PTAuth: Temporal Memory Safety via Robust Points-to Authentication

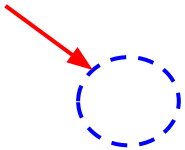
Reza Mirzazade Farkhani Mansour Ahmadi Long Lu

Northeastern University
Khoury College of Computer Sciences

NEU SecLab

iseclab

Motivation



Temporal memory errors remain to be the most commonly exploited software vulnerabilities.

State-of-the-art approaches rely on a huge amount of metadata which leads to high memory overhead.

The metadata is left unprotected.

Motivation

Dynamically detect temporal memory corruptions in the heap

Research questions:

1. Can we design a system with low-memory overhead and reasonable run-time overhead?
2. Can we guarantee the integrity of metadata without relying on other approaches?

System Design

PTAuth checks upon each pointer dereference :

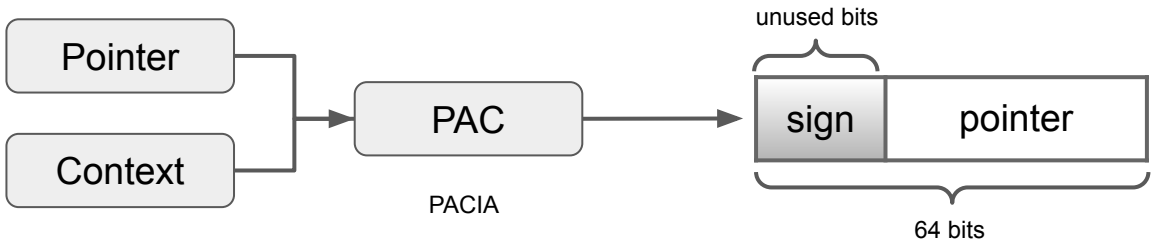
1. Whether the pointer is pointing to the original or intended object
2. Whether the metadata or evidence proving the points-to relationship is genuine

System Design

PTAuth checks upon each pointer dereference :

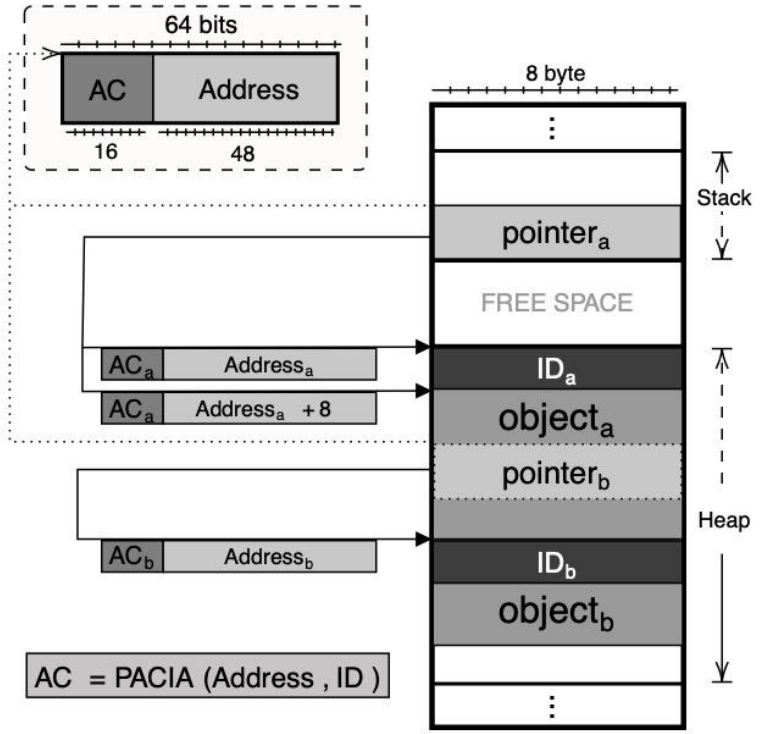
1. Whether the pointer is pointing to the original or intended object
2. Whether the metadata or evidence proving the points-to relationship is genuine (how?)

Pointer Authentication Code (PAC)



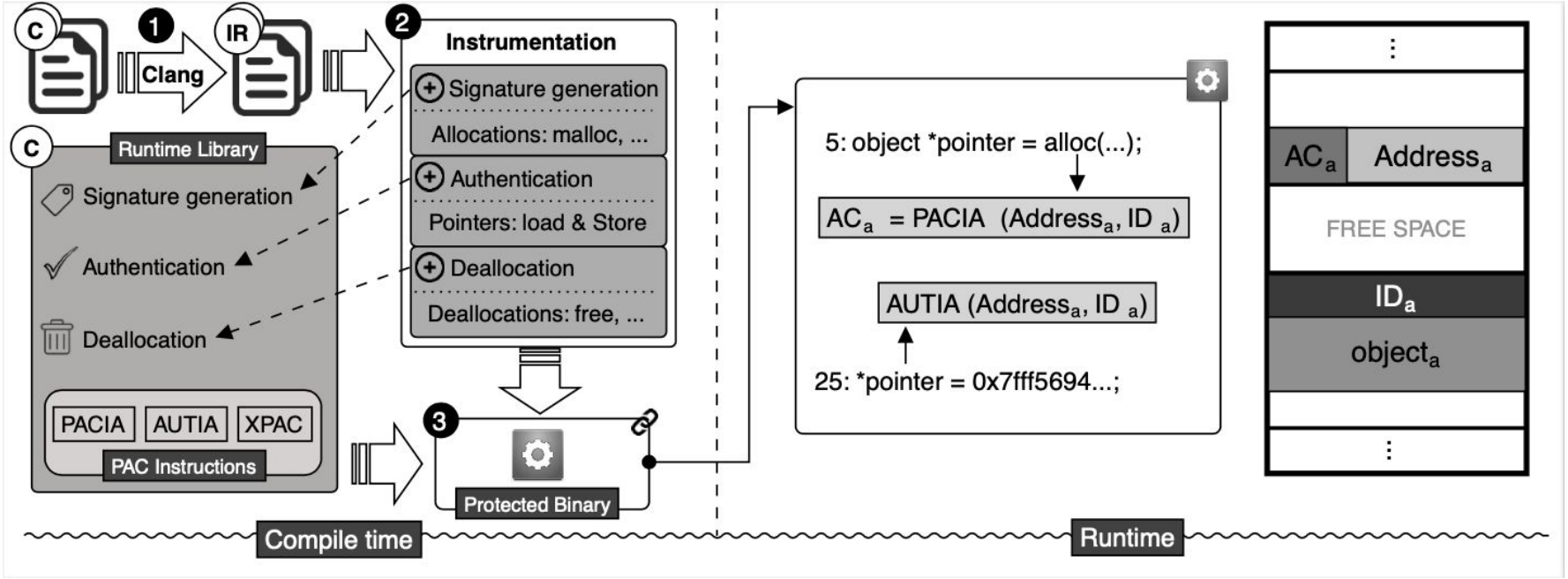
Pointers & Objects

```
ID = RandomID() // 64 -bit

AC = PACIA < BasePointer > < ID >
```



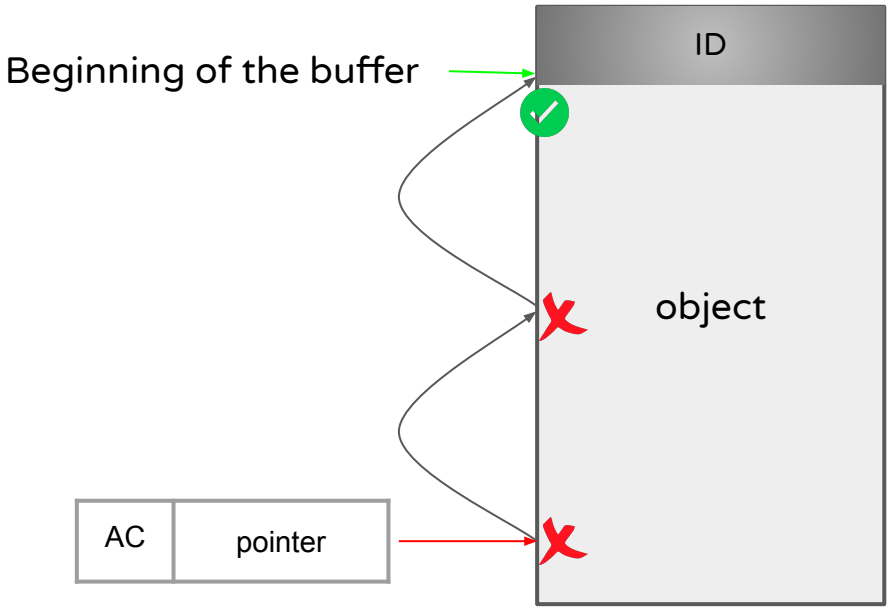
AC = Authentication Code

System Overview



Backward Search

What if the pointer does not point to the beginning of the buffer?



objects are aligned to 16 byte

Optimization

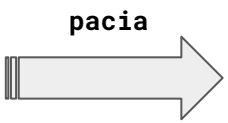
```
void quantum_gate2(quantum_reg * reg) {
    int i, j, k, iset;
    int addsize = 0, decsize = 0;
    if (reg->num > reg->max)
      printf("maximum", reg->num);
    else {
      for (i = 0; i < (1 << reg->hashw); i++)
        reg -> hash[i] = 0;
      for (i = 0; i < reg->size; i++)
        quantum_add_hash(reg->node[i].state, i, reg);
      ...
}
```

The **reg** the pointer is authenticated before passing to the **quantum_gate2** function, no check on it is needed until the pointer is passed to another function as an argument.

Software Implementation of PAC Instructions

```
#if PACENABLED

asm(

  "mov %:

  : "r"(ptr));

asm(

  "pacia %

   : "=r"(ptr)

   : "r"(id));

#else

ptr = __pacia(ptr, id);

#endif
```

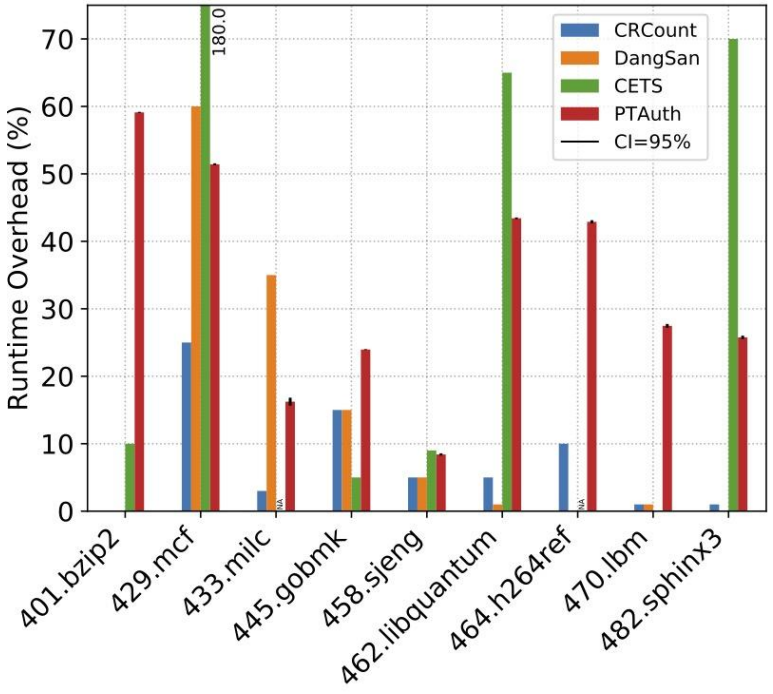
FVP simulator



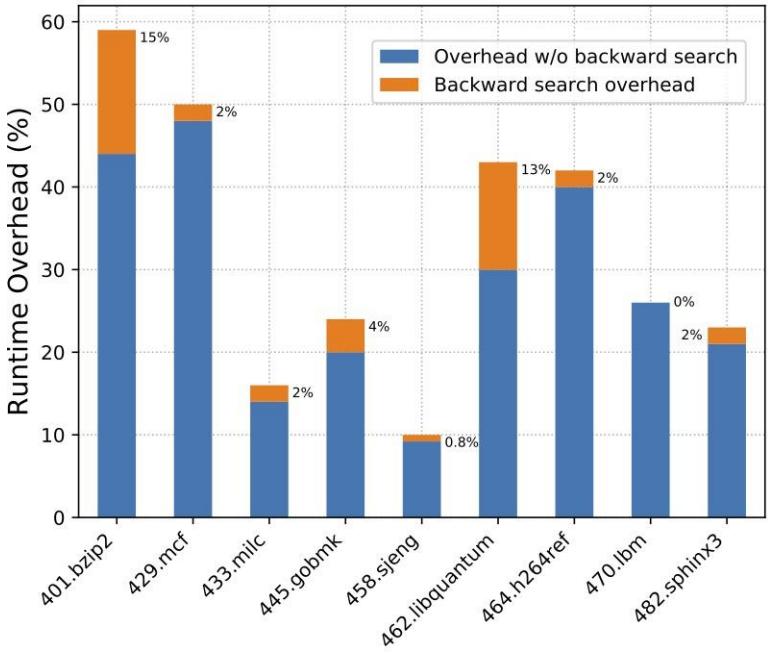

```
long MASKBITS = 0 b000...000111111111111111;

void * __pacia(void * ptr, long id) {

      long ptrbits = (unsigned long) ptr &
MASKBITS;

      long idbits = id & MASKBITS;

      long signature = ptrbits ^ idbits;

      signature = signature << 48;

      unsigned long ptrWithSign = (unsigned long)
ptr | signature;

      return (void * ) ptrWithSign;

}
```

Pi 4

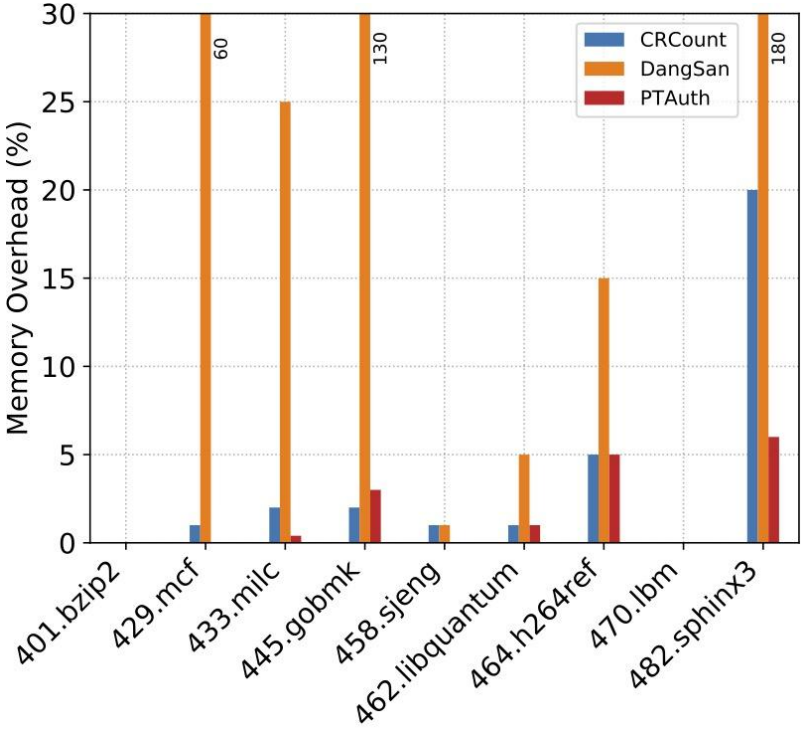
Runtime Overhead



26% overhead



Memory Overhead



2% overhead

Conclusion

- We provide a resilient and efficient **points-to authentication** scheme for detecting temporal memory corruptions.
- PTAuth repurposed **PAC** on ARMv8.3-A to detect temporal memory corruption.
- PTAuth provides metadata integrity for objects and pointers.

Thanks! Questions?

Reza Mirzazade Farkhani

mirzazadefarkhani.r@northeastern.edu