



ÉCOLE  
POLYTECHNIQUE  
DE BRUXELLES



UNIVERSITÉ LIBRE DE BRUXELLES

# Implementation of High-Level Cryptographic Protocols using a SoC Platform

Mémoire présenté en vue de l'obtention du diplôme  
d'Ingénieur Civil en informatique à finalité spécialisée

Quentin Delhay

Directeur

Professeur Frédéric Robert

Superviseur

Sébastien Rabou (Barco Silex)

Service

BEAMS

Année académique

2014 - 2015

## **Abstract**

*by Quentin Delhayé, Master in Computer Science and Engineering, Professional Focus, Université Libre de Bruxelles, 2014–2015.*

### **Implementation of high level cryptographic protocol using a SoC platform**

This is an abstract.

## Résumé

*par Quentin Delhayé, Master en ingénieur civil en informatique, à finalité spécialisée, Université Libre de Bruxelles, 2014–2015.*

# Acknowledgements

Thanks a bunch of people here : - Frédéric Robert for his support - Sébastien Rabou for his insight - Batien Heneffe for his extensive help

# Contents

<b>Abstract</b>	<b>i</b>
<b>Résumé</b>	<b>ii</b>
<b>Aknowledgements</b>	<b>iii</b>
<b>Contents</b>	<b>iv</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Challenge . . . . .	1
1.2 Network security . . . . .	1
<b>2 Presentation</b>	<b>2</b>
2.1 Experimental setup . . . . .	2
<b>3 Technical background</b>	<b>4</b>
3.1 Operating system . . . . .	4
3.2 Cryptography . . . . .	4
3.3 Network and VPN implementation . . . . .	4
<b>4 Implementation</b>	<b>5</b>
<b>5 Conclusion</b>	<b>6</b>
5.1 Future work . . . . .	6
<b>A Toolchain</b>	<b>9</b>
<b>B Cross-compilation</b>	<b>10</b>
B.1 OpenSSL . . . . .	10
B.2 OpenVPN . . . . .	10
B.3 nginx . . . . .	10
B.4 Strongswan . . . . .	10

<i>CONTENTS</i>	v
B.5 kernel . . . . .	10
<b>Bibliography</b>	<b>11</b>

# **Chapter 1**

## **Introduction**

### **1.1 Challenge**

### **1.2 Network security**

# Chapter 2

## Presentation

Here we talk about the protocols, the platform. Show The OS stack (kernel/user)

### 2.1 Experimental setup

The experimental environment is build around a standard x86 host and an ARM Cortex-A9 alongside an Altera Cyclone V FPGA as the target.

#### 2.1.1 x86 host

**OS** Ubuntu 12.04 LTS, kernel 3.16

**CPU** Intel Core-i3 ... (two logical core out of four)

**RAM** 1.5GB DDR3

#### 2.1.2 Altera Socrates SoCFPGA

**OS** Yocto project, kernel 3.14

**CPU** Dual core ARM Cortex-A9, 800MHz

**RAM** ...GB DDR3



**FPGA** Altera Cyclone V

# **Chapter 3**

## **Technical background**

This chapter will address the technical ground inherent to this work: first the operating system, followed by the cryptography and networking.

### **3.1 Operating system**

### **3.2 Cryptography**

#### **3.2.1 Asymmetric cryptography**

#### **3.2.2 Symetric cryptography**

### **3.3 Network and VPN implementation**

There exist several major implementations of VPN: SSL, IPSec and PPTP. The later was developped by a vendor consortium and proposed in the RFC 2637 [4]

#### **3.3.1 SSL/TLS**

#### **3.3.2 IPSec**

# **Chapter 4**

## **Implementation**

# Chapter 5

## Conclusion

### 5.1 Future work

Although the present work presents some promising results, the implementation can certainly be improved in several ways and some further experiments should be conducted.

**Driver improvement** The driver of the BA411E can be made less resources hungry by improving the initialisation of the descriptors and their linking, but the gain would not be significant enough to justify the time investment at this point. A better alternative would be to avoid descriptors altogether by modifying the interface with the IP so that it can use the scatterlist directly. We would then spare a lot of DMA mapping instruction and thus some precious cycles on the software side.

As we already remarked in ??, the use cases involving IPsec were conducted using a previous revision of the driver still actively polling the IP for its results. A better and cleaner way to proceed is to use interruption routines, as shown in ?. However, the kernel does not support their current implementation and panics upon usage. If one were to be willing to spend the time replacing the active polling by clean asynchronous interruptions, he should be aware of the overhead imposed by an interruption. In some cases, when the operation is just a few clock cycle long for the IP, an active polling could still be the better way to go. A more thorough comparison of the mutual trade-off deserves some investigation, and as a starting point, the packet size could be treated as a branching point between the two solutions.

**Registering public key verification with the crypto API** As we saw in ??, the driver is already capable of offloading a large portion of public key operations

to the IP, but only with very specific libraries at the time being – openssl in our case. The next step is to register the very same operations with the crypto API so it can be used without having to rely on a custom openssl engine.

**Conditional offloading in cryptodev** The figure ?? clearly shows a threshold on the packet size from which the hardware has a clear advantage, and below which the user mode software implementation is to go for. Using this tipping point, one could set a conditional branch as shown in listing 5.1

```
1 int some_function() {  
2     if(packet_size < 1024*1024) {  
3         callback_function();  
4     }  
5 }
```

Listing 5.1: cryptodev conditional offloading

He should however be aware that as the tipping point is around 1024kB, the performance for a network application should very close to those of a full software implementation, knowing that the ethernet frame size, the MTU, is set by default at 1500kB.

**Disk encryption** As the hardware is better used with larger blocks of data, disk encryption could be an interesting application to look into.

**Cryptographic libraries** OpenSSL is not the only cryptographic library available; GnuTLS is also a very popular alternative and supports cryptodev engines too.

However, one library definitely worth to keep an eye on is mbed TLS, formally known as PolarSSL, recently bought by ARM [1]. We can expect the future releases of this library to be more optimized for ARM platforms, and maybe the software footprint and overhead to be reduced.

**Cryptodev** If patches adding the GCM support to cryptodev have already been released, those are not compatible with Barco Silex' driver. Adapting the interface would open the GCM hardware offload to the whole user space applications park.

**MAC offloading** While the symmetric and asymmetric encryption ciphers IPs are usable from the operating system, the IP computing MACs does not have a usable driver yet. Wherever there is encryption, authentication is also needed. As such, any real day-to-day use case can not be fully offloaded to hardware yet, even if

some tricks and patches allowed us to bypass this requirement. The implementation of the GCM mode, combining encryption and authentication, showed us that stopping relying on the software implementation of MACs would be a huge step forward.

# Appendix A

## Toolchain

Talk here about linux linaro and shit. This does not need to be long, just explain which version was used, what environment variable to export.

See if this does not enter in conflict with the "cross-compilation" appendix.

# **Appendix B**

## **Cross-compilation**

**B.1    OpenSSL**

**B.2    OpenVPN**

**B.3    nginx**

**B.4    Strongswan**

**B.5    kernel**

Force kernel version

Change list of modules (show the final version)



# Bibliography

- [1] ARM. *ARM buys Leading IoT Security Company Offspark as it Expands its mbed Platform*. February 2015. <http://www.arm.com/about/newsroom/arm-buys-leading-iot-security-company-offspark-as-it-expands-its-mbed-platform.php>.
- [2] Hugo Krawczyk. The order of encryption and authentication for protecting communications (or: how secure is ssl?). Cryptology ePrint Archive, Report 2001/045, 2001. <http://eprint.iacr.org/>.
- [3] Kenneth G. Paterson. A cryptographic tour of the IPsec standards. *Information Security Technical Report*, 11(2):72 – 81, 2006. ISSN 1363-4127.
- [4] J. Viega and D. McGrew. The Use of Galois/Counter Mode (GCM) in IPsec Encapsulating Security Payload (ESP). RFC 4106, RFC Editor, June 2005. URL <https://tools.ietf.org/rfc/rfc4106.txt>.
- [5] Christos Xenakis, Nikolaos Laoutaris, Lazaros Merakos, and Ioannis Stavrakakis. A generic characterization of the overheads imposed by IPsec and associated cryptographic algorithms. *Computer Networks*, 50(17):3225 – 3241, 2006. ISSN 1389-1286.