Verifying Computation in Sequestered Encryption

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Introduction

- **Sequestered Encryption (SE)** is a hardware technology that **supports secure computation** on private data.
  - Unlike trusted execution environments (TEEs), **SE computation is not visible to software.**
- SE uses **two key mechanisms** to achieve its goals:
  - **Encrypted computation**: hides the content of private data from software.
  - **Data oblivious programming**: eliminates data-dependent control flow and memory accesses.

Challenges

SE does not guarantee correct computation.

- Server can intentionally rearrange secret computation.
- Hardware errors may occur during computation.

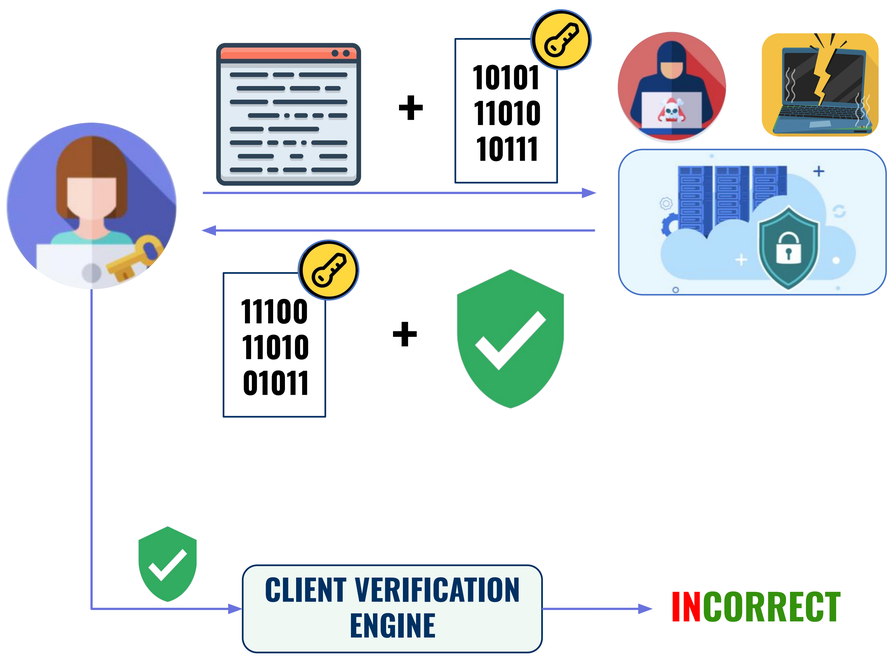
Contribution

It is **important to think about how a client can check if a computation is done correctly**. Since undesired changes to computation **cannot be readily detected**, we extend SE to verify the correctness of computation.

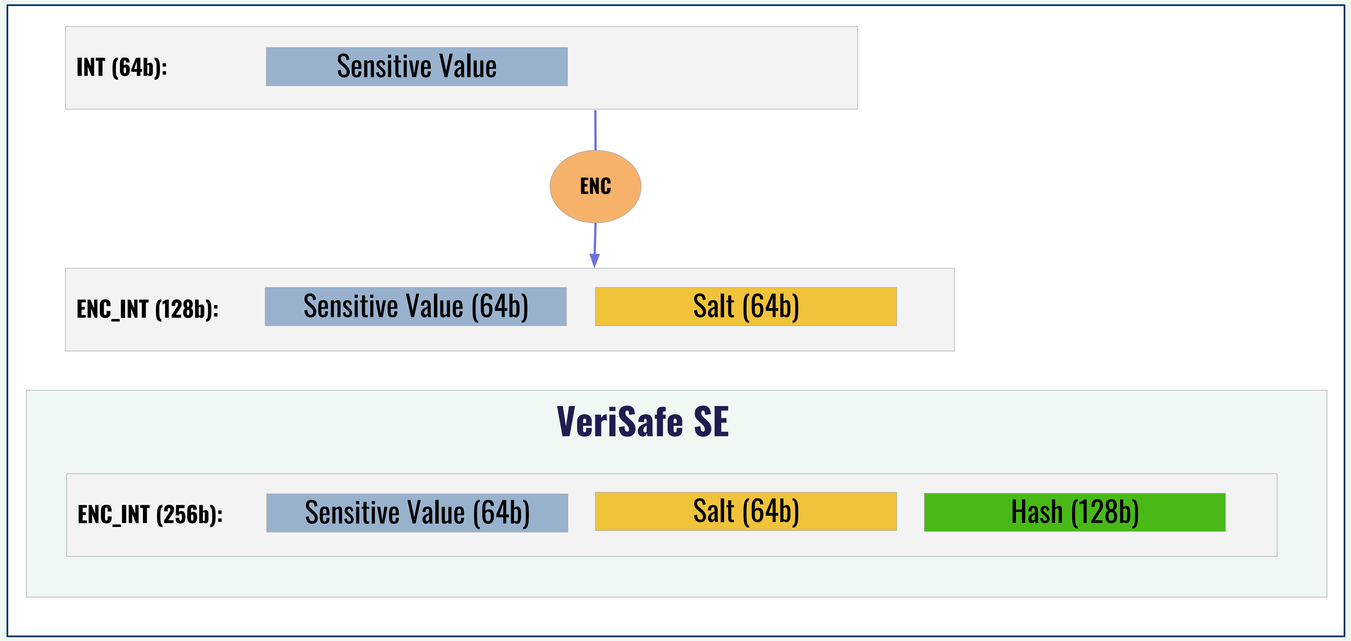
Summary

- **Integrity is an important security property not addressed by SE.**
- This work extends SE to **verify computation by adding metadata to encrypted types**.
- Breaking this mechanism **requires a preimage attack** on a cryptographic hash.

Usage Model



Encrypted Data Type Layout in SE



An Abstraction of Verification in SE

some_program.c

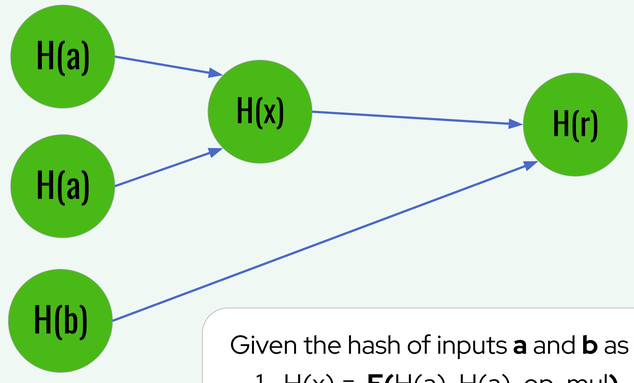
```
ENC_INT square_add(ENC_INT a, ENC_INT b)
{
   ENC_INT result = a * a + b;
   return result;
}

int main(){

   ENC_INT a = 5, b = 6;
   ENC_INT r = square_add( a, b);

   return 0;
}
```

Dataflow Graph



Given the hash of inputs **a** and **b** as **H(a)** and **H(b)**:

1. H(x) = **F(**H(a), H(a), op_mul**)**
2. H(r) = **F(**H(x), H(b), op_add**)**

Conclusion and Future Work

- We **utilize the unchanging data flow graph of programs,** which stems from data oblivious programming used in SE.
- Once the data flow graph of a program is generated, **a hash associated with the data can be passed through the graph using a combining function.**
- **This ongoing work seeks to find ways of simplifying the cost of client-side verification.**

Combining Function (F)

- It **captures any changes in register/memory communication** between instructions.
- It captures **any changes in individual instructions**.
- Given an instruction with inputs, it must be difficult to map the hashes of the input to hash of the instruction's output to ensure strong integrity.