Soluções em Segurança da Informação

FORTUNA – Sorte e Azar

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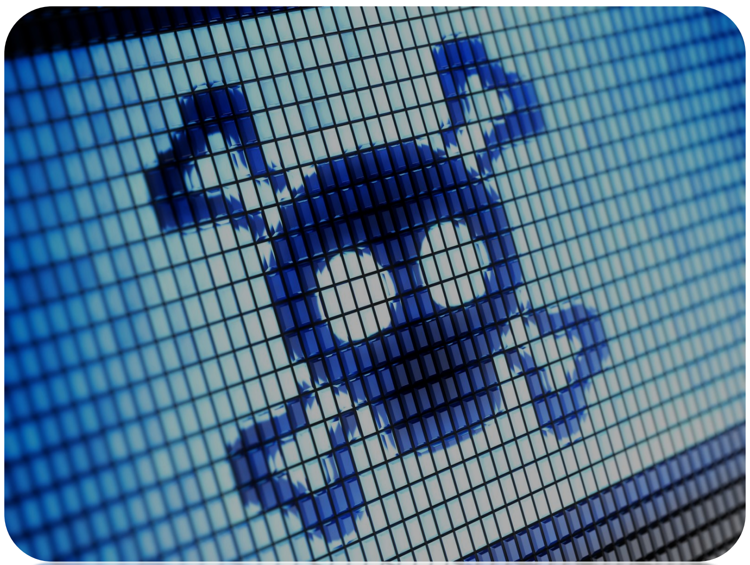
The Problem



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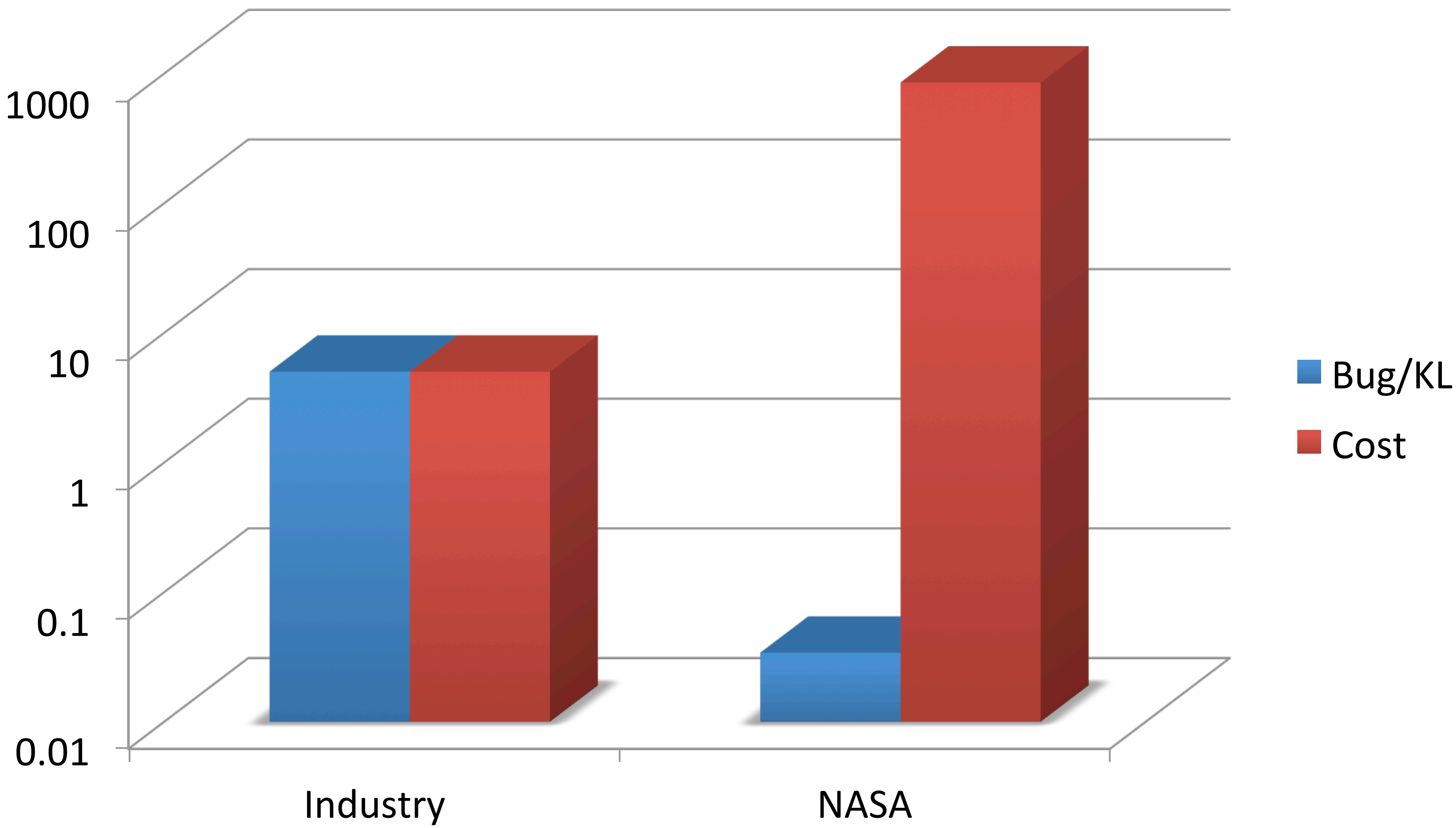
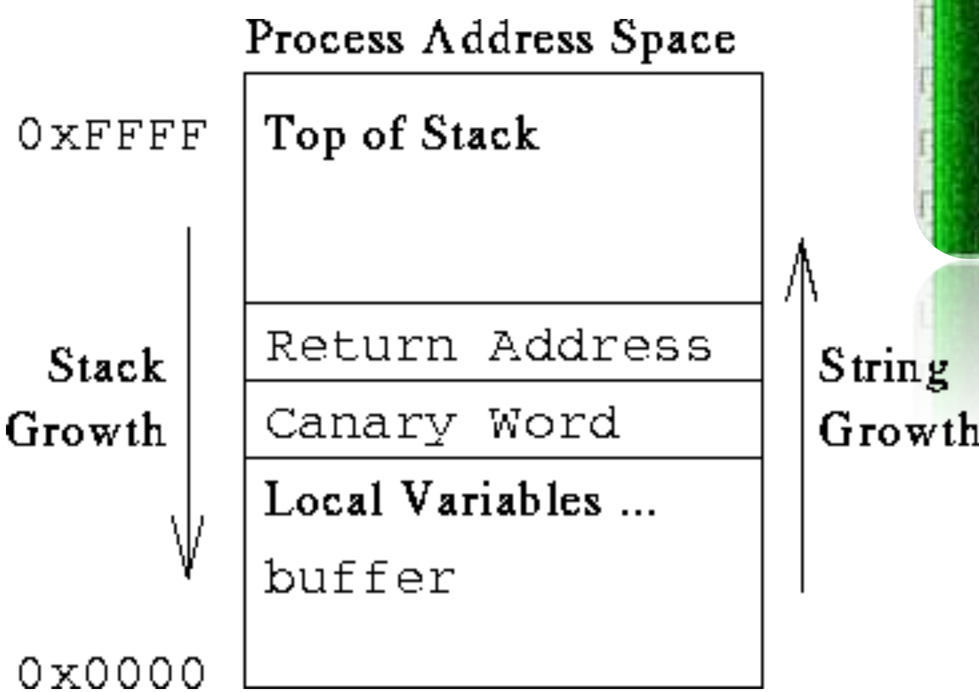
The Problem

The Problem



Attacks


Process Address Space
0xFFFF
Top of Stack
Return Address
Canary Word
Local Variables ...
buffer
0x0000
Stack Growth
String Growth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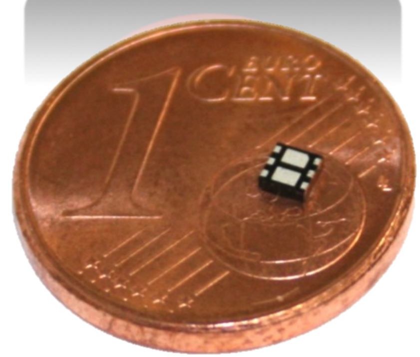
Policies

- **Least privileges**

- **TCB minimization**



- **Security in Layers**

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Agenda

- **The Audience**
- **The Problem**
- **Our Proposals**
- **Implementation Results**
- **Current and Future Work**

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The Audience

- **Generally speaking, security professionals**
- **More precisely:**
  - People managing projects (PMP)
  - People analysing system security
  - People designing secure hardware
- **Problem Importance:**
  - The DHS (NSA, DoD, NIST) Cyber Security Roadmap ranks “Trustworthy Scalable Computing - TSC” the top 1 security challenge for the next years
  - Proper TSC requires trusted computing bases – TCB (software + hardware)

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The Problem - General View

- **Importance of real HW + SW system implementations is fully established**
- **However, even when ample resources are employed, this objective is very hard to attain**
- **Symptom: “is this system secure?” vs “for how long will this system remain secure?”**
- **The stochastic nature of real system implementations must not be ignored**
- **System examples: DRM enabled devices, HSM, DRE, Token, Game Console**

The Problem – Some Reasons

- **"Performance vs features vs TTM" race gains more attention than security does, from Industry**
- **Security is a highly interdisciplinary field and requires a unified view**
- **With current systems, complexity is intractable (even logically, not to mention the physical, probabilistic and human aspects)**
  - Formal proofs for HW + SW logical interactions shown to be NP-hard or intractable
- **There is NO Unified Security Theory**

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The Problem – Some Questions

- How to design and build secure systems?
- How to measure if a given architecture is better than others, prior to deployment?
- How to quickly assess the impact of a system modification?
- How to consider the lack of knowledge about some system characteristics?
- How to succeed even when no component is 100% trusted?
- How to consider at the same time physical and logical aspects?

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Our Objective

- **Reduce** design **hassle** of secure hybrid systems
- **Handle** the growing **complexity**
- **Automate** as much as possible the security **analysis** by using the design files as input
- Allow design of **trustworthy** systems with **faulty** components
- **Prevail** even when many **unknown aspects** are present

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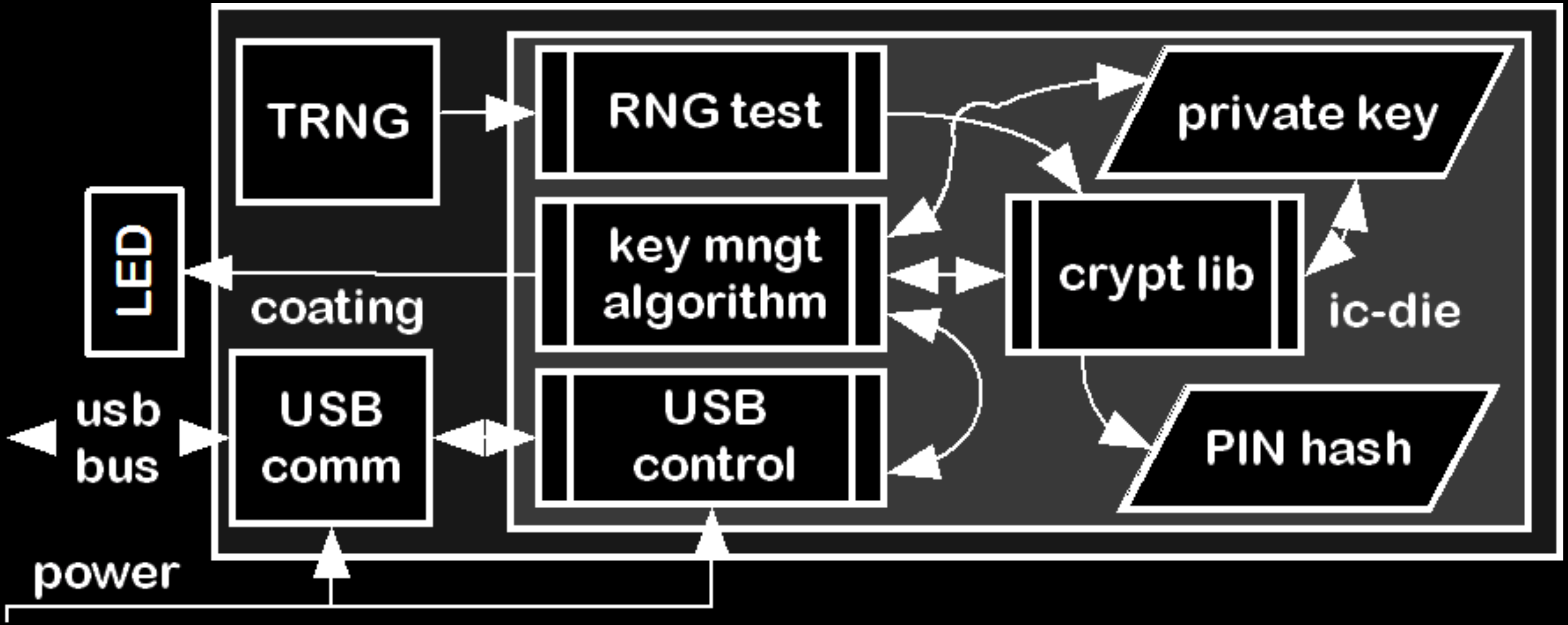
Our Contributions – Overview

- The first framework that deals with early design stages of hardware-based secure systems with broad scope
- A tool that can be applied earliest in the design cycle of secure systems
- A probabilistic model, under which some well know “golden policies” can be proven and others be challenged

System Example – Crypto Token



System Observations

1. A secure system can be composed of other systems (or components);
2. The security of systems has a probabilistic nature;
3. Individually insecure (with respect to a given policy) components can be arranged in the form of a secure system;
4. Secure components (with respect to a given policy) may be arranged into an insecure system;
5. Ultimately, all components are physical. Logical components are abstractions represented in a particular physical component configuration (or state);
6. There are no complete descriptions of non-trivial practical systems;
7. Every component has an associated cost for its deployment;
8. Certain (typically local) components are associated with adversary rewards;

Extracted Properties I

B1. Interaction channel: every subsystem that can be composed with others has one interaction channel. This interaction channel may be a logical abstraction, providing a communication channel. The channel can be directed or not.

B2. Entropic potential: represents the information assets that generate benefits for the opponent. Measured in bits.

B3. Entropic impedance (or resistance to leakage): quantifies the permeability of components and interaction channels to entropy. It is given as the probability that a given entropy amount migrates in a given timeframe from A to B trough an channel AB.

Extracted Properties II

B4. Implicit security: components with a certain set of security policies are subject to different attacks. Each attack has a different cost and a different success probability.

B5. Security provided: expresses the ability an (directional) interaction has of transporting the implicit security experienced by a component A to a component B. Together with the implicit security, it expresses the ``protection relationship''.

Models

- **Our observations and properties are used to produce models where security characteristics can be explored**
- **We present in this paper three models:**
  - Two are graph-based:
    - Model 1: Bit leakage
    - Model 2: Adversary path (not shown here)
  - One is based on Decision Theoretic Probabilistic ProLog - DTProbLog

Graph Model 1 – Bit-Leakage

- **Uses Properties B1, B2, and B3: interaction channel, entropic potential, and entropic impedance**
- **Let *D = (V, A)* be a digraph representing a related system and external agents that interact with it**
- **Each vertex *i* from V represents a system component or a principal. Each arc *ij* from *A* represents a interaction channels (B1).**
- **Let *s* be a bit of the secret (B2) which the system protects and that the adversary aims**

Graph Model 1 – Bit-Leakage II

- **Vertex *i* has probability pv_i of knowing *s***
- **By properties B1 and B3, *s* leaks from its container (say i) through the arcs *ij* with probability $pa_{i,j}$**
- **We are interested in minimizing pv_k for the vertex *k* that represents the attacker**

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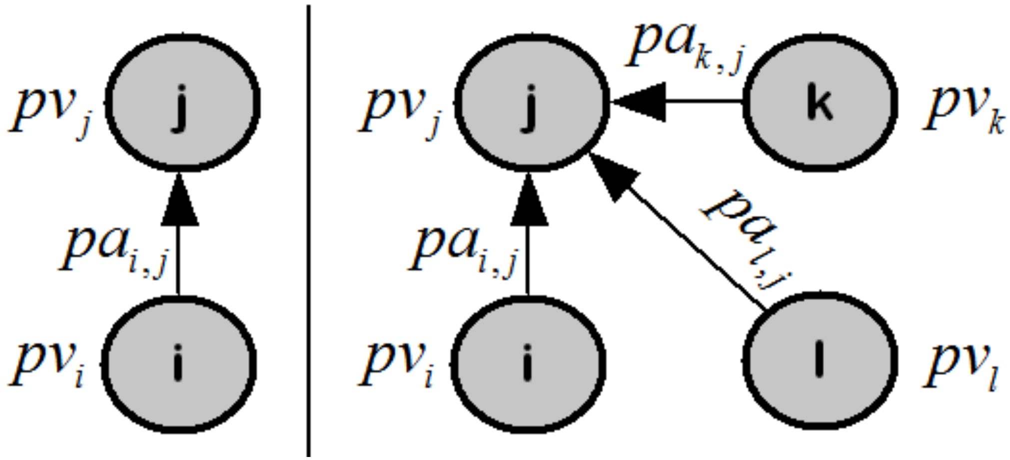
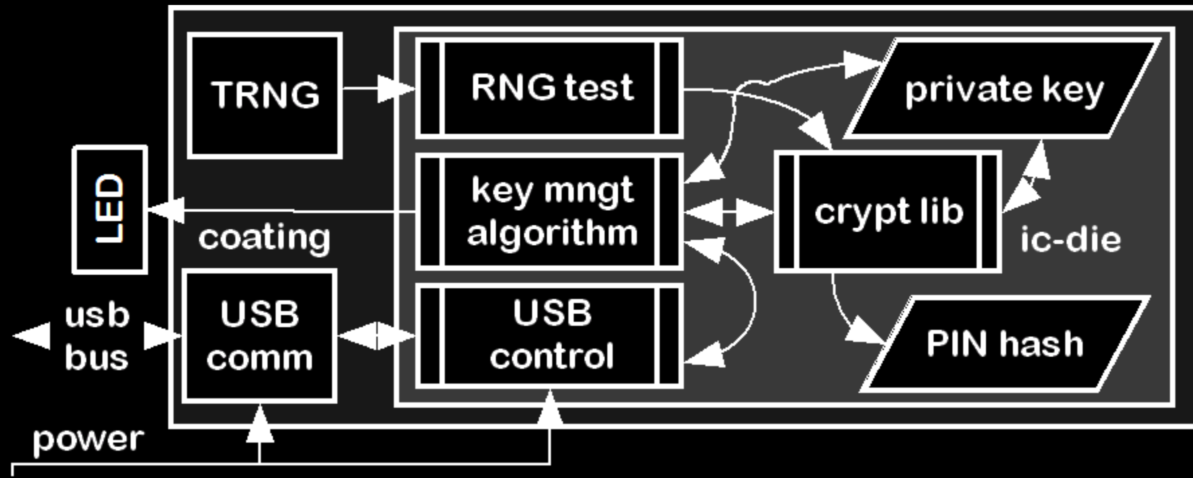


$$pv_j = pa_{i,j} \times pv_i$$

$$pv_j = 1 - \prod_{i \in N_D^-(j)} (1 - pv_i \times pa_{i,j})$$


TRNG
RNG test
private key
LED
key mngt
algorithm
crypt lib
coating
ic-die
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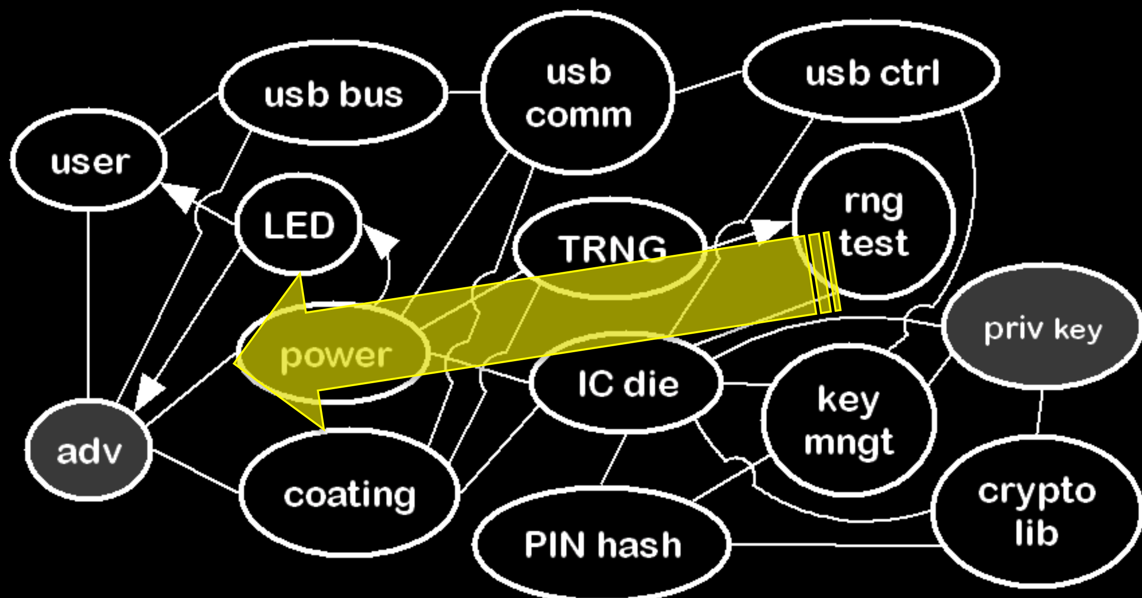
comm
USB
control
PIN hash
power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PIN hash

Graph Model 2 – Attack Path

- **Uses Properties B1, B4, and B5: implicit security, security provided**
- **Let *D = (V, A)* be a connected digraph representing part of a system.**
- **Each vertex *i* of V represents a system component that can establish relations of protection. To each vertex *i* there is a related cost e_v. Each arc *ij* of A represents protection relationships.**

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Graph Model 2 – Attack Path

- **By B4, for each arc ij of A there is a violation cost c_{ij} associated with a given probability of succesful attack pp_{ij}.**
- **The arcs incident on j can be composed in and/or form.**
- **Let C be a subset of V representing the system's CSP. To each vertex j of C is associated a gain g_j.**
- **We are interested in making the best attack plan more expensive than the expected gain for the adversary.**

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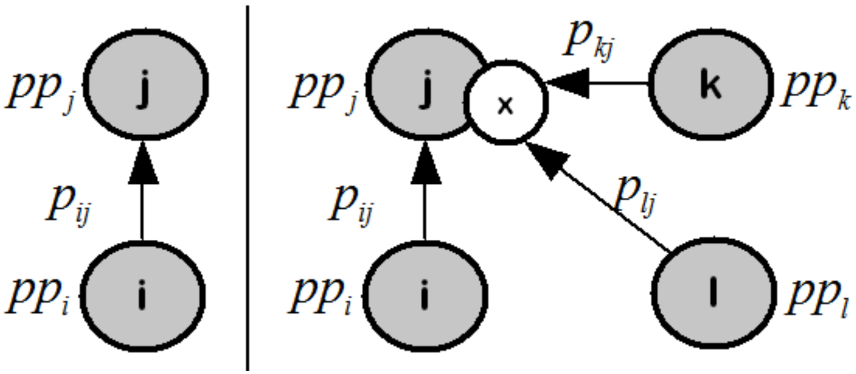
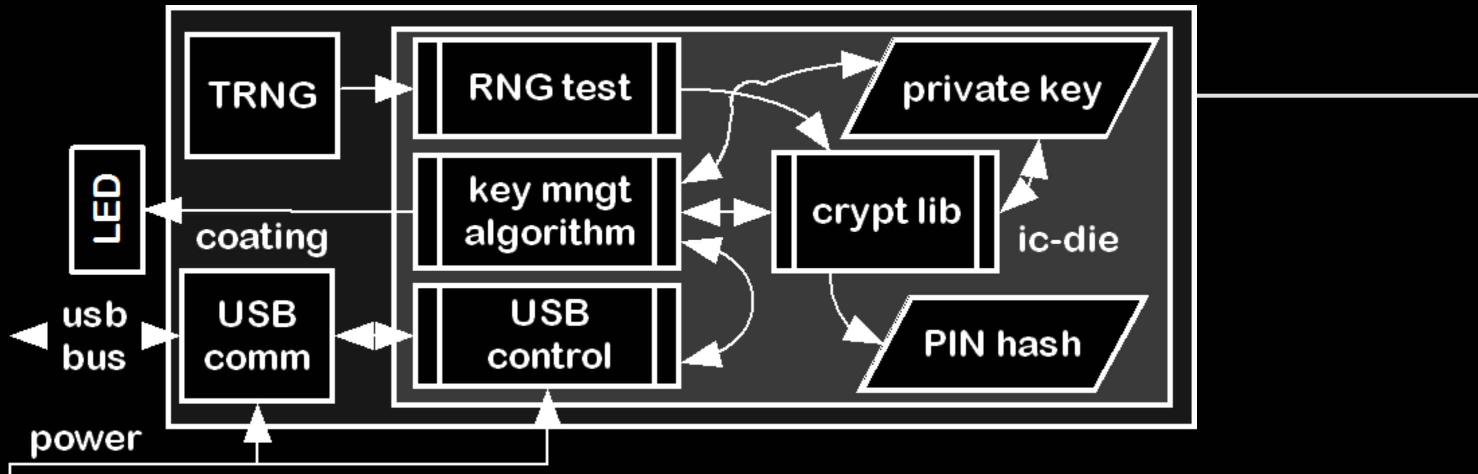


$$pp_j = 1 - \prod_{X \in N_D^-} \left(1 - \prod_{i \in X} p_{ij} \right)$$

$$e_j = e_{ij} = \frac{f(p_{ij})}{p_{ij}} + e_i$$

$$e_j = min \left(\sum_{x \in X} e_{xj}, \sum_{y \in Y} e_{yj}, ..., \sum_{z \in Z} e_{zj} \right)$$


TRNG
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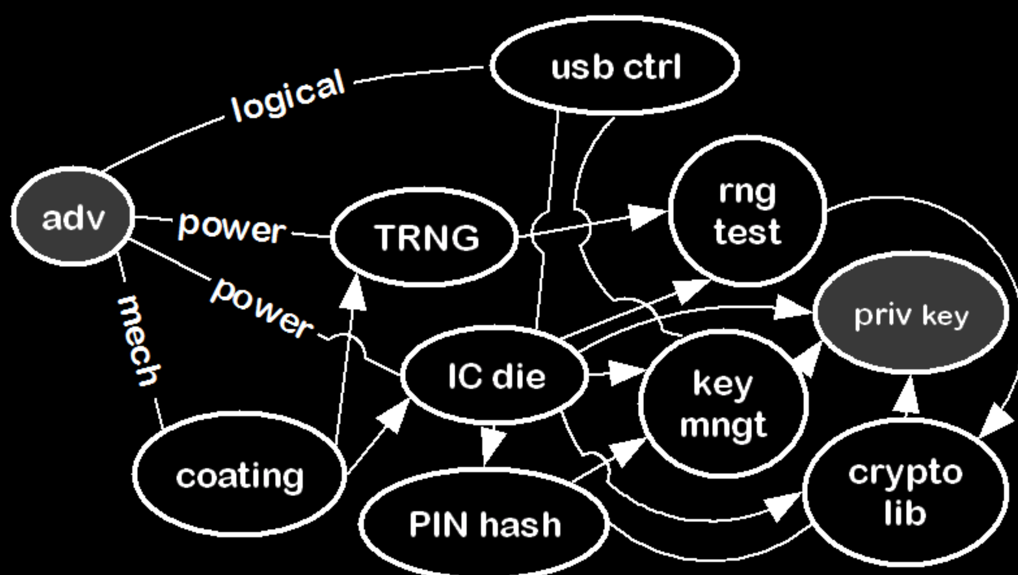
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mngt
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crypto
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PIN hash

Model Results – Policy 1

- **Policy 1: "Grant system principals the least privileges necessary to perform their jobs"**
- **Theorem 1: Policy 1 either does not affect, or it improves the overall system security regarding confidentiality CSPs**
- **Proof 1: Comes from equation for pv_j in model 1 by arc removal where *j* is the vertex that represents the adversary**

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Model Results – Policy 2

- **Policy 2:** **“Minimize the size of the Trusted Computing Base”**
- **Theorem 2:** **Policy 2 does not always hold for integrity CSPs**
- **Proof 2:** **We use model 2. It suffices to show that we can arbitrarily increase system security by increasing the size of the TCB**

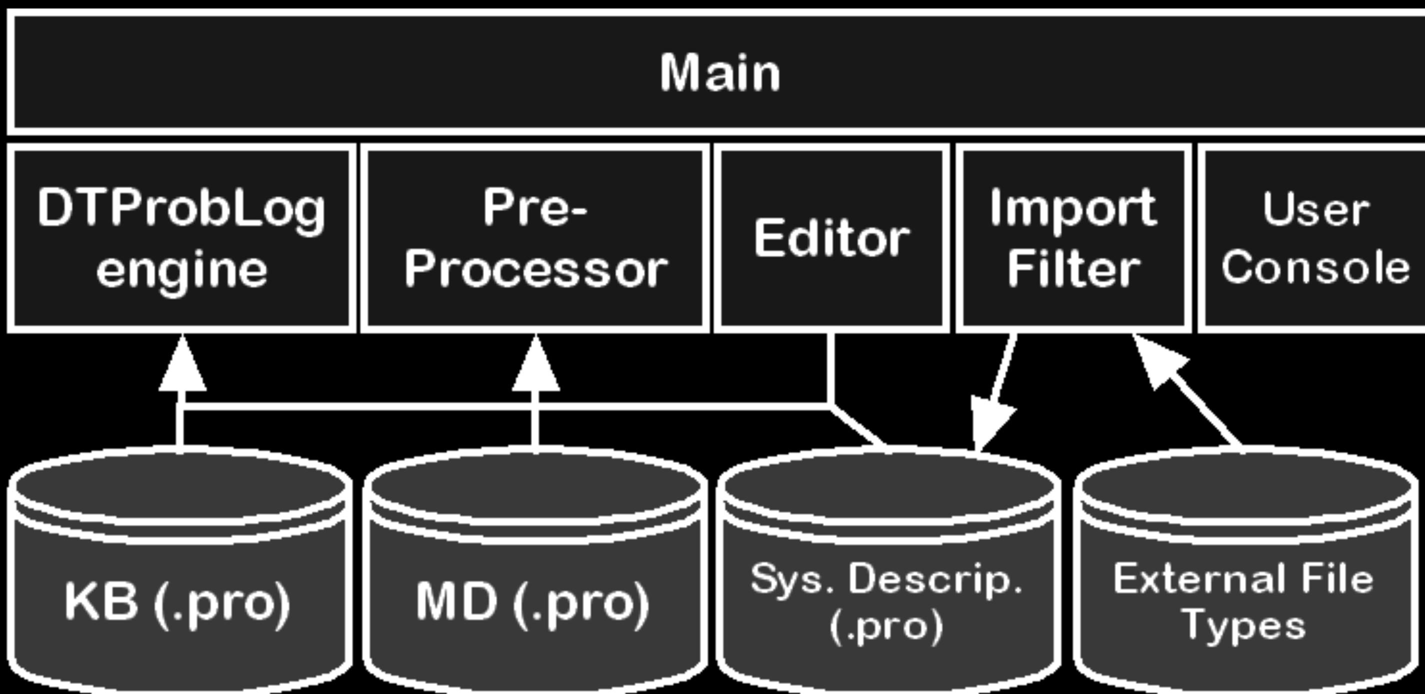
DTProbLog Model

- **Graph model limitations motivated the use of alternative models**
  - Too many annotations for richer descriptions
  - Limits representation for automation
  - Difficult to represent conditional probabilities
- **We chose Decision Theoretic Probabilistic ProLog language**
  - DTProbLog is a recent extension to ProbLog

DTProbLog – Some Features

- **Probabilistic facts and queries in KB:**
  - e.g. 0.9: protects_directed (J, I).
- **Optimization target (or decisions):**
  - e.g. ? :: attacked(C) :- component(C).
- **Utility functions (or costs and gains):**
  - e.g. break_policy(C) => - 5 :- component(C).
- **Because ProLog is expressive, it allowed us to describe all B1..B5 properties**

FORTUNA Tool Architecture



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Main Data Components

- **Model Rules (MB):**
  - Encodes variations of models 1 and 2
  - Supporting tools (e.g. traversing rules, SP calculation, cost adding…)
- **Knowledge Base (KB):**
  - Encodes best current values for costs, bug density, probabilities
  - Initially with industry's defects/kloc metric
- **System Description (SD):**
  - Contains the system description
  - Either from user input or "Import Filter"

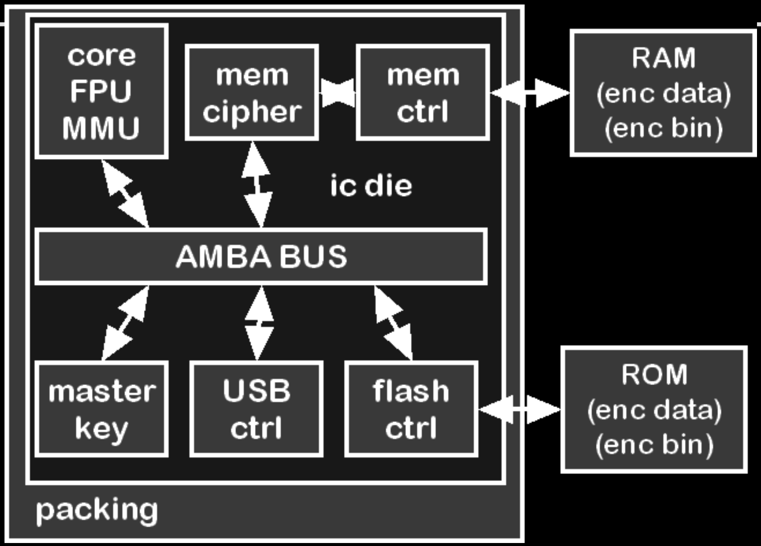
Example Query

```
?- dtproblog_solve(Strategy,ExpectedGain).
ExpectedGain = 17.12121,
Strategy = [attacked(coating),
     attacked(die),attacked(priv_key)]
```

Tool Case Usage

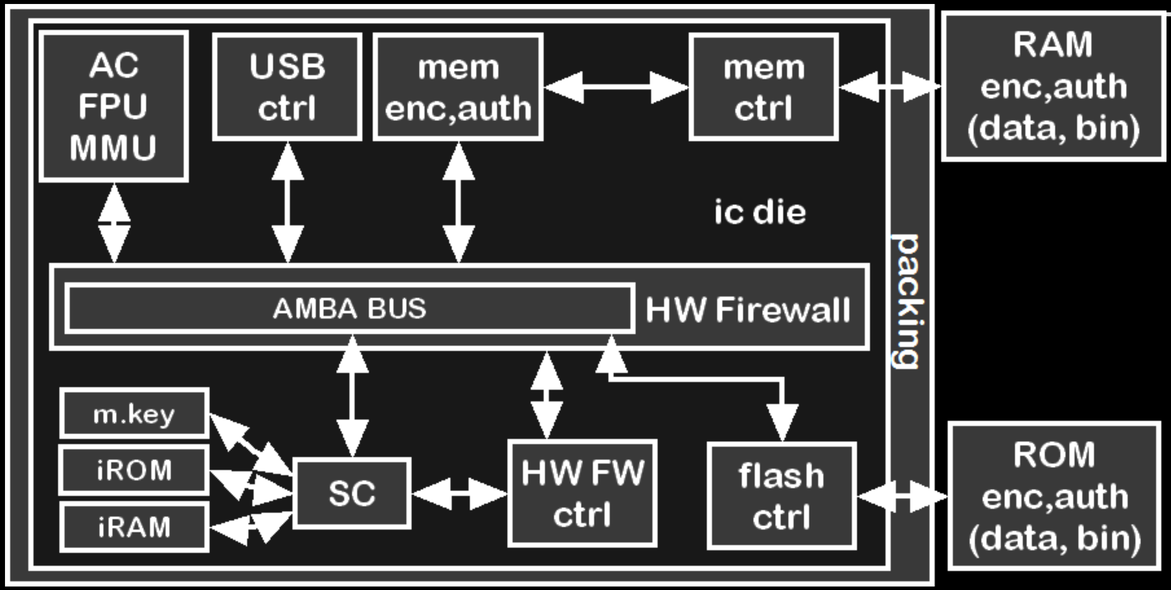
- **We successfully employed FORTUNA during the development of a Cryptographic Secure Processor (SCUP)**
- **FORTUNA allowed 4x faster security design reviews, automatic analysis and cost reduction.**
- **Tool guided important architectural improvements**

SCUP – Early Design




```
?- problog_max(path(adversary,master_key),
      Prob, Strategy).
Strategy = [attacked(usb_ctrl),
      attacked(usb_stack),
      attacked(running_bin),
      attacked(master_key)]
Prob = 0.04809
```

SCUP – Final Design



- **Evolved to a Multi-core Asymmetric Processor**
- **Motivated a second core with minimal software stack**
- **Motivated the HW Firewall**

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Conclusion

- FORTUNA brings both practical and theoretical contributions for hardware-based systems' design
- Models could be used to prove (or challenge) some golden rule heuristics
- The tool was used in the design of a Cryptographic Secure Processor, easing the development process

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Current and Future Work

- **Improve KB precision through usage data feedback**
- **Improve MD with new models from properties B1…B5**
- **Develop new CAD plugins to make the target system description even faster**
- **Adjust model's equations to directly support conditional probability (correlation)**

Thank You!

Questions?

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