



DEPARTMENT OF COMPUTER SCIENCE

Building a Testbed for Evaluating Privacy Enhancing Technologies (PETs)

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A dissertation submitted to the University of Bristol in accordance with the requirements of
the degree of Bachelor of Science in the Faculty of Engineering.

Monday 10th May, 2021

Declaration

This dissertation is submitted to the University of Bristol in accordance with the requirements of the degree of BSc in the Faculty of Engineering. It has not been submitted for any other degree or diploma of any examining body. Except where specifically acknowledged, it is all the work of the Author.

Jacob Daniel Halsey, Monday 10th May, 2021

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Executive Summary

The goal of this project is to produce a simple and lightweight testbed platform for evaluating privacy enhancing technologies. It should provide support for testing varied architectures and network topologies, such as client-server and peer-to-peer applications. It should also support simulating applications for different types of platforms including mobile phone apps.

Summary of work:

- I have developed a flexible command line tool called *kvm-compose* for Linux using the Rust language and *libvirt* library for building and destroying virtual testing environments.
- In the process I have made some contributions to the *libvirt-rust* language bindings open source library.
- I have then implemented some example projects using the testbed tool.

Supporting Technologies

- *Linux KVM* (Kernel-based Virtual Machine) - <https://www.linux-kvm.org/>
- *Open vSwitch* Virtual multilayer switch - <https://www.openvswitch.org/>
- *libvirt* Virtualization API - <https://libvirt.org/>
- *Rust* Language, Compiler, Toolchain, etc. - <https://www.rust-lang.org/>
- *libvirt-rust* Rust bindings to the libvirt - <https://gitlab.com/libvirt/libvirt-rust>
- *clap* Rust command Line Argument Parser - <https://github.com/clap-rs/clap>
- *serde* Rust Serialization framework - <https://github.com/serde-rs/serde>
- *serde-yaml* YAML backend for serde - <https://github.com/dtolnay/serde-yaml>
- *serde-plain* Plain text backend for serde - <https://github.com/mitsuhiko/serde-plain>
- *thiserror* Rust error derive macro - <https://github.com/dtolnay/thiserror>
- *anyhow* Rust error handling framework - <https://github.com/dtolnay/anyhow>
- *simple_logger* Rust logging implementation - https://github.com/borntyping/rust-simple_logger
- *xml-rs* XML library for Rust - <https://github.com/netvl/xml-rs>
- *validator* Rust struct validation - <https://github.com/Keats/validator>
- *directories* User data directories library - <https://github.com/dirs-dev/directories-rs>
- *request* Rust HTTP Client - <https://github.com/seanmonstar/request>
- *indicatif* Rust command line progress indicator - <https://github.com/mitsuhiko/indicatif>
- *tempfile* Rust temporary file library - <https://github.com/Stebalien/tempfile>
- *casual* Rust user input parser - <https://github.com/rossmacarthur/casual>
- *derive-new* Rust new constructor macro - <https://github.com/nrc/derive-new>
- *enum-iterator* Rust macro for iterating enums - <https://github.com/stephanevfx/enum-iterator>
- *rust-embed* Embeds files into Rust binaries - <https://github.com/pyros2097/rust-embed>

Acknowledgements

I would like to thank my supervisor Professor Awais Rashid and co-supervisor Joe Gardiner for their project proposal and support and guidance in completing it.

Chapter 1

Contextual Background

The UK Research and Innovation (UKRI) is a non-departmental public body of the United Kingdom Government sponsored by the Department for Business, Energy and Industrial Strategy [1]. In October 2020 the UKRI announced the creation of the National Research Centre on Privacy, Harm Reduction and Adversarial Influence Online (REPHRAIN) [2]. The centre is made up of researchers in computer science, international relations, law, psychology, management, design, digital humanities, public policy, political Science, criminology, and sociology from five British universities including the University of Bristol.

REPHRAIN should be understood in the context of the UK government’s *Online Harms White Paper* public consultation beginning in April 2019 [3], which sets out plans for new online safety measures; REPHRAIN’s missions and outcomes are aligned with the paper.

REPHRAIN will focus on three core missions [4]:

1. Delivering privacy at scale while mitigating its misuse to inflict harms.
2. Minimising harms while maximising benefits from a sharing-driven digital economy.
3. Balancing individual agency vs. the social good.

The three missions will require looking at Privacy Enhancing Technologies (PETs); including their capabilities, applications of PETs in addressing existing online harms, mitigating the potential abuse of PETs, embedding the PETs into infrastructures, and developing new PETs. In order to facilitate this REPHRAIN intends to build a toolbox of resources including a PETs testbed. The testbed will be used researchers in developing, testing, and evaluating the PETs. The aim of this project is to develop a prototype of this testbed.

1.1 Privacy Enhancing Technologies (PETs)

This chapter should describe the project context, and motivate each of the proposed aims and objectives. Ideally, it is written at a fairly high-level, and easily understood by a reader who is

technically competent but not an expert in the topic itself.

In short, the goal is to answer three questions for the reader. First, what is the project topic, or problem being investigated? Second, why is the topic important, or rather why should the reader care about it? For example, why there is a need for this project (e.g., lack of similar software or deficiency in existing software), who will benefit from the project and in what way (e.g., end-users, or software developers) what work does the project build on and why is the selected approach either important and/or interesting (e.g., fills a gap in literature, applies results from another field to a new problem). Finally, what are the central challenges involved and why are they significant?

The chapter should conclude with a concise bullet point list that summarises the aims and objectives. For example:

The high-level objective of this project is to reduce the performance gap between hardware and software implementations of modular arithmetic. More specifically, the concrete aims are:

1. Research and survey literature on public-key cryptography and identify the state of the art in exponentiation algorithms.
2. Improve the state of the art algorithm so that it can be used in an effective and flexible way on constrained devices.
3. Implement a framework for describing exponentiation algorithms and populate it with suitable examples from the literature on an ARM7 platform.
4. Use the framework to perform a study of algorithm performance in terms of time and space, and show the proposed improvements are worthwhile.

Chapter 2

Technical Background

A compulsory chapter, of roughly 10 pages

This chapter is intended to describe the technical basis on which execution of the project depends. The goal is to provide a detailed explanation of the specific problem at hand, and existing work that is relevant (e.g., an existing algorithm that you use, alternative solutions proposed, supporting technologies).

Per the same advice in the handbook, note there is a subtle difference from this and a full-blown literature review (or survey). The latter might try to capture and organise (e.g., categorise somehow) *all* related work, potentially offering meta-analysis, whereas here the goal is simple to ensure the dissertation is self-contained. Put another way, after reading this chapter a non-expert reader should have obtained enough background to understand what *you* have done (by reading subsequent sections), then accurately assess your work. You might view an additional goal as giving the reader confidence that you are able to absorb, understand and clearly communicate highly technical material.

Chapter 3

Project Execution

A topic-specific chapter, of roughly 15 pages

This chapter is intended to describe what you did: the goal is to explain the main activity or activities, of any type, which constituted your work during the project. The content is highly topic-specific, but for many projects it will make sense to split the chapter into two sections: one will discuss the design of something (e.g., some hardware or software, or an algorithm, or experiment), including any rationale or decisions made, and the other will discuss how this design was realised via some form of implementation.

This is, of course, far from ideal for *many* project topics. Some situations which clearly require a different approach include:

- In a project where asymptotic analysis of some algorithm is the goal, there is no real “design and implementation” in a traditional sense even though the activity of analysis is clearly within the remit of this chapter.
- In a project where analysis of some results is as major, or a more major goal than the implementation that produced them, it might be sensible to merge this chapter with the next one: the main activity is such that discussion of the results cannot be viewed separately.

Note that it is common to include evidence of “best practice” project management (e.g., use of version control, choice of programming language and so on). Rather than simply a rote list, make sure any such content is useful and/or informative in some way: for example, if there was a decision to be made then explain the trade-offs and implications involved.

3.1 Example Section

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foo

Figure 3.1: This is an example figure.

foo	bar	baz
0	0	0
1	1	1
⋮	⋮	⋮
9	9	9

Table 3.1: This is an example table.

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3.1.1 Example Sub-section

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```
for  $i = 0$  upto  $n$  do  
  |  $t_i \leftarrow 0$   
end
```

Algorithm 3.1: This is an example algorithm.

```
for( i = 0; i < n; i++ ) {  
  t[ i ] = 0;  
}
```

Listing 3.1: This is an example listing.

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Example paragraph. This is an example paragraph; note the trailing full-stop in the title, which is intended to ensure it does not run into the text.

Chapter 4

Critical Evaluation

A topic-specific chapter, of roughly 15 pages

This chapter is intended to evaluate what you did. The content is highly topic-specific, but for many projects will have flavours of the following:

1. functional testing, including analysis and explanation of failure cases,
2. behavioural testing, often including analysis of any results that draw some form of conclusion wrt. the aims and objectives, and
3. evaluation of options and decisions within the project, and/or a comparison with alternatives.

This chapter often acts to differentiate project quality: even if the work completed is of a high technical quality, critical yet objective evaluation and comparison of the outcomes is crucial. In essence, the reader wants to learn something, so the worst examples amount to simple statements of fact (e.g., “graph X shows the result is Y”); the best examples are analytical and exploratory (e.g., “graph X shows the result is Y, which means Z; this contradicts [1], which may be because I use a different assumption”). As such, both positive *and* negative outcomes are valid *if* presented in a suitable manner.

Chapter 5

Conclusion

A compulsory chapter, of roughly 5 pages

The concluding chapter of a dissertation is often underutilised because it is too often left too close to the deadline: it is important to allocation enough attention. Ideally, the chapter will consist of three parts:

1. (Re)summarise the main contributions and achievements, in essence summing up the content.
2. Clearly state the current project status (e.g., “X is working, Y is not”) and evaluate what has been achieved with respect to the initial aims and objectives (e.g., “I completed aim X outlined previously, the evidence for this is within Chapter Y”). There is no problem including aims which were not completed, but it is important to evaluate and/or justify why this is the case.
3. Outline any open problems or future plans. Rather than treat this only as an exercise in what you *could* have done given more time, try to focus on any unexplored options or interesting outcomes (e.g., “my experiment for X gave counter-intuitive results, this could be because Y and would form an interesting area for further study” or “users found feature Z of my software difficult to use, which is obvious in hindsight but not during at design stage; to resolve this, I could clearly apply the technique of Smith [7]”).

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