Performance and Scalability of Remote Entrusting Protection

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Agenda

- Performance & Scalability
- Problem Statement
- Optimizing protection method implementation
- Security Policies for configuring the protection mechanism
- Technique of performance evaluation
- Technique of security evaluation
- Empirical study
Performance & Scalability

- Remote Entrusting Protection
  - Variety of Tamper Resistance Protection Methods embedded into the mechanism
- Performance & Scalability
- Protection mechanism implementation in practice
- Minimizing of Trusted Server side computations
- Complexity of protection methods
- Some reasonable tradeoff achieving
  - Security quality vs. Scalability
Problem Statement

General task
to find a set $S$ of protection methods that

\[
\begin{aligned}
\text{minimize } & |\sum p(m_i)| \\
\text{maximize } & \sum s(m_i) \\
\text{subject to } & \sum s(m_i) \geq \text{Const} \\
& \sum p(m_i) \leq \text{Const}
\end{aligned}
\]

Reduced to two extreme problems:

The extreme problems are solved on a basis of classical discrete knapsack problem / exhaustive search.
Performance and Security Evaluation

- Evaluation of
  - resources consumed by each protection method on the TS side
    - $p(m_i) = <p_1, p_2, ...>$ - vector-valued function giving a bundle of metrics for a method $m_i$
  - security level of each method
    - $s(m_i)$ - specific relative value characterizing strength of protection methods
- Specifying and choosing optimal combination of protection methods depending on volume of available resources
Protection methods

- RE-TRUST solutions classified as *Remote* ones
  - Barrier Slicing
  - Barrier Slicing with tamper resistant hardware
  - Continuous Replacement
  - Orthogonal Replacement
  - Secure interlocking and authenticity checking
  - Control Flow Checking
  - Invariant Checking
  - Hardware assisted invariants monitoring
  - Remote Attestation with TPM
  - Monitor that performs Checksums on a program
  - ...
Protection method analysis

- Trusted Server function to hold the protection method could contain
  - Verification procedure
  - TS side execution of the protection method
  - Replaceable SW component construction

- TS performance mainly depends on
  - Activities on TS which computation complexity grows proportionally the amount of clients
Performance of the protection mechanism

- Heightening performance of the protection mechanism
  - optimizing protection method implementation
  - optimizing configuration of the protection methods by choosing some other combination of these methods
Optimizing protection method implementation

- For each protection method to learn
  - if some activities of the method could be fulfilled *in advance* (before the client programs start)
    - The positive answer would mean the required actions on the trusted entity could be accomplished off-line (*e.g. on the deployment phase of the mechanism*). Therefore these actions will not influence essentially upon the overall performance during client running
    - E.g. methods without replacement: *BS, CFC, IC*
  - If the activities of the method could be carried out for *multiple* clients *at once* (or for some groups of them at least)
    - The positive one would mean the performance of these actions don’t depend on the client amount
    - E.g. activities that don’t depend on individual client state: *OR*, the methods without remote attestation
Security Policies for configuring the protection mechanism

- Specify policies for a case when TS can't support all the clients correctly because of a lack of available resources when the current method configuration is optimal.

- Depending on the target application character to determine risks of the program's holder:
  - loosing a legal client
    - let some group of clients to work with a reduced protection for a while
  - a malicious client managed to tamper with the program being not revealed
    - discard some clients

- Choosing these client groups:
  - according to reputation of separate clients
  - some external data, e.g. user mandates; complete/trial/demo client and other gradations, etc.
  - delegate the process of decision taking from the protection mechanism to the target application.
Protection mechanism workflow

Protection Methods

- Security Analysis Techniques
- Performance Analysis Techniques

- Choosing Protection Methods
  - Configuring TS by Security Policy enforcement
    - Off-line operations
    - Real-time operations

- Optimization of method implementation

Applying protection methods to be issued afterwards
Technique of performance evaluation (1/2)

- Modeling the protection methods
- Specifying needed performance metrics
  - Metric realizing
  - Using prepared metrics from performance measuring tools
- Simulation of protection method work
  - Simulation of the work of the server and clients and communication between them
  - Computation of metric values for various protection methods and diversity of their parameters
- Analysis of obtained results
  - Comparison of values for a variety of protection methods and/or total values for protection method combinations
Technique of performance evaluation (2/2)

- Specified performance metrics
  - **Workload** – time gap required to accomplish a single unit of the protection method
  - **Throughput** – quantity of the method copies that can be executed on the server concurrently
  - Server load **intensity** of the protection method - amount of computations fulfilled per a specifically allotted time unit

- Evaluation metrics – combined approach
  - **Theoretically** – modeling the most essential resources consuming operations executed on the TS side
  - **Empirically** – implement the model and measure required data
Technique of security evaluation

- Main difficulty of security evaluation
  - Essential disparateness and heterogeneity of the protection methods
    - Different object of protection
    - Different theoretic protection principles
  - Difficulty of construction of formal evaluation approaches
    - Method strength in many respects is determined reasoning from cognitive abilities of attackers (which may differ drastically for different potential attackers)
    - Such evaluation is very difficult to carry out in a formal way
    - We can try to determine strength of the methods by their heuristic analysis
- Security evaluation by heuristic analysis
  - Protection mechanism developer determines strength of all the methods starting from his/her own experience and intuition
- Expert judgment approach as an extension of the latter one
  - Surveying a number of security experts
  - Computation of averaged values by expert judgments processing
Empirical study – Performance evaluation

- Modeling of Control Flow Checking method
  - Implementation of the basic operations essential for performance evaluating on TS
  - A test program containing several functions of its business logic to be protected was implemented
  - Limitations – merely correctness of the sequence of beginnings and endings of the functions is checked

- Simulation of Control Flow Checking method
  - Machine A simulates the work of Trusted Server side of the protection method
  - Machine B simulates the work of a number of clients communicating with the server
  - Measuring values of specified performance metrics

- Modeling and simulation IC and BS methods
Performance evaluation – experiment results (1/2)

- Dependency between time allotted for tag checking on the TS and maximum amount of clients carrying out Control Flow Checking model.
Performance evaluation – experiment results (2/2)

- Server load intensity for Control Flow Checking model
  - Dependency between server load and client amount

![Bar chart showing dependency between server load and client amount.](chart.png)
Security Evaluation

• On a basis of expert judgments
  ▪ 9 experts within RE-TRUST community
• Survey task
  ▪ For each protection method
    ■ Giving weight (*from 1 to 5*)
    ■ Ranking all the methods
  ▪ With taking into account the method falling into categories
    ■ Methods with/without *code splitting, replacement quality, execution on server*
• Competence
  ▪ A *priori* competence determined by each expert him/herself
  ▪ A *posteriori* competence determined by a degree of consistency of the individual expert estimations with the expert group estimation
• Computation using known recursive formulas of expert judgment processing
Expert judgment based evaluation technique (1/2)

- **Drawbacks and advantages**
  - (-) it represents relatively rough solution for the evaluation of protection methods
  - (-) it can not be exploited as a proof of adequacy of the whole protection mechanism
  - (+) it can be regarded as a supplement to security evaluation methods based on formal approaches having their own drawbacks
  - (+) it enables the following scenario:

  - Revealing disagreement between the experts
  - Probably some lack of understanding of any peculiarities of the protection methods and their strength
  - Eliminate this disagreement by means of discussions
Expert judgment based evaluation technique (2/2)

• Experiment results
  - Obtained security values for the protection methods

![Security Values Diagram]

- Obfuscation
- White Box Cryptography
- Computation in Encrypted Domain
- Software Guards
- Crypto Guards
- Computing with Encrypted Data/Functions
- Continuous Replacement
- Orthogonal Replacement
- Hardware assisted invariants monitoring
- Remote Attestation with TPM
Conclusion

- As a future activities
  - Searching and construction more precise evaluation approaches for the Remote Entrusting based protection