University of Sheffield

Reconfigurable Security for IoT Application in Handling Machine-Learning/Modelling Attacks

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Declaration

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Abstract

This report investigate and provide clear introduction on PUF(physical unclonable function), aim of the project and current progress. In introudction, there are thoroughly description on PUF, reconfigurability framework and concepts corresponding to specific machine learnings for modeling attack on PUF.

The aim for the project is to propose a novel, suitable machine learning to model PUF(physical unclonable function) and then design a reconfigurability framework to fight against such attack. The PUF structure is similar to a road network so machine learning related to ETA(estimated time arrival) problem is strongly considered.

The achievements to date are having robust understanding on PUF, reconfigurability property, and attempt to implement reinforcement learning as modeling attack. SARSALambda Q learning reinforcement learning has been tested on PUF but according to false implementation, only 50% accuracy has been achieved. The Actor-Critic reinforcement learning are considered to be useful at the moment, while further research are progressing to validate the usability.

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Chapter 1

Introduction

In the rapid development of the information era, many daily events are achieved by a various of electronic devices such as computer or phones. Those electronic devices highly rely on integrated circuits(ICs) to perform specific events. For example, bank transaction can be done by different devices, the process contain personal data, and including usage of sensitive information. Therefore, information security like authentication, protecting confidential data has become important in nowadays society. In order to increase security's robustness, a range of ways has been proposed. One conventional way to is by storing secret key in non-volatile memory to encrypt sensitive data with it, and use asymmetric cryptography to authenticate the device [4]. However, the implementation process of cryptography is expensive, especially on resource-constraint device, and the device is still vulnerable to invasion attack. Ideally, devices should be able to handle challenging problems corresponding to energy consumption, computational power and the ability to fight against cyber attack.

PUF(physical unclonable function) has the ability to deal with these challenges. It does not store secret in non-volatile memory, instead, the volatile secret is derived from devices' physical characteristics [4]. This is based on the inevitable random variation in ICs manufacturing process, which leads to the fact that no two IC have exact same physical characteristic. For example, each ICs has unique delay sequences in the transistors and wires. With this property, PUF does not require lots of computational power and is cost-effective because no need to implement cryptographic operation, which works particular well on resources-constraint devices such as RFID. Also, the attacker needs to perform attack when the device is on, which significantly increase the difficulty. As for invasion attack, the attacker needs to have the exact information of its unique physical characteristics to successfully derive secret. Overall, PUF provides another interesting way for reinforce security.

1.1 Aims and Objectives

The objectives split into two parts for this project. In the first stage, propose a novel machine learning to modeling different PUF(physical unclonable function) behavior, so predict the response from a given PUF when given challenge bits. For example, considered the simplest PUF which is arbiter PUF, its operation to create a response is to input a challenge bits(binary), and two signals will go thorough the multiplexers in the PUF structure depend on the value of it. Consequently response a binary bit that will indicate which signal is faster. Therefore, the machine learning for modeling will be related to ETA(estimated time arrival) problem since the structure of PUF is similar to a road network. For instance, traveling through each multiplexer is similar to traveling through each road segment, and both of them have delay to affect the time of arrival. Overall the first stage is to design a machine learning consider these concepts. In the second stage, design a reconfigurability framework to fight against such modeling. In detail, evaluate the machine learning by insert noise in PUF or experiment on OPUF(one-time-PUF) which contain reconfiguration process that can alleviate modeling attack.

1.2 Overview of the Report

The remaining of the paper will organize as follow. Chapter 2 provide literature survey of the concept of PUF, including PUF's properties, detailed circuit structure and operational process, exist modeling attack with experiment results, reconfigurability framework and application in life. Relative machine learning idea will be discuss as well. Chapter 3 describe the aim and objectives for the project , gives in-depth analyzes how the project will be evaluated, the tests and experiments that support this. Chapter 4 demonstrate the current progress on the project. Chapter 5 provide brief summary on the main achievements with a well organized future plan for the project.

Chapter 2

Literature Survey

2.1 The PUF concept

The simplest sentence to describe PUF is "A PUF is an object's fingerprint" [2]. The fingerprint can represent a specific human in the world, such as the PUF can represent an object. The fingerprint is inherently created when people was born, and the so does PUF, which is inherently exist in an object according to unique manufacturing random variation [2]. With the representation and inherent property, the fingerprint and the PUF is said to be unclonable since it is impossible to control and predict human's fingerprint. This is an important concept for PUF.

This intrinsic property can be extract from chip which has PUF circuit existed inside [1]. The way PUF works is by entering a certain length of bits(so called challenge) into the PUF, and it will generate another specific length of bits(so called response). According to the property of PUF that was discuss above, it is impossible to find two different PUF that will produce the same response when entering same challenge(See Figure 2.1).

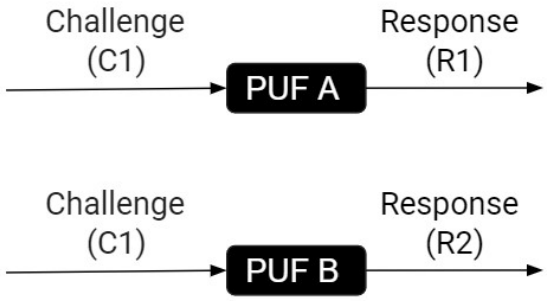

Figure 2.1: Different PUF that generate different response when input same challenge

2.2 Weak and strong PUF

PUF can be classified into two categories, weak and strong PUF according to the strength of PUF. The strength of PUF indicate the number of challenge response pairs(so called CRPs) can be generate from the PUF [3]. The higher numbers of the CRPs can a PUF generate, the better strength it has. For the weak PUF, it represent the PUF that has smaller set of CRPs. While it is impossible to create a clone of PUF, but with small set of CRPs, this will allow attacker to have physical access to all the CRPs [3]. With the knowledge of CRPs, attacker can easily response the corresponding response to challenge as like they have a clone(See Figure 2.2). The weak PUF can be use for authentication and key storage. However, since weak PUF's CRPs can be fully access, ensuring having a secure environment and whether the original PUF is being evaluating is relatively important [3].

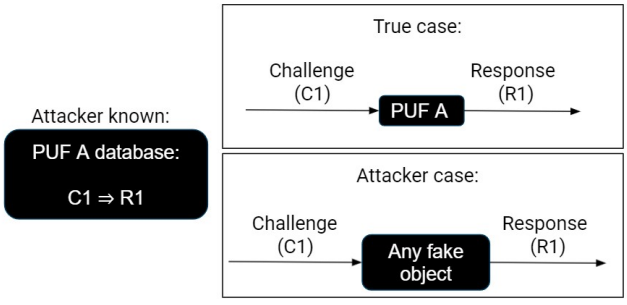

Figure 2.2: Attacker can perform same behavior as Weak PUF when have fully access to CRPs

For strong PUF, means the number of CRPs is significantly large that even attacker get access, having throughout knowledge of CRPs is impossible. While the number of CRPs is so large, and the CRP are randomly selected in usage, the probability that attacker has

knowledge about the CRP currently using is small. In addition, each CRPs that is used once will be discarded(See Figure 2.3) so even if attacker recorded certain CRPs, they will not be able to put into use. The strong PUF can also be use for authentication but do not need to protect CRPs as serious as weak PUF.

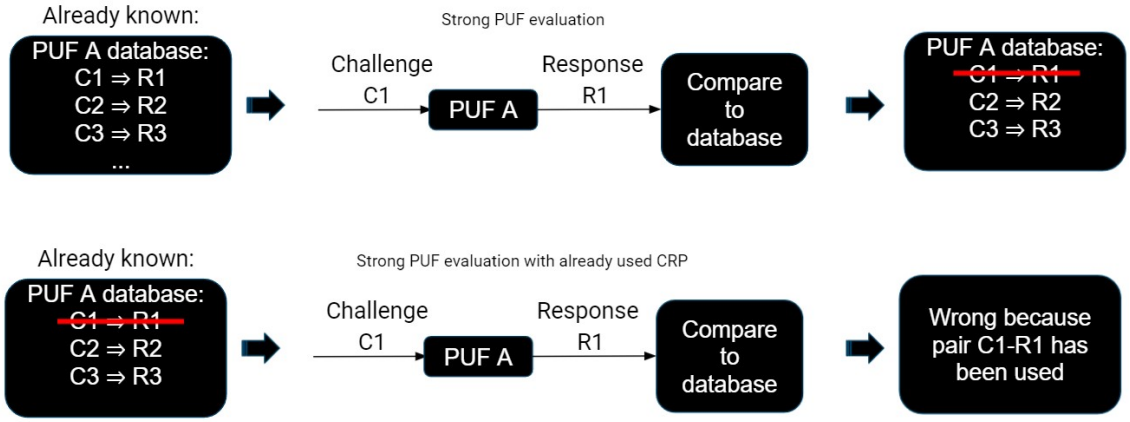

Figure 2.3: Different PUF that generate different response when input same challenge

2.3 Introduce to weak and strong then authentication stage or ...

2.4 Summary

Chapter 3

Analysis

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3.1 Project Requirements

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3.3 Ethical, Professional and Legal Issues

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Chapter 4

Planning

4.1 Risk Analysis

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4.2 Project Plan

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Chapter 5

Conclusions

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Appendices

Appendix A

An Appendix of Some Kind

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Appendix B

Another Appendix

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