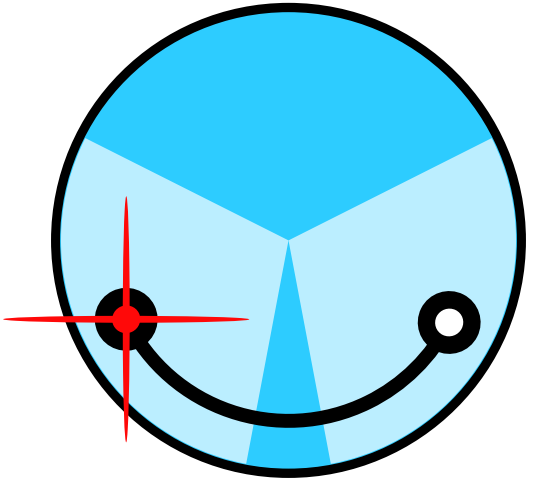

Minemu: Protecting buggy binaries from memory corruption attacks

Erik Bosman <erik@minemu.org>

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WARNING

THIS PRESENTATION
MAY CONTAIN POINTERS

Programming Languages

type-safe vs. not type-safe

Programming Languages

type-safe vs. not type-safe

Java
Python
Ruby
Javascript

Programming Languages

type-safe	vs.	not type-safe
Java		C
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MEMORY CORRUPTIONS!

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MEMORY CORRUPTIONS! but not your fault

MEMORY CORRUPTIONS!

The Stack

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[code]

run(char *name)
{
  char buf[16];

  print("hello ");
  print("world\n")
}
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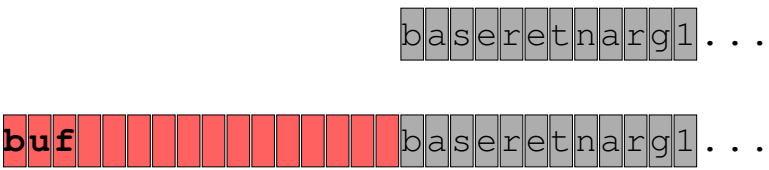

The Stack

```
[address] [code]

 8048751: run(char *name)
          {
            char buf[16];

 8048770:   print("hello ");
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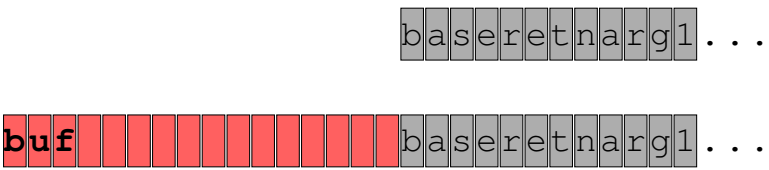
          }
```



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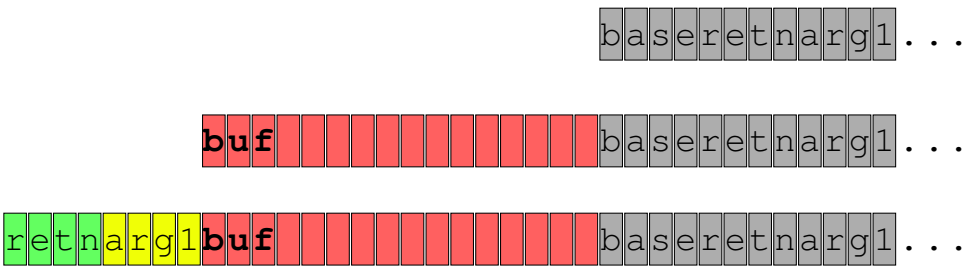

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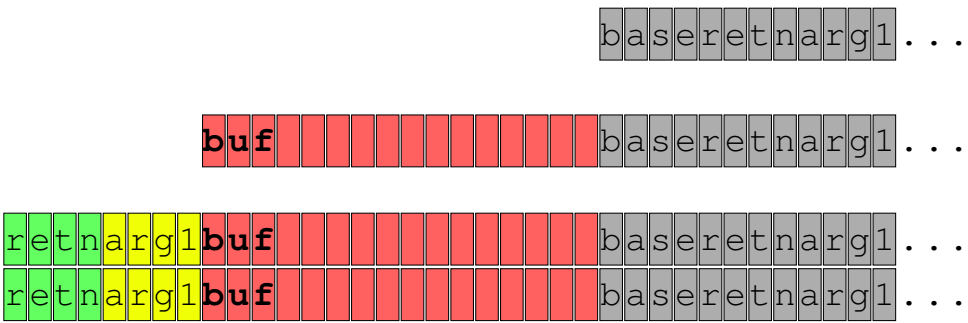
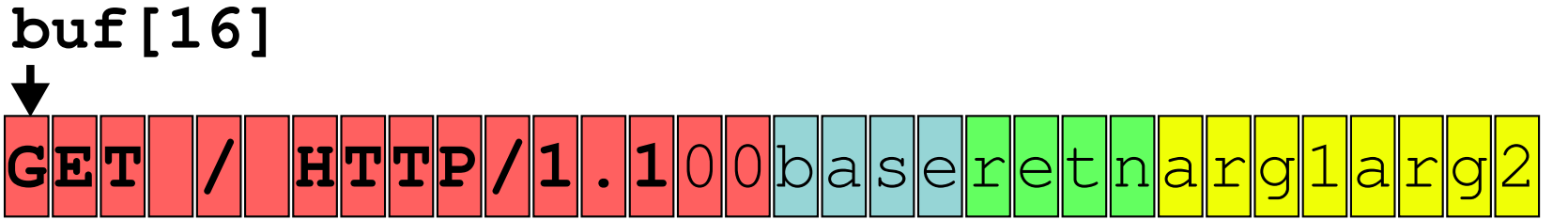


Traditional Stack Smashing



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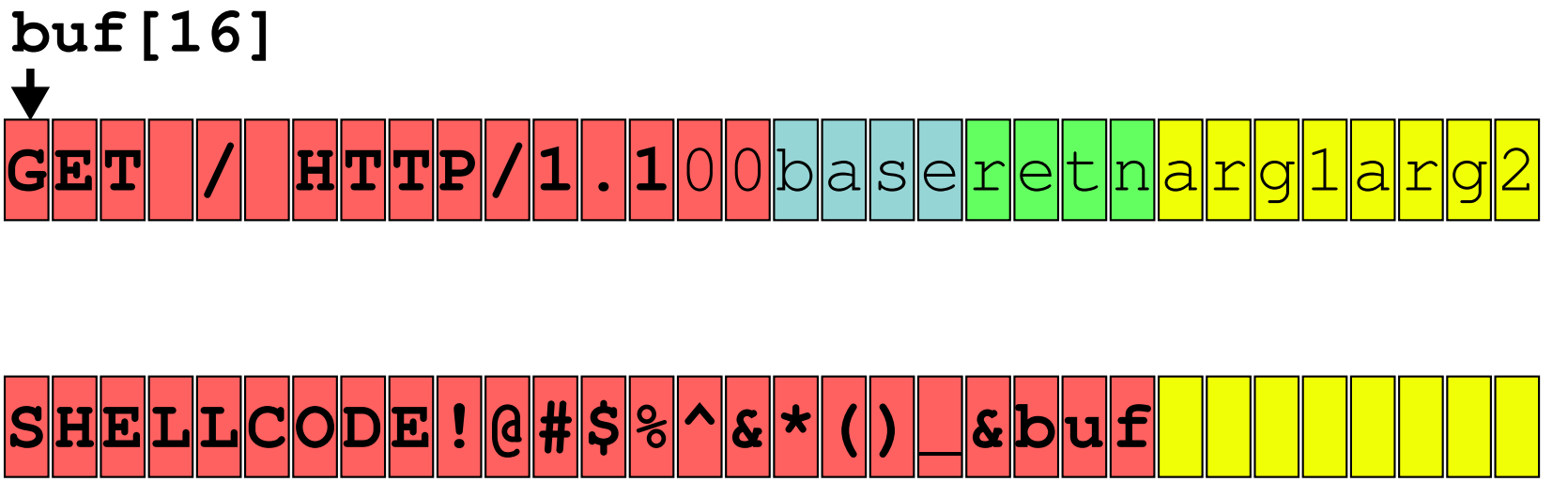
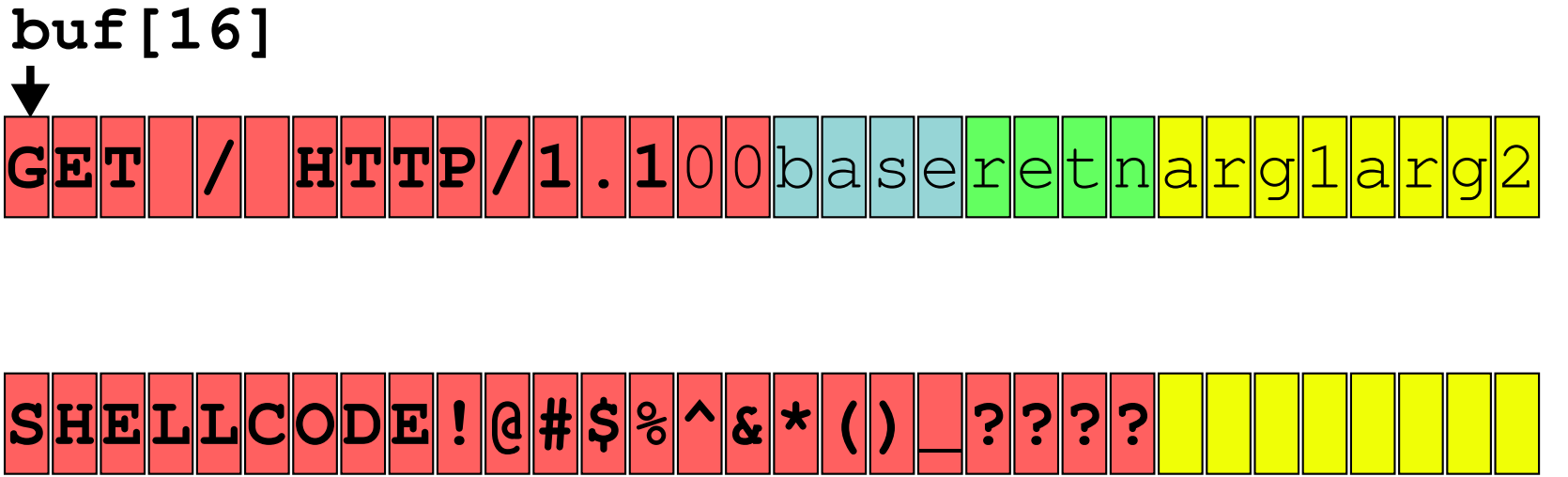
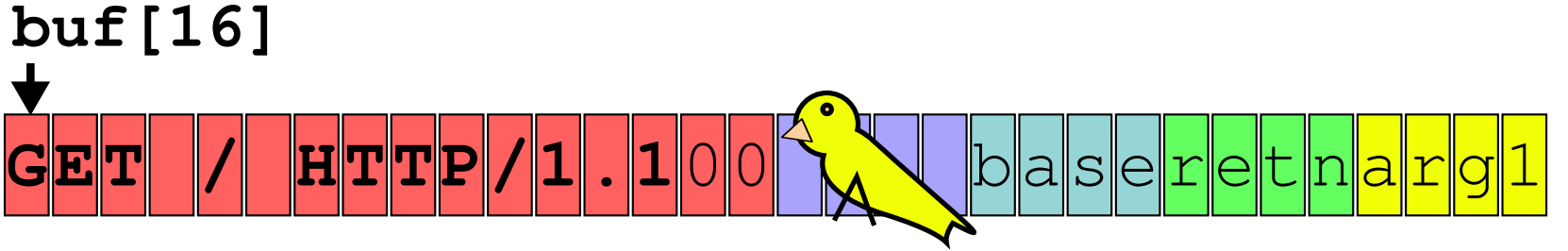


Address Space Layout Randomisation (ASLR)



Stack Canaries



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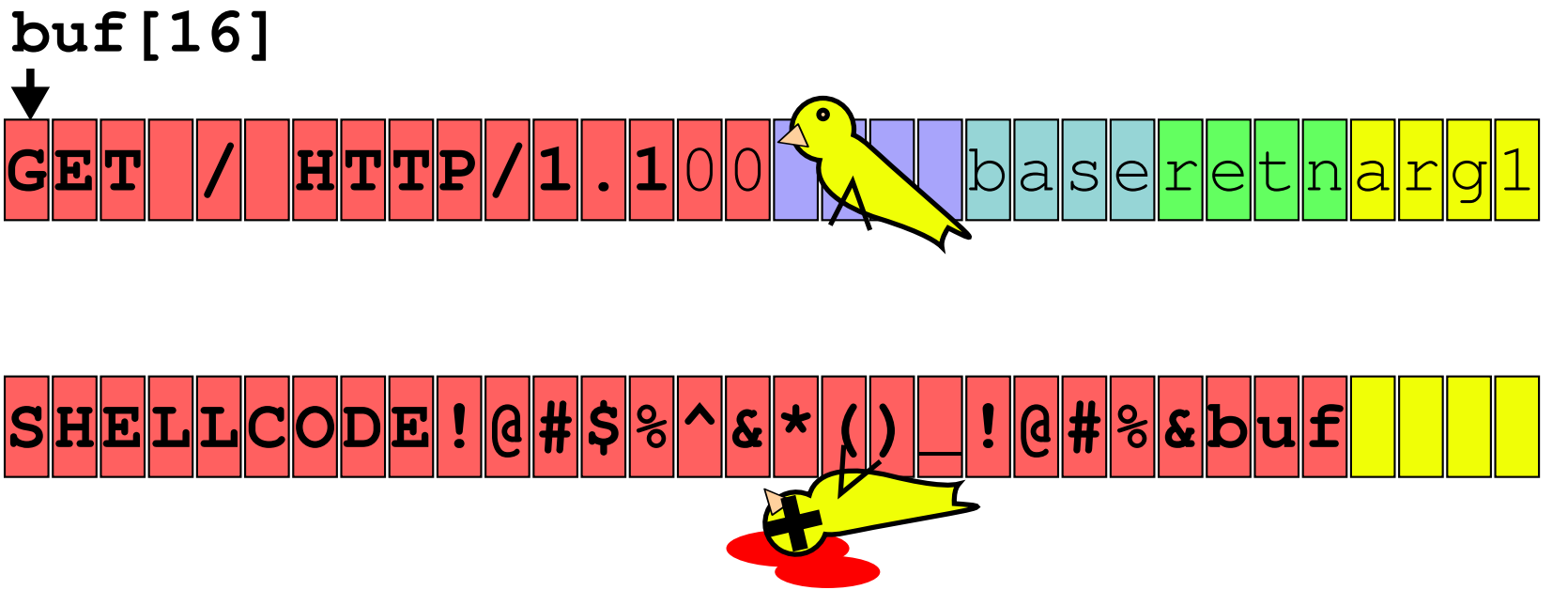
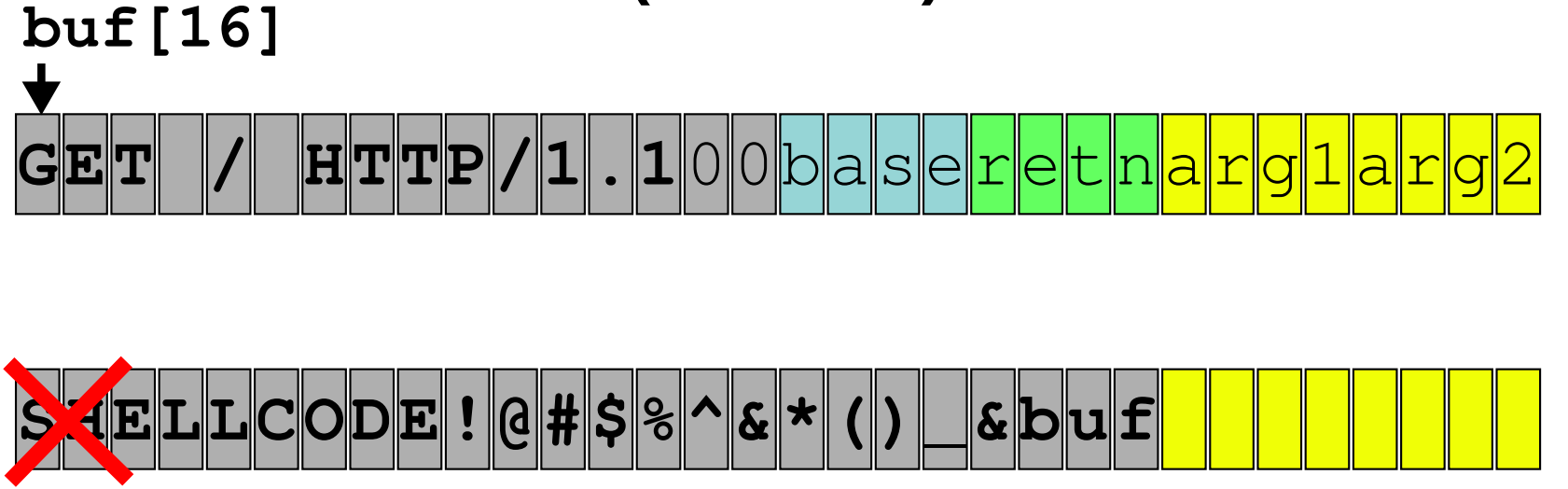
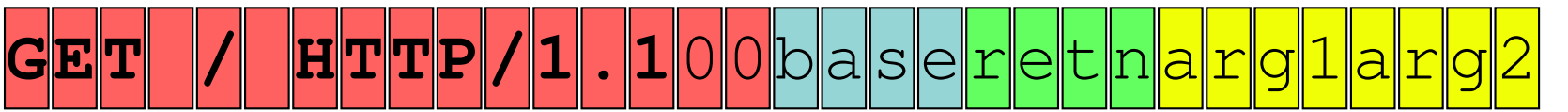


Non-executable data (DEP / NX)



Fortify Source

```
char buf[16];
memcpy(buf, r->buf, r->len);
```



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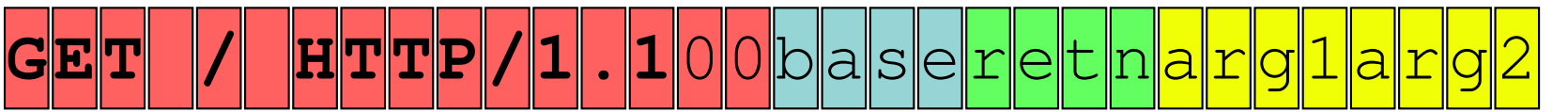
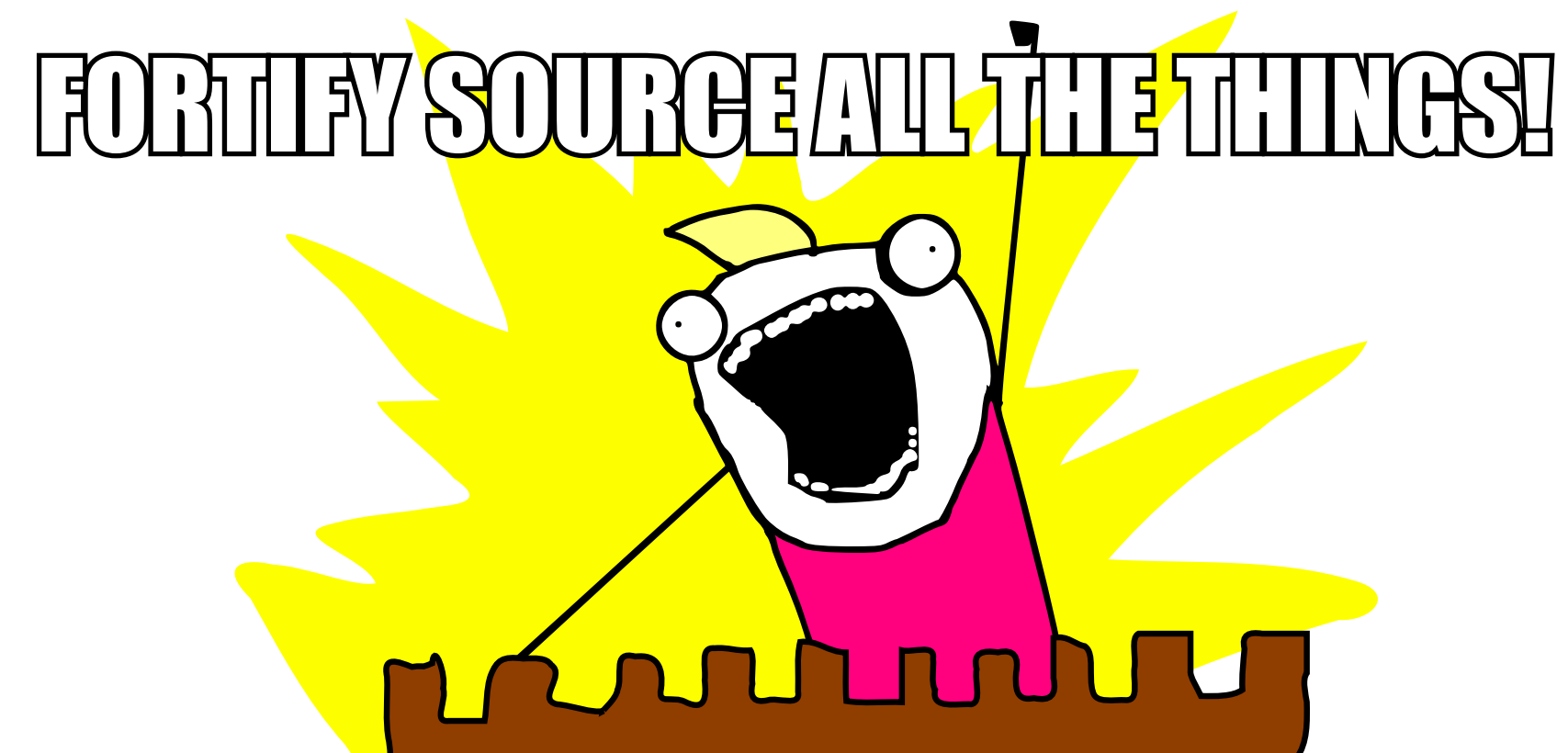


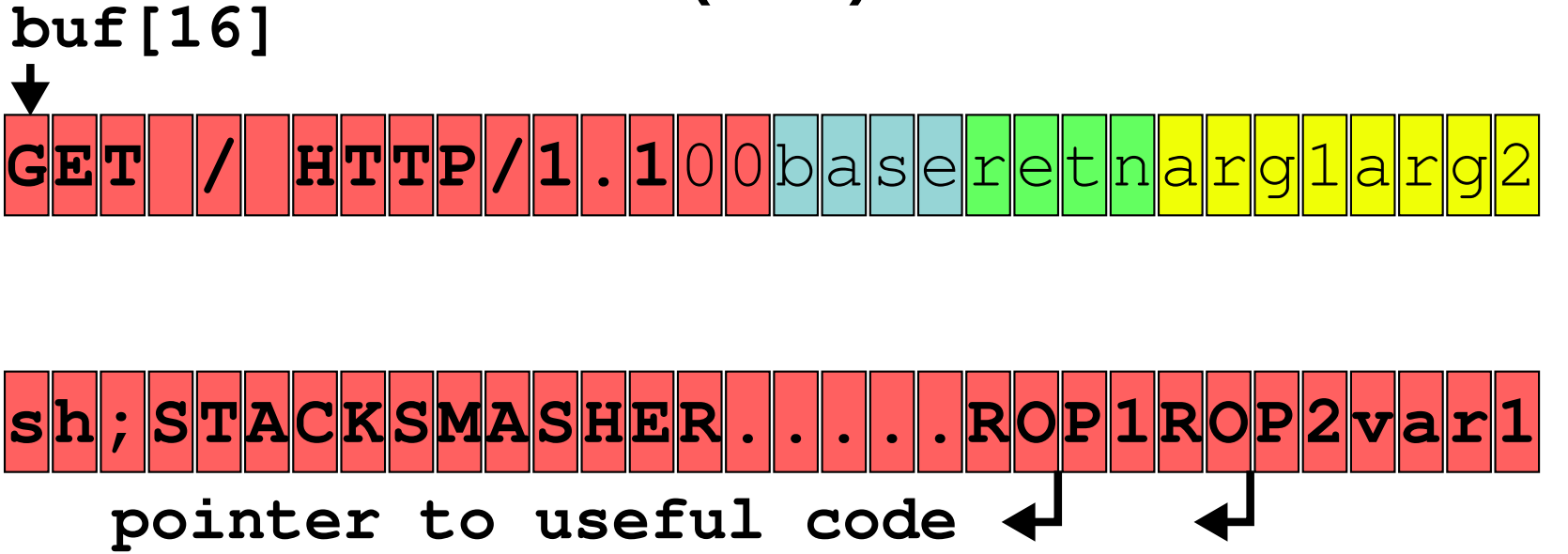

```
char buf[16];
memcpy_chk(buf, r->buf, r->len, 16);
```

```
*** buffer overflow detected ***: /my/fortified/binary terminated
======= Backtrace: =========
/lib/i386-linux-gnu/i686/cmov/libc.so.6(__fortify_fail+0x50)[0xb774a4d0]
/lib/i386-linux-gnu/i686/cmov/libc.so.6(+0xe040a)[0xb774940a]
/my/fortified/binary[0x8048458]
/lib/i386-linux-gnu/i686/cmov/libc.so.6(__libc_start_main+0xe6)[0xb767fe46]
/my/fortified/binary[0x8048371]
======= Memory map: ========
08048000-08049000 r-xp 00000000 fe:00 282465     /my/fortified/binary
08049000-0804a000 rw-p 00000000 fe:00 282465     /my/fortified/binary
08600000-08621000 rw-p 00000000 00:00 0          [heap]
b764b000-b7667000 r-xp 00000000 fe:00 131602     /lib/i386-linux-gnu/libgcc_s.so.1
b7667000-b7668000 rw-p 0001b000 fe:00 131602     /lib/i386-linux-gnu/libgcc_s.so.1
b7668000-b7669000 rw-p 00000000 00:00 0
...

Aborted
```


FORTIFY SOURCE ALL THE THINGS!

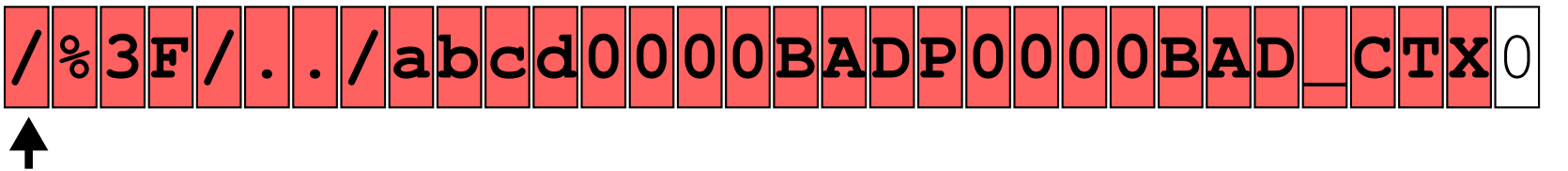
Return Oriented Programming (ROP)



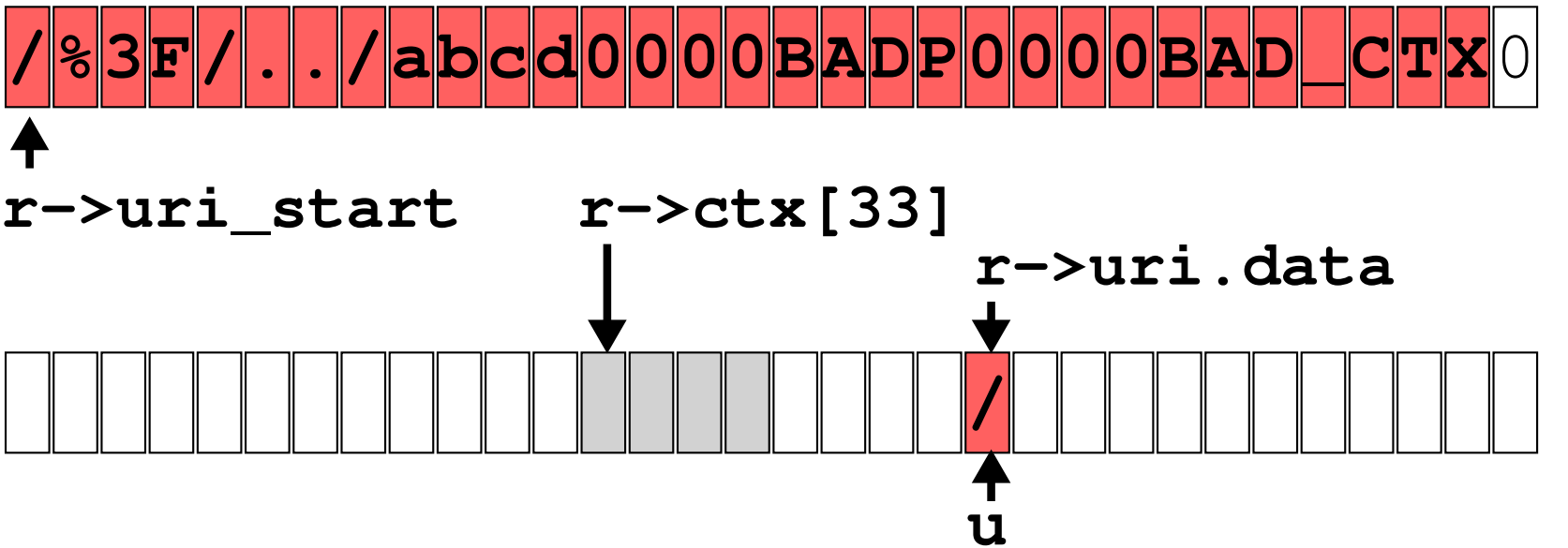
Some exploits still work with all these defense measures.

Example: nginx buffer underrun (CVE-2009-2629)

CVE-2009-2629



CVE-2009-2629



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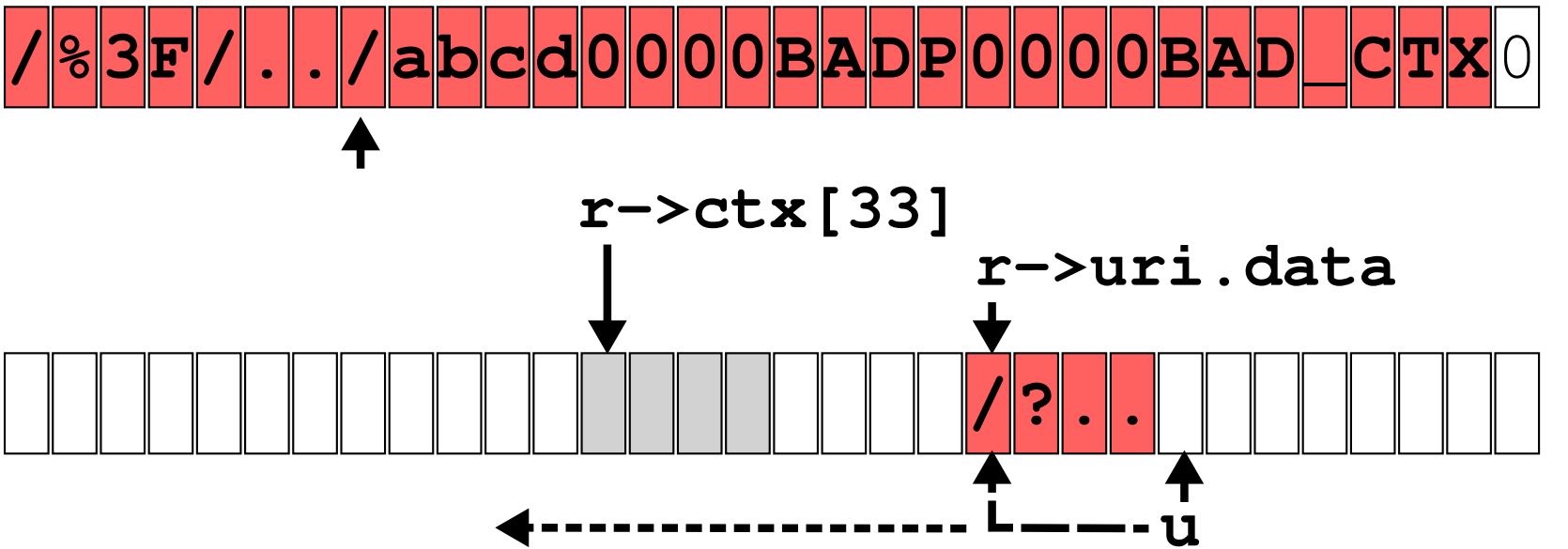

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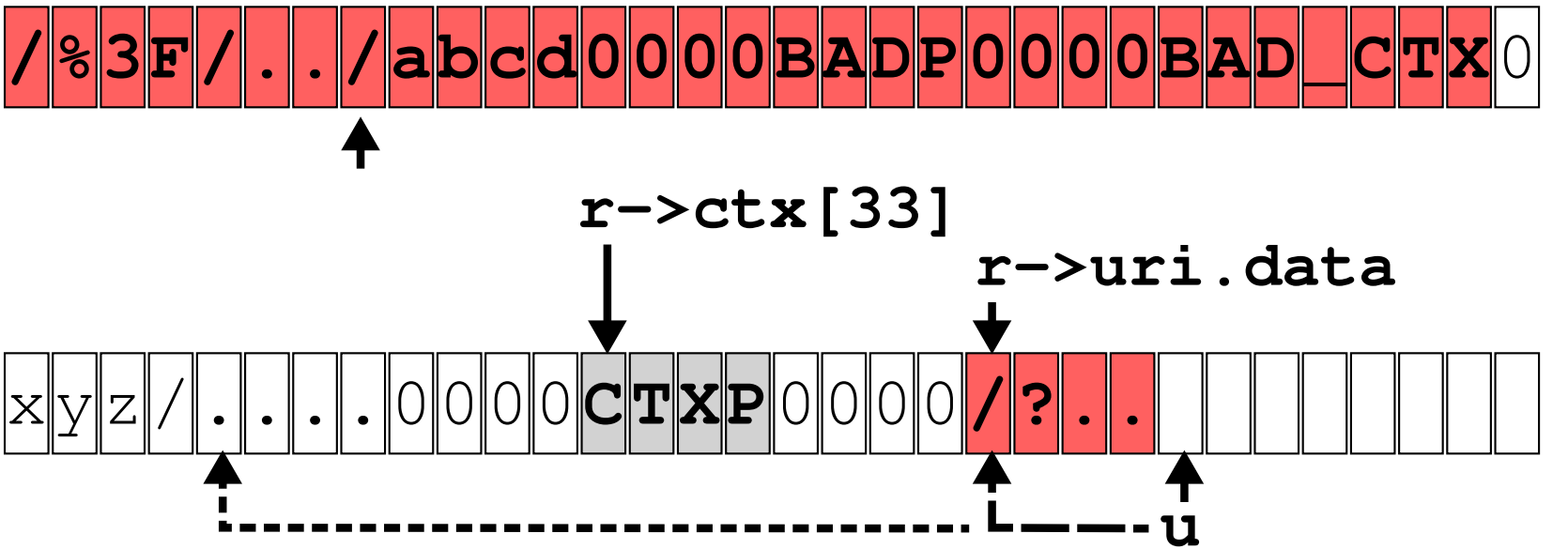

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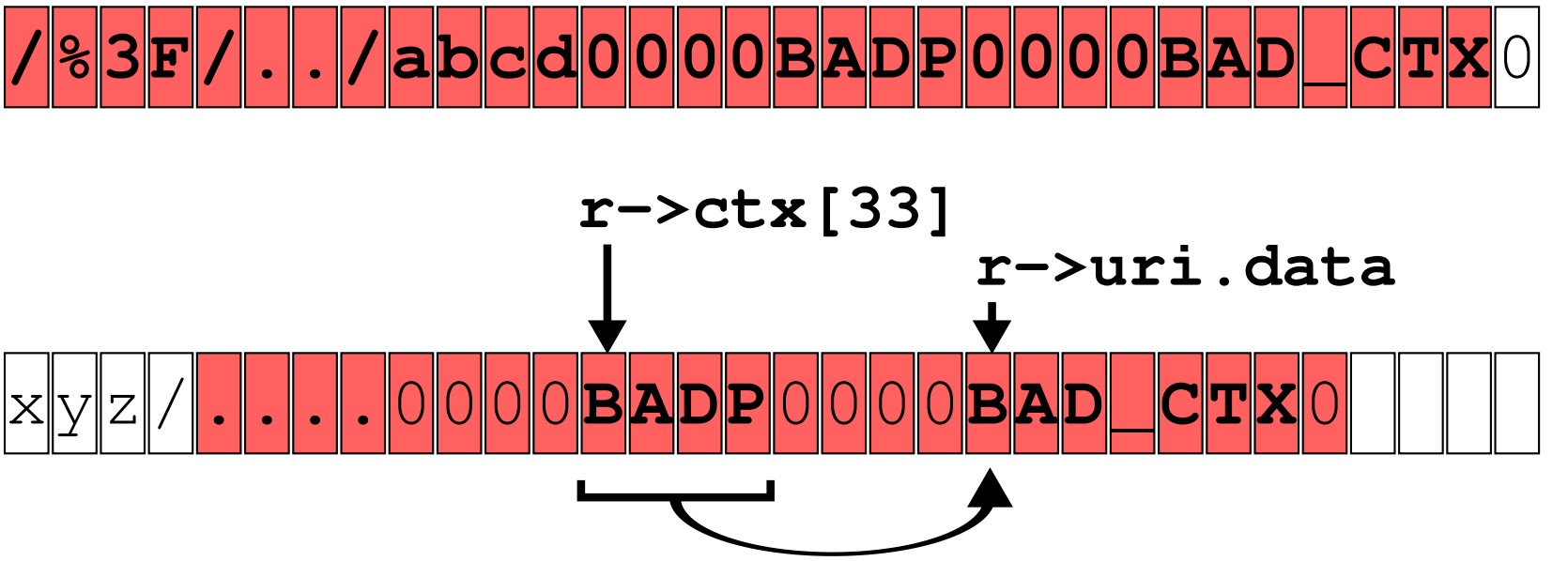

```
typedef struct {
    ngx_buf_t                    *buf;
    ngx_chain_t                  *in;
    ngx_chain_t                  *free;
    ngx_chain_t                  *busy;

    unsigned                      sendfile;
    unsigned                      need_in_memory;
    unsigned                      need_in_temp;

    ngx_pool_t                   *pool;
    ngx_int_t                     allocated;
    ngx_bufs_t                    bufs;
    ngx_buf_tag_t                 tag;

    ngx_output_chain_filter_pt    output_filter;
    void                         *filter_ctx;
} ngx_output_chain_ctx_t;
```

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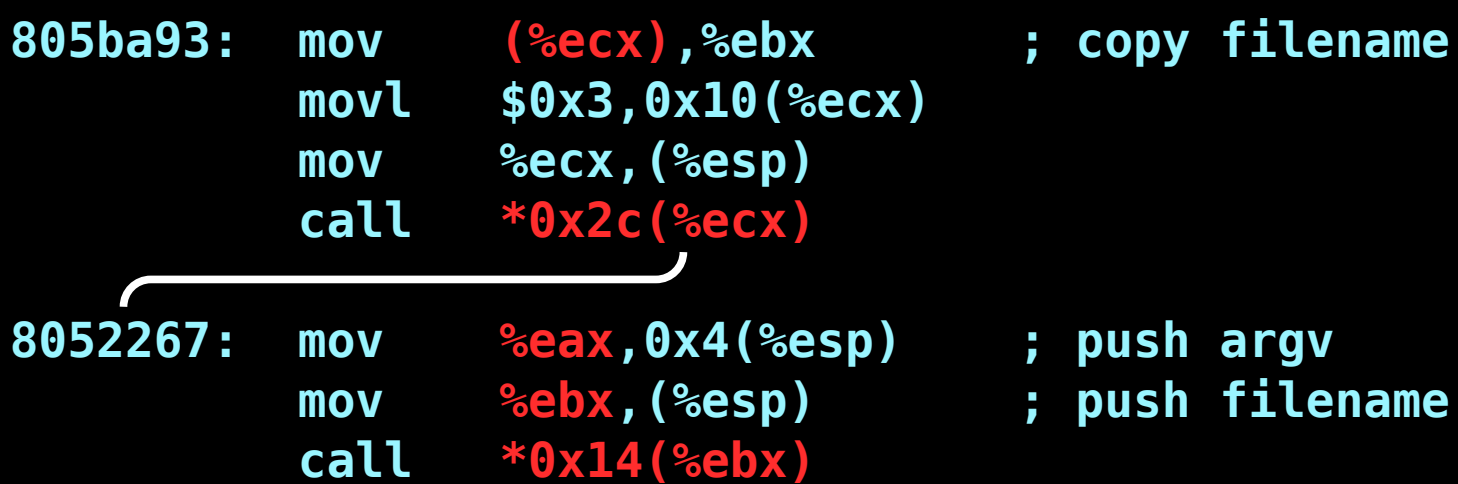
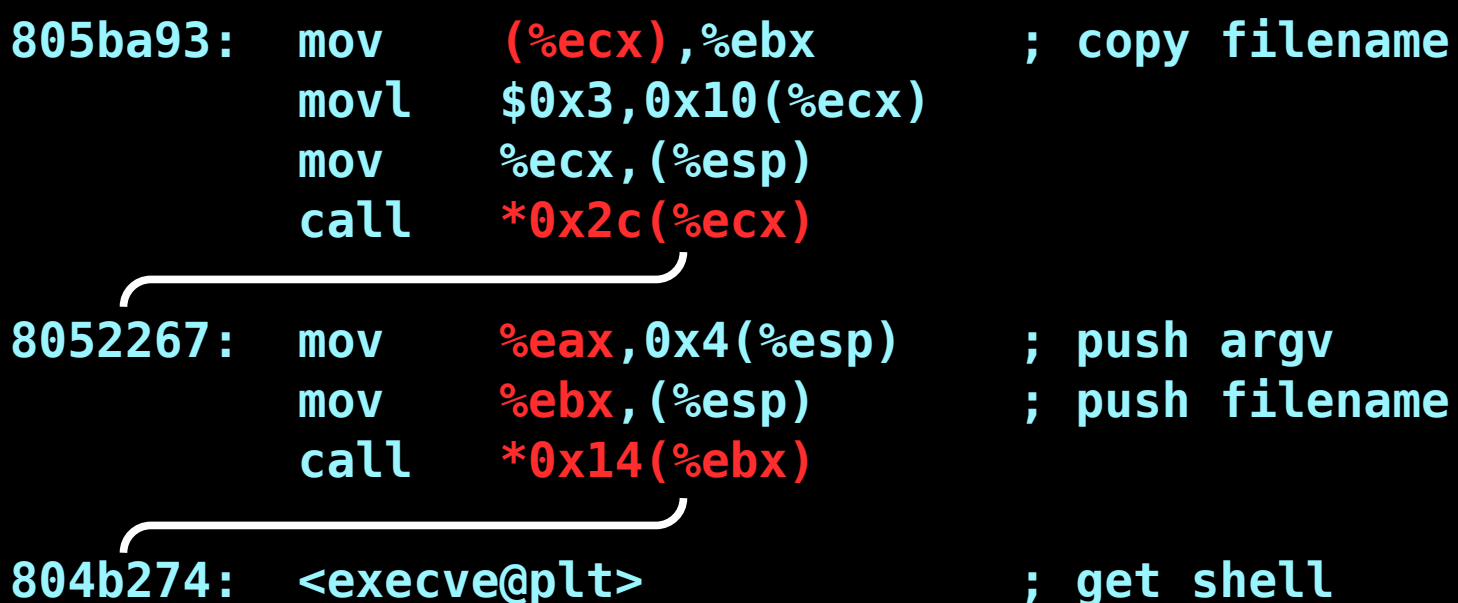
```

function pointer

```
805ba93:  mov    (%ecx),%ebx          ; copy filename
          movl   $0x3,0x10(%ecx)
          mov    %ecx,(%esp)
          call   *0x2c(%ecx)
```


805ba93: mov (%ecx),%ebx ; copy filename
movl $0x3,0x10(%ecx)
mov %ecx,(%esp)
call *0x2c(%ecx)
8052267: mov %eax,0x4(%esp) ; push argv
mov %ebx,(%esp) ; push filename
call *0x14(%ebx)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mov %ebx,(%esp) ; push filename
call *0x14(%ebx)
804b274: <execve@plt> ; get shell

- defeats address randomisation (through info leak)

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- not return oriented, so stack smash protection does not matter

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- needs to be enabled at compile time, and
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- many packages do not apply these defence mechanisms even today

- implementation flaws

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<< Return oriented programming replaces untrusted code with pointers to original code.

>> Can we prevent untrusted pointers from being used as jump addresses?

Taint analysis

```
0805be60   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   |................|
0805be70   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   |................|
0805be80   00 00 00 00 02 00 00 00  d8 4b 06 08 a0 2e 05 08   |.........K......|
0805be90   94 be 05 08 78 a0 04 08  ef be ad de a4 be 05 08   |....x...........|
0805bea0   ac be 05 08 2f 62 69 6e  2f 73 68 00 a4 be 05 08   |..../bin/sh.....|
0805beb0   00 00 00 00 53 41 4d 45  54 48 49 4e 47 57 45 44   |....SAMETHINGWED|
0805bec0   4f 45 56 45 52 59 4e 49  47 48 54 50 49 4e 4b 59   |OEVERYNIGHTPINKY|
0805bed0   00 00 00 00 4e 41 52 46  90 be 05 08 ef 1f 05 08   |....NARF........|
0805bee0   ff fa 26 08 ff f0 00 00  00 00 00 00 00 00 00 00   |..&.............|
0805bef0   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   |................|
0805bf00   00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   |................|
```

Taint tracking (1/2):

- remember whether data is trusted or not
- untrusted data is 'tainted'
- when data is copied, its taint is copied along
- taint is ORed for arithmetic operations

Taint tracking (2/2):

When the code jumps to an address in memory,
the source of this address is checked for taint.

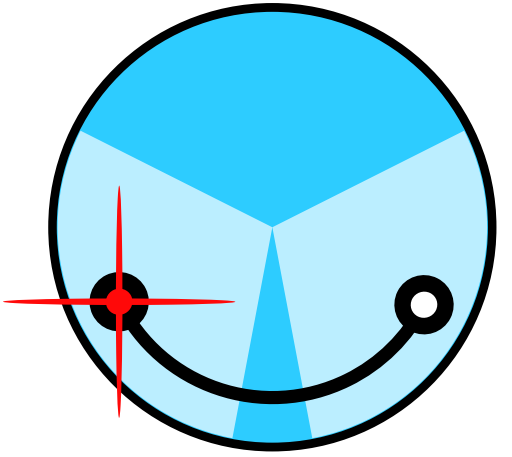
eg.:
- RET
- CALL *%eax
- JMP *0x1c(%ebx)


photo: colinbrown on flickr (cc-by 2.0)

Taint tracking

useful, but slow as hell

Is this slowness fundamental?



minemu

fast emulator
memory layout
use SSE registers to hold taint

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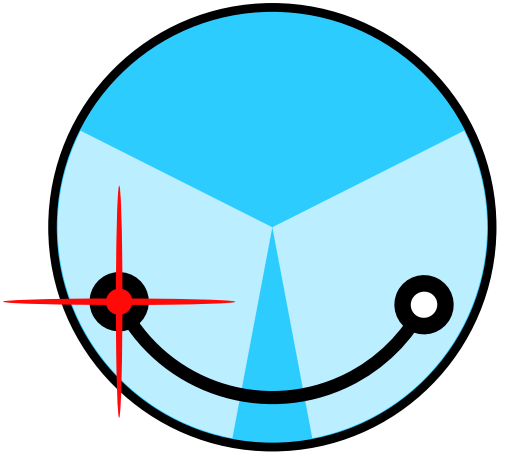

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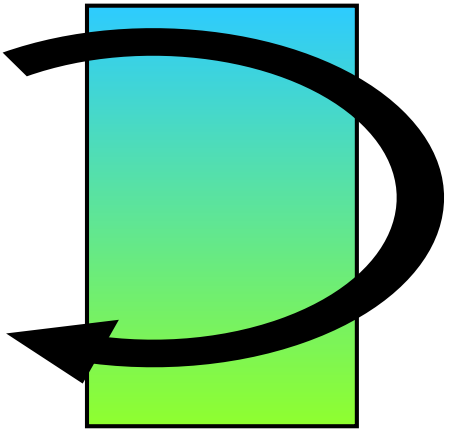
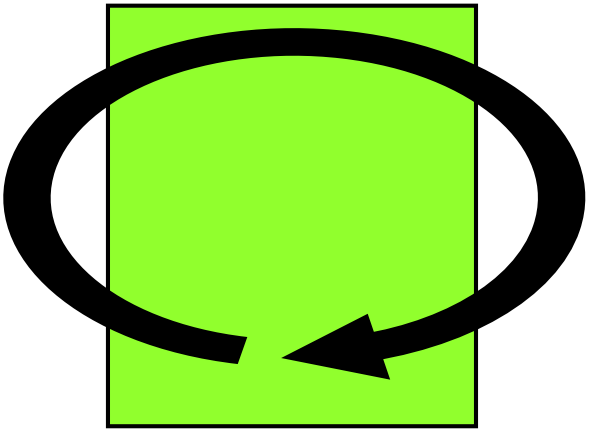
Emulator

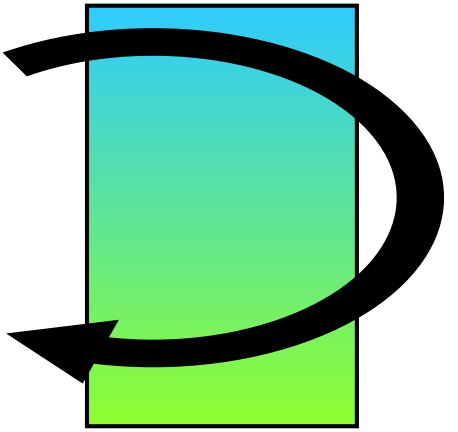


compile jit code

Emulator



run jit code



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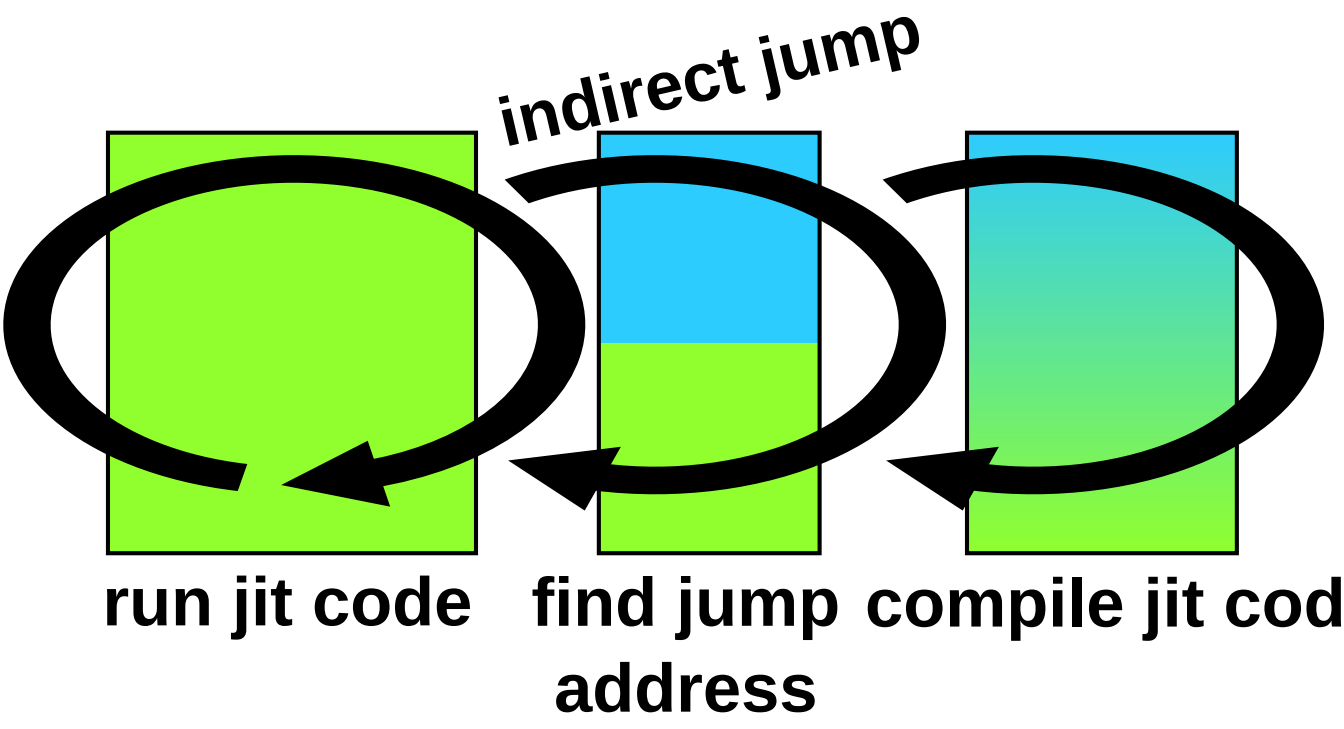
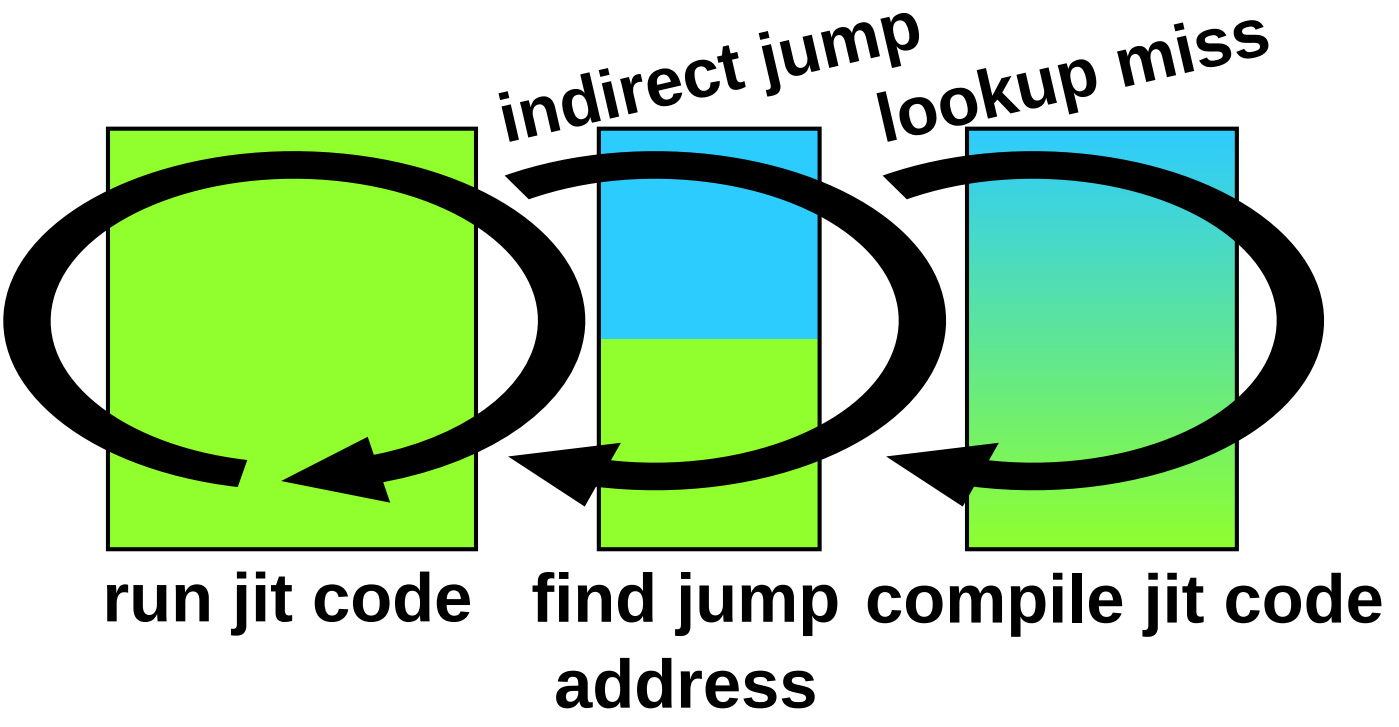
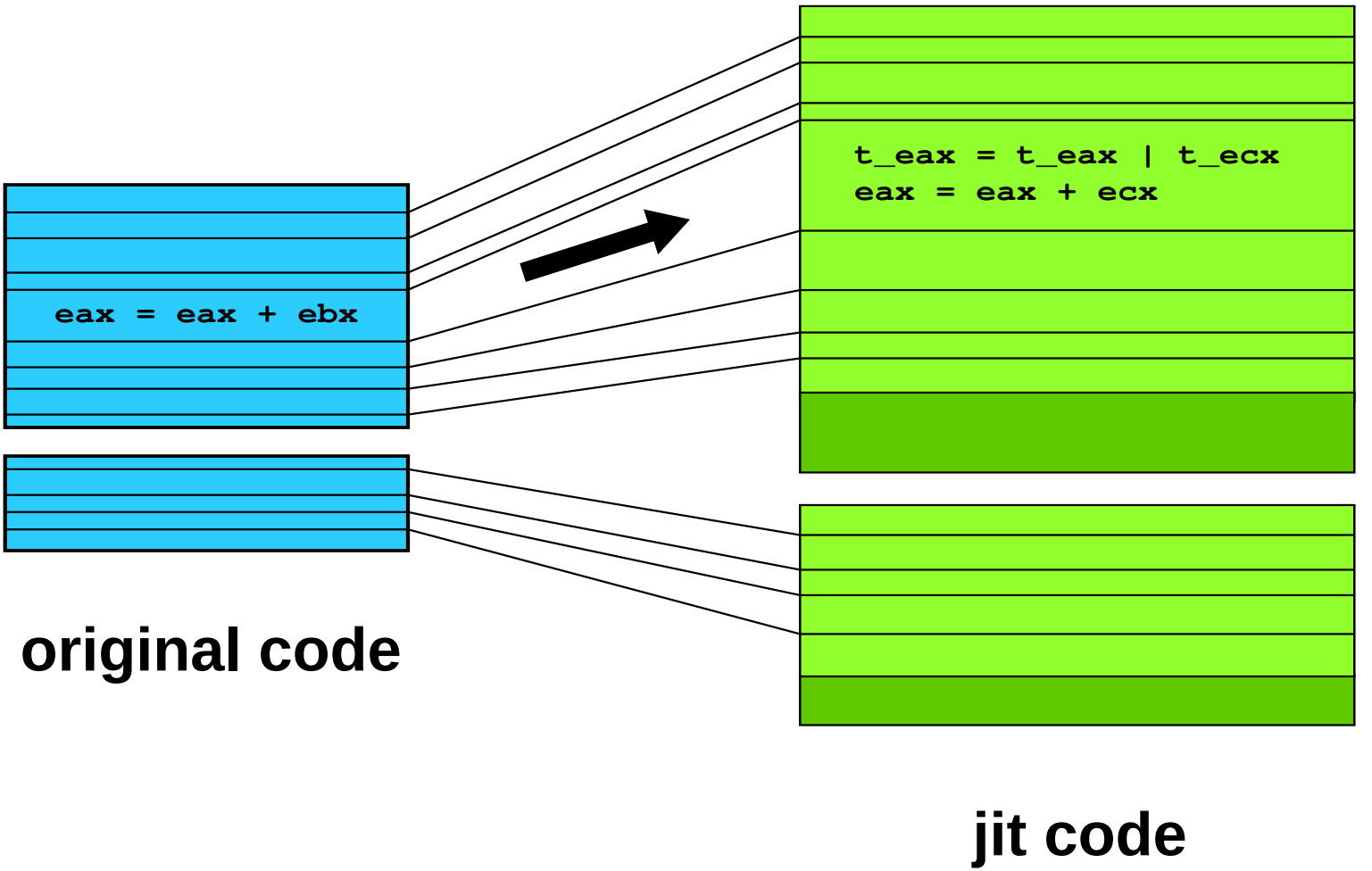

indirect jump
run jit code
find jump address
compile jit code

Emulator


indirect jump
lookup miss
run jit code
find jump address
compile jit code

Dynamic instrumentation



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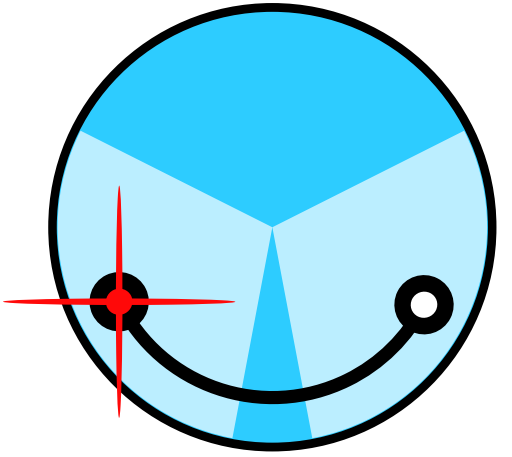

minemu

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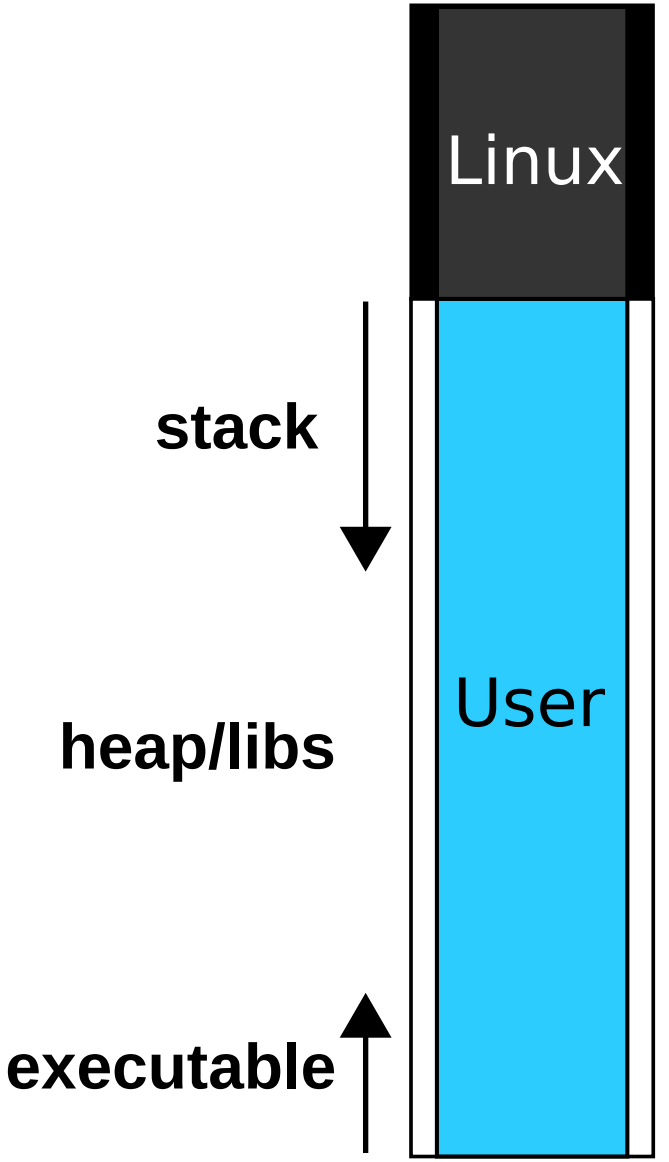
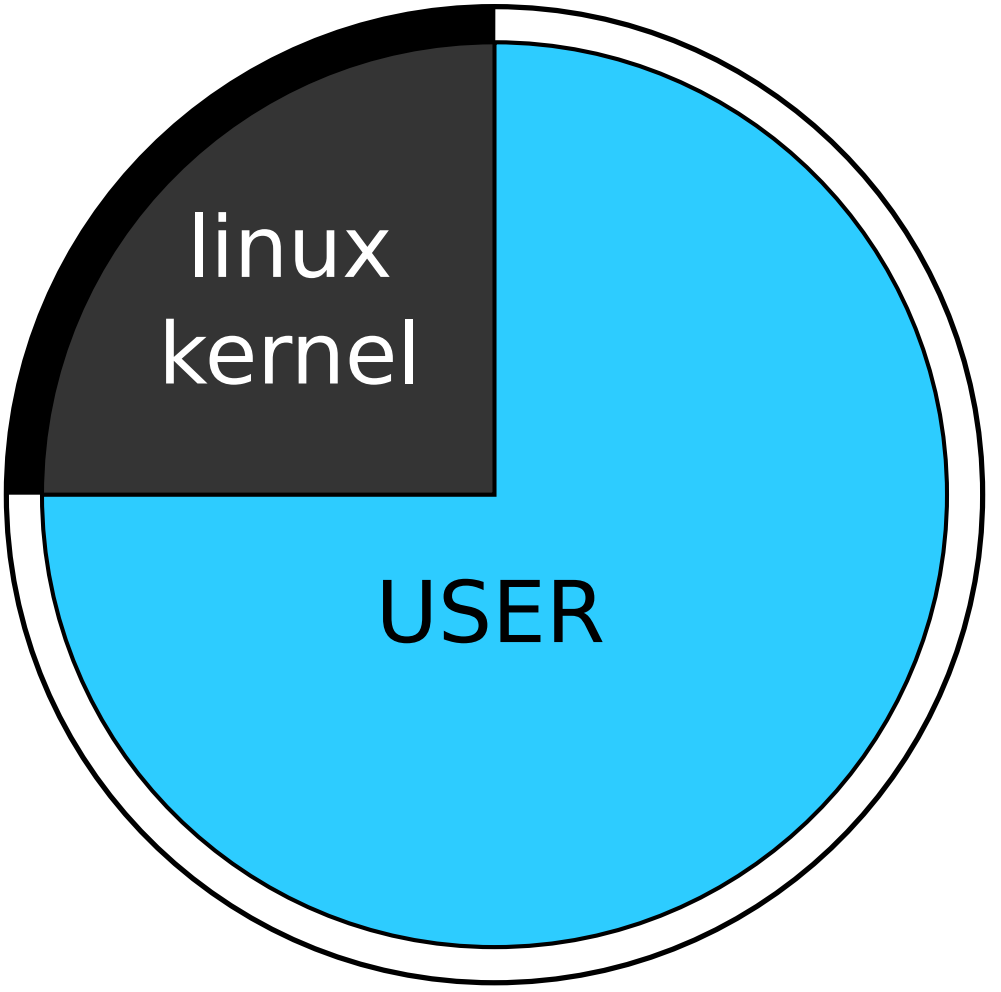
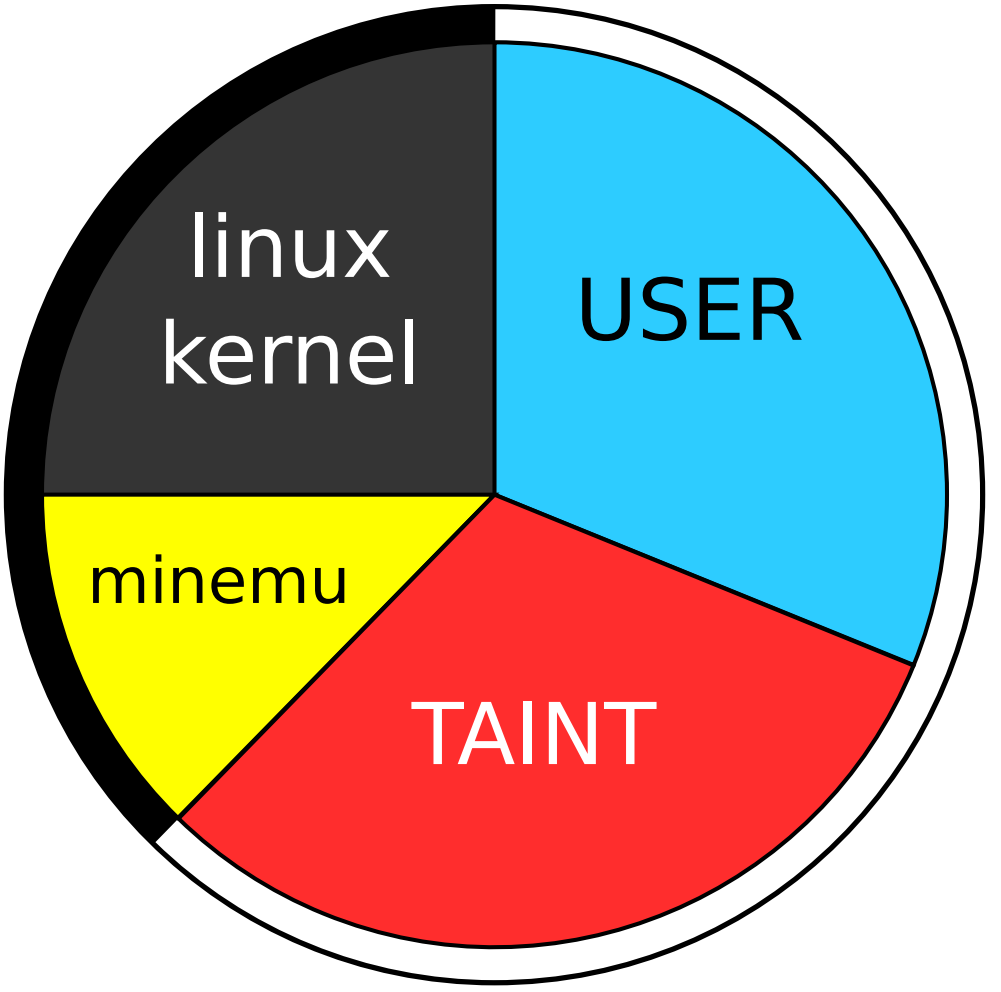
- memory layout
- use SSE registers to hold taint


Linux
stack
User
heap/libs
executable

Memory layout (linux)



Memory layout (minemu)



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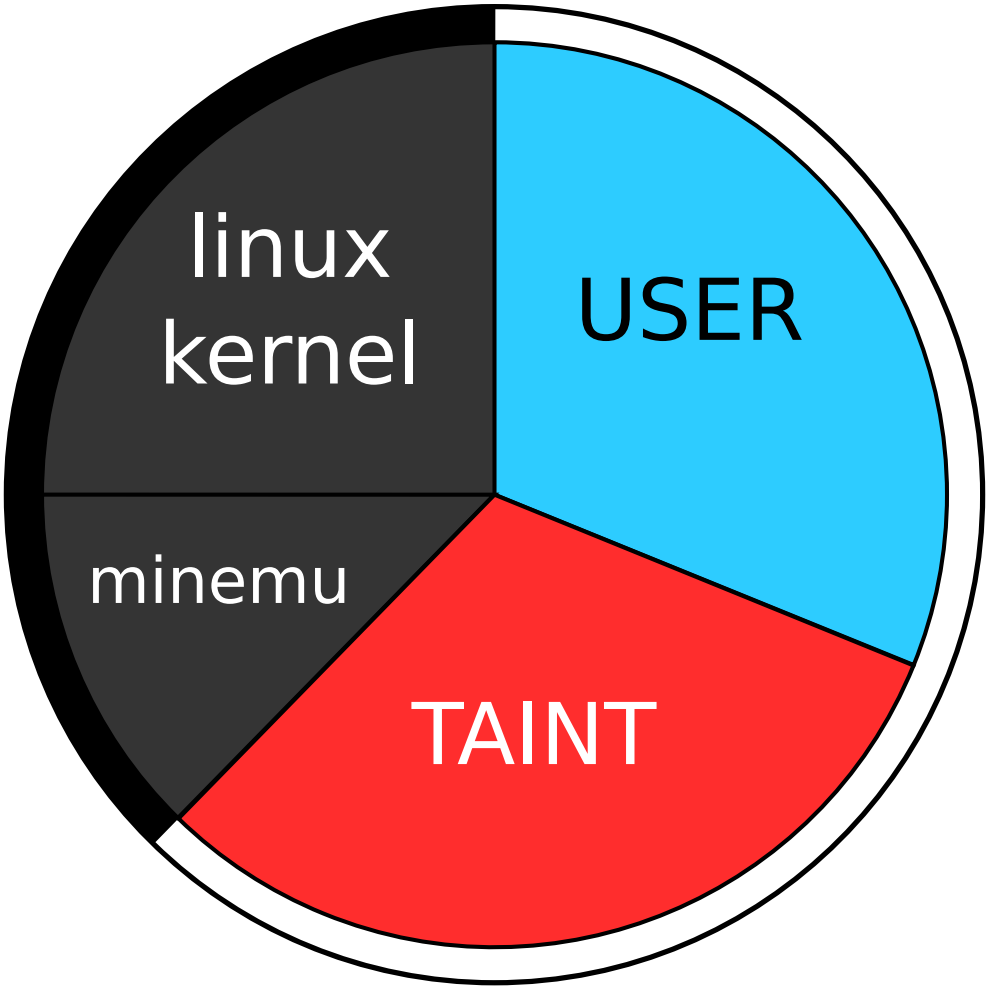

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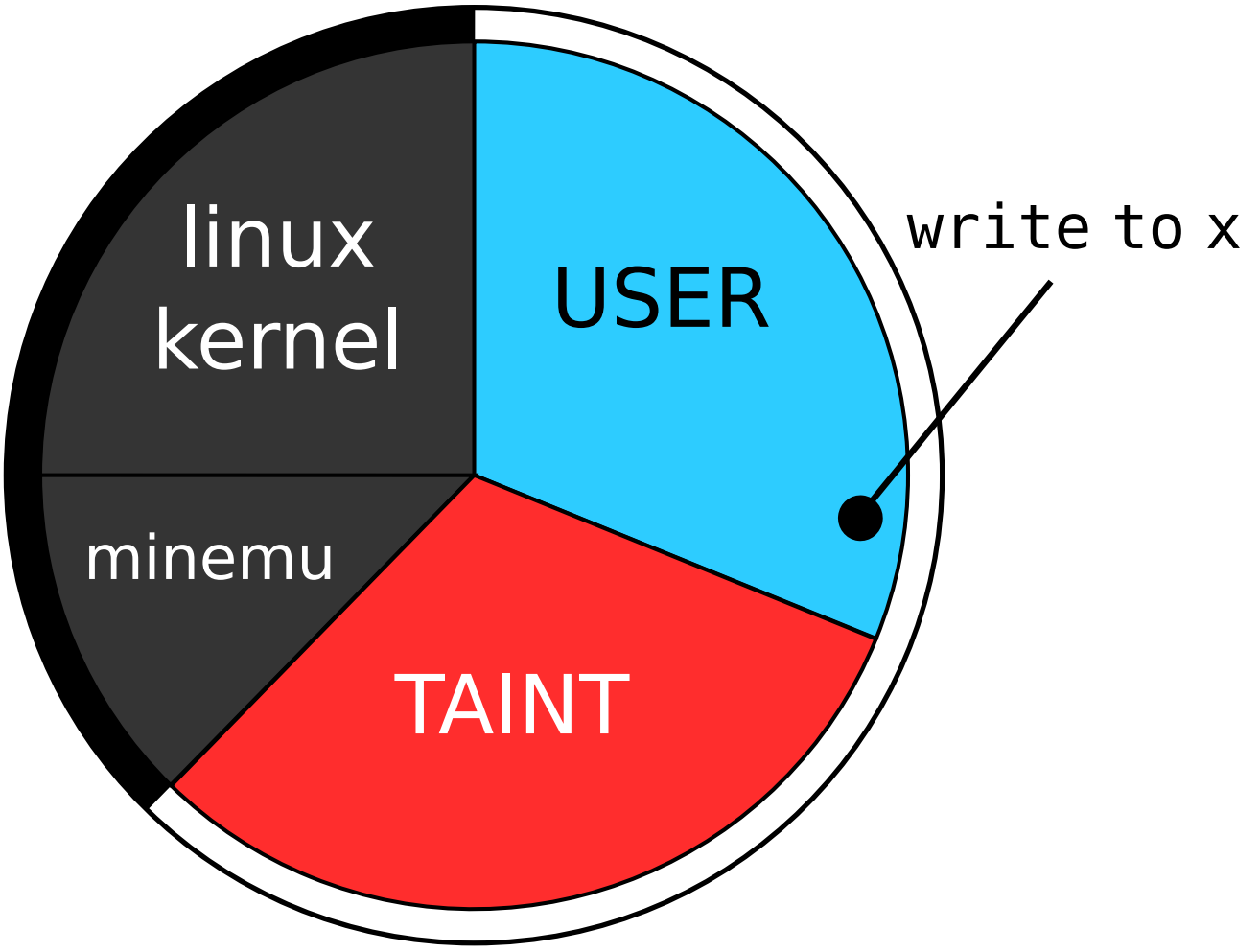

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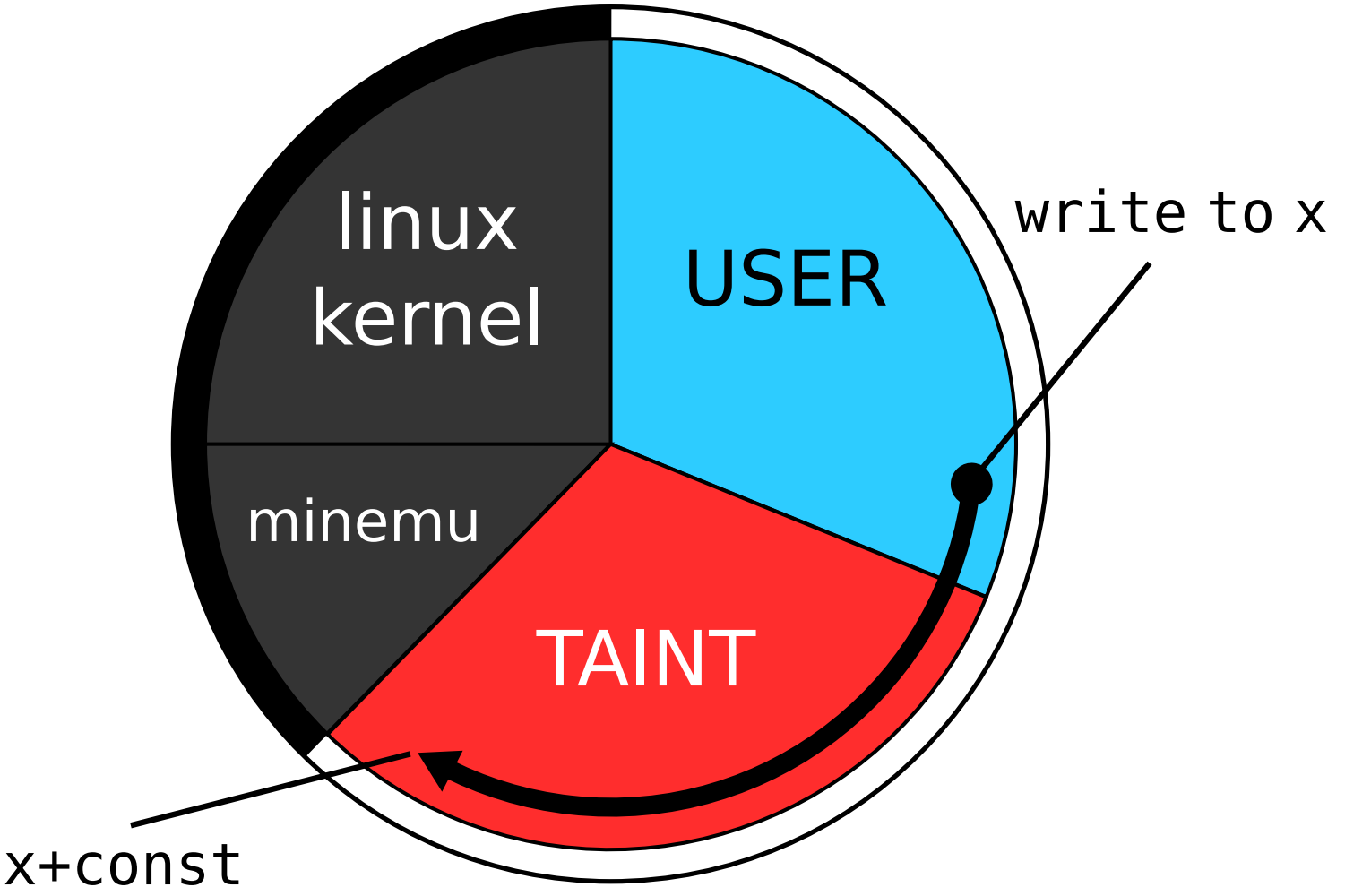

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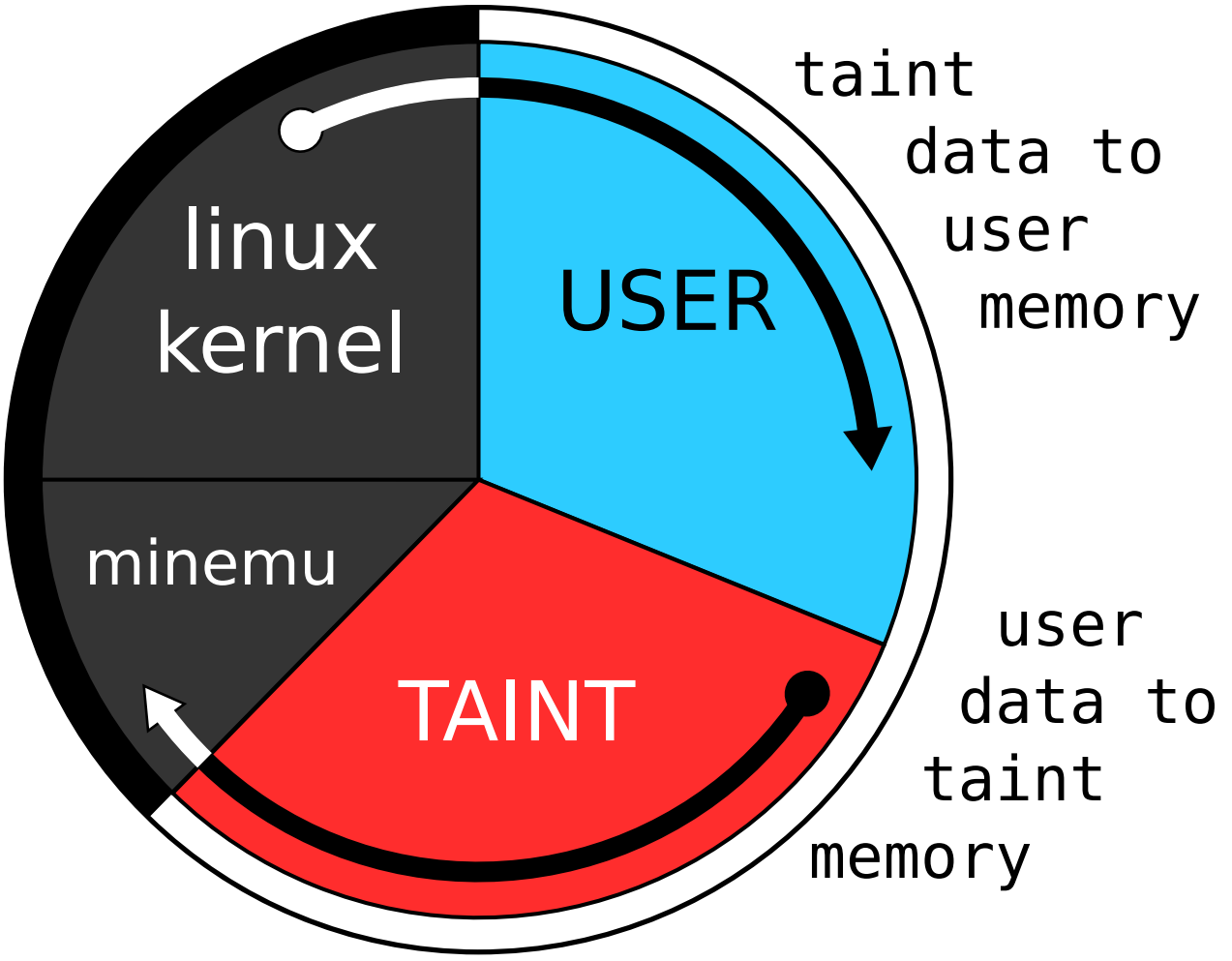

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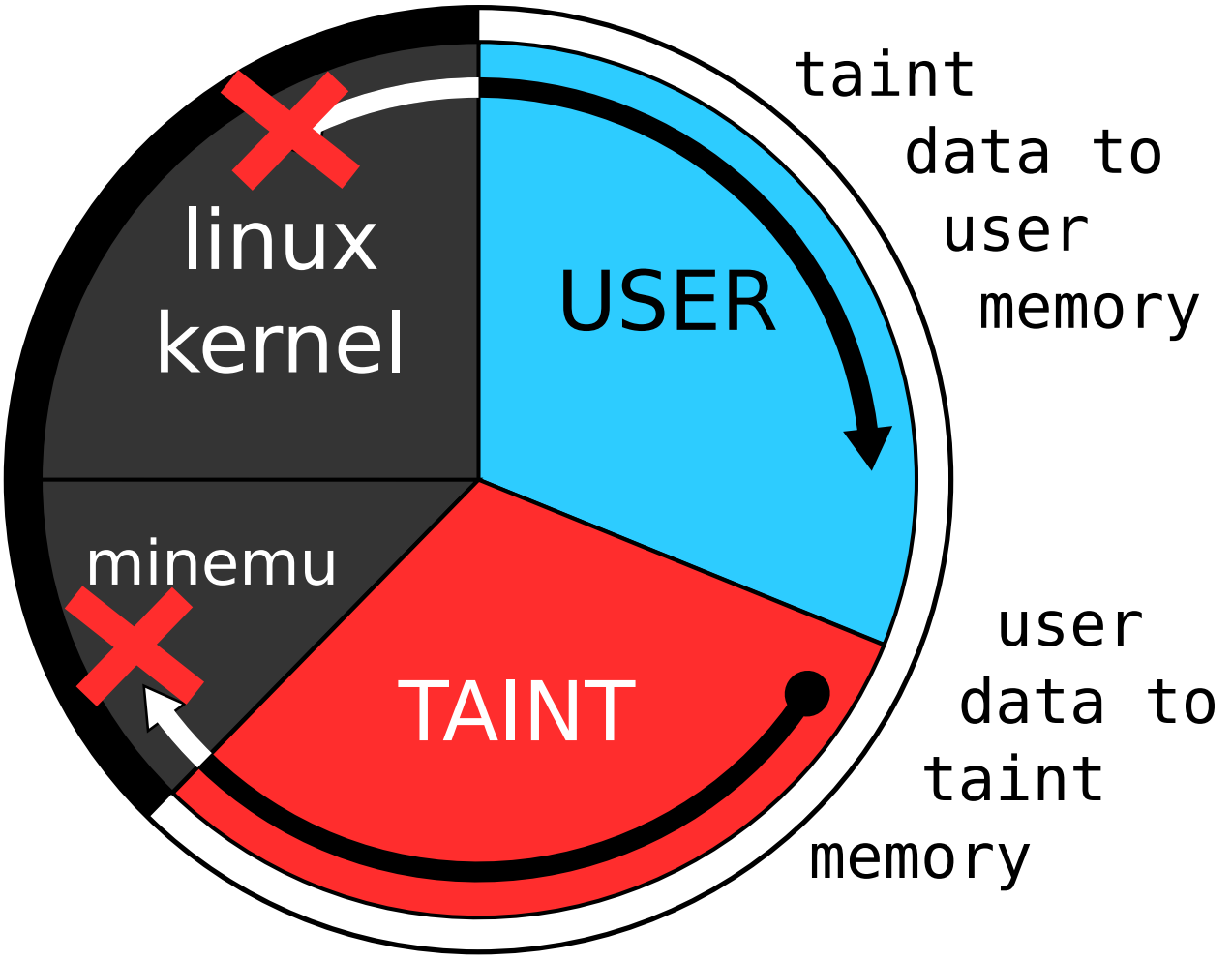

Addressing shadow memory

```
mov EAX, (EDX)
```

Addressing shadow memory

```
mov EAX, (EDX)

address:

    EDX
```

Addressing shadow memory

```
mov EAX, (EDX)

address:

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taint:

    EDX+const
```

Addressing shadow memory

```
mov EAX, (EDX+EBX*4)
```

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address:

    EDX+EBX*4
```

Addressing shadow memory

```
mov EAX, (EDX+EBX*4)

address:

    EDX+EBX*4

taint:

    EDX+EBX*4+const
```

Addressing shadow memory

```
push ESI
```

Addressing shadow memory

```
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address:

    ESP
```

Addressing shadow memory

```
push ESI

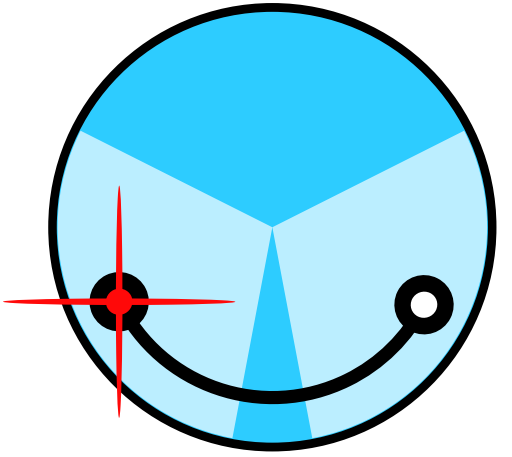
address:

    ESP

taint:

    ESP+const
```

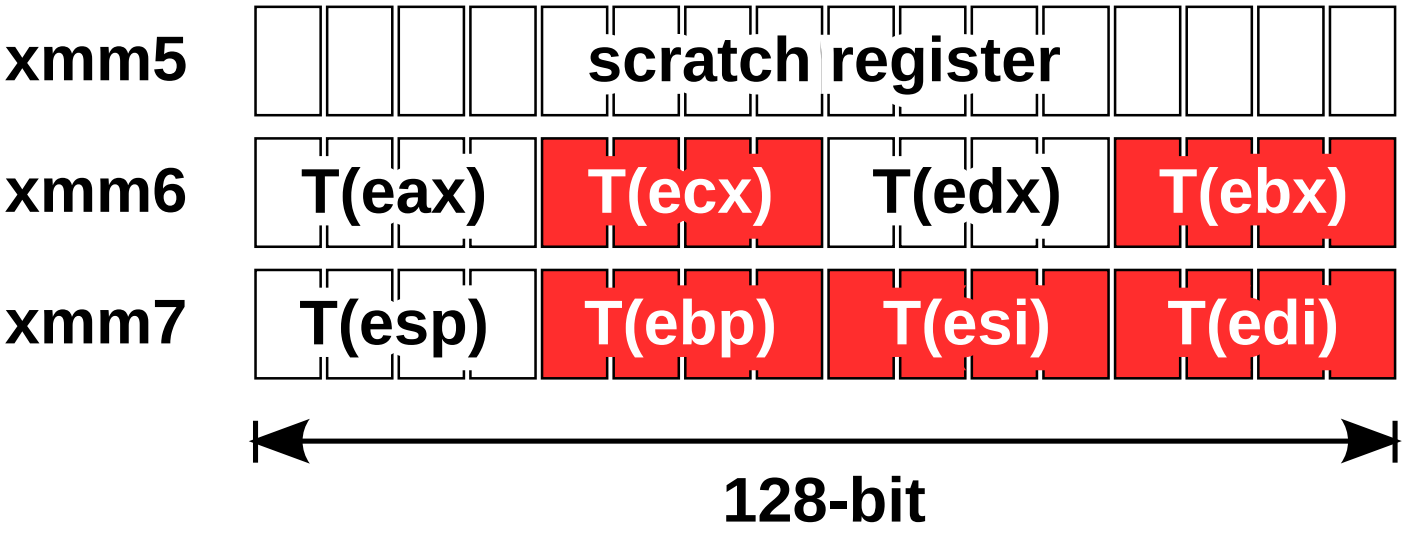
Is this slowness fundamental?



minemu

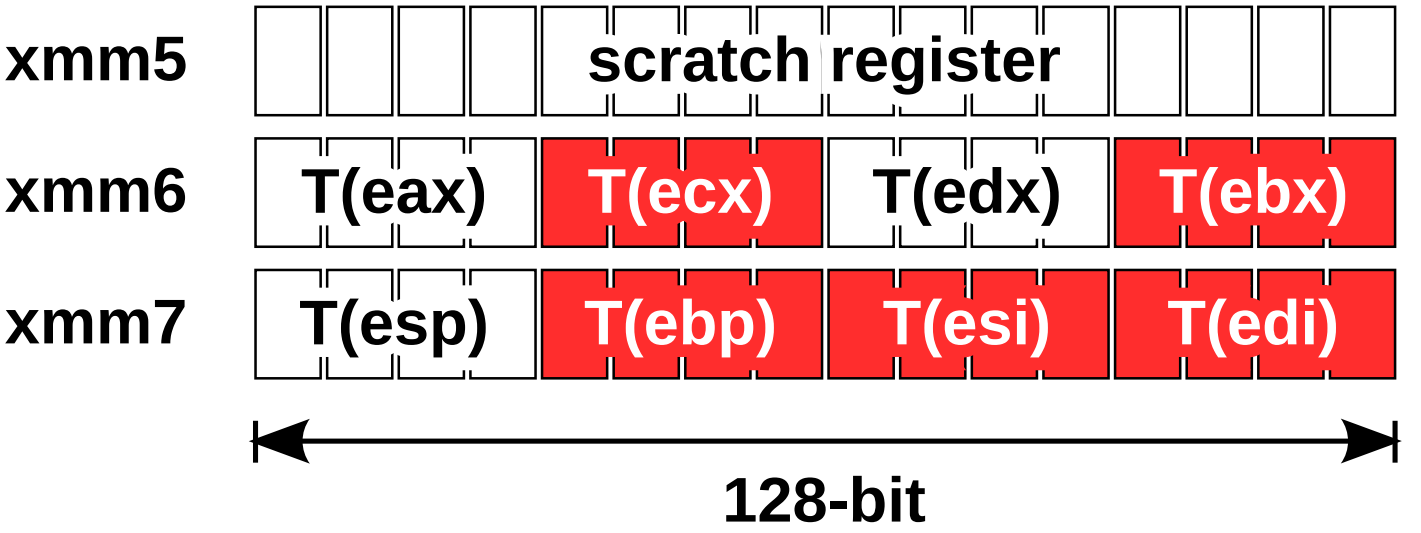
- fast emulator
- memory layout
- use SSE registers to hold taint

Taint propagation in SSE registers



Taint propagation in SSE registers

```
add EDX, x
```



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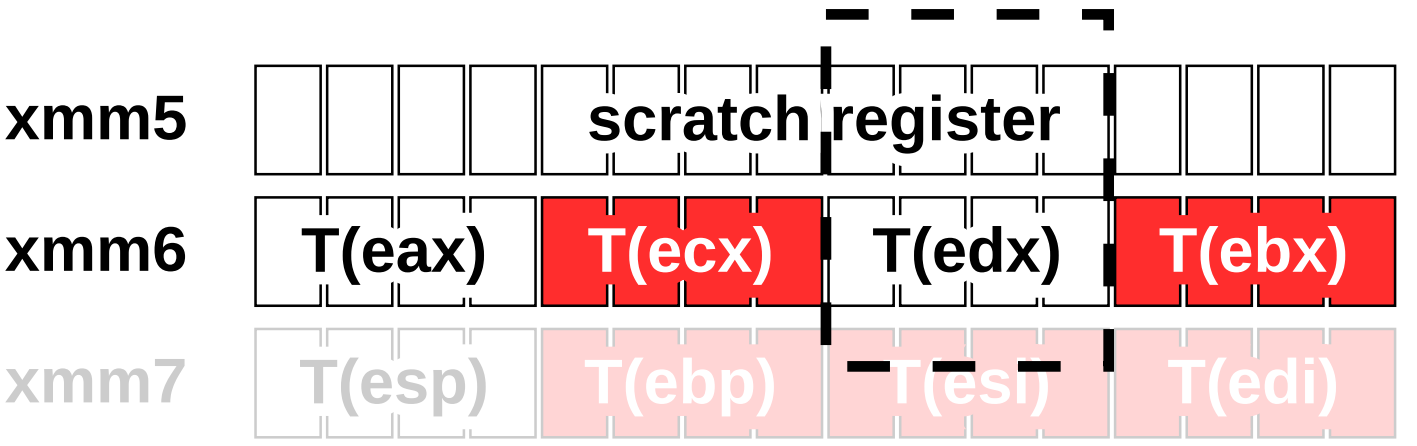
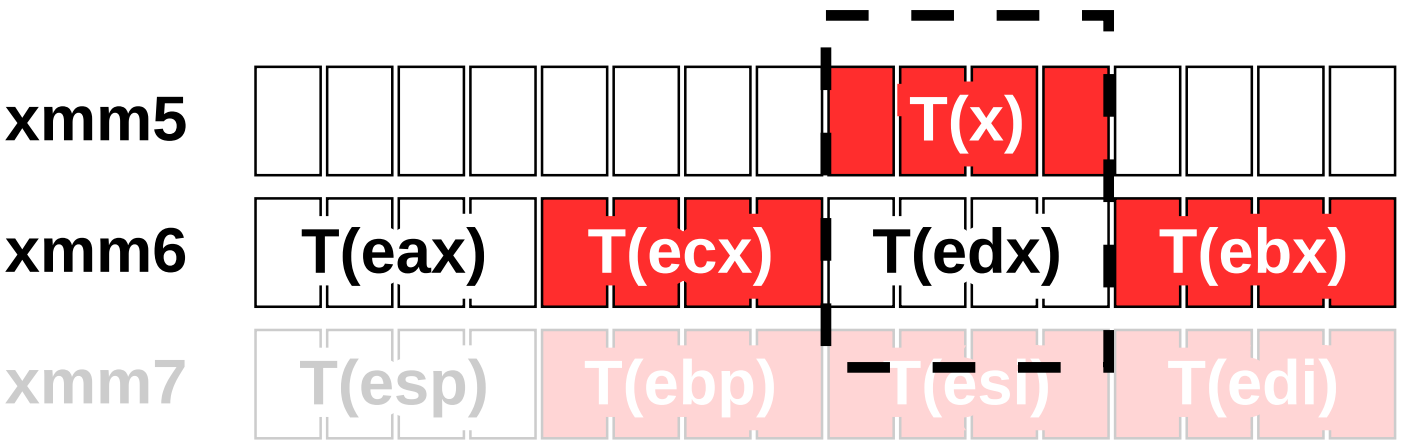


Taint propagation in SSE registers

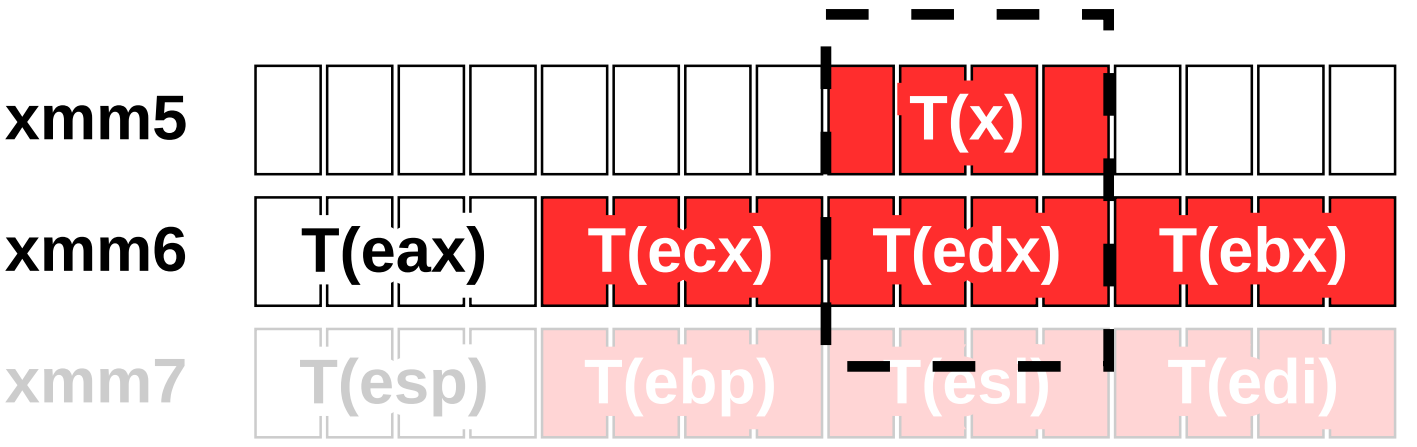
`add EDX, x`



`vector insert`

Taint propagation in SSE registers

`add EDX, x`

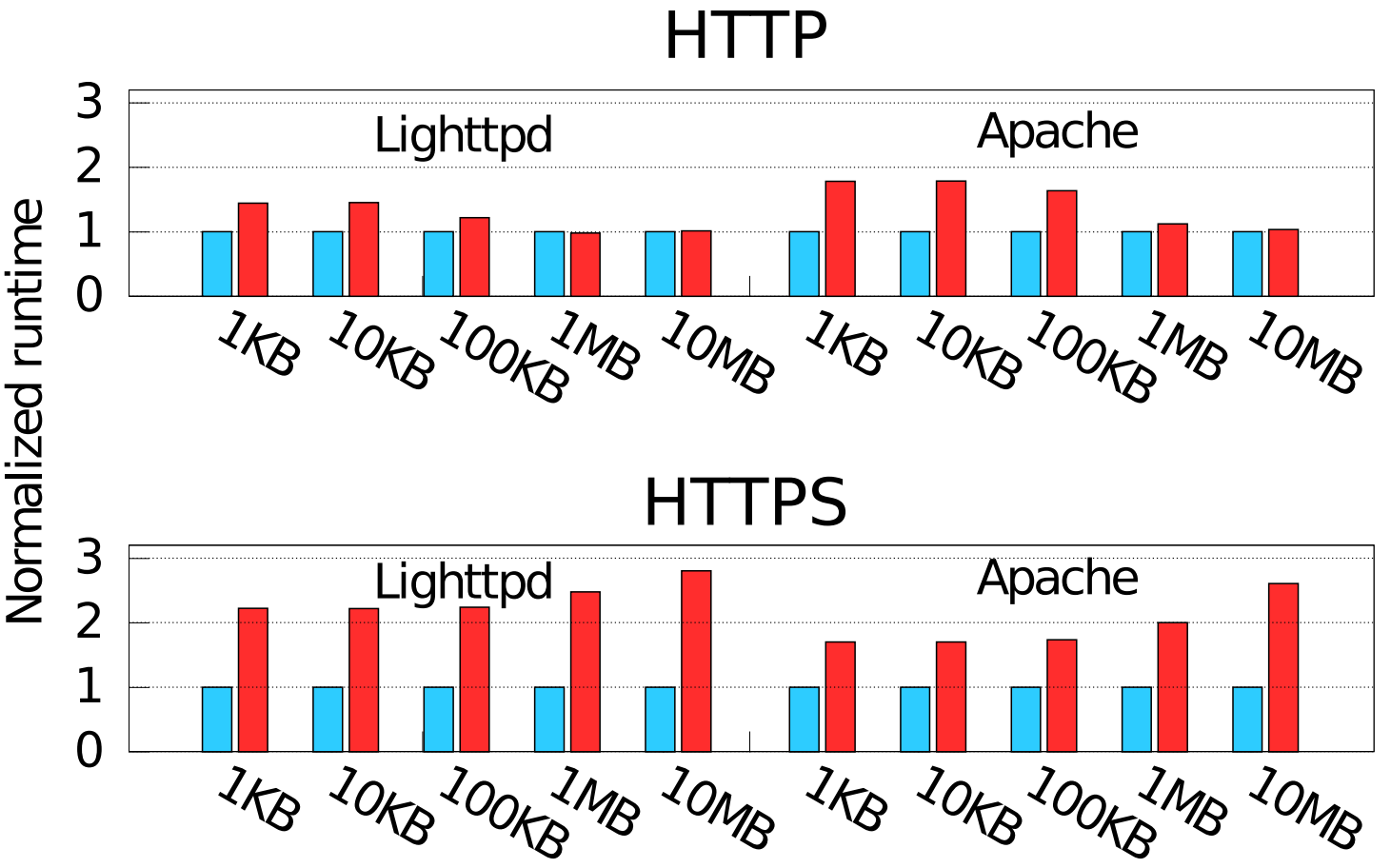


or

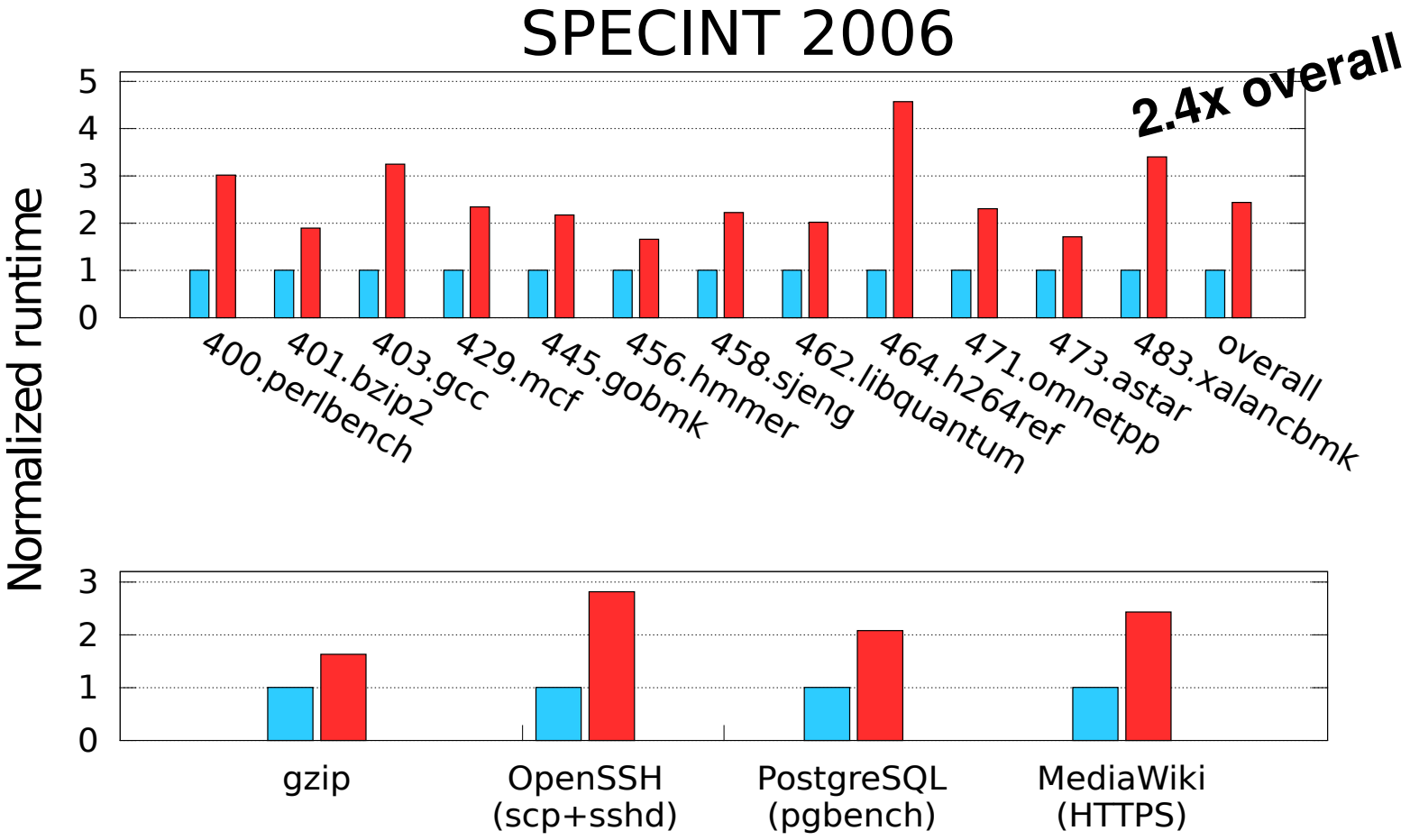
Effectiveness

Application	Type of vulnerability	Security advisory
Snort 2.4.0	Stack overflow	CVE-2005-3252
Cyrus imapd 2.3.2	Stack overflow	CVE-2006-2502
Samba 3.0.22	Heap overflow	CVE-2007-2446
Memcached 1.1.12	Heap overflow	CVE-2009-2415
Nginx 0.6.32	Buffer underrun	CVE-2009-2629
Proftpd 1.3.3a	Stack overflow	CVE-2010-4221
Samba 3.2.5	Heap overflow	CVE-2010-2063
Telnetd 1.6	Heap overflow	CVE-2011-4862
Ncompress 4.2.4	Stack overflow	CVE-2001-1413
Iwconfig V.26	Stack overflow	CVE-2003-0947
Aspell 0.50.5	Stack overflow	CVE-2004-0548
Htget 0.93	Stack overflow	CVE-2004-0852
Socat 1.4	Format string	CVE-2004-1484
Aeon 0.2a	Stack overflow	CVE-2005-1019
Exim 4.41	Stack overflow	EDB-ID#796
Htget 0.93	Stack overflow	
Tipxd 1.1.1	Format string	OSVDB-ID#12346

Performance



Performance



Limitations

Limitations

Doesn't prevent memory corruption, only acts when the untrusted data is used for arbitrary code execution.

Limitations

Tainted pointer dereferences

```
tainted_pointer->some_field = useful_untainted_value;
```

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```
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```

propagation can lead to false positives:

```
dispatch_table[checked_input]();
```

Limitations

Taint whitewashing

```
out = latin1_to_ascii[in];
```

Limitations

Format string attacks:

```
printf("%65534s %123$hn"); // Propagates taint in glibc

printf("FillerFiller...%123$hn"); // Does not :-(
```

Limitations

Does not protect against non-control-flow exploits

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```
void try_system(char *username, char *cmd)
{
    int user_rights = get_credentials(username);
    char buf[16] ; strcpy(buf, username);
    if (user_rights & ALLOW_SYSTEM)
        system(cmd);
    else
        log_error("user %s attempted login", buf);
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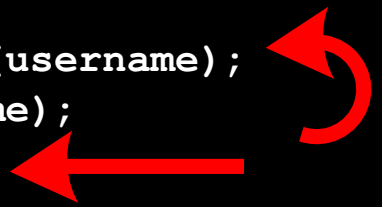

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in some cases we can add validation hooks.

- `mysql_query()` can be hooked to check for taint outside of literals in SQL queries.

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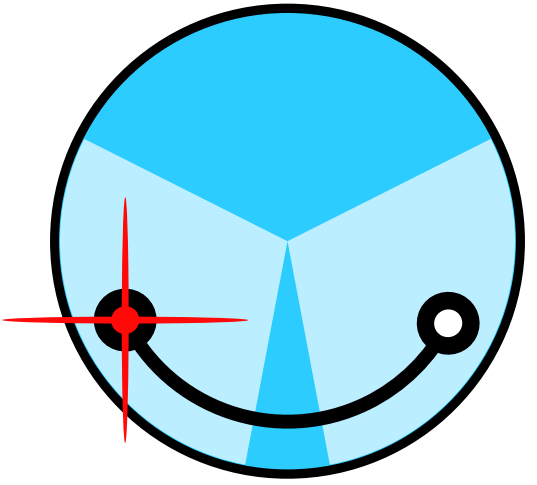
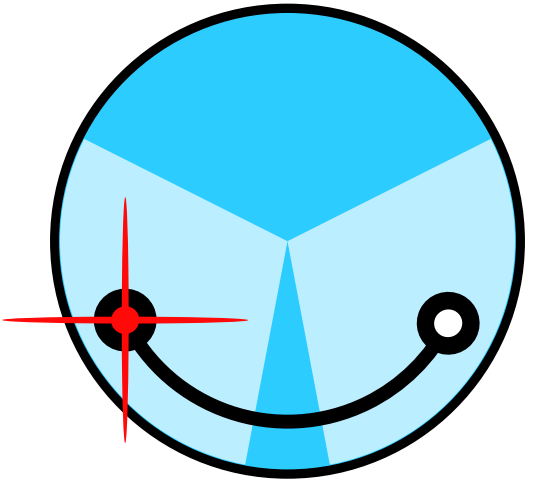
`mysql_query()` can be hooked to check for taint outside of literals in SQL queries.

`_IO_vfprintf()` in glibc can be hooked to check format strings for taint.



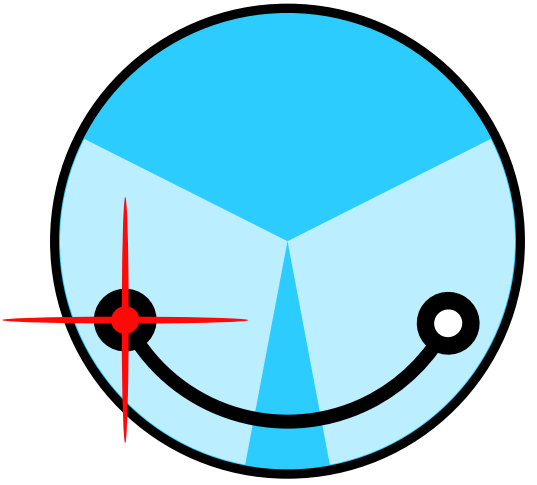
Demo

```
demo@demo:~#  ./minemu bash
```



Minemu

```
git clone https://minemu.org/code/minemu.git
```



Minemu

```
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```

any questions?

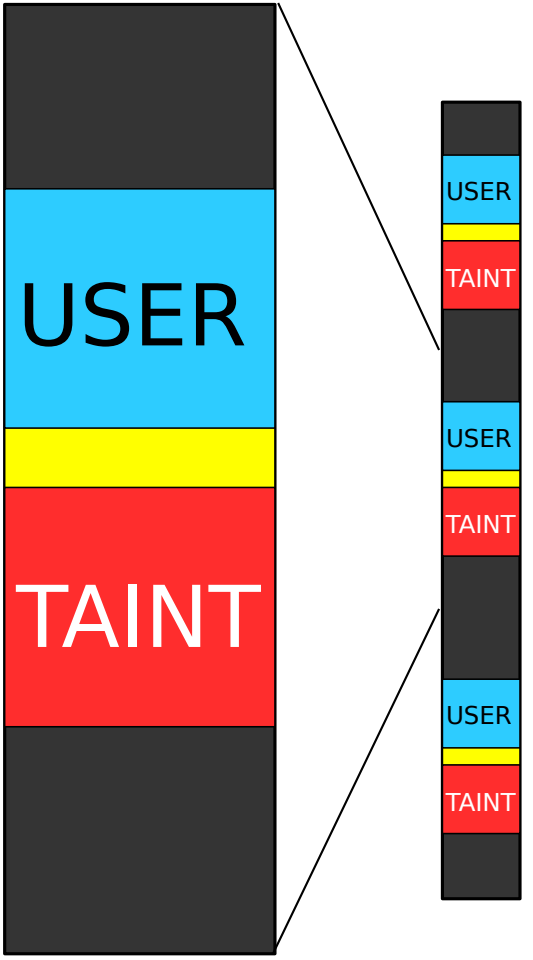
VU VRIJE UNIVERSITEIT AMSTERDAM

```
https://minemu.org/vms/

5f1ee00029e2c68699a7670de7aef02e  minemu-demo.ova
c4ee74155a858676bfb54e1fcfb6db0e  minemu-demo.qcow2
5b8b910c38901f43d406a21fe9767822  minemu-demo.vdi.gz
7ba81ae9d35bfa05a70068a804a331ac  minemu-demo.vmdk.gz
c37acdc455ebac700139f60da621bc38  minemu-demo.xml

minemu needs CPU with SSE 4.1
```

Memory layout (64 bit)



Memory layout (64 bit) alternative