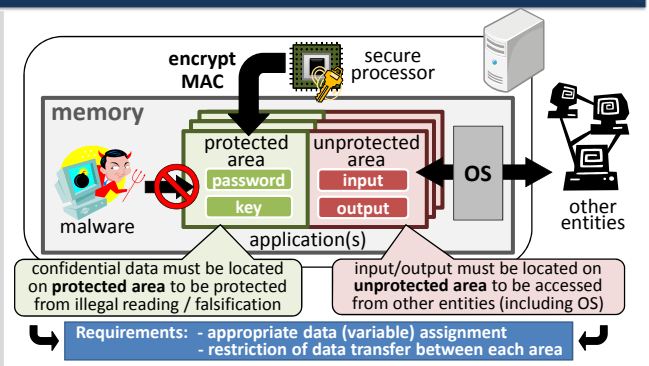
DFITS: Data Flow Isolation Technology for Security –Security Software Development Environment–

Ryotaro Hayashi, Fukutomo Nakanishi, Hiroyoshi Haruki, Yurie Fujimatsu, Mikio Hashimoto
Corporate Research & Development Center, TOSHIBA Corporation
{ryotaro.hayashi, fuk.nakanishi, hiroyoshi.haruki, yurie.fujimatsu, mikio.hashimoto}@toshiba.co.jp

Background & Motivation

- Software protection
  - Protect (the confidential data of) the software from both reading and falsifying by malicious users
  - Guarantee the correct behavior of the software
    - Operating system may be cracked or conspire with malware
- Secure processor (XOM[1], AEGIS[2], LMSP[3], etc.)
  - provides a protected memory area for confidential data, on which the confidential data of the software is encrypted and MAC is generated, and cannot be read and falsified from other entities,
  - also provides an unprotected memory area which anyone can access, since considerable amount of data, for example input and output, belonging to the software should be accessed from other entities.
- **For implementing security software (e.g. cryptographic protocol) with secure processor, the software programmer has to classify every data of the software (source code) according to protection requirement, and assigns appropriate memory area to every data.**
- Difficulty of classification and assignment
  - Specialist knowledge of security is required,
  - There exist enormous amount of data (variables)
  - **Once the confidential data is located on the unprotected area, it is hard to detect such an error!**
    - **Such vulnerabilities cannot be detected by a functional test** and it become obvious only after the confidential data on the unprotected memory is found and cracked by adversaries!!

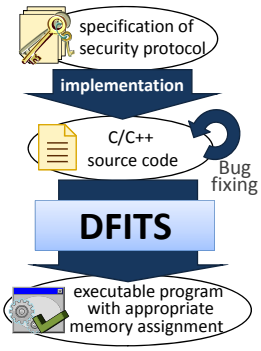


[1] D. Lie et al, Architectural support for copy and tamper resistant software. *ASPLOS-IX.* [2] G. E. Suh et al, AEGIS: Architecture for tamper-evident and tamper-resistant processing. *ICS 2003.*
[3] M. Hashimoto et al, Secure Processor Consistent with both Foreign Software Protection and User Privacy Protection. *SPW2004, LNCS 3957.*

DFITS (Data Flow Isolation Technology for Security)

1. What is DFITS?

- DFITS
  - takes as input a source code,
  - analyzes data flow of the source code **focusing on cryptographic processing**,
  - **classifies every data according to the protection requirement**,
  - generates executable program **with appropriate memory assignment.**
- By using DFITS system, we can develop security software without human error efficiently.
  - DFITS assigns data (variable) to the memory appropriately.
  - DFITS detects improper data transfer between protected and unprotected memory areas by finding protection attribute mismatch.



2. Basic data classification algorithm

(1) Protection attribute ⟶ classify data from the viewpoint of whether the data must have the **confidentiality** and the **integrity**

- Confidentiality: the data is accessible only to those authorized to have access
- Integrity: the data is consistent and correct

memory area	protection attribute	confidentiality	integrity	usage example
unprotected	exposed	✗	✗	input / output
protected	verified	✗	✓	public key
	concealed	✓	✗	unverified decrypted-message
	confidential	✓	✓	secret key

(2) Basic attribute inference algorithm
⟶ solving a constraint satisfaction problem

Constraint 1: Input/output of cryptographic functions

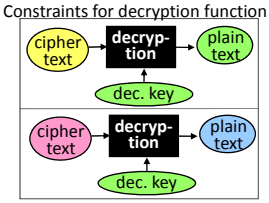
We can restrict the protection attributes of input/output for each cryptographic function.

ex.) Decryption function
- Decryption key must have confidentiality and integrity
- Plaintext must have confidentiality
- The integrity of ciphertext is the same as that of the plaintext

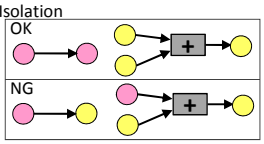
Constraint 2: Isolation

In non-cryptographic functions, all variables within each processing must have the same attribute.

Constraints for decryption function



Isolation

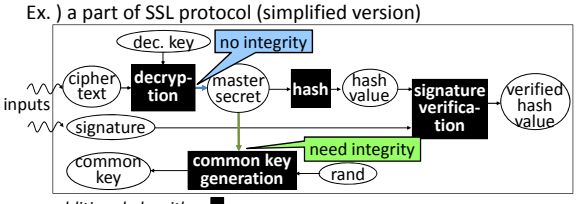


3. Additional algorithm for implicit integrity verification

- In order to analyze some existing cryptographic protocols (PGP, S/MIME, SSL, etc.), the analysis of a relation with two (or more) branch data flow is required.
- Representative case: **implicit integrity verification**
  - When the integrity of an output ***F(x)*** of the function ***F*** is verified, then the integrity of an input ***x*** is implicitly verified at the same time,
    - if, for the function ***F***, no one can find two different inputs ***x1***, ***x2*** such that ***F(x1) = F(x2)***.
- In the additional algorithm, the integrity dependency relation described above is defined for each function

⟶ Detect the variables whose integrity is implicitly verified, and modify the data flow

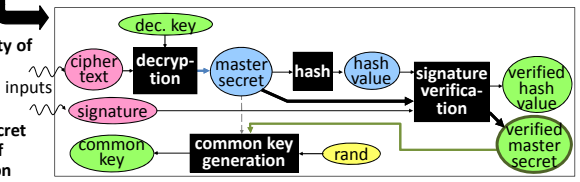
Ex.) a part of SSL protocol (simplified version)



- The basic algorithm cannot determine the attribute of master secret.
- Hash value is verified by signature verification.
- **At the same time, the integrity of master secret is implicitly verified.**

additional algorithm

- **Detect that the integrity of hash input (master secret) is implicitly verified**
- **The verified master secret can be used as input of common key generation**

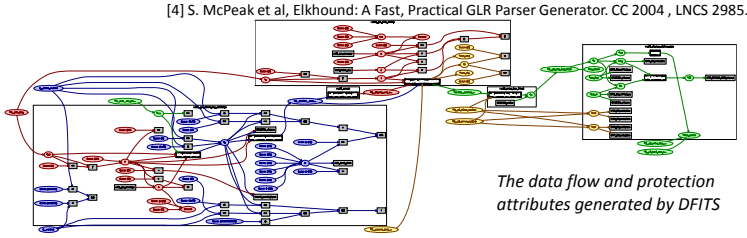


4. Prototype Implementation & Experimental Validation

- Prototype implementation of DFITS
  - Syntax analysis library Elsa[4] for syntactic analysis
  - Class templates of C++ with suitable memory allocators
- Apply our prototype to a part of source code of OpenSSL
  - Remove the reuse of variables
  - Adaptation of source code to our prototype

⟶ DFITS system appropriately outputs the protection attributes of at least 108 variables in the target source code.

[4] S. McPeak et al, Elkhound: A Fast, Practical GLR Parser Generator. CC 2004 , LNCS 2985.



The data flow and protection attributes generated by DFITS

Future and Related Works

- Improve DFITS in aspects of both theory (the classification algorithm) and implementation for applying DFITS system to much more cryptographic protocols.
- Comparison between DFITS and standard information flow analysis (IFA) [5]

	DFITS	standard IFA
attacker model	read and falsify internal and temporary variables of the system on unprotected memory	obtain pairs of arbitrary input and the output of the system, and observe their relations
scope of analysis	confidentiality and integrity are considered from the viewpoint of *whether proper cryptographic operation is applied to each data* Ex.) It is judged to be *secure* to publish a signature signed with a secret key, *only when* the message to be signed has the integrity and the secret key has both the confidentiality and the integrity.	rigorous consideration to confidentiality using the non-interference property, which prevents *any* flow of confidential data to public data Ex.) It is judged to be *insecure* to publish a signature signed with a secret key.

[5] D. Volpano et al, A Sound Type System for Secure Flow Analysis. J. of Comp. Sec. 4, 2-3.