University of BRISTOL

Return Oriented Programming

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The Idea

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- Not the new attacking technique as such!
- Attack vector is different.
- Instead of passing shellcode, generate it.
- You still require to change the control flow => you still need to overflow something to start with!!
- Useful under non-executable stack and W(+)X

The Intuition behind ROP

- Lets visit past
  - Security of information is not new.
  - Internet gave new means of security attacks and thus new measures to address.
  - Cryptography and Steganography are much older techniques.
  - One among the older crypto systems is:

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- The same news paper (book) is available to both.
- There are plenty of sentences and words!!
- The key is the set of offsets of words in a news article.

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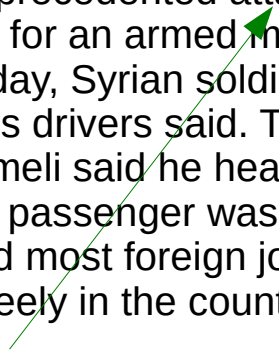

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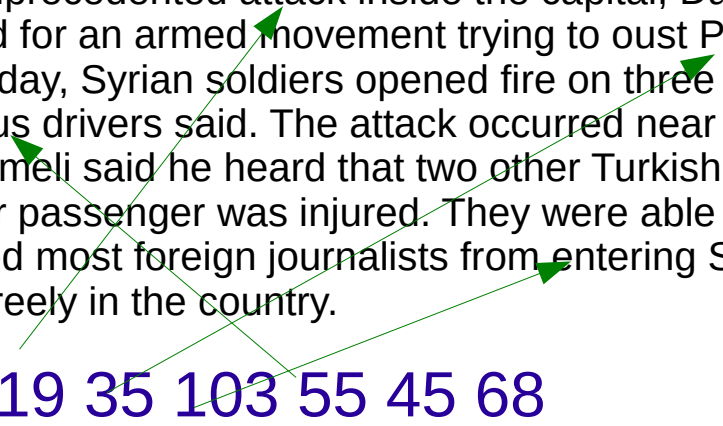

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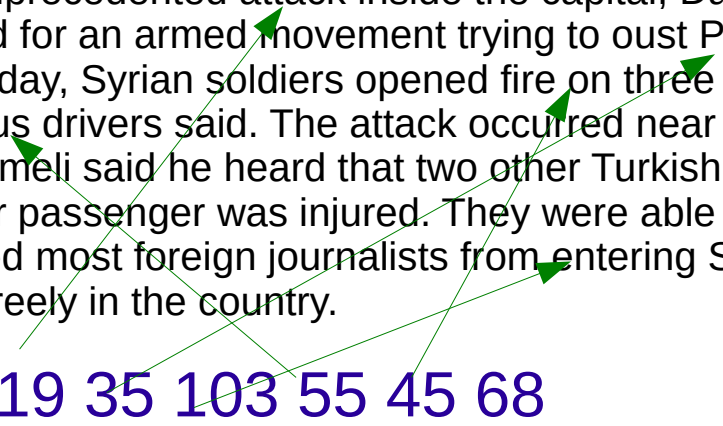

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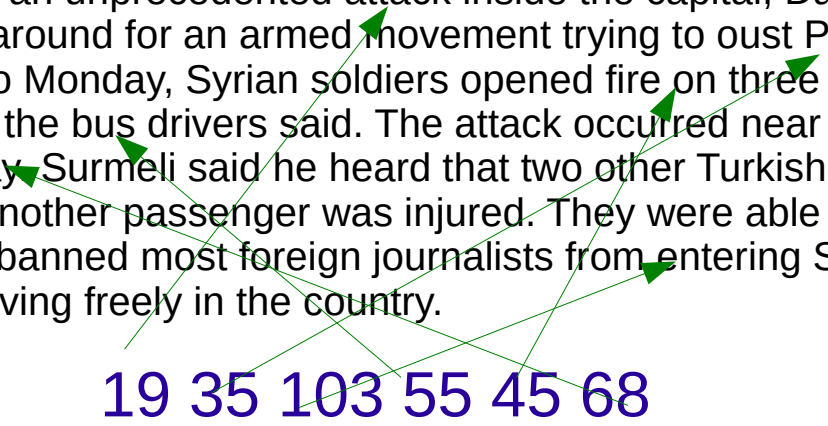

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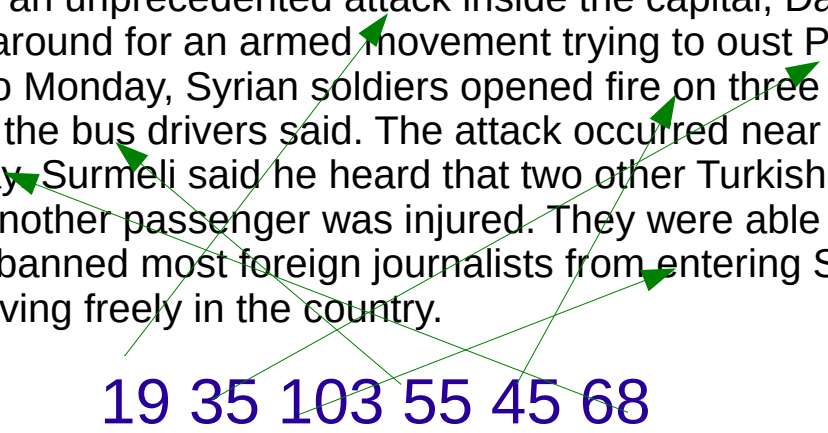

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"Attack President entering bus on monday#"

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Extending to computers → ROP

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- Newspaper → available memory

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- Newspaper → available memory
- Words → instructions

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And we get....

Conti...

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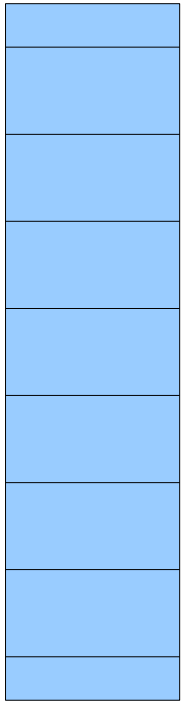

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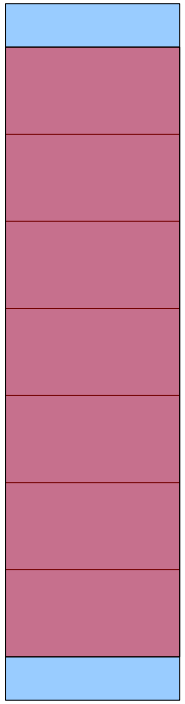

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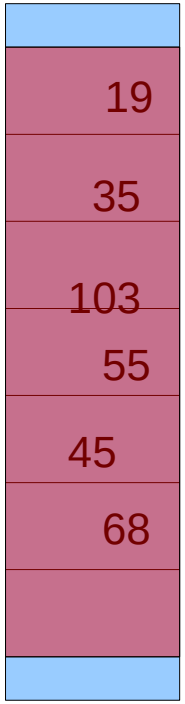

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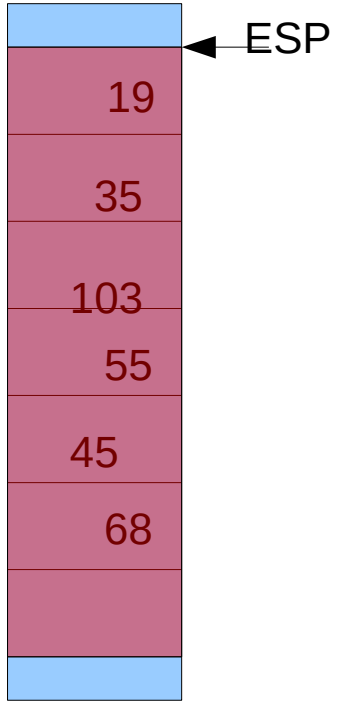

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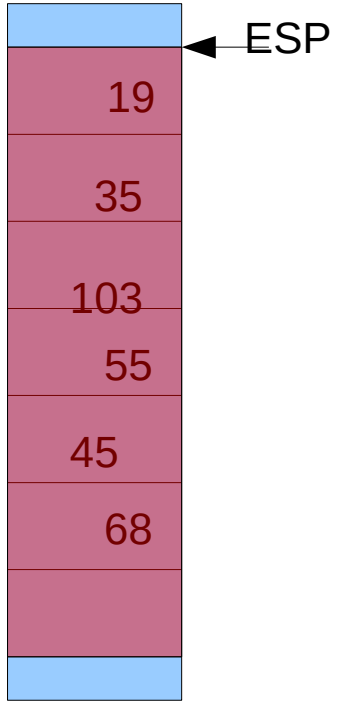

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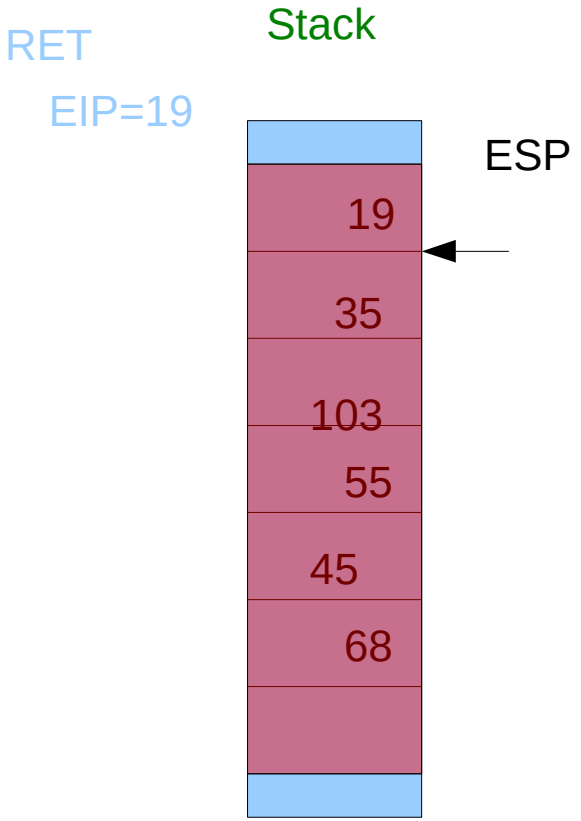

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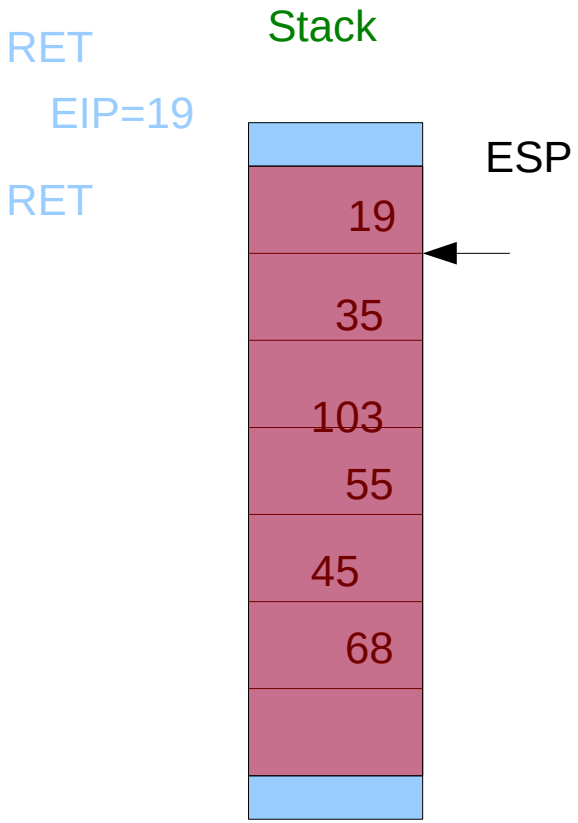

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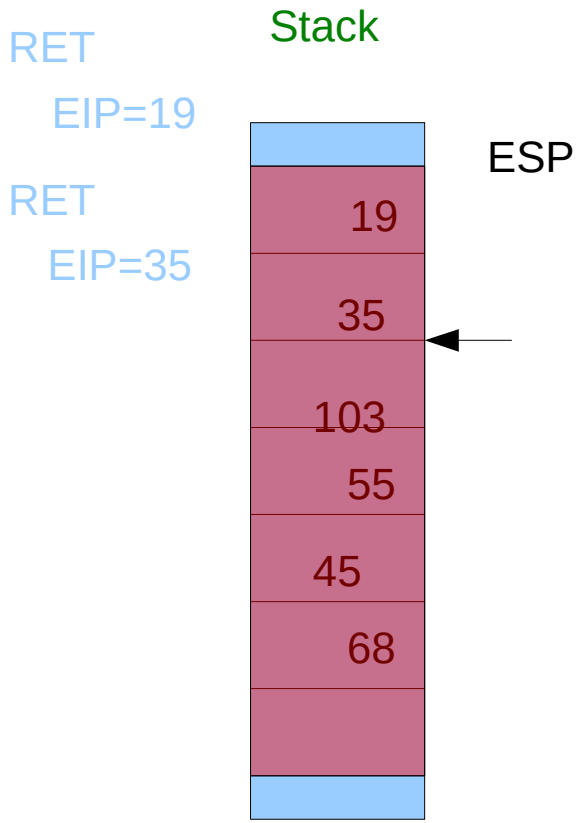

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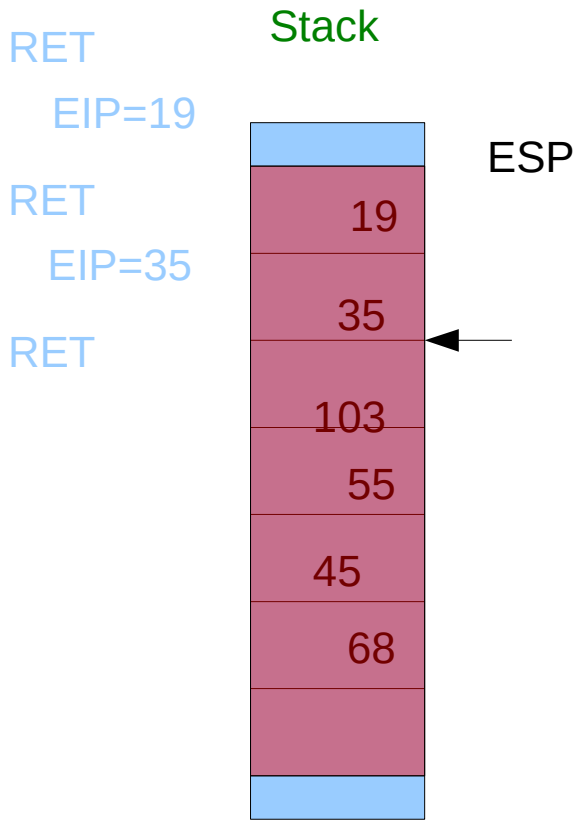

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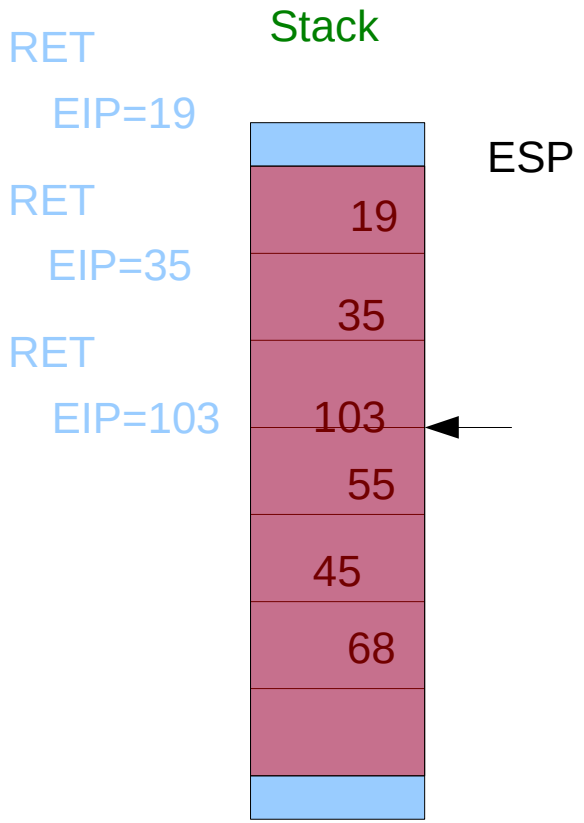

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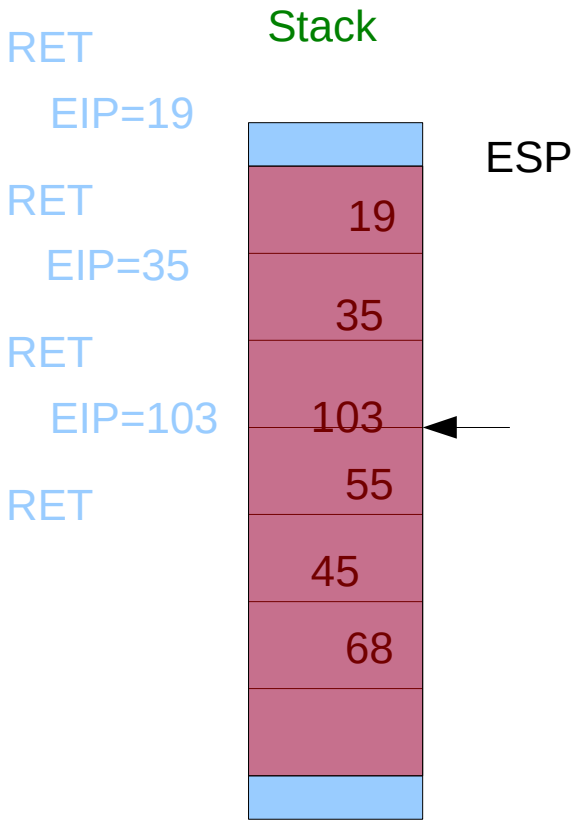

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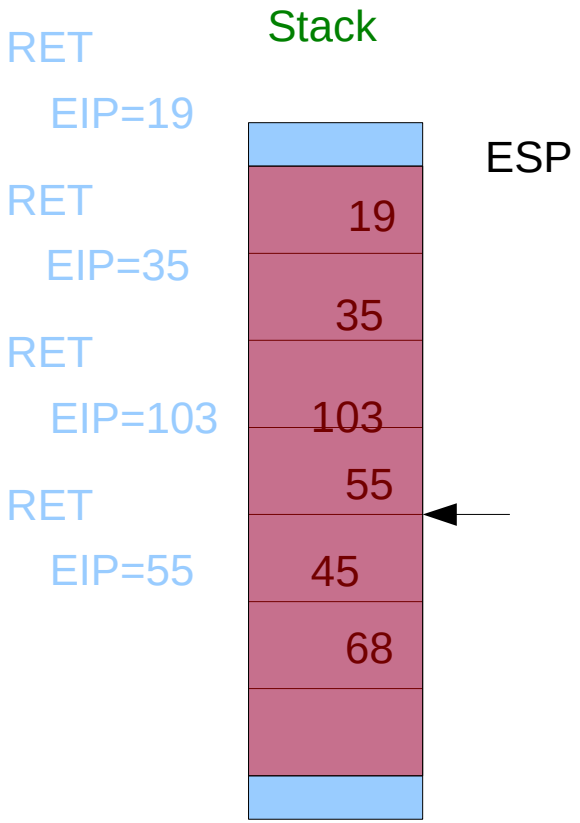

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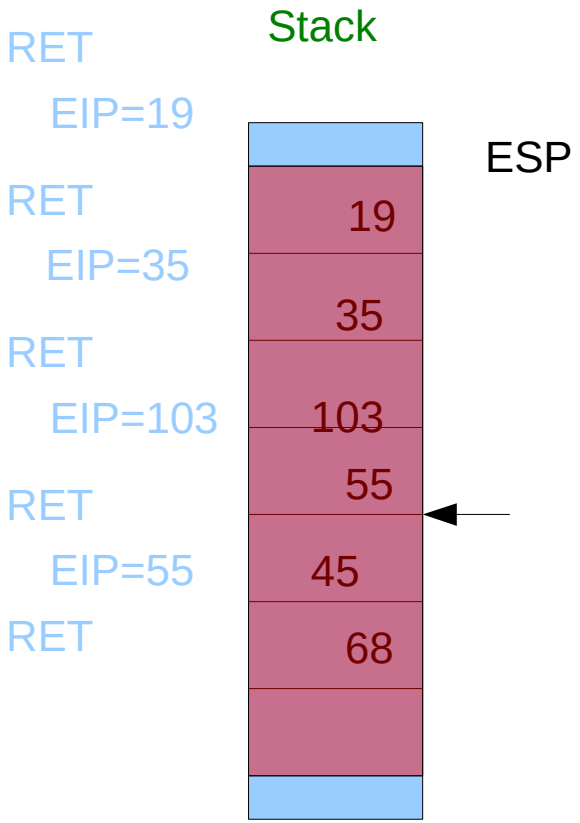

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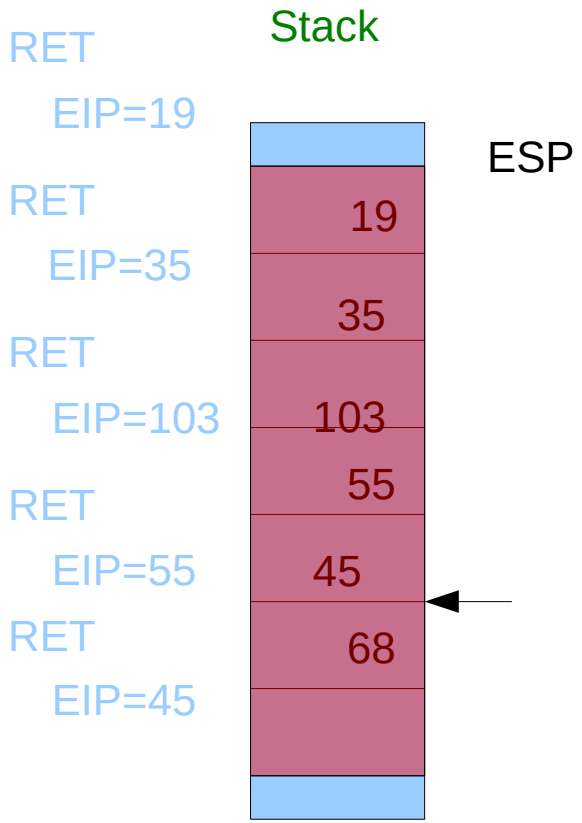

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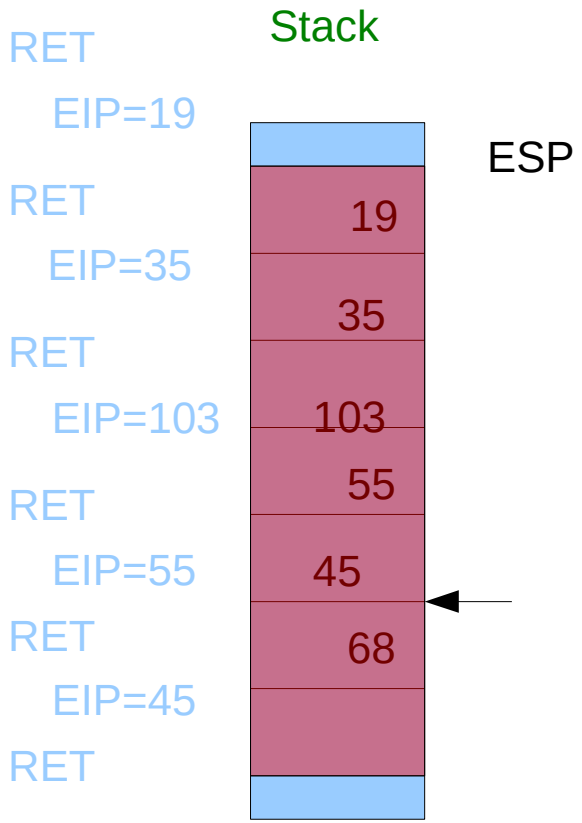

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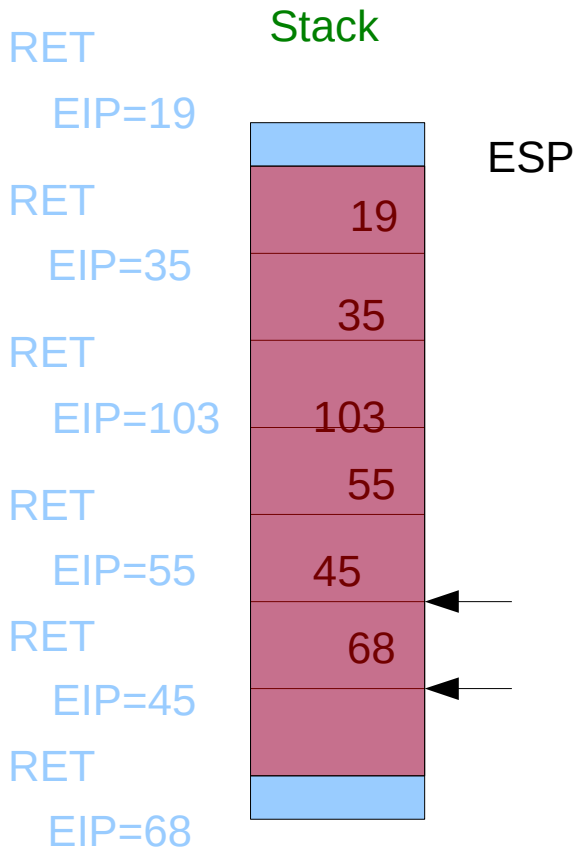

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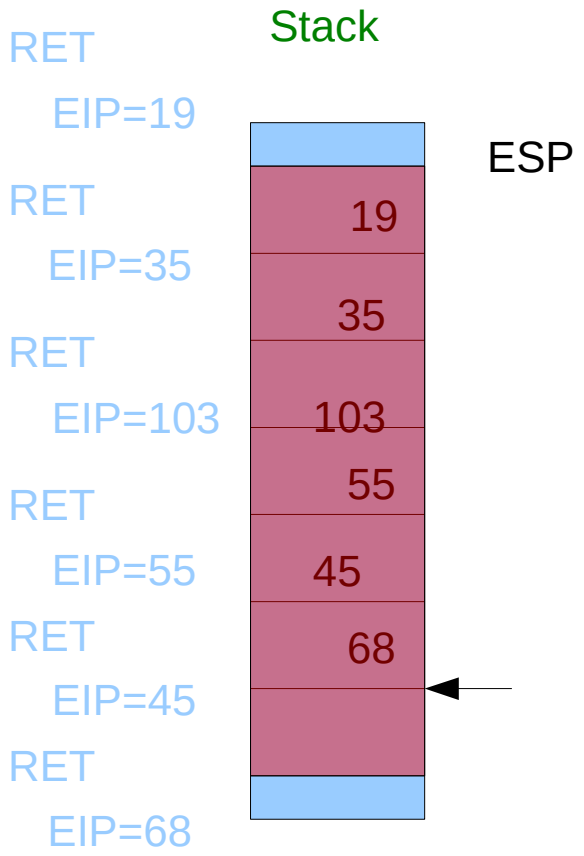

An Example

- "*How to make backdoor with Return Oriented Programming & ROPgadget tool*" (Jonathan Salwan) @Shell-Storm.org
- Executables have code and data for computing
  - We need to supply necessary data
  - ROP is for code part.

A Vulnerable Program

```
int copyData(char *string)
{
    char buf[32];
    strcpy(buf, string);
    return (0);
}

int main()
{
    char buffer[700];
    FILE *file;
    printf("opening file");
    file = fopen("exploitFile","rb");
    if (!file)
    {
        fprintf(stderr,"file not opened %s",
strerror(errno));
        return (0);
    }
    printf("file opened");
    fread(buffer, 699,1,file);
    fclose(file);
    copyData(buffer);
    return (0);
}
```

What We Want to Get...

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We want to get a shell… (as usual!)

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int main()
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      char *env[1] = {NULL};
      char *arguments[3]= { "/bin//sh",
                NULL
               };
      execve("/bin//sh", arguments, env);
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```

We use INT80 instruction →

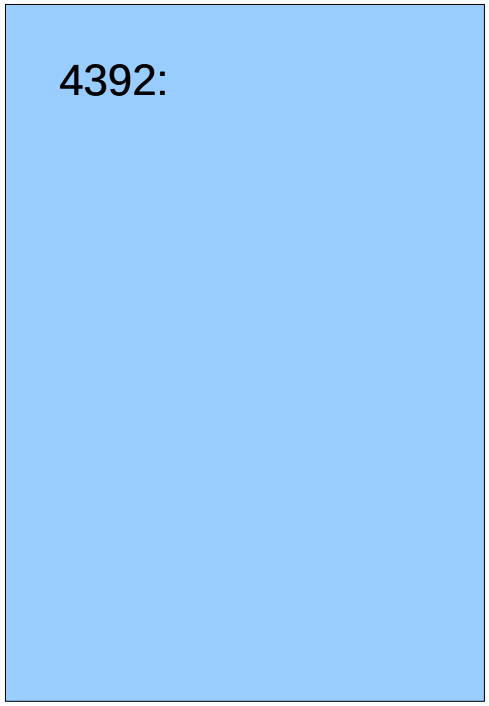
EAX = 11
EBX = "/bin//sh" (char *)
ECX = arguments (char **)
EDX = env (char **) (NULL)
ESI =...., EDI = ...

Execution Plan

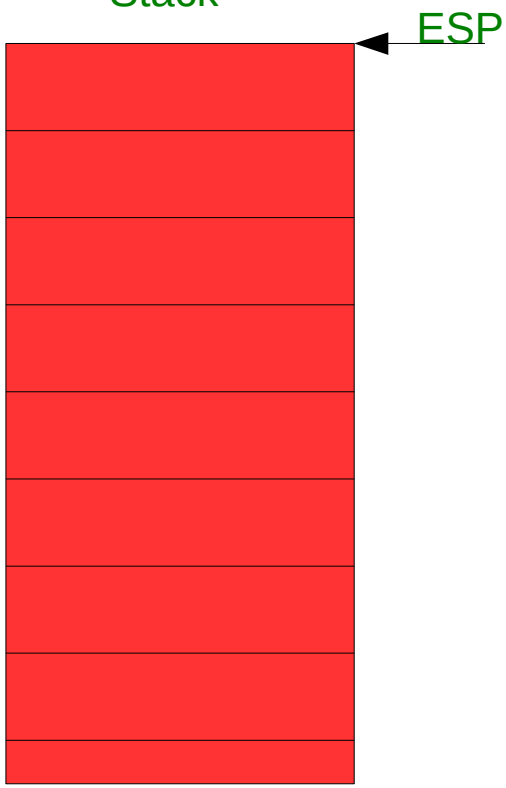
- Find a place in the executable to store data (dummy-stack)
- Use objdump utility for .data section
- Select a region, initialized with zeros
- Find gadgets to POP data from stack and MOV that to dummy-stack
- Find gadgets to INC EAX (syscall number)

Preparing Data

Data section



Stack



Preparing Data

Preparing Data

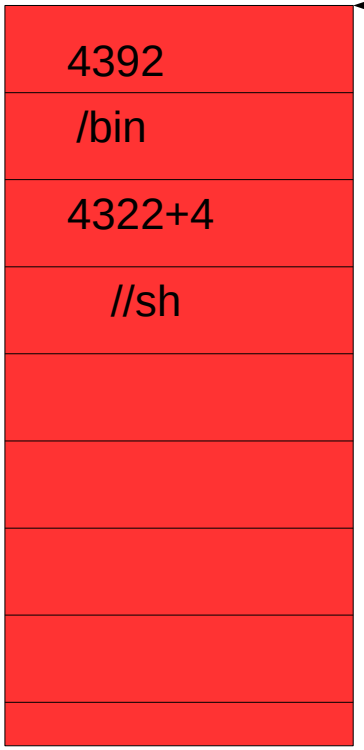
Data section

4392:

POP ecx ret

Stack

ESP



Preparing Data

Data section

4392:

POP ecx ret

ecx=4392

Stack

ESP

Preparing Data

Data section

4392:

POP ecx ret

POP eax ret

ecx=4392

Stack

ESP

Preparing Data

Data section

4392:

POP ecx ret

POP eax ret

ecx=4392

eax=/bin

Stack

ESP

Preparing Data

Data section

4392:

POP ecx ret

POP eax ret

MOV [ecx] eax ret

ecx=4392

eax=/bin

Stack

ESP

Preparing Data

Data section

4392: /bin

POP ecx ret

POP eax ret

MOV [ecx] eax ret

ecx=4392

eax=/bin

Stack

ESP

Preparing Data

Data section

4392: /bin

POP ecx ret

POP eax ret

MOV [ecx] eax ret

POP ecx ret

ecx=4392

eax=/bin

Stack

ESP

Preparing Data

Data section

4392: /bin

4396:

POP ecx ret

POP eax ret

MOV [ecx] eax ret

POP ecx ret

ecx=4392

eax=/bin

ecx=4396

Stack

ESP

Preparing Data

Data section

4392: /bin

4396:

POP ecx ret

POP eax ret

MOV [ecx] eax ret

POP ecx ret

POP eax ret

ecx=4392

eax=/bin

ecx=4396

Stack

ESP

Preparing Data

Data section

4392: /bin

4396:

POP ecx ret

POP eax ret

MOV [ecx] eax ret

POP ecx ret

POP eax ret

ecx=4392

eax=/bin

ecx=4396

eax=//sh

Stack

ESP

Preparing Data

Data section

4392: /bin

4396:

POP ecx ret

POP eax ret

ecx=4392

eax=/bin

MOV [ecx] eax ret

POP ecx ret

POP eax ret

ecx=4396

eax=//sh

MOV [ecx] eax ret

Stack

ESP

Preparing Data

Data section

4392: /bin

4396: //sh

POP ecx ret

POP eax ret

ecx=4392

eax=/bin

MOV [ecx] eax ret

POP ecx ret

POP eax ret

ecx=4396

eax=//sh

MOV [ecx] eax ret

Stack

ESP

Preparing Data

Data section

4392: /bin

4396: //sh

POP ecx ret

POP eax ret

ecx=4392

eax=/bin

MOV [ecx] eax ret

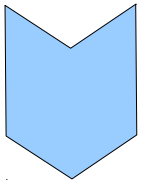
POP ecx ret

POP eax ret

ecx=4396

eax=//sh

MOV [ecx] eax ret



Stack

ESP

Preparing Data

Data section

4392: /bin

4396: //sh

POP ecx ret

POP eax ret

MOV [ecx] eax ret

POP ecx ret

POP eax ret

MOV [ecx] eax ret

ecx=4392

eax=/bin

ecx=4396

eax=//sh

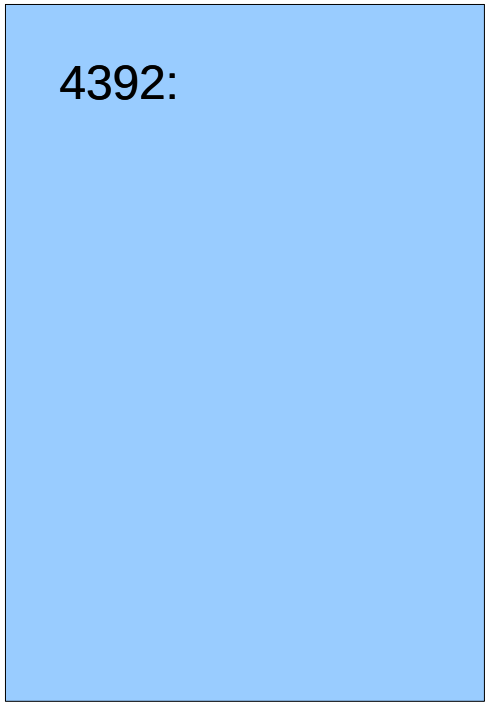
Stack

ESP

ROP Gadget

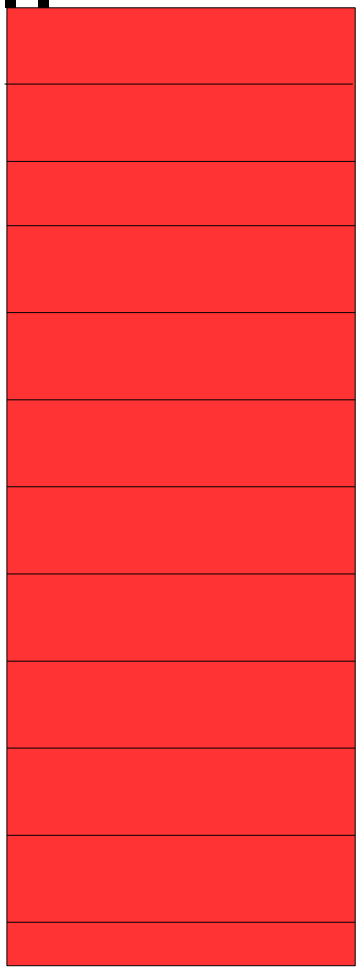
Preparing Data II

Data section



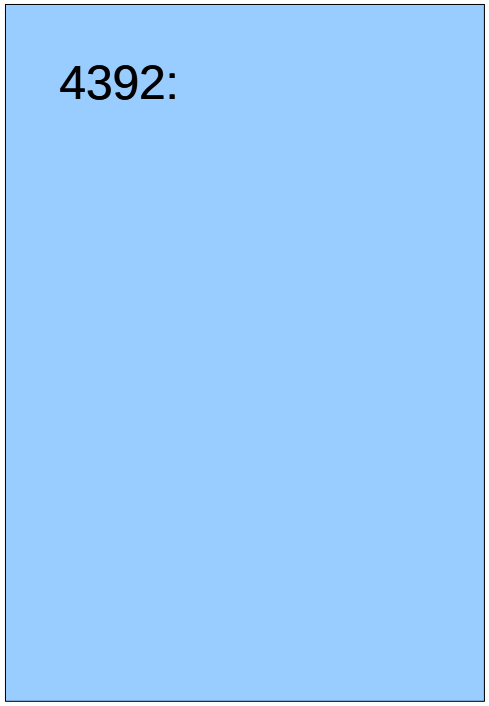
Stack

ESP



Preparing Data II

Data section



Stack

ESP

Preparing Data II

Data section

4392:

POP ecx ret

Stack

ESP

Preparing Data II

Data section

4392:

POP ecx ret

ecx=4392

Stack

ESP

Preparing Data II

Data section

4392:

POP ecx ret

POP eax ret

ecx=4392

Stack

ESP

Preparing Data II

Data section

4392:

POP ecx ret

POP eax ret

ecx=4392

eax=/bin

Stack

ESP

Preparing Data II

Data section

4392:

POP ecx ret

POP eax ret

ecx=4392

eax=/bin

MOV [ecx] eax ret

Stack

ESP

Preparing Data II

Data section

4392: /bin

POP ecx ret

POP eax ret

ecx=4392

eax=/bin

MOV [ecx] eax ret

Stack

ESP

Preparing Data II

Data section

4392: /bin

POP ecx ret

POP eax ret

ecx=4392

eax=/bin

MOV [ecx] eax ret

POP ecx ret

Stack

ESP

Preparing Data II

Data section

4392: /bin

4396:

POP ecx ret

POP eax ret

ecx=4392

eax=/bin

MOV [ecx] eax ret

POP ecx ret

ecx=4396

Stack

ESP

Preparing Data II

Data section

4392: /bin

4396:

POP ecx ret

POP eax ret

ecx=4392

eax=/bin

MOV [ecx] eax ret

POP ecx ret

POP eax ret

ecx=4396

Preparing Data II

Data section

4392: /bin

4396:

POP ecx ret

POP eax ret

ecx=4392

eax=/bin

MOV [ecx] eax ret

POP ecx ret

POP eax ret

ecx=4396

eax=//sh

Preparing Data II

Data section

4392: /bin

4396: //sh

POP ecx ret

POP eax ret

ecx=4392

eax=/bin

MOV [ecx] eax ret

POP ecx ret

POP eax ret

ecx=4396

eax=//sh

Stack

ESP

Preparing Data II

Data section

4392: /bin

4396: //sh

POP ecx ret

POP eax ret

ecx=4392

eax=/bin

MOV [ecx] eax ret

POP ecx ret

POP eax ret

ecx=4396

eax=//sh

Stack

ESP

And process is repeated.....

The real code

- Lets look at the real python code

Few References

- http://research.shell-storm.org/
- Ryan Roemer and Erik Buchanan and Hovav Shacham and Stefan Savage (2011), “Return-Oriented Programming: Systems, Languages, and Applications” In: Trans. Info. \& Sys. Sec.
- H. Shacham. “The Geometry of Innocent Flesh on the Bone: Return-into-libc without Function Calls (on the x86).” In S. De Capitani Di Vimercati and P. Syverson, eds., Proceedings of CCS 2007, pages 552–561. ACM Press, Oct. 2007
- Kaan Onarlioglu, Leyla Bilge, Andrea Lanzi, Davide Balzarotti, and Engin Kirda. 2010. G-Free: defeating return-oriented programming through gadget-less binaries. In Proceedings of the 26th Annual Computer Security Applications Conference (ACSAC '10). ACM, New York, NY, USA, 49-58

Thank You!