Pointless Tainting?

Evaluating the Practicality of Pointer Tainting

Asia Slowinska, Herbert Bos
Vrije Universiteit Amsterdam

Why pointer tainting?

- Attacks

  Exploit low-level memory errors

  - Buffer overflows
  - Dangling pointers
  - Format strings

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- Keyloggers, etc.

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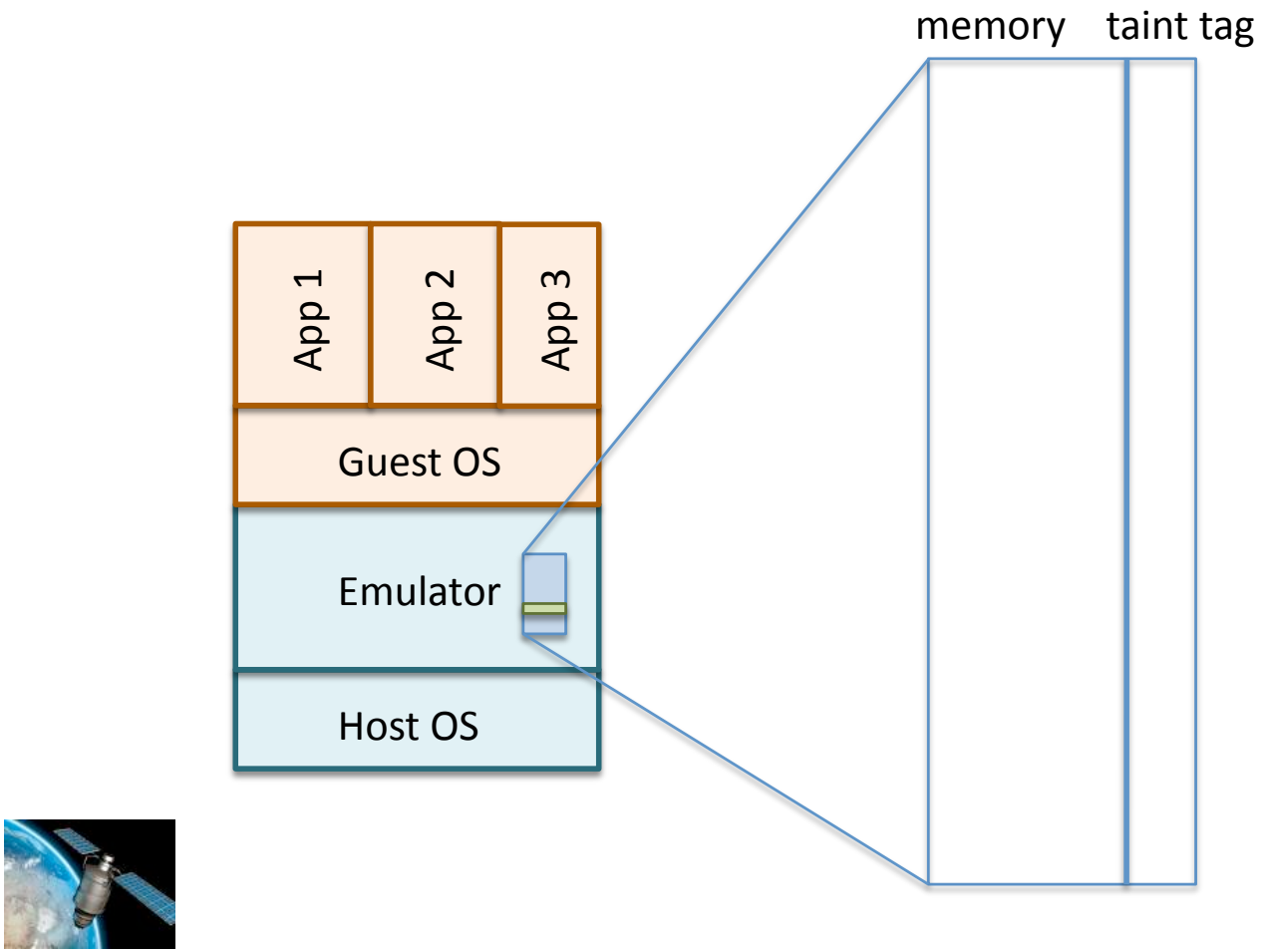
- **Pointer tainting**
  - Capable of detecting
    - Memory corruption attacks
      - Both control- and non-control-diverting
    - Privacy-breaching malware
  - PROBLEMATIC

Basic tainting



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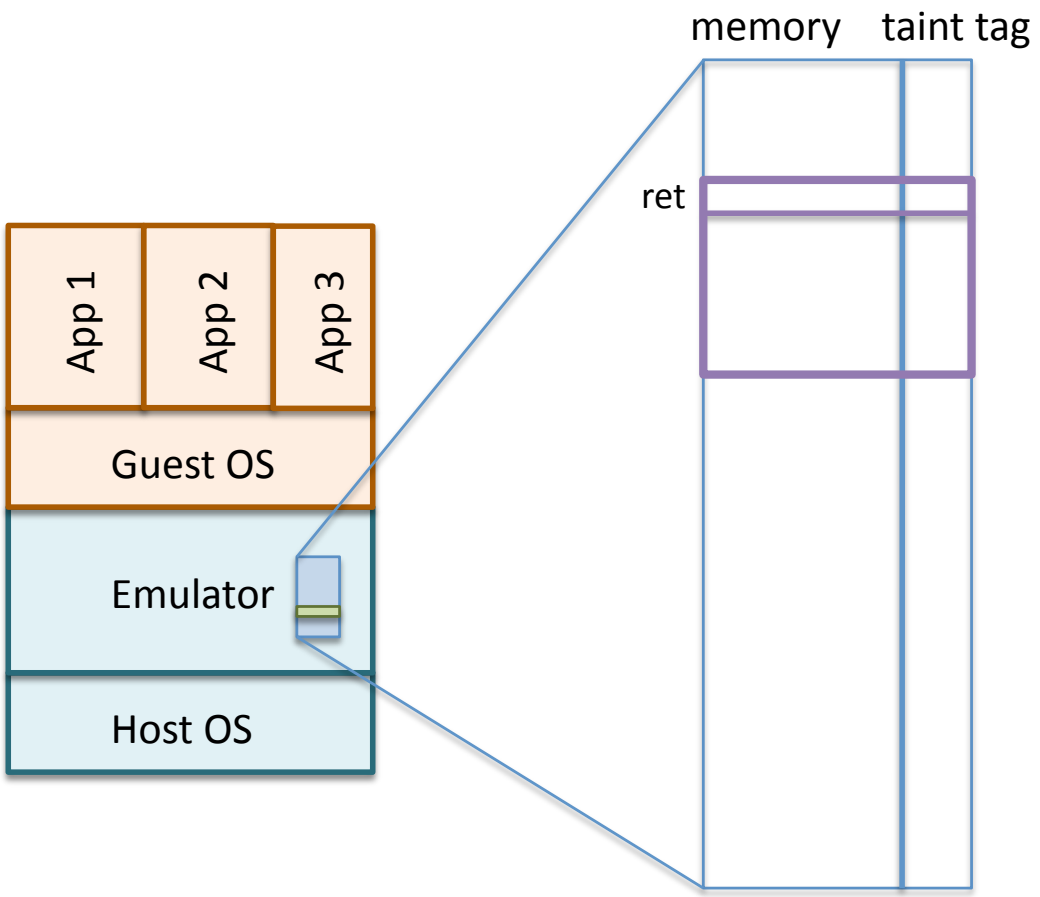

Basic tainting

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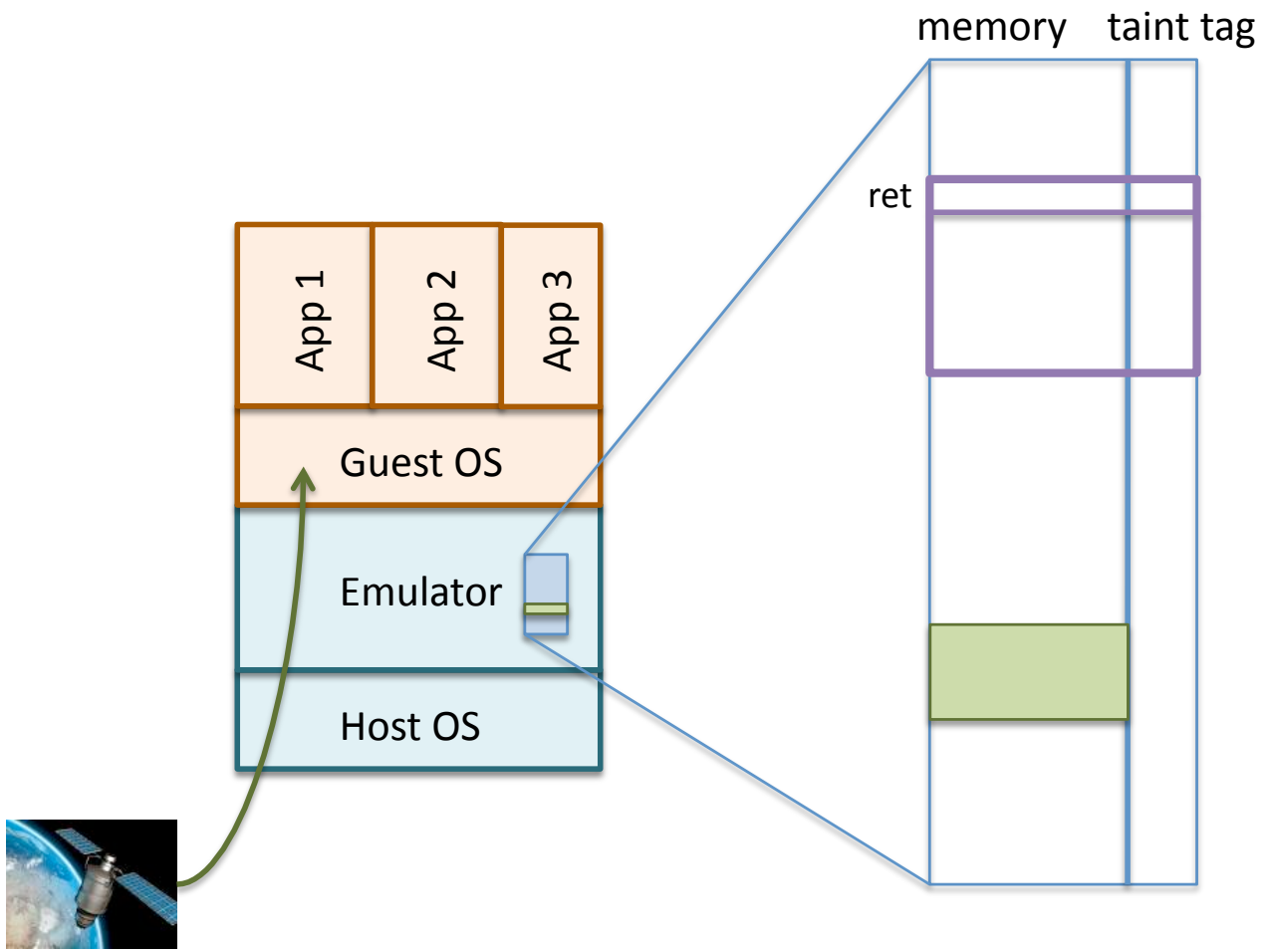

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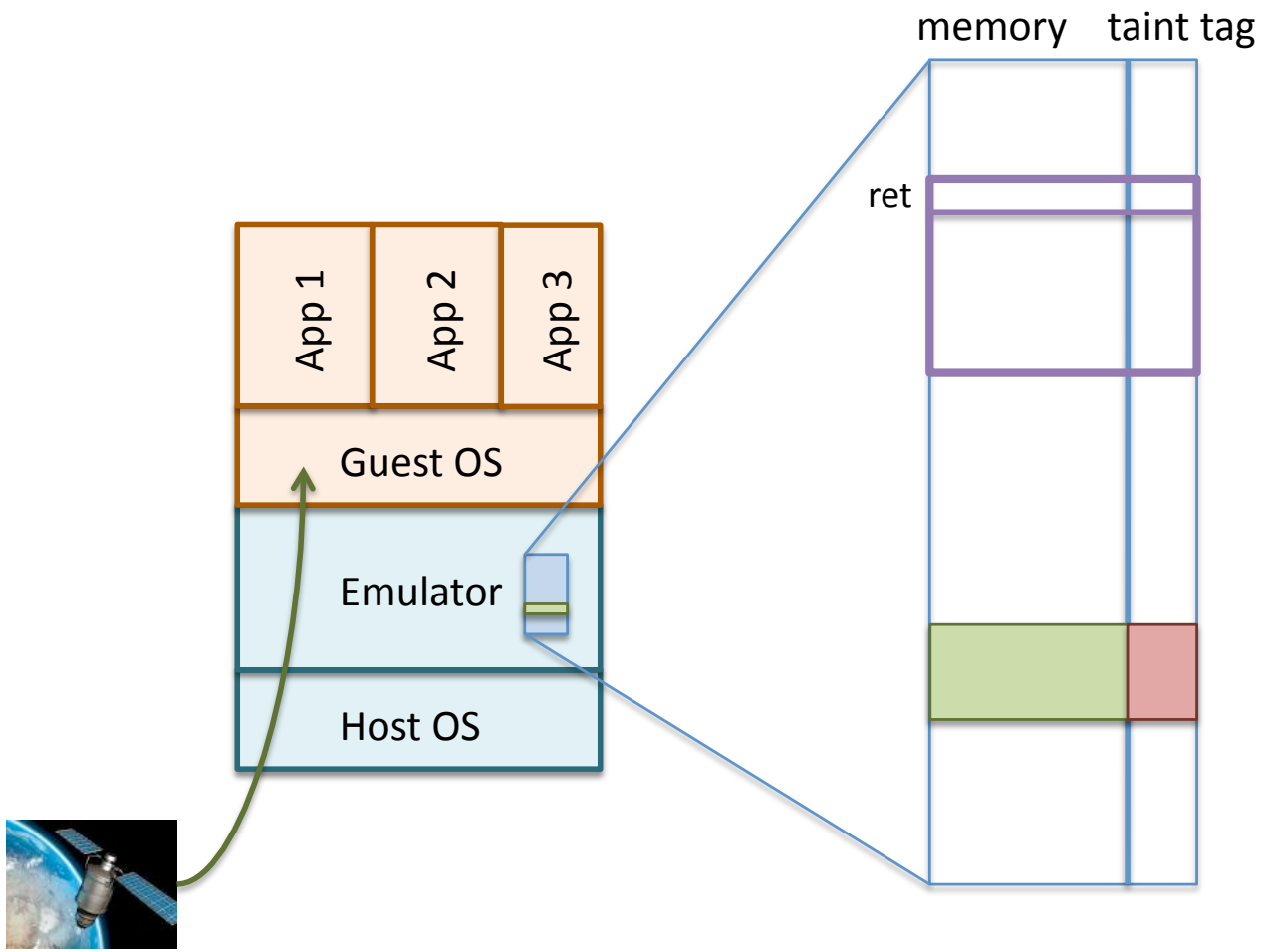

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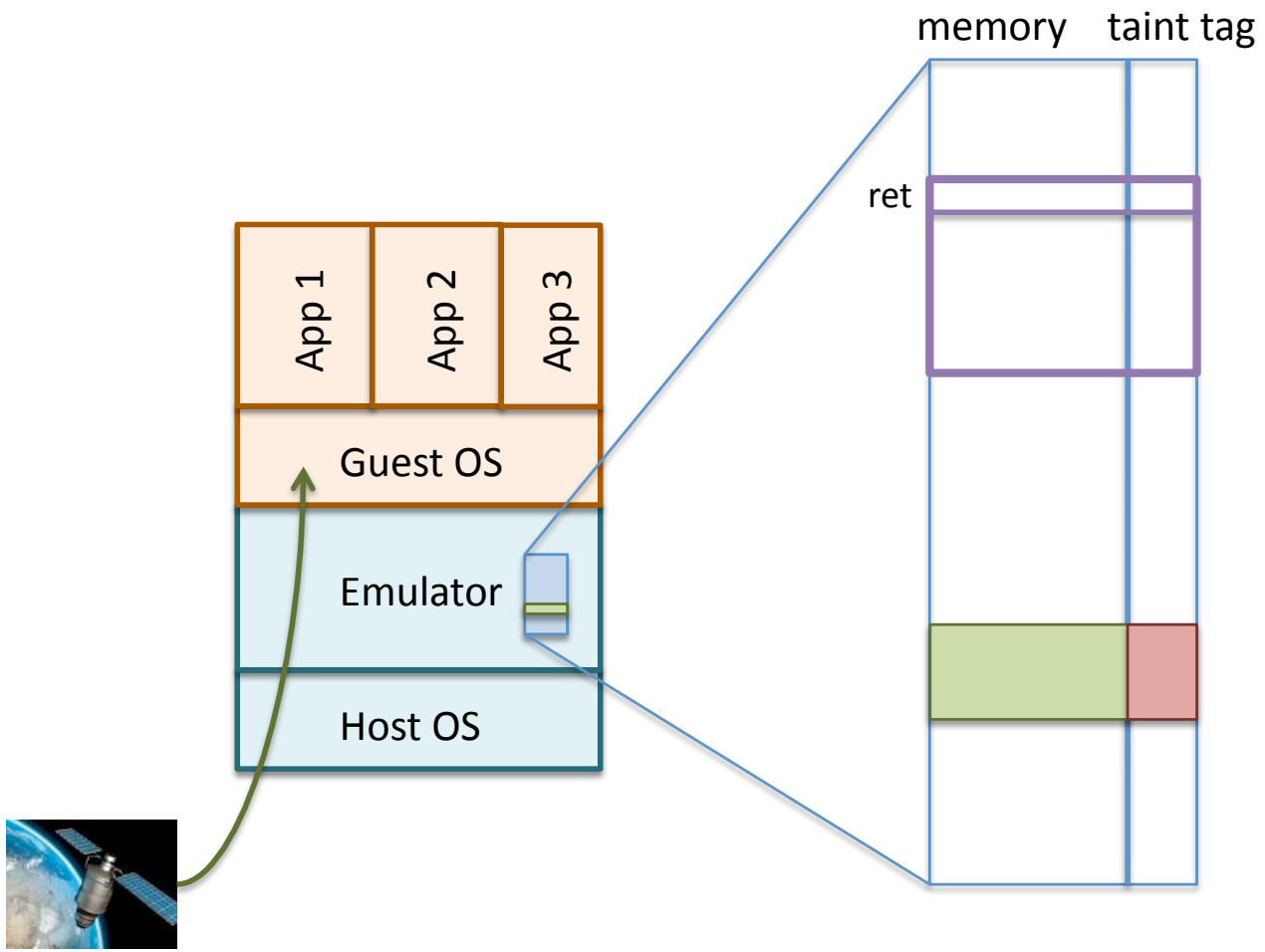

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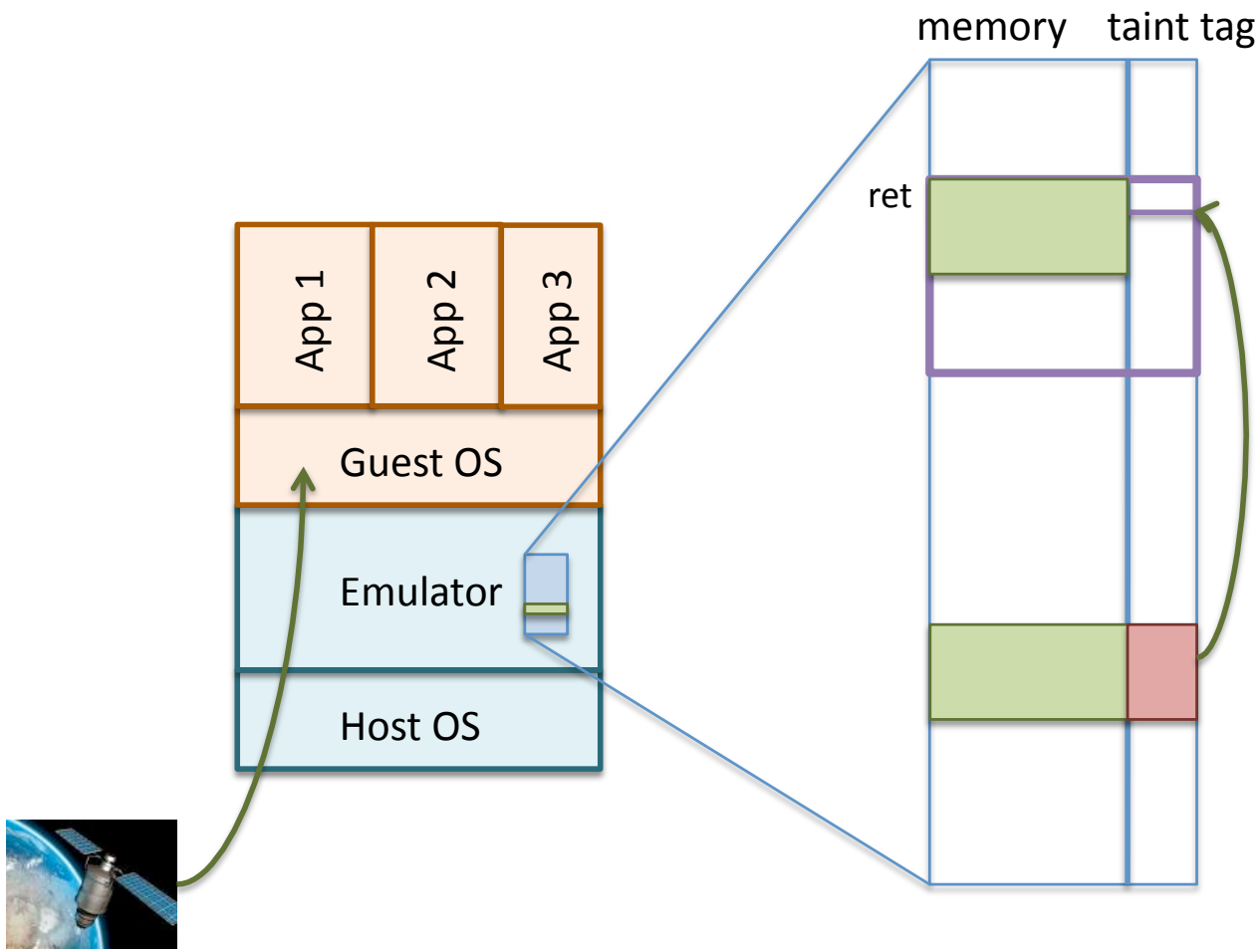

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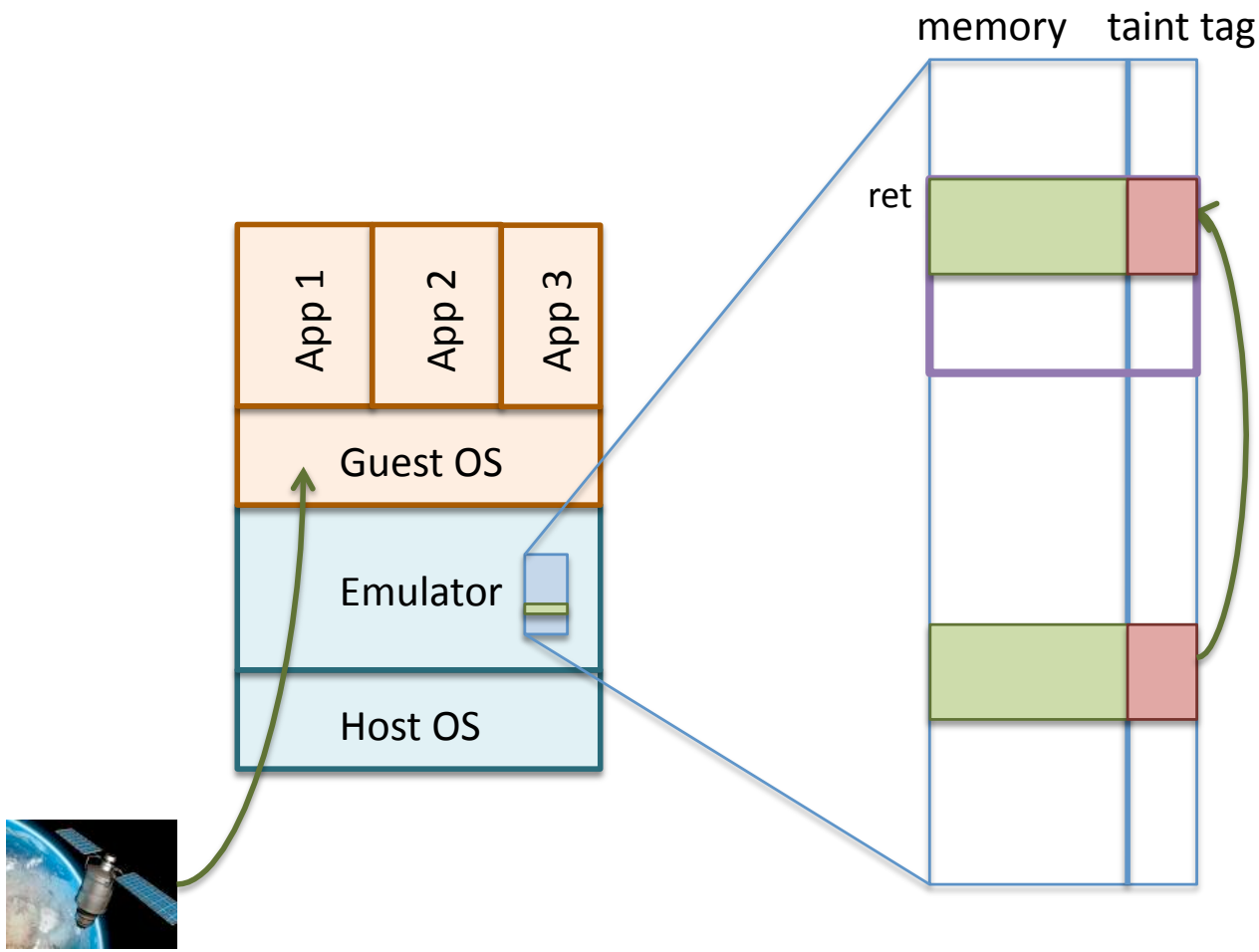

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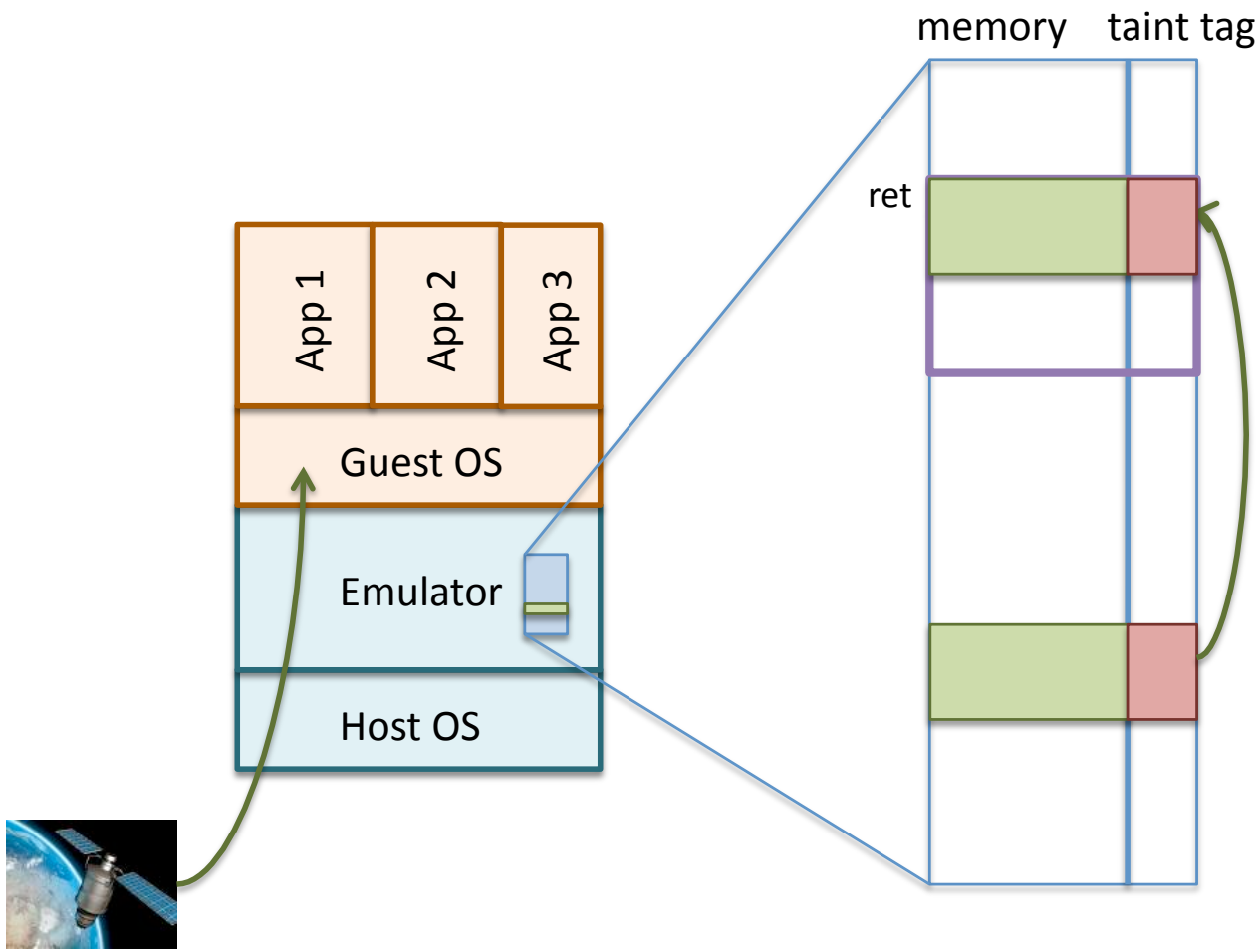

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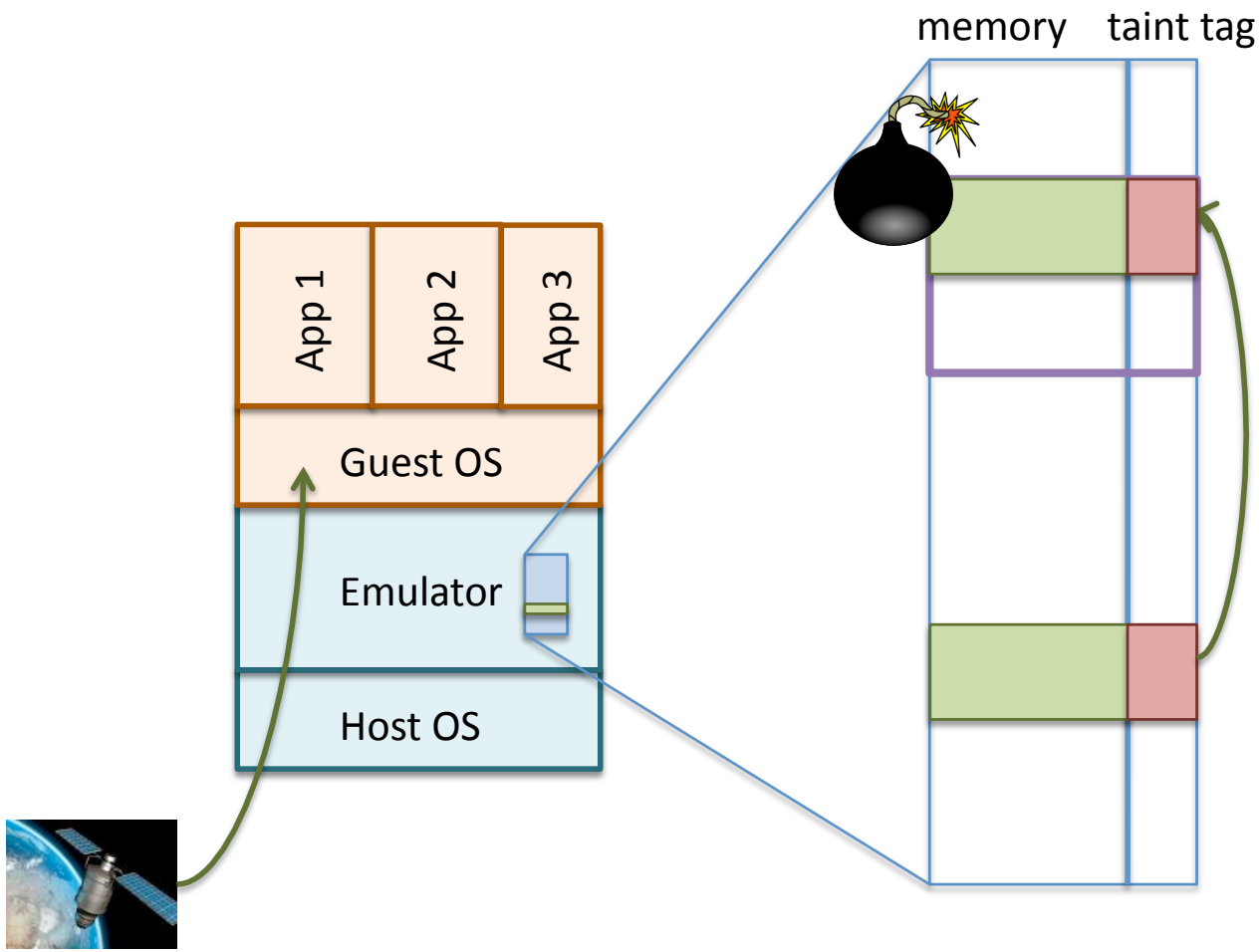

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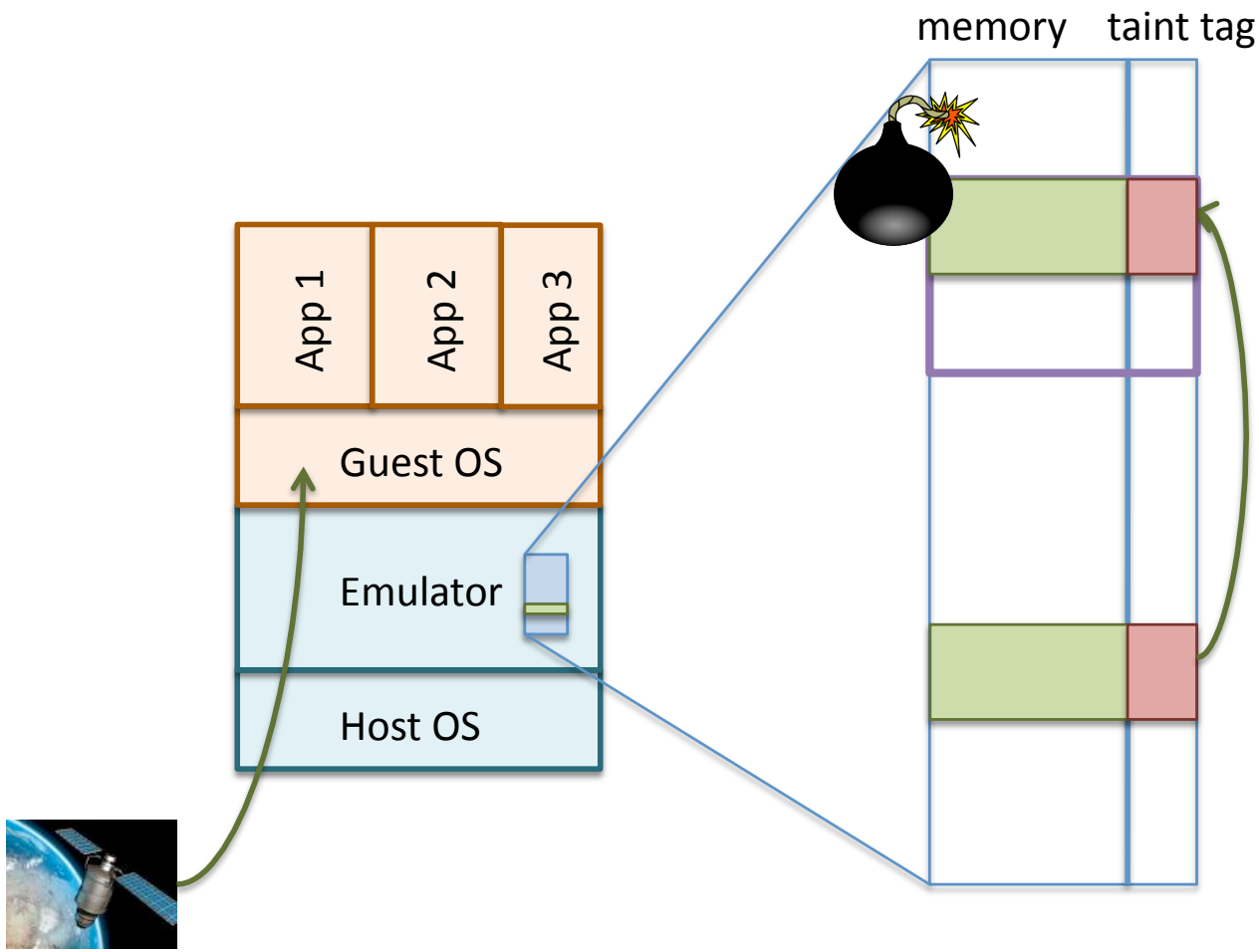

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Minos, MICRO 2004

Vigilante, SOSP 2005

Taintcheck, NDSS 2005

Argos, EuroSys 2006

Attacks: (in)effectiveness of basic tainting

```
void serve(int fd)
{
  char *reply = ...;
  char request[64];

  read(fd, request, 128);
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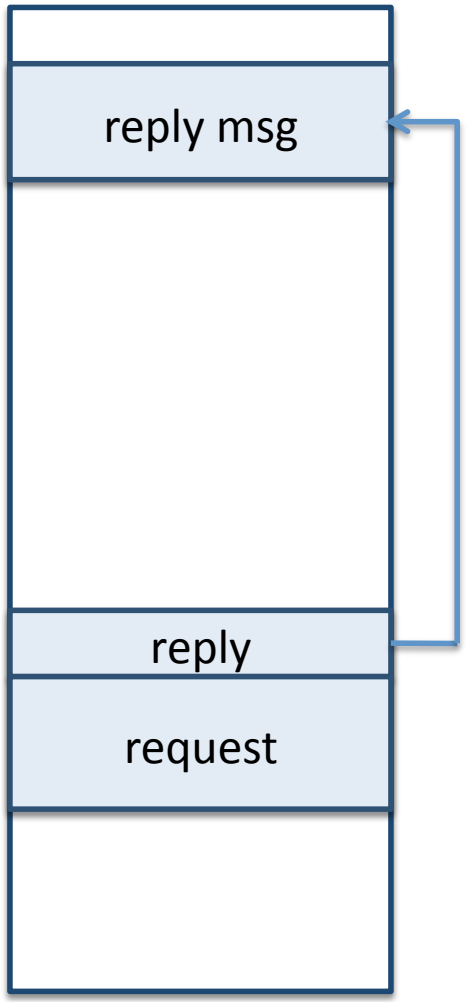

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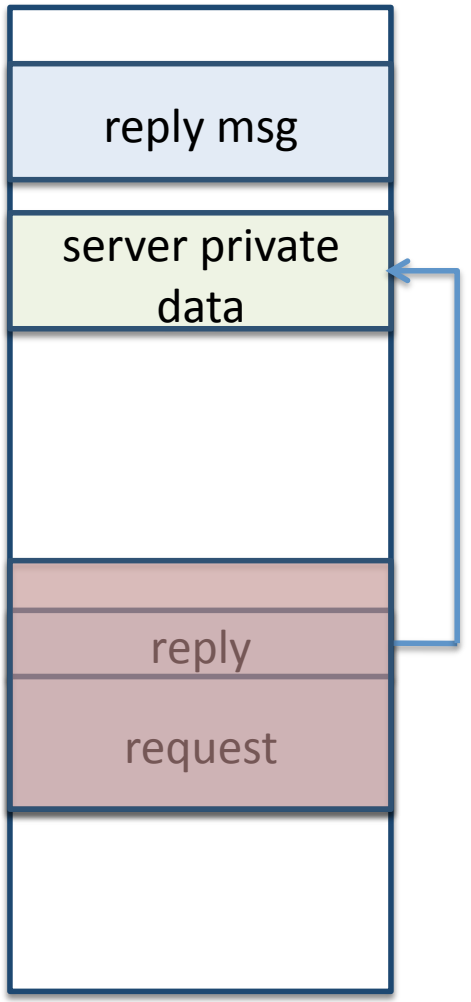

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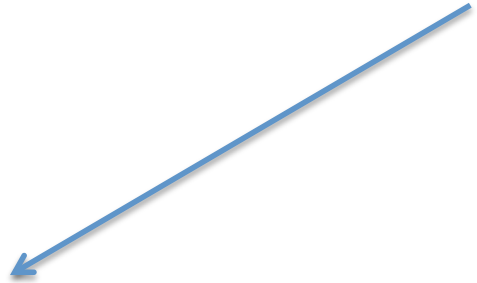

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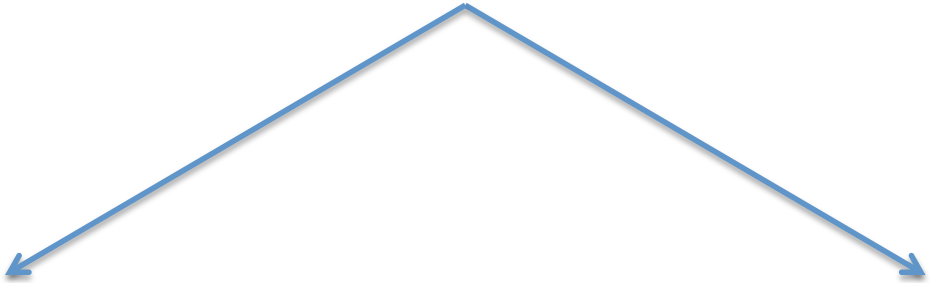

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- Keylogger detection

  + If p is tainted, any dereference of p taints the destination

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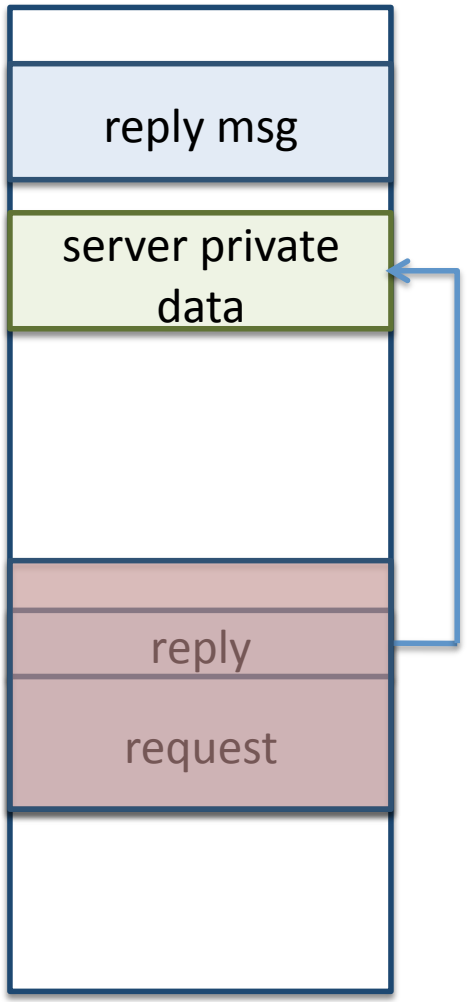

Pointer tainting: FPs likely

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void serve(int fd)
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  char *reply;
  char request;

  read(fd, request, 1);

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void serve(int fd)
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  read(fd, request, 1);
  reply = to_lower[request];
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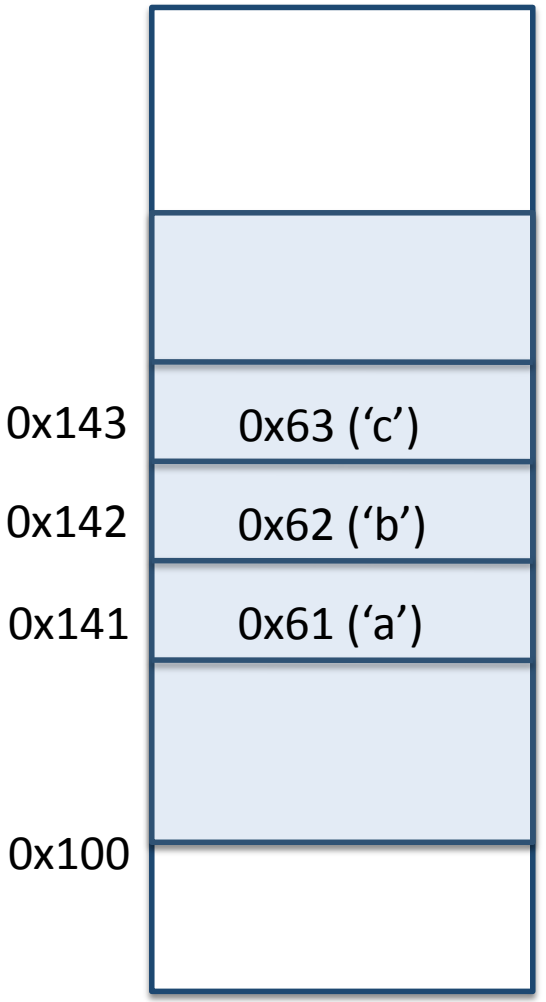

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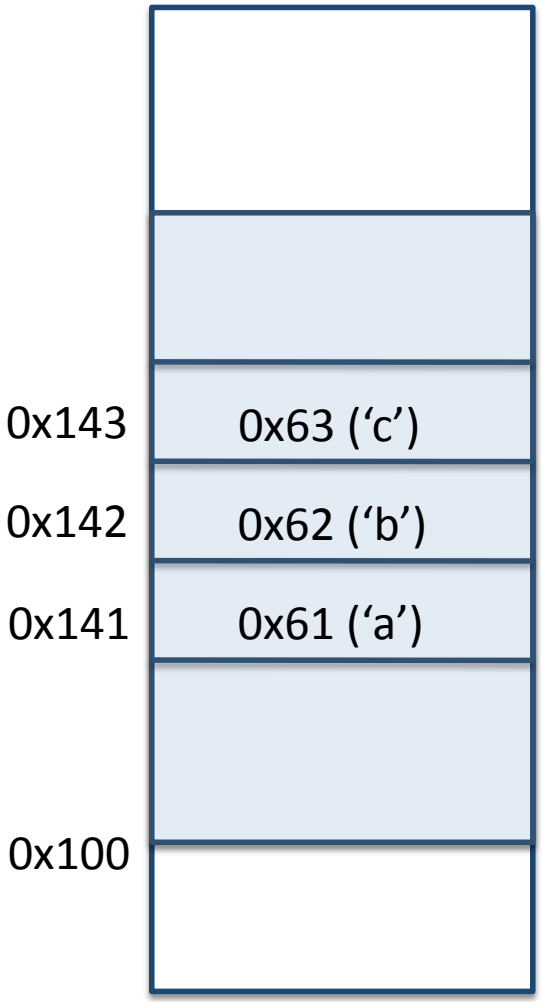

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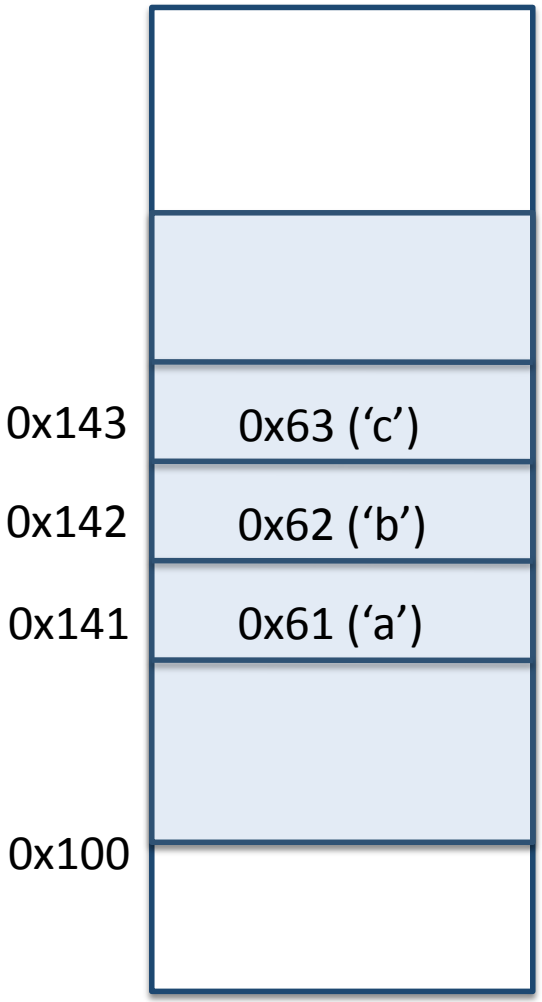

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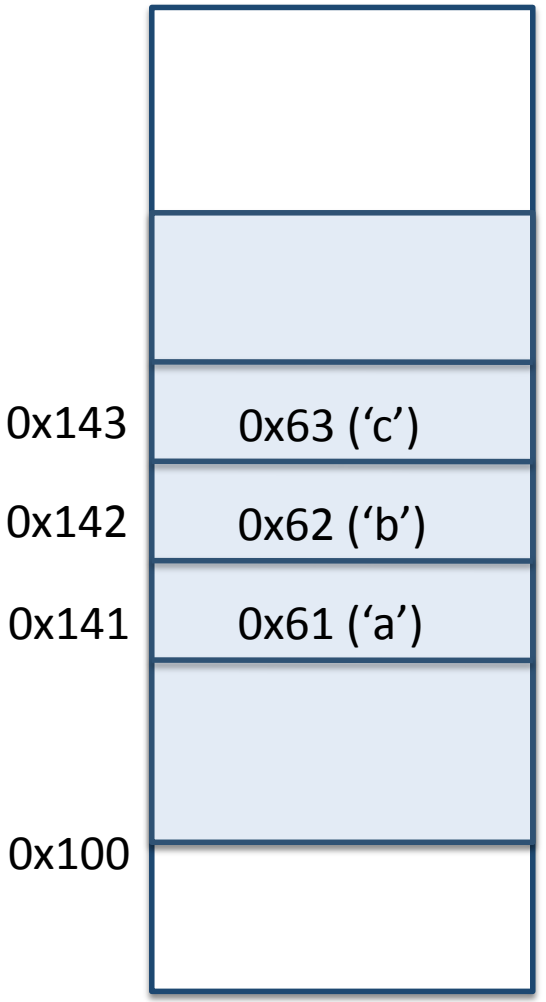
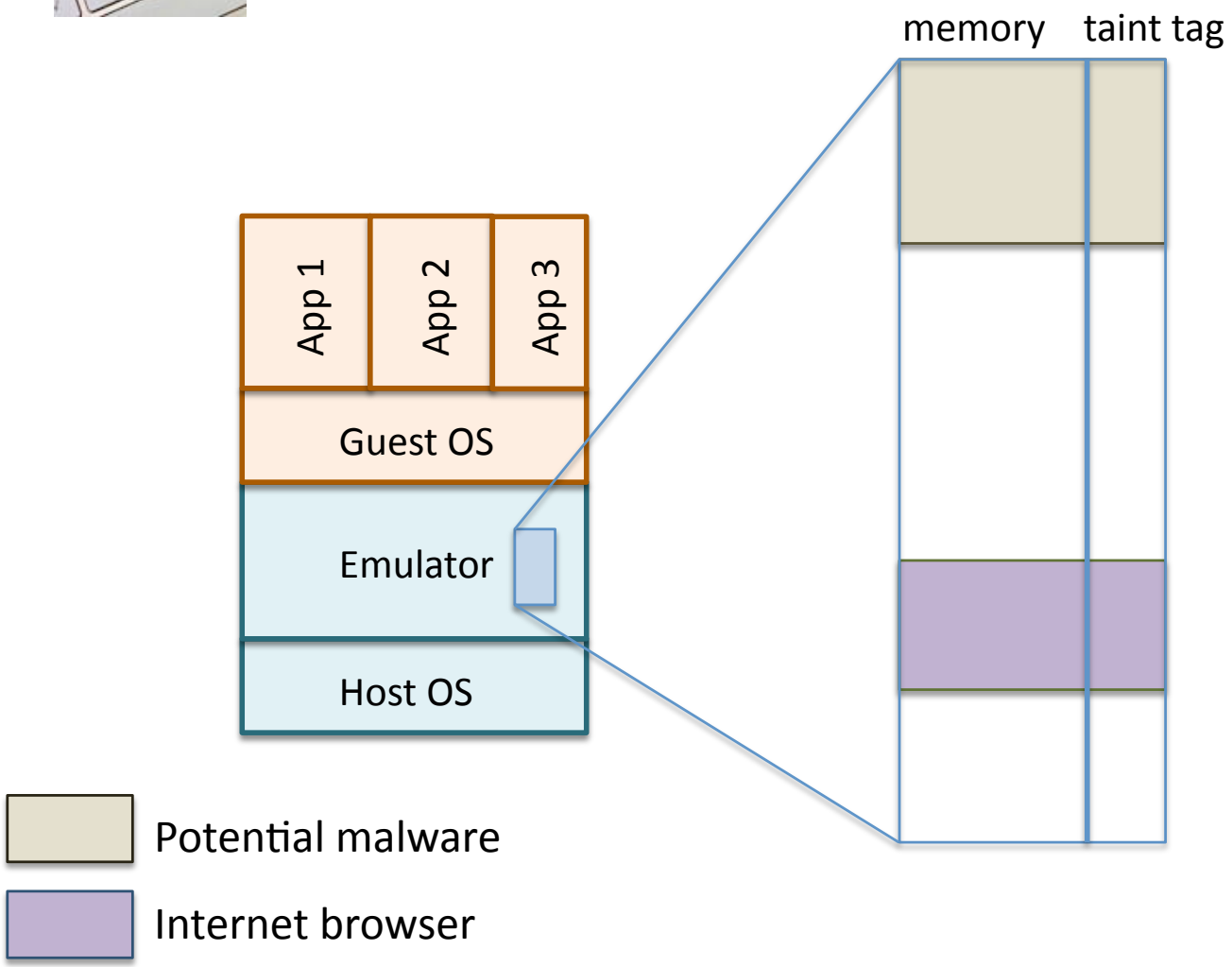


Keylogger detection



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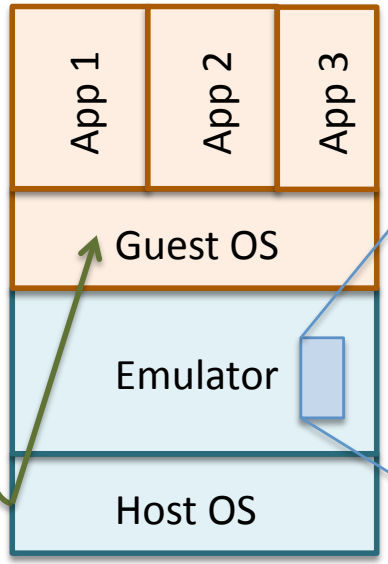
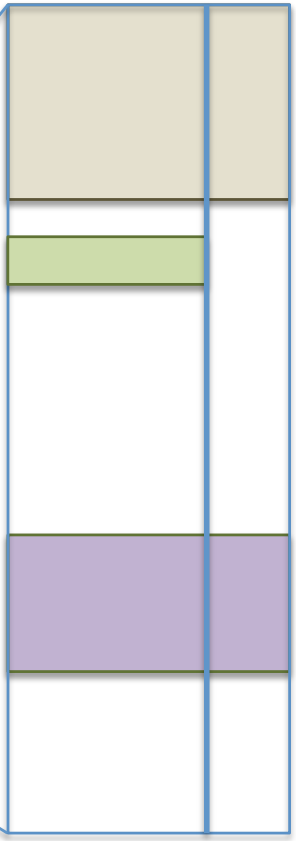
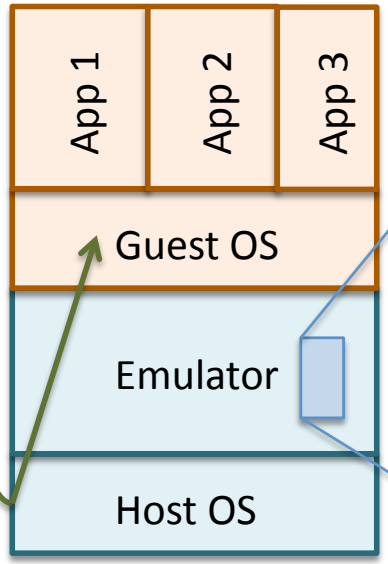


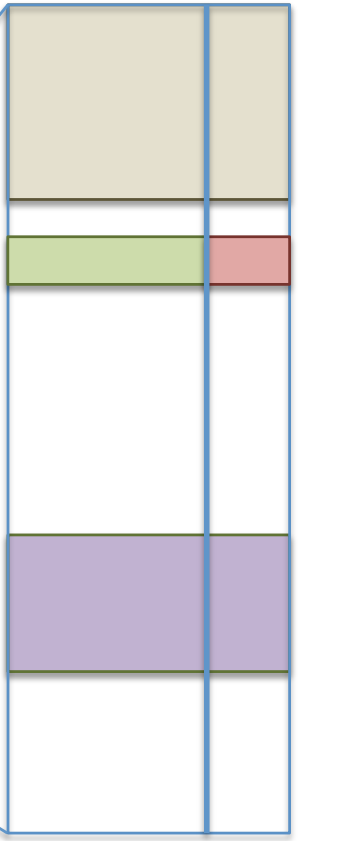


Potential malware

Internet browser

Keylogger detection





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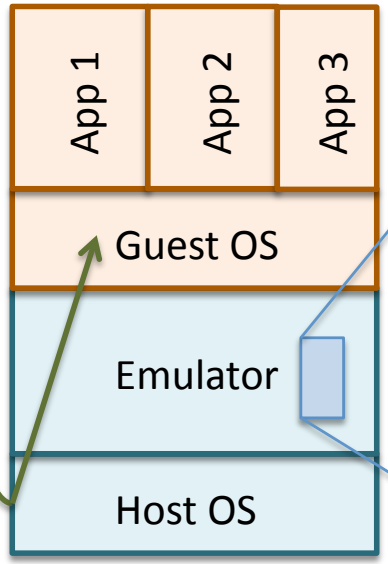

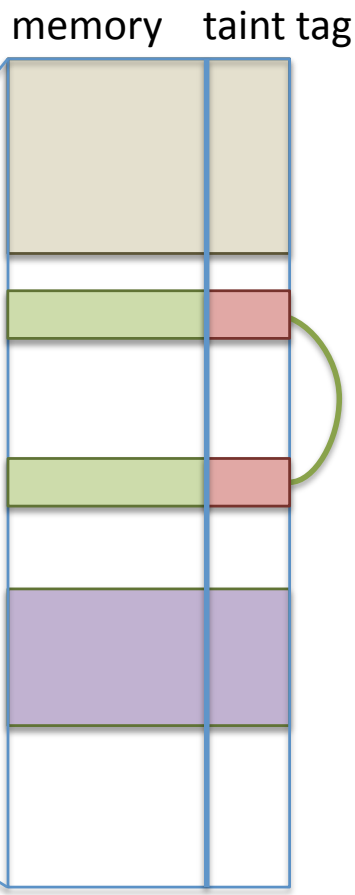

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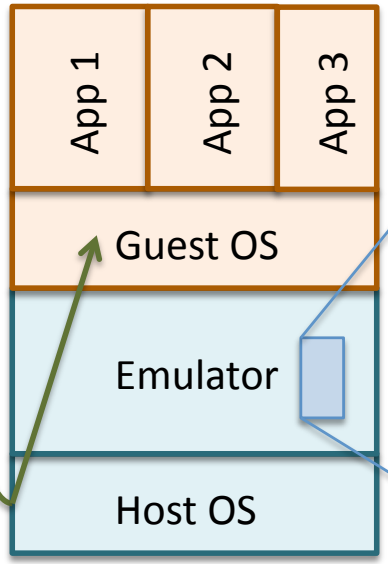

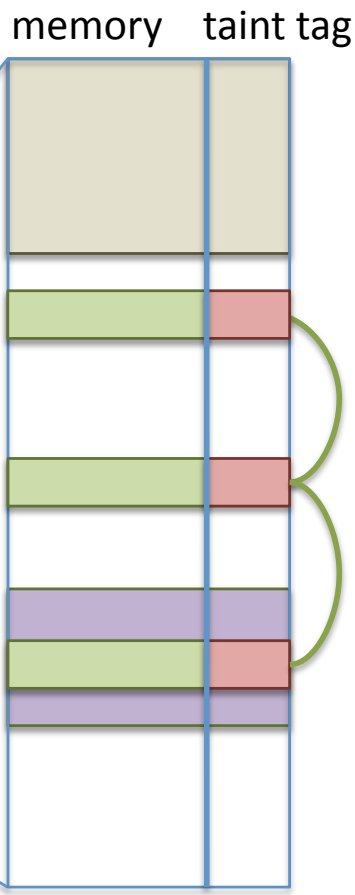

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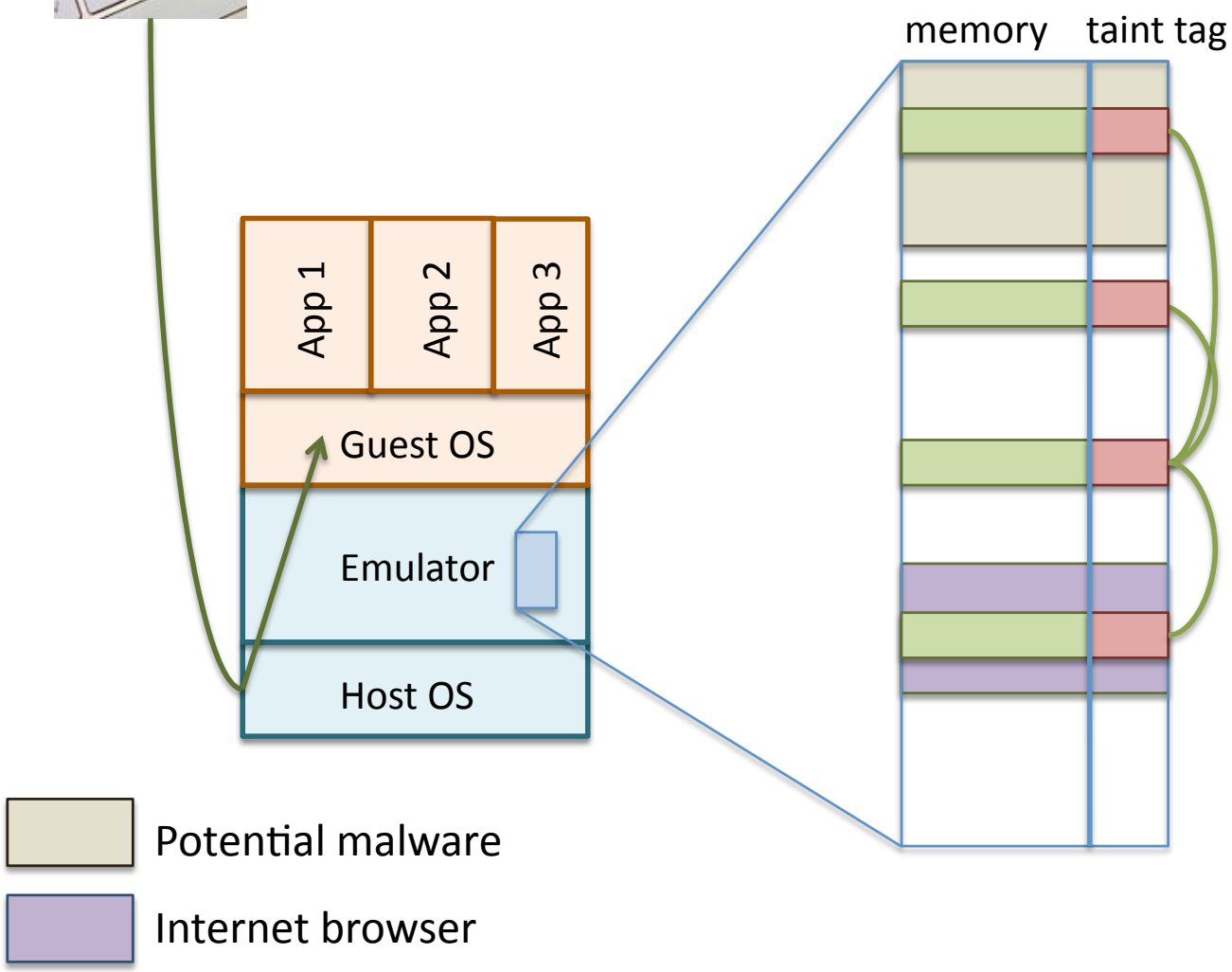

Keylogger detection: FPs likely (again)

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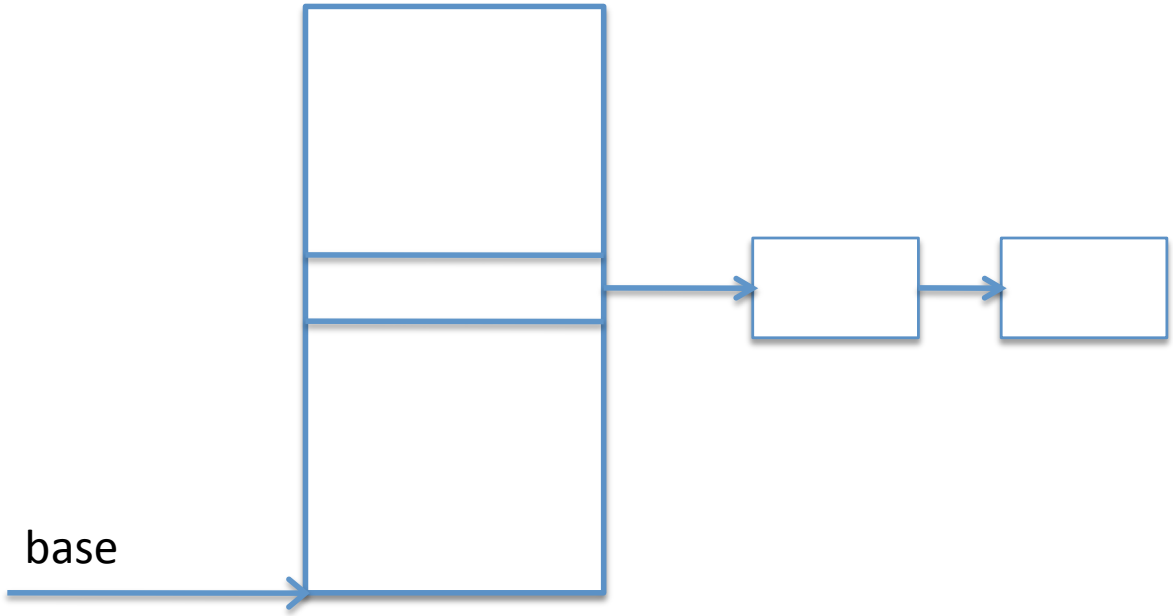

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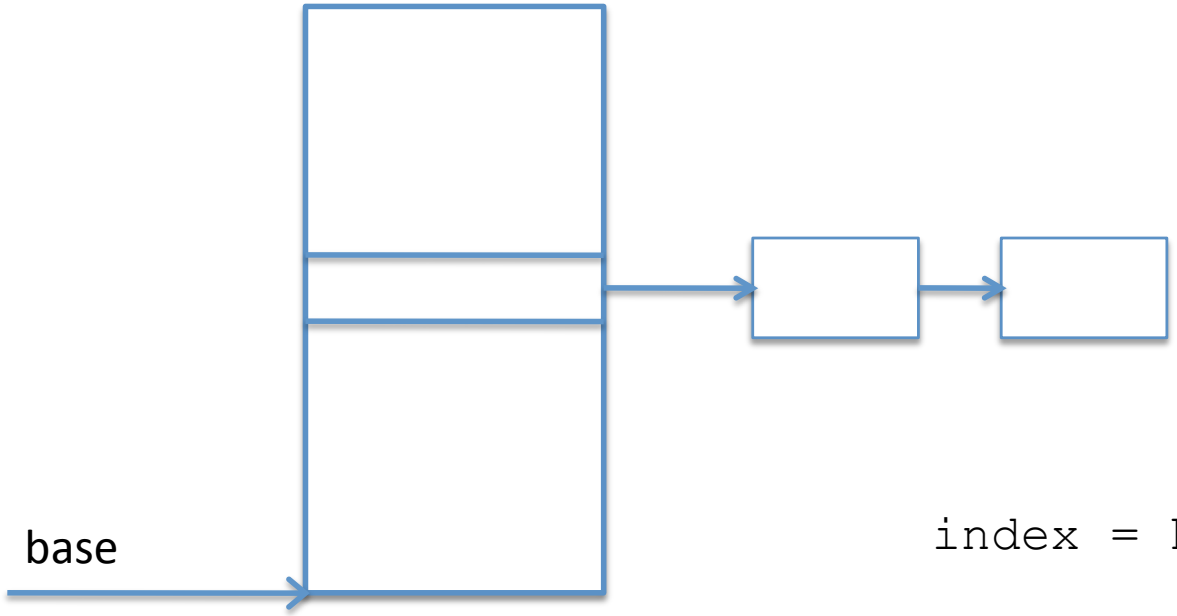


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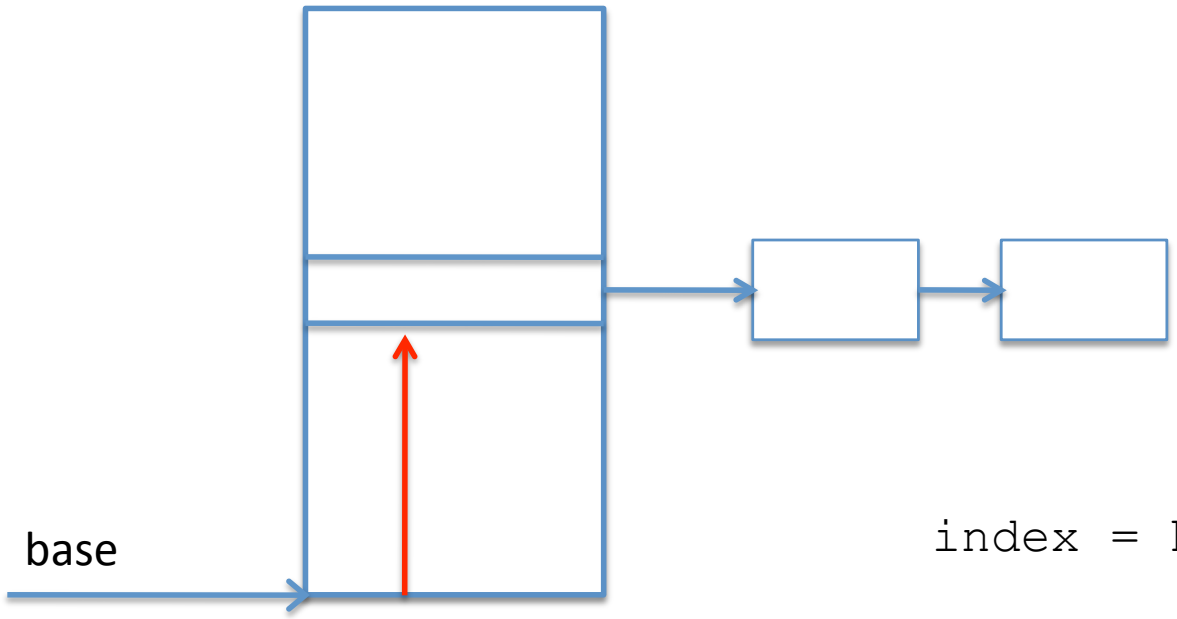


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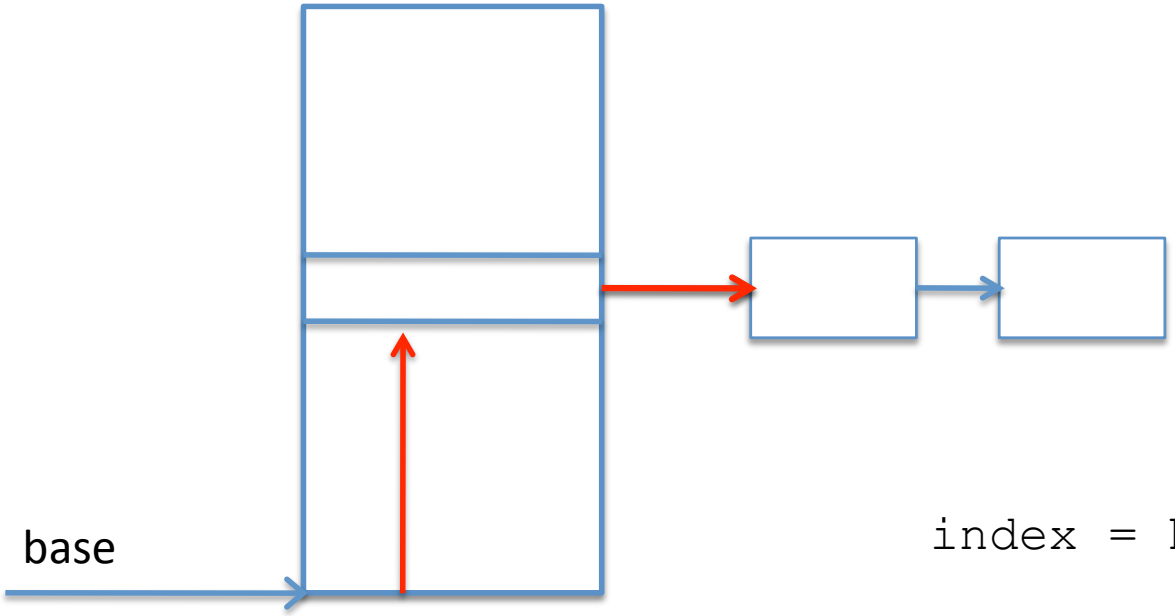


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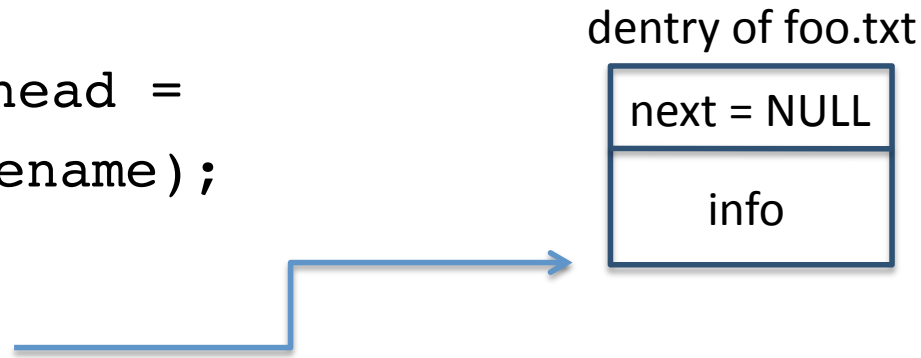
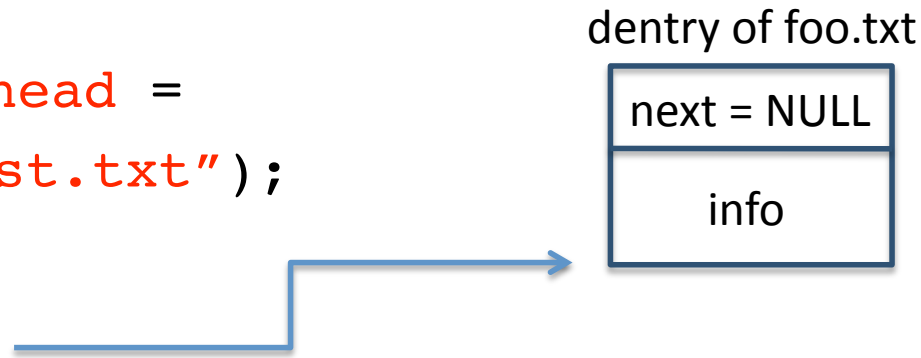


Keylogger detection: FPs likely (again)

```
struct hlist_head *head =
   get_list_head("test.txt");

struct dentry
   *dentry = head->first;
```



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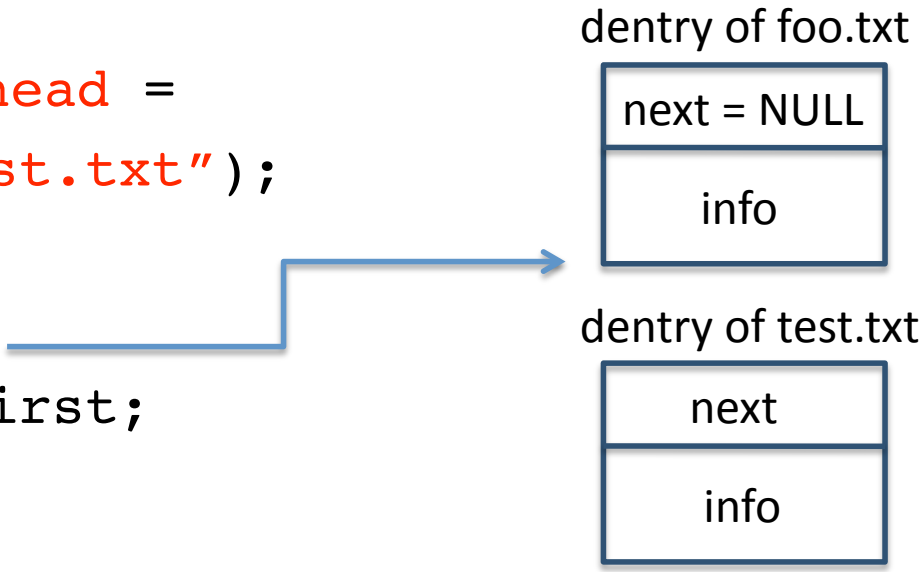

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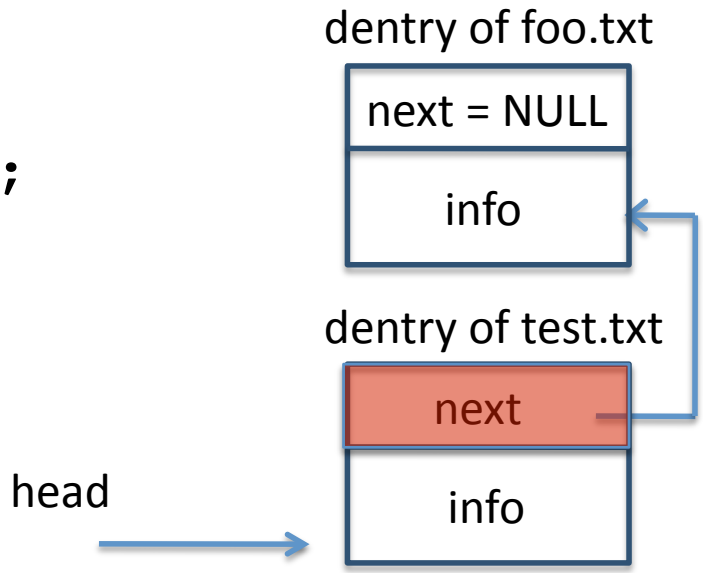

Keylogger detection: FPs likely (again)

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   *dentry = head->first;
```

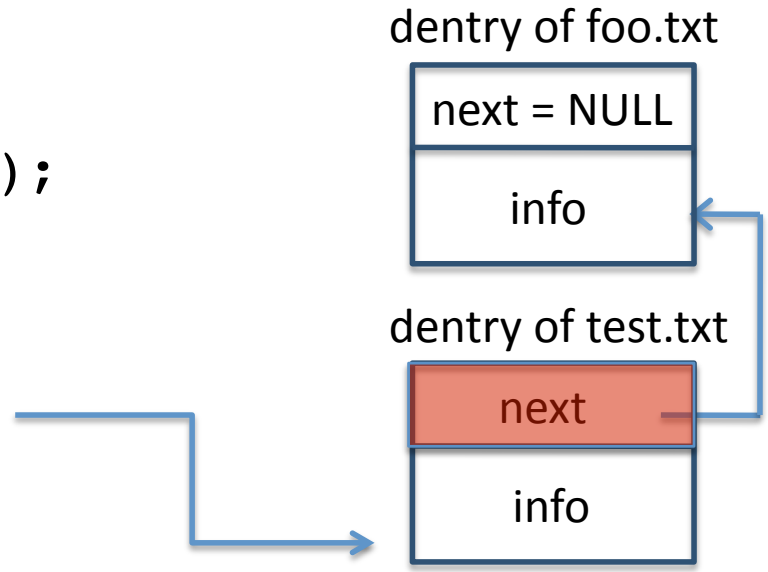

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struct hlist_head *head =
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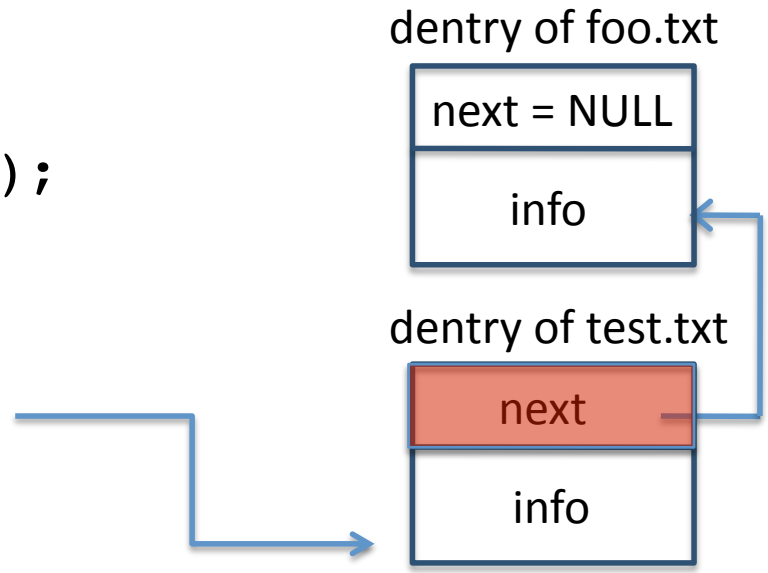
struct dentry
   *dentry = head->first;

dentry = dentry->next;
return info = dentry->info;
```



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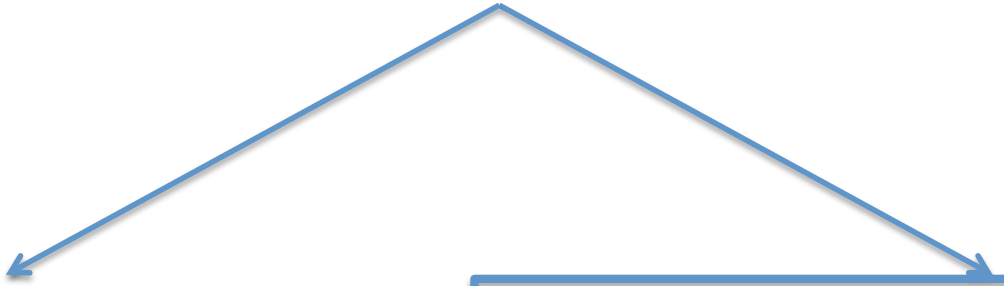

- Attacks

  3. Alert for dereferences due to tainted jumps, function calls/returns.

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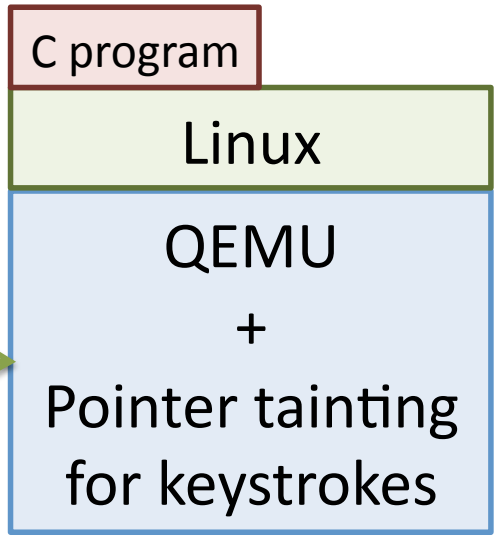
- Keylogger detection
  – If p is tainted, any dereference of p taints the destination

Experiment



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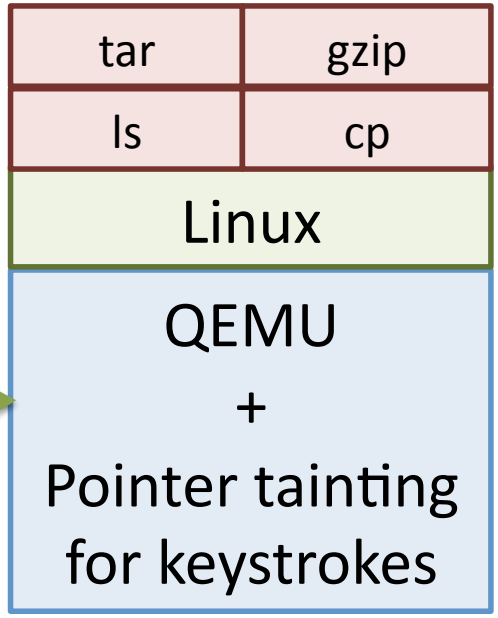
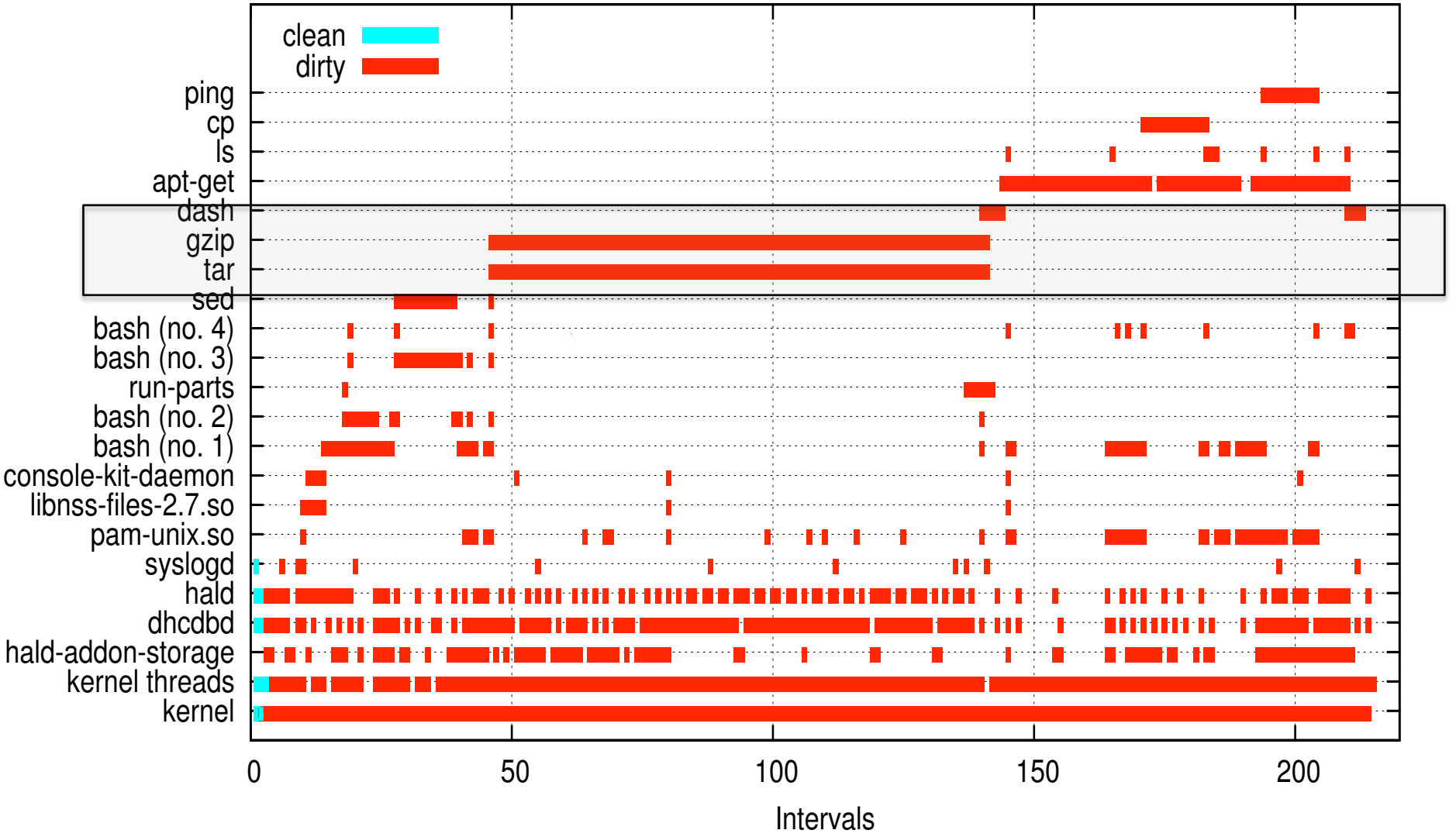


Keyloggers… false positives!



Containment

- White and black lists
- ESP/EBP protection
- Landmarking
- …

Landmarking - motivation

Should NOT be tainted

```
struct dentry dentry =
   prev_dentry->next;
```

Should be tainted

```
val = transl_table[index]
```

Landmarking - motivation

Should NOT be tainted

```
struct dentry dentry =
   prev_dentry->next;
```

affect tainted address with a **clean** value

Should be tainted

```
val = transl_table[index]
```

Landmarking - motivation

Should NOT be tainted

```
struct dentry dentry =
   prev_dentry->next;
```

affect tainted address with a **clean** value

```
B = prev_dentry + offset

dentry = *B
```

Should be tainted

```
val = transl_table[index]
```

Landmarking - motivation

Should NOT be tainted

```
struct dentry dentry =
   prev_dentry->next;
```

affect tainted address with a **clean** value

Should be tainted

```
val = transl_table[index]
```

affect address with a **tainted** value

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B = prev_dentry + offset

dentry = *B
```

Landmarking - motivation

Should NOT be tainted

```
struct dentry dentry =
   prev_dentry->next;
```

affect tainted address with a **clean** value

```
B = prev_dentry + offset

dentry = *B
```

Should be tainted

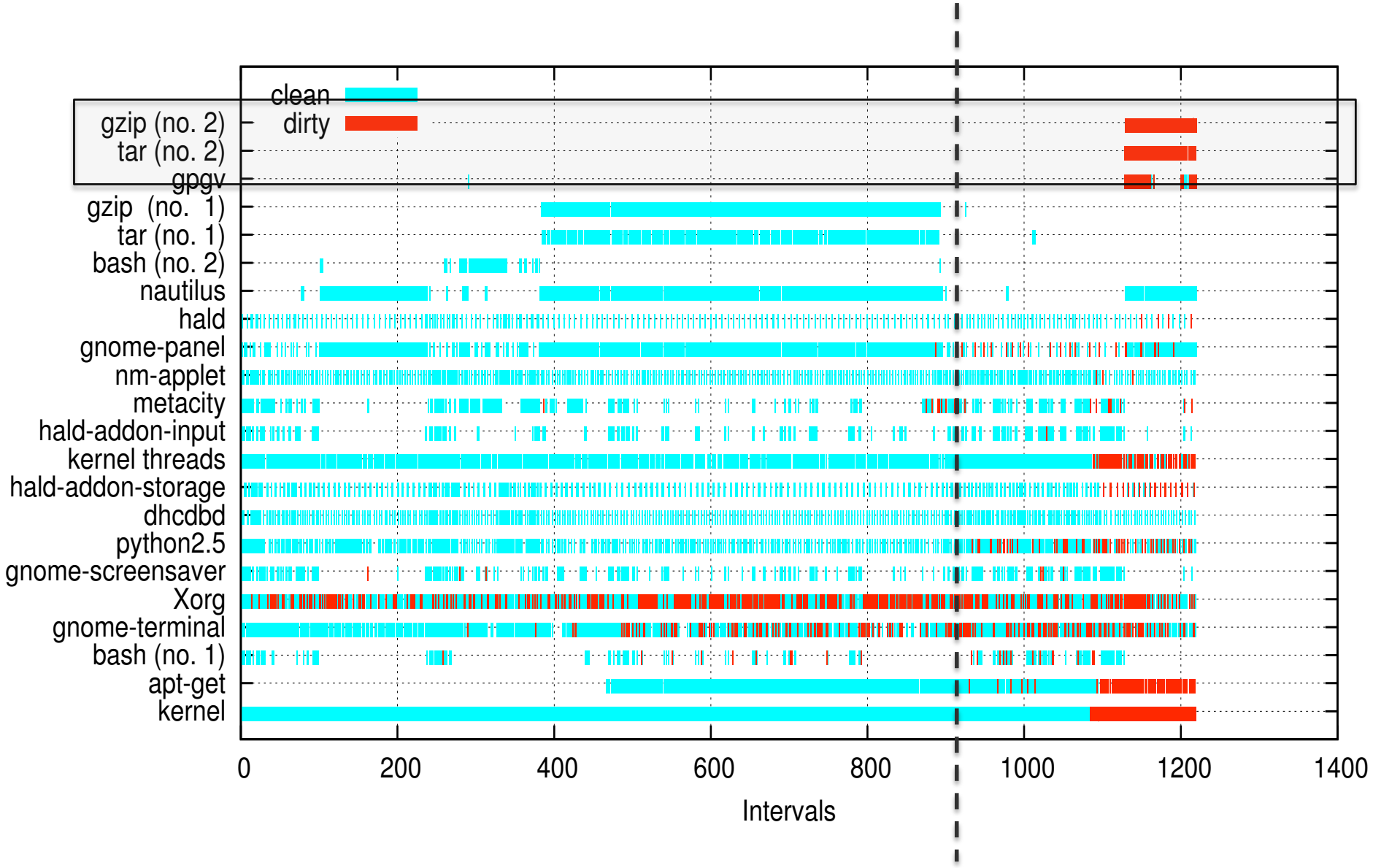
```
val = transl_table[index]
```

affect address with a **tainted** value

```
A = address of an array
B = A + index*4

val = *B
```

Full containment - results



How bad are things?

Should NOT be tainted

```
struct hlist_head *head =
  d_hash(parent, hash);
```

Should be tainted

```
attributes =
  transl_table[kbd_data];
```

1. `addr`: combine clean pointer with a tainted index

```
struct dentry *dentry =
  head->first;
```

```
lower_case =
  attributes->lower;
```

2 `new_addr`: modify the resulting pointer with a constant

Conclusions

- We have analyzed pointer tainting
  - A popular technique for detecting memory corruption attacks and keyloggers
- Not suited for detecting privacy-breaching malware, like keyloggers
  - False positives hard to avoid
- Could be applied to detect memory corruption attacks
  - Not suitable for x86 and Windows

Backup slides

Pollution due to tainted ESP/EBP

- If ESP/EBP get tainted, taint spreads instantly
  - `mov eax, dword ptr [ebp + 08h]`
  - `pop eax`
- How ESP/EBP can become tainted?
  - Linux kernel has numerous places where it can happen,
    - E.g., a common operation like opening a file ends up tainting EBP,
    - Details in the paper

Pollution due to pointer arithmetic

Should NOT be tainted

```
struct fd {
   HANDLER handler;
   STRING filename;
   struct fd *next;
};

A = address of filename
B = A – 0x0004

h1  = *(B + 0x0000)
fd2 = *(B + 0x0020)
```

Should be tainted

```
A = address of an array
i = index to be accessed
B = A + i*4

Translated value:
val = *B
```

Pollution due to pointer arithmetic

Should NOT be tainted

```
struct fd {
   HANDLER handler;
   STRING filename;
   struct fd *next;
};
```

A = address of filename

B = **A** – 0x0004

h1 = *(**B** + 0x0000)

fd2 = *(**B** + 0x0020)

How to distinguish between these two cases?

Should be tainted

A = address of an array

i = index to be accessed

B = A + **i***4

Translated value:

val = ***B**

Landmarking

```
typedef struct test_t {
   int i;
   struct test_t *next;
} test_t, *ptest_t;
ptest_t table[256] = …;

ptest_t i1 = table[index];          // tainted
   A = (table+index*sizeof(test_t))

ptest_t i2 = i1->next;              // clean
   addr: *(A + offset(next))

int i3 = i1->i;                     // clean
   addr: *(A)
```

Landmarking – why FPs?

- Possible scenarios:
  - Assume eax contains a calculated tainted address
    - It can be copied and altered before dereference
    - Then both values become tainted
  - Addresses calculated directly
    - an array A of struct {int a; int b;}
      - A[index].b: `int b = *((char*)A+8*index+4)`
    - Very simplistic, but the same problem might hold for queues, stacks and hashtables

Landmarking – more problems

- False negatives
  - Translation table containing structures instead of single elements

```
attributes = transl_table[kbd_data];
lower_case = attributes->lower;
```

- Much more problems in the paper