Fast and Generic Metadata Management with Mid-Fat Pointers

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Cristiano Giuffrida Herbert Bos
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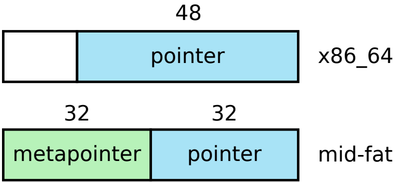
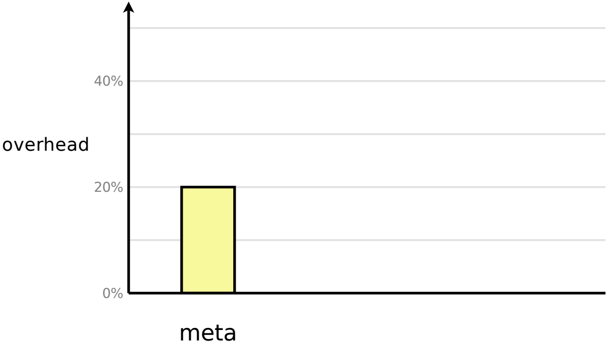
Summary



- Cache metapointer in upper bits
- Reduce metadata lookup cost
- 45% ⇒ 20% overhead on load+store lookups

Motivation



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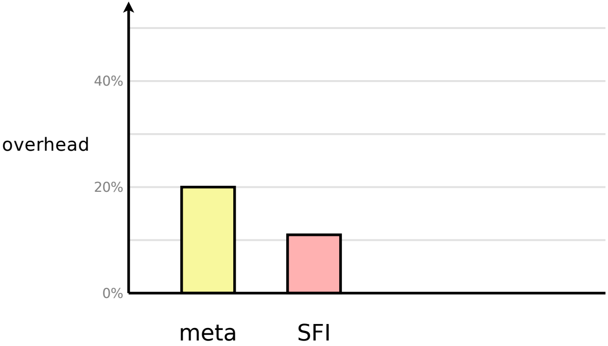

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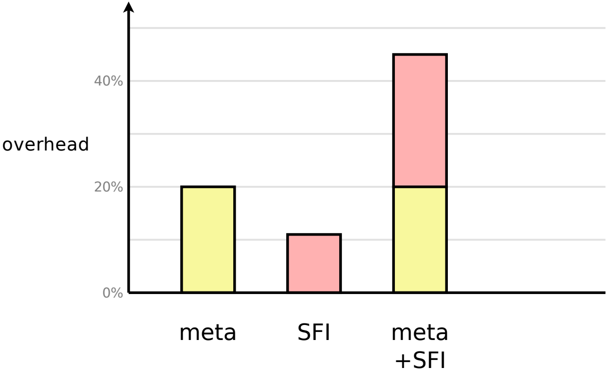

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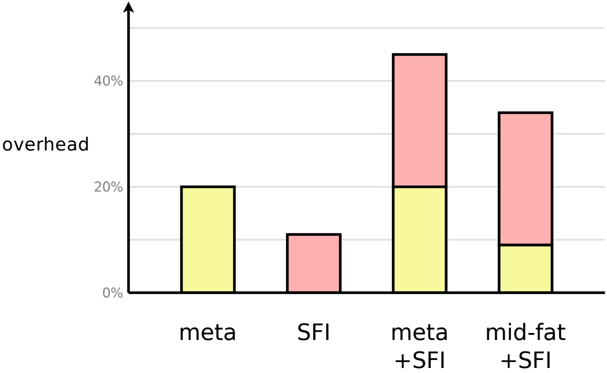

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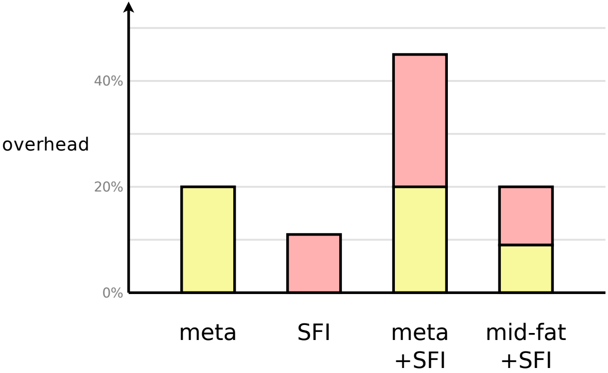

Per-object metadata

- Basis for memory safety defenses
- Associate metadata to each allocated object
- Look up metadata when pointer is used
  - Bounds checking
  - Type confusion detection
  - Use-after-free detection
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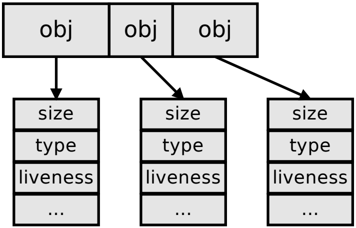

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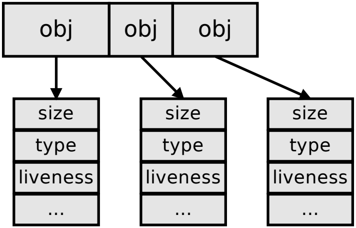

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Software Fault Isolation (SFI)

- Protect sensitive program data
- E.g., metadata

- Mask dereferenced pointer

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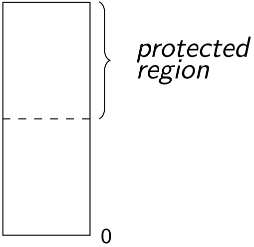

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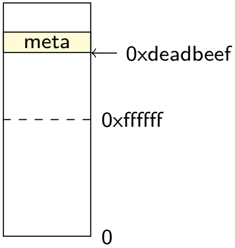

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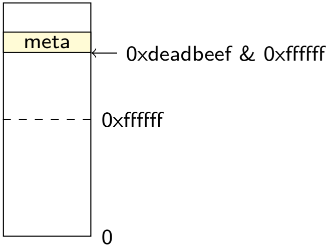

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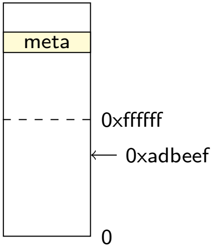

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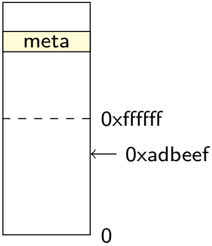

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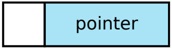
Tagged pointers

Regular pointer



- 48-bit address space

Fat pointers

- increase pointer size
- Generic, but slow and incompatible

Low-fat pointers

- Small metadata tag in pointer
- Modify memory layout
- Fast and compatible, but not generic

Our approach: *Mid-fat pointers*

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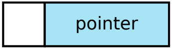

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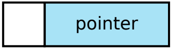

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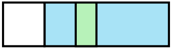

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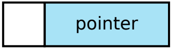

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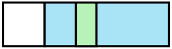

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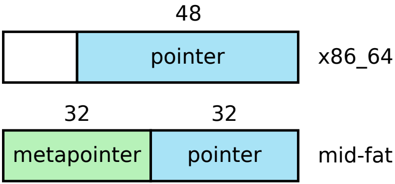

- Cache metapointer in unused pointer bits
  - Reduce address space
- Fast and generic, but still compatible
- For SFI-backed defenses

Compatibility

- Libraries
  - Cannot dereference tagged pointer
  - Need to mask at callsites

```
strdup(ptr)
⇓
strdup(MASK(ptr))
```

- Pointer comparisons

```
p1 == p2
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MASK(p1) == MASK(p2)
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- Unions

```
union {
  char buf[8];
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- Pointers from memory

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uint64_t *p;
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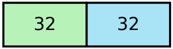
Implementation

- Track metadata for C/C++ heap
- 32-bit address space 

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- METAlloc for metadata management
- Shrink address space from user space

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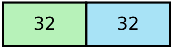
- 32-bit address space 

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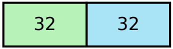
- 32-bit address space 

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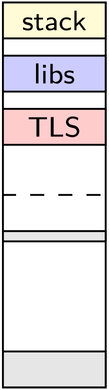
Shrinking the address space

1. Prelink shared libraries
2. Move stack and TLS
3. Reserve upper virtual memory area



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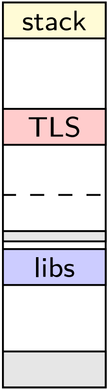

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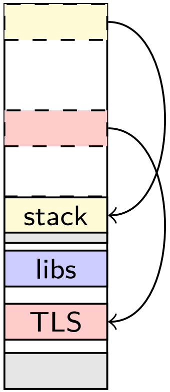

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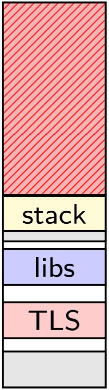
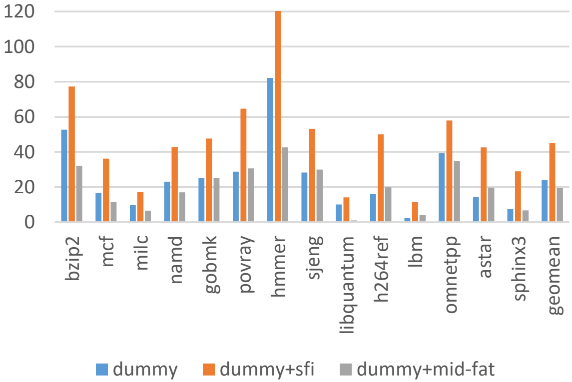


Experiment

- Representative “dummy” defense
- Expected overhead between METAlloc and METAlloc+SFI

Runtime overhead



Limitations

- Only 4GB memory
- Reduces entropy for ASLR
- Conflicts with custom pointer tagging
- Implementation does not protect metadata memory

Conclusion

- We piggy-back on SFI to cache metapointers as pointer tags
- Performance is practical
    - Can even reduce overhead!
- Source will be at `https://github.com/vusec/midfat`

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