PARTS: Towards pointer integrity using ARM pointer authentication

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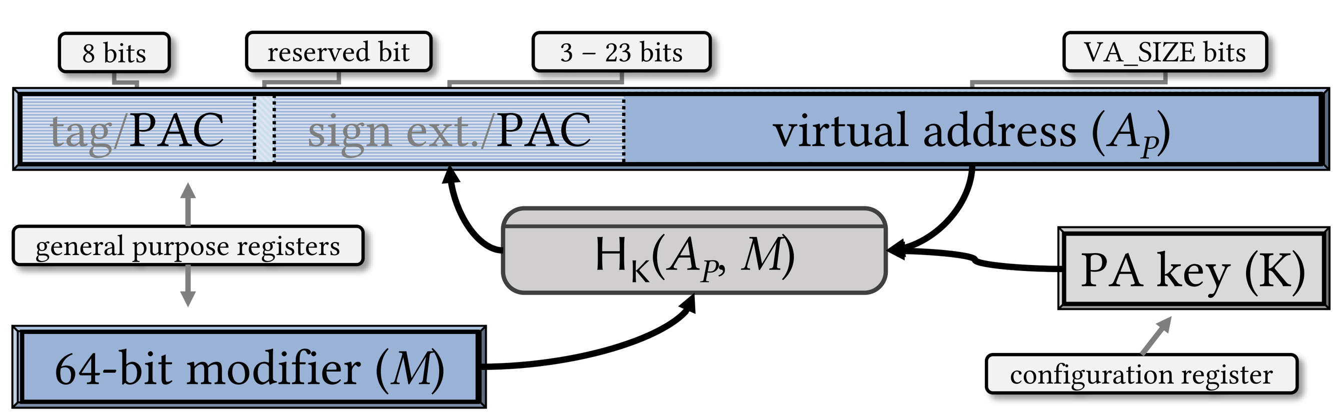
https://github.com/pointer-authentication

PARTS, Pointer Authentication for Run-time Type Safety

- Approximates *pointer integrity* using ARMv8.3-A pointer authentication
- Protects *return addresses*, *code pointers*, and *data pointers*
- Prevents pointer reuse attacks by enforcing run-time type safety

ARMv8.3-A Pointer Authentication

- Embeds and verifies embedded Pointer Verification Codes (PACs):
  - Embedded in unused bits of a pointer
  - Keyed, tweakable MAC based on address and given modifier
- User-space support in Linux 5.0 with kernel-managed keys
- Used via new PA-specific `pac` and `aut` instructions

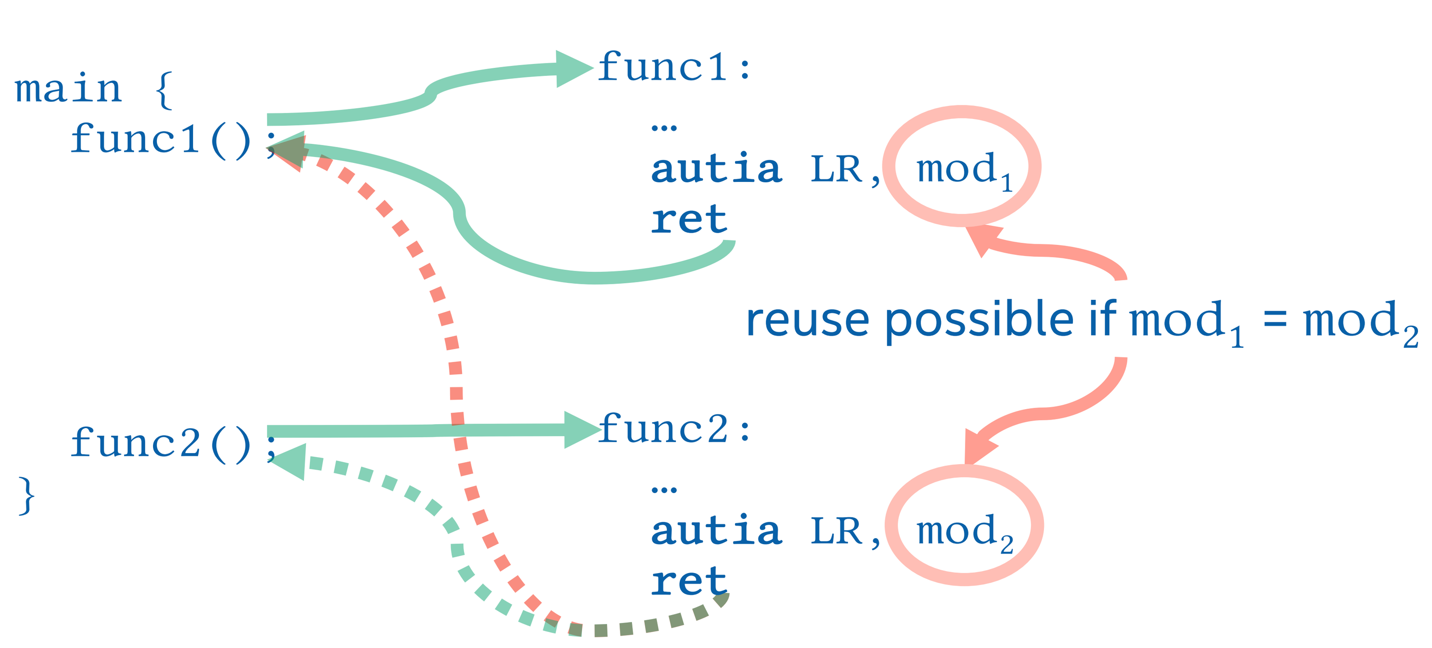


Structure of an authenticated pointer

- Modifier can be used to define *context* for pointer

Pointer reuse

- Vulnerable to pointer reuse when modifiers coincide!
  e.g., stack pointer as modifier in GCC / LLLVM –msign-return-address



Challenge: to prevent modifier must be sufficiently unique to value and:

- **Secure:** Cannot be stored in memory, hence cannot be random
  e.g., if securely stored, then why not just store pointer itself?
- **Available:** Known at both creation and use of pointer
  e.g., these could be spatially and temporally disjoint events
- **Location independent:** Storage location cannot be tied to mod
  e.g., must allow `memcpy` and embedding in other data structures

PACing it up with PARTS

- Uses run-time type safety to generate modifiers:
  - Secure modifiers created based on *read-only code section*
  - *Pointer type known* both at creation and use
  - Modifier *not affected by memory copy*
- LLVM 6.0 based implementation + Linux RFC patches for PA

Return address protection `pacib(ret, funcID‖SP)`

- Unique function specific identifiers generated at compile-time
- Different function activations distinguished using stack pointer

Code pointer protection `pacia(ptr, type)`

- Modifier from pointer type (`LLVMElementType`)
- Pointers signed on creation and verified on use

Data pointer protection `pacda(ret, type)`

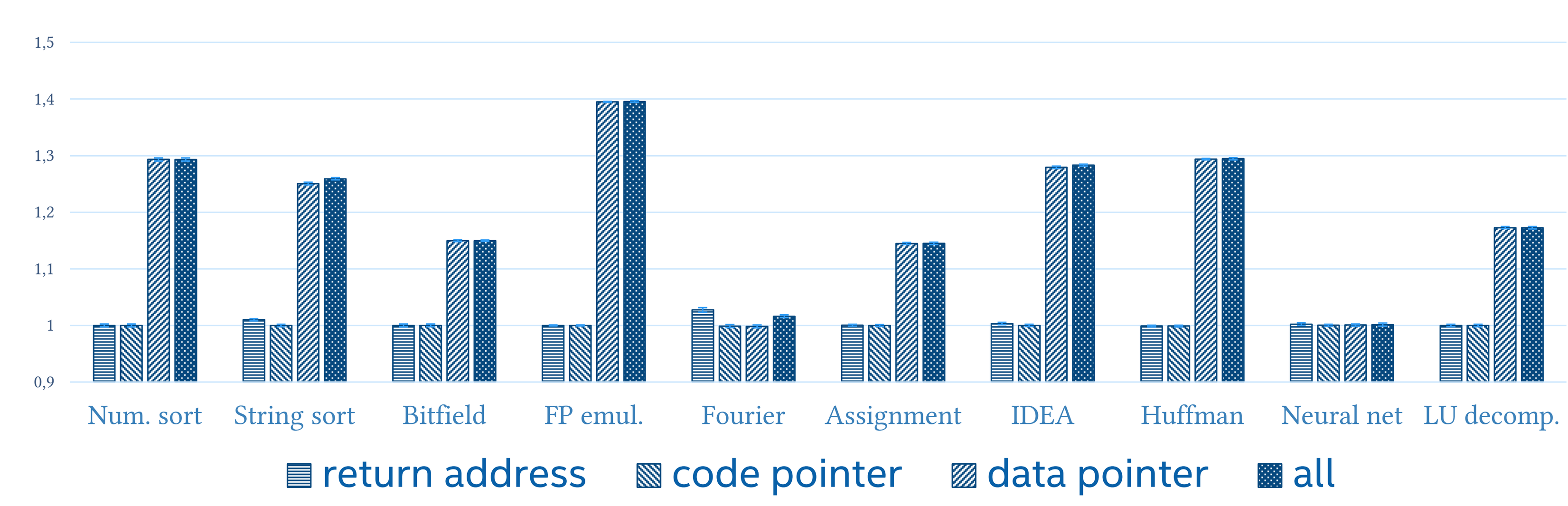
- Modifier from pointer type (`LLVMElementType`)
- Pointers signed on memory write and verified on memory load
  - Allows efficient register use

Implementation challenges

- LLVM backend looses high-level semantics, including pointer type
  - Solution: define new *intrinsics* for `pac` / `aut` operations
- Register spilling looses retains no semantics
  - Solution: must analyze spills to protect data-pointer spills
- Interoperability with non-instrumented libraries
  - Verify and sign pointers to / from non-instrumented code

PARTS performance evaluation

- Based on estimated overhead of 4-cycles per PA instruction



- Return address and code pointer protection **0.5%** overhead (geo.mean)
- Full protection, including data pointers, **19.5%** overhead (geo.mean)

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