.9: This piece of C code is taken from `network.c`.

where

  - `context` is the address of the `gl_3des_ctx` structure.
  - `tmp` is the address of an array containing the 8 bytes to encrypt.
  - `encrypted_msg_to_send` is the address of an array where the encrypted characters must be written.

- **Decryption**: The decryption process is performed via a call to `gl_3des_ecb_decrypt()`. In order to retrieve the 7 bytes of the original message, the last byte of the recovered plaintext is ignored. A graphical representation of this mechanism is shown on the right side of Figure 6.5.

```
int t = MSG_LENGHT / 8;
if(MSG_LENGHT % 8 != 0){
    t++;
}
for(int i = 0; i < t; i++){
    strncpy(tmp, encrypted_received_msg+(8*i), 8);
    gl_3des_ecb_decrypt(&context, tmp, recovered_plaintxt);
    strncpy(original_msg+(7*i), recovered_plaintxt, 7);
}
```

Listing 6.10: This piece of C code is taken from `network.c`.

where

  - `context` is the address of the `gl_3des_ctx` structure.
  - `tmp` is the address of an array containing the 8 bytes to decrypt.
  - `recovered_plaintxt` is the address of an array where the decrypted characters must be written.
  - `original_msg` is the address of an array where the 7 bytes of the original message must be written.

6.3.3 Network interactions

There exists two well known transport modes that can be used for the nodes to communicate: TCP and UDP. A best-effort delivery message service such as UDP is amply sufficient. The GeoSharing project requiring low forwarding delays, it is better to avoid the TCP overhead (3-way handshake, congestion control mechanisms, etc.). Moreover, even if TCP connections are established between nodes, because of the always changing topology, those TCP connections need to be re-established very often. Therefore, UDP is preferred over TCP for the GeoSharing application.

In order to send data on the network, the GeoSharing application uses internet sockets. On each device, the socket is configured to send UDP packets (`SOCK_DGRAM`) on port 50000 which is a non-reserved port that anyone can use. The destination address is set to the default multicast address: `"224.0.0.1"` allowing the data packets to be forwarded over the entire network thanks to the BMF plugin of OLSRd.

```c
#define MULTICAST_ADDR      "224.0.0.1"
#define GEO_SHARING_PORT    50000

struct sockaddr_in sock;
int sd;

    /* Fill in the structure with the multicast
       address and destination port */
    memset((char *) sock, 0, sizeof(struct sockaddr_in));
    sock->sin_family = AF_INET;
    sock->sin_addr.s_addr = inet_addr(MULTICAST_ADDR);
    sock->sin_port = htons(GEO_SHARING_PORT);

    /* UDP socket */
    if((sd = socket(PF_INET, SOCK_DGRAM, 0)) < 0){
        perror("Impossible to create the socket");
        exit(EXIT_FAILURE);
    }
```

Listing 6.11: This piece of C code is taken from `geo_sharing.c`.

Data packets flowing through the network are simple UDP packets. Besides the UDP header, each packet contains the ciphertext of multiple information formatted as a string. The formatted string is represented hereafter.

`seq-nbr # latitude # longitude # altitude # fix # sender-IP-address $`

- **seq-nbr** is the sequence number of the data (e.g. 123).
- **latitude** is the latitude of the device (e.g. 50.668533°).
- **longitude** is the longitude of the device (e.g. 4.622025°).
- **altitude** is the altitude of the device (e.g. 456.78m).

- **fix** is an indication of the precision of the coordinates. A value of 2 means that it may be better to not rely on the altitude measurement. A value of 3 means that the altitude can be supposed to be correctly evaluated. As explained in Section 3.3, only these two values (2 and 3) are possible in GeoSharing messages.
- **sender-IP-address** is the IP address of the device whose coordinates are in the packet (e.g. `"10.0.0.2"`).

As explained in Section 6.3.2, the string containing the information about the node is encrypted before being sent through the network.

```
int size = (strlen(msg) + 1) * sizeof(char);

int err_code = sendto (sd, msg, size, 0, (struct sockaddr *) sock, sizeof(struct
     sockaddr_in));

if(err_code < 0) {
    perror("Error while sending on the socket");
}
```

Listing 6.12: This piece of C code is taken from `network.c`.

where

– `sd` is the socket descriptor of the socket previously initialized.

– `msg` is the address of an array containing the message to be sent.

– `size` is the number of bytes to be sent on the socket.

The GeoSharing application always listen on port 50000 for incoming UDP packets.

```
#define MAX_PACKET_SIZE     255

if(recvfrom(sd, msg, MAX_PACKET_SIZE, 0, (struct sockaddr *) 0, (socklen_t *) 0)
     < 0){
    perror("An error occured while receiving data on the socket...");
    exit(EXIT_FAILURE);
}
```

Listing 6.13: This piece of C code is taken from `network.c`.

where

– `sd` is the socket descriptor of the socket previously initialized.

– `msg` is the address of an array where the received message has to be written.

– `MAX_PACKET_SIZE` is the number of bytes to be read on the socket. Since the exact length of the message cannot be known in advance, a maximum message length has been defined and is equal to 255 bytes.

The data contained in the packet payload is then extracted and stored in a structure.

```
typedef struct geo_sharing_data geo_sharing_data;
struct geo_sharing_data {
    int seq_number;
    double latitude;
    double longitude;
    double altitude;
    int fix;
    char ip[IP_ADDR_SIZE];
    time_t timestamp;
};
```

Listing 6.14: This piece of C code is taken from `geo_sharing.h`.

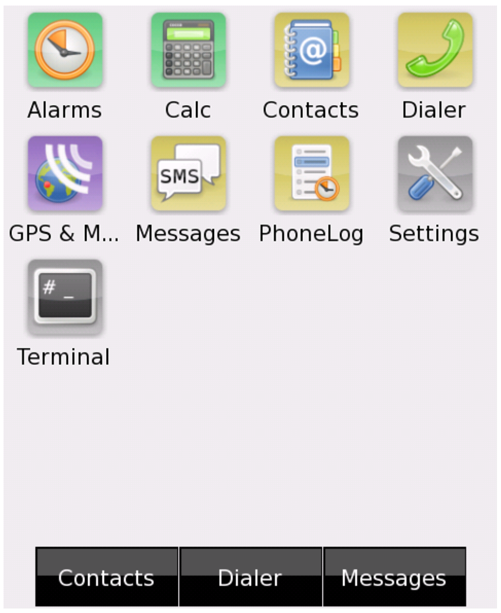
If the IP address contained in the packet payload is different from the IP address of the device, the packet is sent to the graphical user interface via a Unix socket. Otherwise, the packet is discarded.

```
geo_sharing_data data;
geo_sharing_parse(&data, msg);

/* (...) */

if(strcmp(data.ip, my_ip) != 0){
    gui_management(&data);
}
// else, the packet is discarded
```

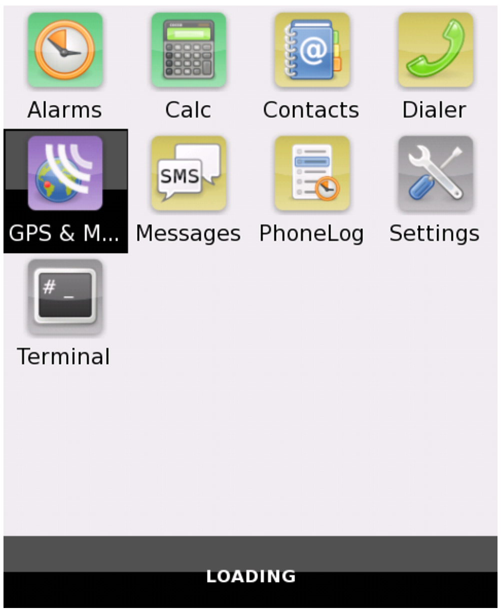
Listing 6.15: This piece of C code is taken from `network.c`.

6.4 User manual

From an end-user standpoint, the GeoSharing application is easy to use. When the Neo FreeRunner is booted on the SHR operating system, the main screen (shown on Figure 6.6(a)) displays icons of already installed applications. The user can choose to launch different applications such as the dialer, settings, a terminal, etc. One of those applications is tangoGPS. This application is called “GPS & Maps” on the main screen. If the user clicks on the “GPS & Maps” icon (Figure 6.6(b)), tangoGPS is launched and a loading message appears at the bottom of the screen until tangoGPS is runnning.



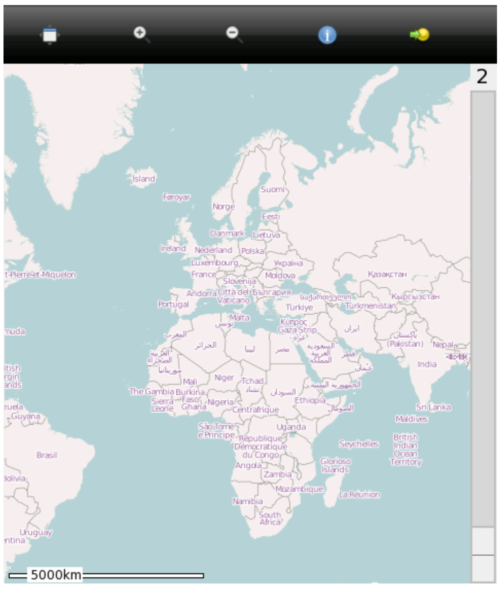
(a)



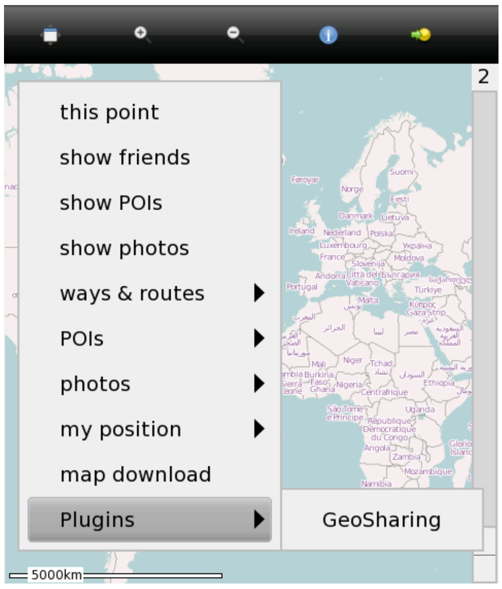
(b)

Figure 6.6: (a) On the main screen, the user can choose to launch different applications. (b) If the user clicks on the “GPS & Maps” icon, tangoGPS is launched.

Once tangoGPS is running, the user can see the map of the Earth. Usual features such as zoom in and zoom out are accessible in the black bar on top of the screen (Figure 6.7(a)). A brief press on the screen makes the menu appear. This menu shows several entries. In the sub-menu of the "Plugins" entry, the user can select "GeoSharing" (Figure 6.7(b)). When the button is clicked, tangoGPS launches the GeoSharing application.



(a)



(b)

Figure 6.7: (a) On tangoGPS main screen, a map is shown. The menu can be accessed with a brief press on the screen. (b) The user can select "GeoSharing" in the plugins list.

If there are other devices running the GeoSharing application in the radio range, the application running on the user's device automatically connects to the network. The application also begins to share the position of the device with the other users and displays the other users positions on the map (Figure 6.8).

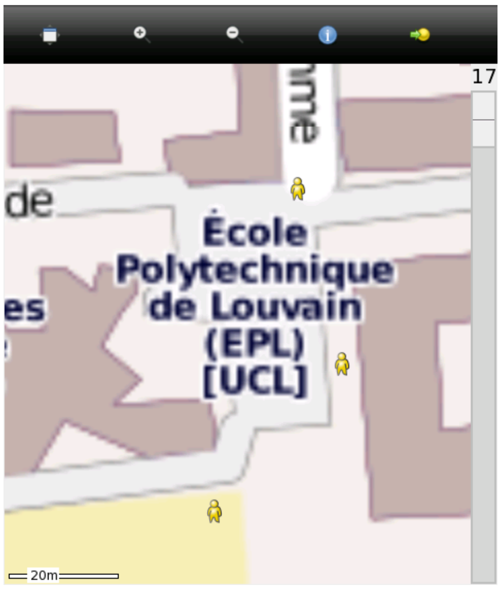


Figure 6.8: The GeoSharing application displays other users positions on the map.

6.5 Limitations and further work

Obviously, the GeoSharing application is not perfect. It has some limitations. These limitations can be the next objectives for future development work.

One main limitation of the GeoSharing application in its first version is the manual configuration of the wireless interface of each device. In a classic home network, a DHCP server is indeed often used to distribute different IP addresses to all the devices which want to join the network. In the GeoSharing project, such a mechanism does not exist yet as discussed in Section 4.2.3. Hence it is mandatory to manually configure IP addressed on each Neo FreeRunner.

Other possible future development works are, as discussed in Section 4.4, the deployment of WPA2 security in the GeoSharing MANET, the improvement of the encryption mechanism, the implementation of a Message Authentication Code and a better management of the keys used in the GeoSharing project. The security mechanisms involved in the first version of the GeoSharing project consist in a combination of a WEP-secured wireless network and a 3DES encryption scheme of the sensitive data.

- Since a WEP key can nowadays easily be found by an attacker, the WEP security is more a mechanism to force attackers to do something illegal if they want to eavesdrop on the network. The WEP should be replaced by a stronger security scheme such as WPA2 which is a standard believed to be stronger than WEP. The deployment of WPA2 could be an added value for the GeoSharing project.
- In the current version of the GeoSharing project, 3DES in ECB mode is used to encrypt and decrypt sensitive data. Since this mode does not provide a total privacy in certain conditions (described in Section 4.4.2), the analysis of other modes of 3DES or other encryption algorithms could be the focus of further work in order to find a better solution.
- A Message Authentication Code mechanism could be added to the GeoSharing application in order to provide an integrity check for each packet coming from another node of the network. An analysis of the different keyed hash function that can be used in MAC schemes has to be performed. The implementation of such a mechanism could be, as well as the WPA2 deployment, an added value for the GeoSharing project.
- In the current version of the GeoSharing project, four different keys have to be used. The WEP-key is stored in the clear in the `/etc/network/interfaces` configuration file. The three keys used for the 3DES algorithm are hard-coded in the `network.c` source file of the GeoSharing application. An analysis of more secured places to store those credentials have to be performed to prevent attackers to have a direct access the the keys if a device is compromised. This more secured place should be easily accessible by the GeoSharing application while providing a high level of security.

A last possible improvement is the development of a stand-alone graphical user interface as discussed in Section 5.3. The solution currently proposed with the GeoSharing application is reliable but not optimized for CPU and memory utilization. The installation of tangoGPS is indeed required and lots of tangoGPS functionalities are useless for the GeoSharing project.

Conclusion

Nowadays, the demand for geo-positioning systems is growing because of the large number of possible application domains such as companies which want to track their goods in their warehouse, companies which want to track their vehicles, military head-quarters which want to track their soldiers, etc. There also exists applications developed in the scope of social networks where users like sharing their current geographical position with their friends (e.g. Facebook Places, Foursquare, Mobbyway). Most of those applications need a connection to the internet. The GeoSharing project differs from all those examples by the way it uses to share geographical positions. With GeoSharing, the geographical positions are indeed directly shared over a network of connected devices without the need of an internet connection or any additional infrastructure.

The military sector is a precursor in this domain mainly because this sector needs systems that can be used in many different places and in many environments where a connection to the internet is not always straightforward. For example, an American company (called *Mesh Dynamics*) has developed a product dedicated to Military, Defence and Public Safety. The name of this project is *P3M* for Persistent Third-Generation Mesh [Mob11]. The main difference between the P3M project and the GeoSharing project is that P3M is more focused on communication data (voice over IP, video, etc.) while GeoSharing is more specific for real-time location.

Wireless ad hoc networks are also widespread in sensor networks. Military sensor networks can be used to collect information about enemy movements or to track enemy vehicles moving around the network nodes.

Another project whose aim is to allow each node belonging to a mesh network to get an internet access has been implemented an is called MokoMesh. The main idea is to use a single GPRS connection on one phone and share this internet connectivity with all nodes over the network.

The GeoSharing project proposes geoposition sharing system based on Openmoko. Openmoko Neo FreeRunner devices running SHR, a Linux-based operating system, are used. This operating system choice is compliant with the prerequisites of such a project that are stability, maintenance, widespread usage and low energy consumption. The underlying network established for position sharing is build and maintained thanks to a Linux dæmon implementing the Optimized Link State Routing protocol (OLSR). This dæmon fits very well the needs of the GeoSharing application since it guarantees an efficient topology and routing tables management at a very low cost in term of CPU and memory usage. It is therefore well adapted for low power mobile devices such as the Openmoko Neo FreeRunner. The entire GeoSharing application is interfaced with an already existing open source navigation application called tangoGPS. It is integrated as a lightweight plugin displaying the position of every node belonging to the application network. This solution provides an additional feature to tangoGPS and can be executed in parallel to other functionalities such as point of interests display, etc. Furthermore, the main features of tangoGPS can be exploited allowing the user to zoom and slide the map. The major drawback of the solution as it is proposed is that the tangoGPS application and the GeoSharing plugin for tangoGPS must be installed. It is indeed an important investment even if tangoGPS has been developed for mobile devices. The GeoSharing project is integrated in geo-positioning applications by bringing a new way to share geographical position through a network.

Since this project can be reused by other people or by studies, GeoSharing is available as an *open-source* application. The GeoSharing project is still alive. Thanks to the website and the wiki, interactions with people who want to do something with this work are facilitated.

- The website: http://www.geosharing-project.org
- The wiki: http://wiki.geosharing-project.org
- The sources: http://sources.geosharing-project.org

Appendix A

Installation guide

This appendix is divided into two parts. The first part presents preliminary configurations that must be done before starting any development on the Opemoko Neo FreeRunner (GTA02). The second part describes the technical steps to follow in order to install the GeoSharing project on the Neo FreeRunner.

All those steps have been tested on a Neo FreeRunner and on a laptop running Ubuntu 10.10 with access to root privileges.

A.1 Preliminary configurations

This section consists in three parts. The first thing to do is to configure a connection between the Neo FreeRunner and a computer via a USB cable. Most of the operations that must be executed on the Neo FreeRunner are easily performed on a computer disposing of a keyboard and a larger screen than the GTA02. A SSH connection should thus be established from the computer to the Neo FreeRunner in order to have access to it.

The second part details the installation steps of an operating system (OS) on the Neo FreeRunner. This operation is made possible thanks to the communication channel created before via the USB cable. The operating system called SHR was chosen to be used in the scope of the GeoSharing project.

The third part shows how it is possible to share the internet connection of a computer with the Neo FreeRunner via the USB cable.

A.1.1 USB interface configuration

An important thing to notice is that the USB connectivity is considered as an ethernet connection by both the Neo FreeRunner and the computer. This implies the use of IP addresses to identify both ends of the connection. By default, the Neo

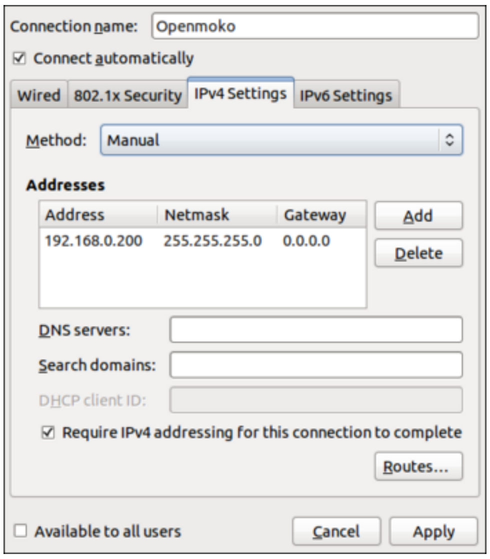
FreeRunner has a static IP address: `192.168.0.202` and nothing must be done to change that. The goal is then to configure the computer to have an IP address in the same sub-network than the Neo FreeRunner to be able to communicate with it.

1. The first thing to do on the computer is to create an alias for the IP address of the Neo FreeRunner. Edit the file `/etc/hosts` by adding the line:

   ```
   192.168.0.202 openmoko
   ```

2. There exists two possible methods to set up an ethernet connection between both devices via the USB cable. On the computer, it is possible to choose:

   (a) **Via the network manager:** As shown on Figure A.1, the easiest way to set up the connection with the Openmoko is to create a new connection (called Openmoko here) in the wired networks tab of the computer network manager. For this new connection, choose a static (manual) IP address: `192.168.0.200`.


Connection name: Openmoko
☑ Connect automatically
Method: Manual
Addresses

Address	Netmask	Gateway
192.168.0.200	255.255.255.0	0.0.0.0

DNS servers:
Search domains:
DHCP client ID:
☑ Require IPv4 addressing for this connection to complete
☐ Available to all users

Figure A.1: A static IP address is chosen for the connection with the Neo FreeRunner.

   (b) **Without the network manager:**

      i. On the computer, open the file located at the following location: `/etc/network/interfaces` and add the following lines at the end of the file:

      ```
      # The Openmoko network interface
      auto eth1
      iface eth1 inet static
      address 192.168.0.200
      netmask 255.255.255.0
      ```

ii. On the computer, restart the network service by running the following command as root:

```
# /etc/init.d/networking restart
```

3. If an operational OS is running a SSH dæmon on the Neo FreeRunner, it is possible to establish an SSH connection from the computer to the root session of the Neo FreeRunner.

```
$ ssh root@openmoko
root@om-gta02 ~ #
```

If it is not the case (i.e. there is no SSH dæmon or no operating system at all), the Neo FreeRunner can be flashed with, for example, the operating system used in the scope of the GeoSharing project: SHR.

A.1.2 Flashing the SHR operating system on the Neo FreeRunner

The easiest way to flash the Neo FreeRunner is to use `neoTool` on the computer. It is mandatory to install `dfu-utils` via the Synaptic Package Manager of the computer before running `neoTool`. The version of `neoTool` that have been used to realise this manual is the version 1.3.

Before going any further, the Neo FreeRunner must be connected to the computer with the USB cable, the IP address of each device must have been previously configured (See Appendix A.1.1) and the Neo FreeRunner must be booted on the NOR memory as explained in Section 1.3.3 of this document (POWER + AUX buttons).

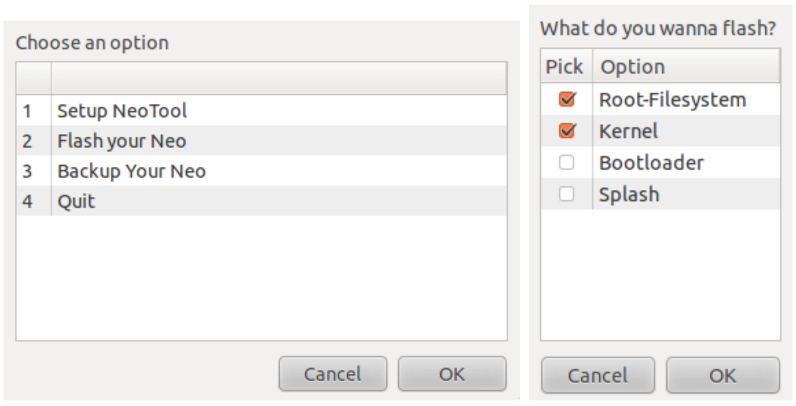
1. The first step is to copy the bash script that can be found at http://users.on.net/~antisol/neotool into an empty file on the computer. Rename this file `neoTool` and give it the execution rights.

```
$ chmod u+x neoTool
```

2. The second step is to run neoTool on the computer with root privileges.

```
$ sudo ./neoTool
```

3. The application is now running and the interface looks like Figure A.2(a).



Choose an option

1	Setup NeoTool
2	Flash your Neo
3	Backup Your Neo
4	Quit

Cancel OK

What do you wanna flash?

Pick	Option
✓	Root-Filesystem
✓	Kernel
☐	Bootloader
☐	Splash

Cancel OK

(a) (b)

Figure A.2: (a) Different actions are possible to be performed with the `neoTool` application. (b) The Root-Filesystem, the kernel, the bootloader and the splash can be flashed separately.

4. On the computer, download the latest version of the SHR operating system. The version of SHR used to realise this manual is the version SHR-testing $2.6.29 - oe11$. Images of the SHR operating system can be found at http://build.shr-project.org/shr-testing/images/om-gta02/. Two files are required:
   - lite-om-gta02.jffs2
   - uImage-*.bin
5. In neoTool (which is running on the computer), select the second item 'Flash your Neo' and click 'OK'. The interface looks like Figure A.2(b). On the next screen, don't change anything and click 'OK'.
6. The path to the *.jffs2 and the *.bin files are respectively asked.
7. Click on the OK button of `neoTool` to launch the flashing process.
8. When the process is done, the Neo FreeRunner restarts automatically and the new operating system is ready to be used.

A.1.3 Internet connectivity

When the operating system is installed and running, the configuration steps required in order to share the internet connectivity of the computer with the Neo FreeRunner via the USB cable are the followings. These steps must be done on the computer connected to the Neo FreeRunner.

1. On the computer, edit the file `/etc/sysctl.conf`

   ```
   $ gedit /etc/sysctl.conf
   ```

2. Look for the following line in this file:

   ```
   #net.ipv4.conf.default.forwarding=1
   ```

   and uncomment it (remove the # character if not already done).

3. The iptables of the computer must be configured such that the computer behaves as a simple router for the Openmoko. The computer must forward packets coming from the Neo FreeRunner to the internet and the other way around. Edit the file `/etc/rc.local`:

   ```
   $ gedit /etc/rc.local
   ```

   and add these lines at the end of the file:

   ```
   /sbin/iptables -P FORWARD ACCEPT
   /sbin/iptables --table nat -A POSTROUTING -s 192.168.0.202/32 -o iface -j
       MASQUERADE
   ```

   where iface corresponds to the interface of the computer connected to the internet (wlan0, eth0, eth1, ...).

4. The computer have now to be rebooted.

The internet connection of the computer is now shared with the Neo FreeRunner. In order to check if the sharing of the internet connection is well configured, from the Neo FreeRunner, perform a `ping` to `www.google.com` and the results should look like this:

```
root@om-gta02 ~ # ping www.google.com
PING www.google.com (66.102.13.103): 56 data bytes
64 bytes from 66.102.13.103: seq=0 ttl=55 time=19.548 ms
64 bytes from 66.102.13.103: seq=1 ttl=55 time=35.519 ms
(...)
```

A.2 GeoSharing project installation

Since the GeoSharing project is based on the OLSRd Linux dæmon and on tangoGPS, it is mandatory to compile and install those two applications as well as the GeoSharing application.

Before going any further, extra packages such as a C compiler (`gcc`) and libraries (`libglib`, `libconfig`, `libgps`, etc.) need to be installed on the Neo FreeRunner. In order to install these packages, an internet connection is required. The following commands must then be executed on the Neo FreeRunner.

```
root@om-gta02 ~ # opkg update

root@om-gta02 ~ # opkg upgrade

root@om-gta02 ~ # opkg install make gcc gcc-symlinks libc6 libc6-dev binutils
    binutils-symlinks coreutils kernel-module-tun kernel-module-tunnel4 mdbus
    libglib-2.0-dev libdbus-glib-1-dev gconf orbit2 libidl-2-0 policykit eggdbus
     libexif12 libgps gpsd-dev gtk+ gconf libxml2-dev libsoup-2.4-dev bluez4-dev
     curl curl-dev libexif-dev libconfig-dev
```

Listing A.1: Packages to install on the Neo FreeRunner.

Now that the needed packages are installed, OLSRd, tangoGPS and the GeoSharing application can be compiled and installed on the Neo FreeRunner.

A.2.1 OLSRd Linux dæmon

As stated in Section 6.1, the compilation process of OLSRd requires `bison` and `flex` packages to compile the syntactical analyser used inside OLSRd. Since the version of SHR proposed in this manual does not provide those packages (`bison` and `flex`) in the package repository, the compilation of the syntactical analyser have to be done on another version of the OS.

The entire compilation and installation process of OLSRd on the Neo FreeRunner is detailed in the following steps. Some steps are performed on a Neo FreeRunner running the SHR-unstable version of the operating system while some other steps are performed on the SHR-testing version. The SHR-unstable version provides much more packages in the package repository. `Bison` and `flex` are fortunately part of the list. On the Neo FreeRunner running the SHR-unstable version, all the packages listed in Listing A.1 have been installed. In addition to them, `bison` and `flex` have been installed as well.

A computer is used to easily manage file transfers between the Neo FreeRunner devices.

1. On the computer, download the last stable release of OLSRd (*.tar.gz file) from http://www.olsrd.org. The version of OLSRd used to realise this manual is the version 0.6.

2. Extract the archive content on the computer filesystem and open a terminal pointing to the folder that has just been extracted.

3. At this time, only the Neo FreeRunner running SHR-unstable must be connected to the computer. From the computer, copy the entire olsrd folder to the Neo FreeRunner running SHR-unstable.

   ```
   $ scp -r olsrd-0.6.0 root@openmoko:/home/root/
   ```

4. On the Neo FreeRunner running SHR-unstable, open a terminal, go in the olsrd folder and compile the project. This process may take a while.

   ```
   root@om-gta02 ~ # cd olsrd-0.6.0
   root@om-gta02 ~ # make
   ```

5. From the computer, it is now necessary to collect the generated files from the SHR-unstable device.

   ```
   $ scp -r root@openmoko:/home/root/olsrd-0.6.0 /home/user/
   ```

6. The Neo FreeRunner running SHR-unstable must be disconnected from the computer and may be shut down. This device is never used anymore.

7. The Neo FreeRunner running SHR-testing has to be connected to the computer.

8. From the computer, copy the entire olsrd folder to the Neo FreeRunner running SHR-testing.

   ```
   $ scp -r olsrd-0.6.0 root@openmoko:/home/root/
   ```

9. On the Neo FreeRunner running SHR-testing, open a terminal, go in the olsrd folder and install the compiled OLSRd dæmon.

   ```
   root@om-gta02 ~ # cd olsrd-0.6.0
   root@om-gta02 ~ # make install
   ```

The OLSRd dæmon is now installed on the Neo FreeRunner.

In the scope of the GeoSharing project, the BMF plugin (always provided in the OLSRd archive file) is required. Its compilation and its installation are quite easier than for the OLSRd dæmon. On the Neo FreeRunner, open a terminal, go in the folder located at `/home/root/olsrd-0.6.0/lib/bmf`, compile and install the plugin.

```
root@om-gta02 ~ # cd /home/root/olsrd-0.6.0/lib/bmf
root@om-gta02 ~ # make
root@om-gta02 ~ # make install
```

The final configuration required for the dæmon to be fully effective is a configuration file. This file is located at `/etc/olsrd.conf`. There are two things to adapt for the GeoSharing project:

1. At the end of the file, the OLSRd interface must be specified. Since OLSRd must be running on the Wi-Fi interface of the Neo FreeRunner, the OLSRd interface should be `eth0`. On the Neo FreeRunner, the `VI` editor can be used to edit this file accordingly.

   ```
   Interface "eth0"
   {
       Mode "mesh"
   }
   ```

2. In the plugin section of the file, an entry must be added to load the BMF plugin when the dæmon is launched. On the Neo FreeRunner, the `VI` editor can be used to edit this file accordingly.

   ```
   LoadPlugin "olsrd_bmf.so.1.7.0"
   {
       # no option
   }
   ```

The OLSRd Linux dæmon is now ready to serve the GeoSharing objectives in terms of network topology management.

A.2.2 TangoGPS application

TangoGPS is provided in some editions of the SHR-testing version. But, as stated in Section 5.3, a modified version of tangoGPS has been developed in the scope of the GeoSharing project. This new version adds a plugins interface allowing plugins to easily interact with tangoGPS. The compilation and the installation of the modified version of tangoGPS is described in the following steps.

1. Before going any further, make sure that the Neo FreeRunner is free of any version of tangoGPS. On the Neo FreeRunner, open a terminal and execute the following command:

```
root@om-gta02 ~ # opkg remove tangogps
```

2. On the computer, download the latest version of tangoGPS-modified from http://download.geosharing-project.org.
3. Extract the archive content on the computer filesystem and open a terminal pointing to the folder that has just been extracted.
4. From the computer, copy the entire tangogps folder to the Neo FreeRunner.

```
$ scp -r tangogps root@openmoko:/home/root/
```

5. On the Neo FreeRunner, open a terminal, go in the tangogps folder, compile and install the project. Pay attention to the third, fourth and fifth commands. They are really important to avoid compilation issues. This process may take a while.

```
root@om-gta02 ~ # cd tangogps
root@om-gta02 ~ # sh configure
root@om-gta02 ~ # CFLAGS="-march=armv4t"
root@om-gta02 ~ # PACKAGE_CFLAGS="-lconfig"
root@om-gta02 ~ # PACKAGE_LIBS="-lconfig"
root@om-gta02 ~ # make
root@om-gta02 ~ # make install
```

TangoGPS is now ready to serve the GeoSharing objectives in terms of graphical display.

A.2.3 WEP security

On the Neo FreeRunner, the wireless interface is denoted as `eth0`. The following lines need to be added in the configuration file of the device interfaces in order to set the wireless network in ad hoc mode with the WEP security enabled. On the Neo FreeRunner, the `VI` editor can be used to edit the file located at `/etc/network/interfaces` accordingly.

```
auto eth0
iface eth0 inet static
    address 10.0.0.1
    netmask 255.0.0.0
    network 10.0.0.0
    wireless-mode ad-hoc
    wireless-essid GeoSharing
    wireless-key F4C3DEB3BE
```

Once the configuration file has been modified, the network interfaces have to be restarted. The simplest solutions are to restart the device or execute the following command in a terminal of the device:

```
root@om-gta02 ~ # /etc/init.d/networking restart
```

A.2.4 GeoSharing

Now that OLSRd Linux dæmon and tangoGPS are correctly installed, the main module of the GoeSharing project must be installed as well. This installation is detailed in the following steps.

1. On the computer, download the latest version of the GeoSharing application from http://download.geosharing-project.org.
2. Extract the archive content on the computer filesystem and open a terminal pointing to the folder that has just been extracted.
3. From the computer, copy the entire geo_sharing folder to the Neo FreeRunner.

   ```
   $ scp -r geo_sharing root@openmoko:/home/root/
   ```

4. On the computer, download the latest version of the run_geosharing.sh script from http://download.geosharing-project.org.
5. From the computer, copy the run_geosharing.sh script to the Neo FreeRunner.

   ```
   $ scp run_geosharing.sh root@openmoko:/home/root/
   ```

This script (shown in Listing A.2) is the entry point of the GeoSharing application. It first configures the wireless network interface. Then, it launches the OLSRd dæmon. Finally, it compiles the GeoSharing application if it is not already done and launches it.

As explained in Chapter 3, two methods for GPS data retrieval have been implemented. By default, the D-Bus method is used to retrieve GPS data. To use the TCP method instead, on the Neo FreeRunner, using `VI`, edit the script `run_geosharing.sh` and replace the last line:

```
./geo_sharing -m dbus
```

by

```
./geo_sharing -m tcp
```

```
#!/bin/sh
cd /home/root/
CURRENT_STATE=`mdbus -s org.freesmartphone.ousaged /org/freesmartphone/Usage org
    .freesmartphone.Usage.GetResourceState WiFi`

if [ $CURRENT_STATE = "False" ]; then
    echo WiFi is currently down ... Setting it up now ...
    mdbus -s org.freesmartphone.ousaged /org/freesmartphone/Usage org.
        freesmartphone.Usage.SetResourcePolicy WiFi enabled
    mdbus -s org.freesmartphone.ousaged /org/freesmartphone/Usage org.
        freesmartphone.Usage.RequestResource WiFi
    ifconfig eth0 up
    /etc/init.d/networking restart
else
    echo WiFi is already up !
fi

echo "0" > /proc/sys/net/ipv4/icmp_echo_ignore_broadcasts

mkdir -p /dev/net
mknod /dev/net/tun c 10 200
chmod 0700 /dev/net/tun
olsrd

cd /home/root/geo_sharing/
make
clear
./geo_sharing -m dbus
```

Listing A.2: The run_geosharing.sh script is the entry point of the GeoSharing application.

This script eases the launch of the GeoSharing application. Besides, it can be executed for two different purposes.

- The GeoSharing application can be launched by tangoGPS when an end-user clicks on the GeoSharing entry of the plugins menu. The interactions with the end-user takes place through the graphical interface provided by tangoGPS. In order to provide to tangoGPS the path to the run_geosharing.sh script, the tangoGPS configuration file (located at `/etc/tangogps_plugins.conf`) has to be filled accordingly.

  ```
  # TangoGPS Plugins Interface
  nbr_plugins = 1;

  Plugin1 = {
      name        =   "GeoSharing";
      path        =   "sh /home/root/run_geosharing.sh";
      options     =   "";
      running     =   "/tmp/geosharing.run";
  };
  ```

- The GeoSharing application can also be launched alone in a terminal. The interactions with the end-user takes place through messages displayed in the terminal.

Appendix B

Licence

GeoSharing is distributed under the “Creative Commons BY SA”[1].

- You are free:
  - to **Share** — to copy, distribute and transmit the work
  - to **Remix** — to adapt the work
- Under the following conditions:
  - **Attribution** — You must attribute the work in the manner specified by the author or licensor (but not in any way that suggests that they endorse you or your use of the work).
  - **Share Alike** — If you alter, transform, or build upon this work, you may distribute the resulting work only under the same or similar license to this one.

[1] http://creativecommons.org/licenses/by-sa/3.0/legalcode

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Acronyms

3DES	Triple Data Encryption Standard
AES	Advanced Encryption Standard
AODV	Ad hoc On-demand Distance Vector
API	Application Programming Interface
APN	Access Point Name
BMF	Basic Multicast Forwarding
CBC	Cipher Block Chaining
CPU	Central Processing Unit
DBF	Distributed Bellman-Ford
DHCP	Dynamic Host Configuration Protocol
DOS	Denial Of Service
DSR	Dynamic Source Routing
ECB	Electronic Code Book
FSR	Fisheye State Routing
GPS	Global Positioning System
GSR	Global State Routing
GTK	GIMP Tool Kit
GUI	Graphical User Interface
HSLS	Hazy Sighted Link State
IANA	Internet Assigned Numbers Authority
IEEE	Institute of Electrical and Electronics Engineers

IP	Internet Protocol
ISO	International Organization for Standardization
IV	Initialization Vector
LSDB	Link State Database
LSP	Link State Packet
MAC	Message Authentication Code
MANET	Mobile Ad hoc NETwork
MPR	Multipoint Relay
OLSR	Optimized Link State Routing
OLSRd	Optimized Link State Routing dæmon
OS	Operating System
OSI	Open Systems Interconnection
P3M	Persistent Third-Generation Mesh
PSK	Pre-Shared Key
RFC	Request For Comments
RREP	Route Reply
RREQ	Route Request
SHR	Stable Hybrid Release
SSID	Service Set Identifier
TCP	Transport Control Protocol
TKIP	Temporal Key Integrity Protocol
TTL	Time-to-live
UDP	User Datagram Protocol
WEP	Wired Equivalent Privacy
Wi-Fi	Wireless Fidelity
WPA/WPA2	Wi-Fi Protected Access

Glossary

Ad hoc mode
: A wireless mode allowing multiple devices to be interconnected without the need of external support.

D-Bus
: A software message bus system behaving as a hardware bus and allowing applications to register on it to offer services.

Distance vector routing
: A distributed routing protocol based on the advertisement of the distance from the originator towards each known destination.

Link State routing
: A distributed routing protocol learning the entire network topology via message exchanges. The shortest path between nodes is computed thanks to the Dijkstra's shortest path algorithm.

MANET
: Mobile Ad hoc NETwork, a self-configuring ad hoc network combined with an underlying routing protocol.

OLSR
: Optimized Link State Routing, an experimental proactive protocol defined in RFC3626 [CJ03]. The protocol is based on multipoint relays election to decrease the overall bandwidth consumption.

OLSRd
: Optimized Link State Routing dæmon, a Linux dæmon proposed by Andreas Tønnesen implementing the Optimized Link State Routing protocol.

Openmoko Neo FreeRunner
: The second Linux-based touchscreen smartphone designed by the Openmoko Inc. to run Openmoko softwares. In production since June 2008.

Proactive routing
A class of protocols trying to keep the routing table up-to-date on every node belonging to the network.

Reactive routing
A class of protocols computing the path toward a destination whenever a packet has to be sent.

SHR
Stable Hybrid Release, a Debian-based operating system providing an X server environment.

TangoGPS
A free navigation software based on OpenStreetMap project.

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