

FLINDERS UNIVERSITY

COMP-9710A Master Project Thesis

by

Theo DE FRAMOND

Functional testing and qualification
of the Serval Mesh Extender

in the
School of Computer Science

May 2017

Declaration of Authorship

I, Theo DE FRAMOND, declare that this thesis titled, ‘Functional testing and qualification of the Serval Mesh Extender’ and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed:

Date:

“Communications should not just be for the geographically, financially otherwise fortunate for it is the unfortunate who need it most.”

Serval

FLINDERS UNIVERSITY

Abstract

School of Computer Science

Master Project Thesis

by Theo DE FRAMOND

This paper is the thesis of my Master Project COMP9710A in Flinders University, School of Computer Sciences as an exchange student from France. It explains all the work, tasks and experiments I have done during my project which is the Serval Project and how I did it. The remainder of this content concerns the perspectives and the motivations of such a project and also what I have retained about it.

Keywords : Serval Project, testing, Mesh Extender, emergency communications, LBARD, automatic tests, Servald, Expect.

Acknowledgements

I would like to thank the all telecommunication laboratory of Flinders in Tonsley for their participation in the project and for having supported my work and helped me get results of better quality. I am particularly grateful to my supervisor Paul Gardner-Stephen for his patience and support in overcoming numerous obstacles I have been facing through my research. Thanks him for having accepted me in his team.

I would like to thank my fellow students and the ISS of Flinders University for their feedback, cooperation and kind welcome.

Nevertheless, I am also grateful to my French school INSA Lyon for having given me the opportunity to get here and work in this wonderful country which is Australia. Thanks Isabelle Auge-Blum and the DRI for having organized my student exchange and thanks the jury for having changed their decision regarding this exchange which was at first forbidden for me.

I would like to thank my friends for accepting nothing less than excellence from me. Last but not the least, I would like to thank my family: my parents and to my sister for supporting me spiritually throughout writing this thesis and my life in general.

...

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Abbreviations

LAH List Abbreviations **Here**

Physical Constants

Speed of Light $c = 2.997\,924\,58 \times 10^8 \text{ ms}^{-\text{s}}$ (exact)

Symbols

a	distance	m
P	power	W (Js^{-1})
ω	angular frequency	rads^{-1}

For/Dedicated to/To my...

Chapter 1

Introduction

This chapter of my thesis is the "why?" of my project. I am explaining here what are my motivations that led me to this and why I wanted to choose this work as my end study project instead of another one. The scope and the context of this experiment are also part of this chapter. The two last points I am discussing here concern all my research questions and the global structure of my thesis.

1.1 Motivation

1.1.1 Australia

Of course and since I live in France, an important motivation was to travel and discover Australia. But as this "touristic" motivation is not very appropriate in this thesis I will not develop it that much. But I still want to say that traveling is essential for a human to grow and get mature. This applies for becoming an engineer as well. Now that the semester is almost finished, I can tell that this abroad experiment has helped me to get prepared for my future life by making me think in a different way and more.

1.1.2 Telecommunication

Second motivation is the field of telecommunications. This is my studies and what I am interested in. It was thus obvious that this project will fit to me. Indeed, the Serval Project concerns an emergency phone network. It deals thus with antennas, communication protocols and signal processes. All these topics will be helpful for my

future jobs. All what I learned in the past years in my school, I can apply it here on this project which is totally on the continuous of my studies track.

1.1.3 Laboratory and Research

In my five years of study, I have never really worked in a laboratory as a researcher. I have done many tutorials and practical works with my class but it was just study and nothing to see with research. I wanted thus to discover the world of research and how all of this work. How is running a laboratory ? Who is in charge of it ? What are the relationships in it ? How are the projects financed ? I am really happy now to know much more about this part of the engineer world.

1.1.4 Humanitarian

Last and not the least, I really appreciate the humanitarian aspect of the project. Indeed, as I will explain in the next section, the Serval Project is here to help poor islands from the pacific to recover after a natural disaster for example. It can also be the first step for poor villages to have access to distant communication without having to invest into expensive and permanent infrastructures. If I can work for a good and human purpose, it is better. I am really happy to help in this adventure rather to work for big industries who just care about money despite the environment or human conditions.

1.2 Scope

The Serval Project is a suite of technologies designed to facilitate and sustain mobile telecommunications in the absence of supporting infrastructure, such as cellular networks or electricity.

The two main components of the Serval Project are the Serval Mesh Extender Hardware and the Serval Mesh App. Basically the Serval Mesh Extender is a low-cost communications relay device that extends the range of communications among phones using Wifi technology. The laboratory has a partnership with my university in France named INSA de Lyon so that each year, French students can help on the project as a one semester exchange program. I am one of these student.

For the year 2017, the Australian Department of Foreign Affairs and Trade have commissioned the University to pilot Serval in the Pacific. Consequently, we have to prepare

the Serval Mesh Extender technologies for field use in tropical-maritime environments, and without any dependencies on mains electricity. To this end the first Serval Mesh Extender is being redesigned to satisfy these requirements. However, this process is not yet complete.

Therefore there is an need to devise and apply a testing regime for the new Serval Mesh Extender design, to ensure that it meets the necessary functional requirements, and that the units are possible to easily manufacture. The focus of this project will be on the creation and application of such test protocols, to ensure that the Serval Mesh Extender devices are ready for deployment in the field pilot.

1.3 Research questions

For this work I am following an Agile methodology. Therefore I have to organize my experiments in an iterative way and plan them with precise steps and precise goals. A list of the automatic tests I have to implement will help me with this.

The tests must be automatic and quick. That is why I need to implement them in a logical and low-level software environment. Basically I will connect the Mesh Extenders with a laptop and then run all the tests on it. In the end, it will display all the results so we can know if the extenders are ready to use or if we have to do some changes on the settings and if the manufacturing of the extender is okay.

Finally and with the help of my supervisor instructions, I used Expect and Shell scripts to code my test. These are the different parts of the Serval Project I will have to implement tests for :

- Mesh Extender hardware
- Mesh Extender cables
- Mesh Extender software
- Mesh Extender network functions
- end-to-end connection testing with various topologies
- manufacturing quality control
- acceptance testing

Since we have to be ready for the Vanuatu expedition which will happen in May, work must be done in two or three months. That makes thus two or three tests by months. According to the fact I have to see and learn how the Mesh Extender operates and the callback I need in Expect and Shell language.

1.4 Structure of Thesis

The structure of my thesis will follow a height points pattern. After this introduction, I'm going to do some literature review in order to get the context of the Serval Project and to know exactly where about we are in it. I will deal with the different versions of the Serval Mesh extender and introduce the new design of the last version. Then, the methodology will be an other part follow by the Pacific Humanitarian Project which is the reason why we can run this project at this level now. The next big part is the hardware tests split into two categories : the Environmental Testing and the Post-Assembly testing. The first one concerns the abilities of the Mesh Extender to run into a certain environment, for example rain or dust. The second one is more about the software and utility requirements. Next part is obviously the software tests. I will finally present the simulated field operation of the Mesh Extender before discussing all the project and to conclude introduce the future direction of the Serval Project.

Chapter 2

Serval

2.1 The Serval Project

2.1.1 What is Serval ?

Serval is a humanitarian open source project aiming at providing means of communication to people in the incapacity to of having cellular coverage. "Cellular communication is great when it's available" but it is not always the case. This is why Serval offers an independent and autonomous cellular network which works with mesh extenders and normal smartphones without the need of external cellular infrastructures.

This project was created in 2010 by my supervisor Paul Gardner-Stephen and Romana Challans in response to the terrible and disastrous earthquake that happened in Haiti just before. Years after years, many people join the team to work and help on the project which is based in the telecommunications laboratory of Flinders University in Tonsley, Mitchell Park, SA.

2.1.2 Why Serval ?

Serval is here to help with one main purpose: COMMUNICATE, regardless the conditions and circumstances.

- Communicate anytime, even when the usual and main phone network is down or the cellular infrastructures are broken.
- Communicate anywhere, as cellular networks are not available everywhere. For instance, 75% of Australia is not covered as lots of poor countries in the world.
- Communicate privately, with end-to-end encryption for phones calls and SMS.

2.1.3 Serval purposes

As cellular network is not everywhere and always accessible, the Serval Project is about creating an alternative communication network that does not depend on a big, official and expensive infrastructure. That means they do not need a license neither nor a carrier. In this conditions, Serval is using a Mobile Ad-Hoc Network (MANETs) which is appropriate for this.

An other goal of the Project is to connect sensors to this network in order to monitor wide remote area. For example, a farmer wants to know if a door is open on the other side of his huge farmland. By connected sensors to the Mesh Extender of the network we can in addition to the cellular network, create a sensor network. Of course we can imagine lots of other use to this network as far as it does not need a big amount of data speed.

2.1.4 Serval's funding

In the past years, Serval had several partnerships which include the Shuttlerworth Foundation, NLet Foundation, the Awesome Foundation for the Arts and Science, the New America Foundation, Internews, Open Internet Tools Project, Flinders University of course and many other institutional and private contributors. But this year is a special year since the Serval Project has been nominated by the Australian Government in the Pacific Humanitarian Challenge which I will explain in the next point. The Australian Department of Foreign Affairs is thus one of the more important funder this year thanks to this challenge.

2.2 The Pacific Humanitarian Challenge

2.2.1 The challenge

In November 2015 the Australian government called on innovators, entrepreneurs, designers, NGOs, and academics to rethink humanitarian response. They received 129 applications from 20 countries across five continents. Ten First Round Winners were selected to attend a Design Sprint in March 2016 where they further refined their applications with coaching from advisors. After much consideration, five teams were selected to share in a 2 million AUD fund for running pilot projects in the Pacific. Serval is part of them.

As a consequence, they have to pilot a first experiment of this project in Vanuatu in May 2017 to test and qualified their work. If this is a success, Serval Project will have

more help from the government in the future to make the project evolve further. To this end, there is a need to develop and increase the Mesh Extender so it will be ready for the pacific conditions and can handle it.

2.2.2 Mesh Extender, first version

To create that communication network and as the UHF radios in the smartphones can not be used that easily, Serval invented the Mesh Extender which is an external device basically working like a smart wifi antenna. As the Serval network is based on a wifi ad-hoc topology, people can only communicate to each other within the range of their wifi device. Of course this one is not that important. This is why we need the Mesh Extender which can extend the range of every device nearby thanks to his radio antennas. With the Mesh Extender, the Serval Network can finally be used like a traditional cellular network with minimizing range problems.

This device is made on a PCB base including both RFD900X + Atheros 9k based embedded Linux computer, a wifi antenna, two radios antennas, an SD card slot, a USB slot, an Ethernet port, a serial port so we can connect with many different possible ways.

2.2.3 Mesh Extender, second version

The first version of the Mesh Extender was not ready to face the conditions of the pacific challenge. Therefore there was a need to prepare it for this. By this, i mean the tropical climate, the heavy rains and the lack of electricity in some places. For this points we need to improve the Mesh Extender in order to make it resilient against the rain, the dust and the wind. Moreover we also have to make it autonomous in terms of energy. For the first issue, Serval visited the world of injection moulding with a colleague from the university. Together with a local injection moulding company, they have found a way to get full-custom polycarbonate injection-moulded cases designed and manufactured at a relatively affordable price. With this, we have now an IP65 or IP66 rating for the case, so that it can be safely used in dusty outback conditions, as well as in tropical maritime climates.

The second issue has been fixed with the interesting idea to include a solar and battery controller in the unit. We can now just plug in a solar panel, car battery or other supply to run the unit, in addition to the normal 5V USB supply. We are also able to connect two LiFePO4 cells, that the unit would charge from the supply, and use to operate when there is no power supply available.

Chapter 3

FAC Method and Material

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3.1 Test methodology...

My work methodology is following an Agile method. Every tests can be considered as a single task or a user-story such as my supervisor can be considered as the scrum-master. Each time I chose a new ticket, I try to chose a deadline to fix the ticket according to its complexity. Obviously it is not often easy for me to respect this delay since I am not familiar with the technologies i have to use here. For example, a really simple task can take me a huge amount of time to execute because of my lack of knowledge in these new languages.

The test methodology is not completely defined and can be different depending on the test himself. Nonetheless, the global aspect follows the same basic pattern every time.

3.1.1 Test overlook

The first task to do before each test is to sort it and classify it between hardware and software categories. This also helps to chose which language will be more adequate to test it and in which environment I have to code it. Most of the time, I write the codes either with a Shell script either with an Expect Script, either with both.

3.2 Simulation methodology...

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Chapter 4

Functionnal Hardware testing of Serval Mesh Extender

4.1 Environmental testing

4.2 Post-assembly testing

4.2.1 Test 1 : Boot-loader and flash firmware update

This is the very first task I have to implement. The goal is to prepare the manufactured Mesh Extender units for the tests and use. In order to do it, we have to install a special Linux distribution on it called OpenWrt. OpenWrt is an embedded operating system based on Linux, primarily used on embedded devices to route network traffic. All components have been optimized for size, to be small enough for fitting into the limited storage and memory available in home routers as the Serval Mesh Extender.

In order to install the latest version of the OS, we will use here the command-line interface Shell. This will allow to boot directly the Domino from a laptop. But at this point, we need to make these two entities capable of communicate to each other. That is why we need cables and especially one that can deals with the extender serial port. For this one, we have for the moment a home-made cable that use a D-SUB 25 pins male port on one side and whatever we want on the other side by cutting the edge of the cable and weld components on the desired nude wires. That is why we have welded here a serial port to USB adapter and a power plug to power the PCB.

So now we can talk to the PCB with the laptop through command lines. But there is a problem remaining. Serial port is too slow to transfer data and at some point, we will have to download on the Domino the OpenWrt software binaries. That is why we also

use an ethernet cable to install the distribution in addition to the serial cable.

The procedure is simple, we first connect the laptop and the Mesh Extender with the serial and ethernet cables. Then we plug the power cable in order to make the PCB run. We have to install the Serval software which create the OpenWrt files to transfer to the PCB on a linux environment. To this end, we have to install lots of dependencies like for example GNU awk, SVN, OpenSSL library ...etc. That is why we need to install VirtualBox on Macintosh laptop first. Then, just clone the repository OpenWrt from the Serval Project Github source and run the following commands :

```
└ ./scripts/feeds update serval
└ ./scripts/feeds install -p serval
└ ./scripts/feeds install -a serval
└ make world (long time running...)
```

Therefore, the binary for installation should then be in: bin/ar71xx/openwrt-ar71xx-generic-gl-ar150-initramfs-kernel.bin

To flash the PCB, we have to connect to the serial port at 115200 by typing:

```
└ cu -l /dev/cu.usbserial -s 115200
```

or if we have trouble with cu:

```
└ screen /dev/cu.usbserial 115200
```

In either case, we will have to reboot the node in some way, so that we see the uboot prompt. Then we have to press any key to interrupt the boot process.

The Mesh Extender node will have an IP of 192.168.1.1, so we should pick another IP address on that subnet for the connected computer and type "httpd" to start the firmware update webserver. Then, just browse to <http://192.168.1.1> and select the firmware file to upload, and trigger the firmware update.

So here is my very first expect script for that :

```
#!/usr/bin/expect
#Expect script installing an openWrt image on the Serval Mesh Extender
```



```
set timeout -1
log_user 0

spawn cu -l /dev/cu.usbserial -s 115200

expect {
    "Connected."
    {
        puts "\n#####\n# MESH EXTENDER
        FIRMWARE UPDATER\n#\n# 1/7 > Please, boot or reboot the PCB"
    }
}

expect {
    "Hit any key"
    {
        send "\r"
        puts "# 2/7 > Autoboot well interrupted"
    }
}

expect {
    "uboot>"
    {
        send "httpd\r"
        puts "# 3/7 > Server HTTP well started"
    }
}

expect {
    "HTTP server is ready!"
    {
        puts "# 4/7 > Uploading the image..."
        system curl --silent -o /dev/null -F
        'firmware=@./openwrt-ar71xx-generic-gl-ar150-squashfs-sysupgrade.bin' -F
        'filename=\$openwrt-ar71xx-generic-gl-ar150-squashfs-sysupgrade.bin'
        http://192.168.1.1/
    }
}

expect {
    "upload is done!"
    {
```

```

        puts "# 5/7 > Upload successful\n# 6/7 > Upgrading the firmware... DO
        NOT POWER OFF "
    }
}

expect {
    "done!"
    {
        puts "# 7/7 > HTTP upgrade is done! Rebooting..."
    }
}

expect {
    "Hit any key"
    {
        send "\r"
        puts "#\n# FIRMWARE SUCCESSFULLY UPDATED,
        ENJOY!\n#####\n"
    }
}

```

And this is what it outputs :

```

#####
# MESH EXTENDER FIRMWARE UPDATER
#
# 1/7 > Please, boot or reboot the PCB
# 2/7 > Autoboot well interrupted
# 3/7 > Server HTTP well started
# 4/7 > Uploading the image...
# 5/7 > Upload successful
# 6/7 > Upgrading the firmware... DO NOT POWER OFF
# 7/7 > HTTP upgrade is done! Rebooting...
#
# FIRMWARE SUCCESSFULLY UPDATED, ENJOY!
#####

```

4.2.2 Test 2 : Network connections

The second automatic test i have to implement are related to the Mesh networks. Indeed we have to make sure that, after an upgrade or any random boot, the Mesh Extender will

provide the expected networks. That means two wireless connections and one Ethernet connection. The first wireless connection is actually a hotspot on which every device can connect. The second one is the ad-hoc peer connection in order to communicate with other Mesh Extenders. This is the one who will diffuse all the Rhizome messages. Then the Ethernet connection is here to enable the transfer of data on the Mesh from a laptop. It will be a way to connect whatever else devices locally to the Extender as well.

This test is a bit more complicated than the first one because it needs the output of the program to react according to it. This is a highest level of expect and did a lot of research to finally understand how we can fix this issue. Actually with expect, we can definitely not read the output of a shell. Or at least not directly. What we can though is to record or redirect this output into a file and then, read this file with expect. It is not very practical, it consumes time and memory but this is the only way...

In this program, first of all i need to check the presence of the wireless networks. For this purpose, i use the airport tool available in the Unix environment. There is one little problem though. The airport software is most of the time already installed on laptops but we have to add it to the global PATH before we can use it. Once this is done, we can check for the Wifi networks from the shell with the command :

```
❯ airport -s
```

We filter the result of it by piping the output with the grep command which i redirect directly into a file in order to use it with expect after :

```
❯ airport -s — grep servalproject ❯ networks-found
```

Now, we have to check if the networks-found file contains indeed the networks we are looking for. We also have to make sure that, if there is many Mesh Extender working at the same time, the networks we are looking at is really the one from the Mesh Extender we are testing and not the one from another. For this, we can just compare the mac address of both the Mesh Extender and the one from the Wifi network. For testing the test script, i just simulate and assume that the mac-address of the testing Mesh Extender will be in an other file. I just have then to open both of these files and compare them. If both of the addresses match, test is successful.

Chapter 5

Functionnal Software testing of Serval Mesh Extender

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5.1 A Section

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5.1.1 A Subsection

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5.2 Another Section

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Chapter 6

Simulated Field Operation of Serval Mesh Extender

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Chapter 7

Discussion

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Chapter 8

Conclusions and Future Direction

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Appendix A

An Appendix

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