CTF Workshop
Seshagiri Prabhu
The Stack
Process

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Seshagiri Prabhu

Day 3

Amrita Vishwa Vidyapeetham
Amritapuri

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Outline

AMRITA
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University Established u/s 3 of UGC Act 1956
Amritapuri Campus

1 The Stack

2 Process

The stack

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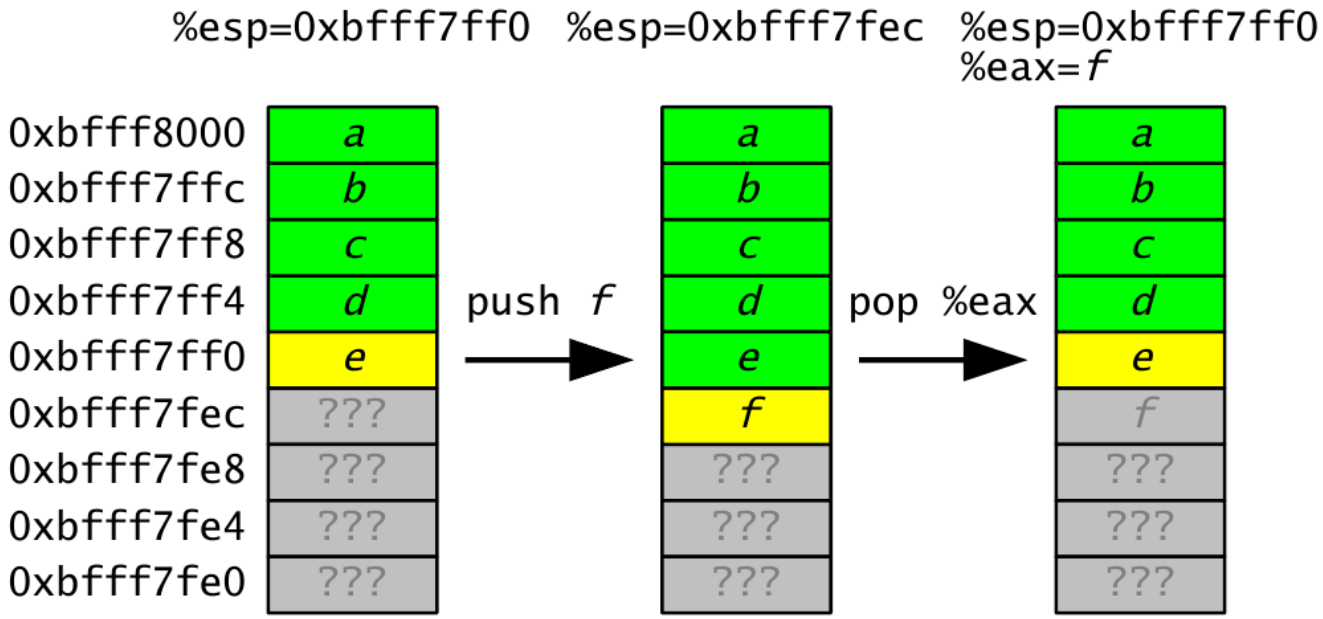
- The stack grows towards lower memory addresses
- The stack pointer (%esp) points to the top of the stack (the lowest valid address)



Frames & function call I

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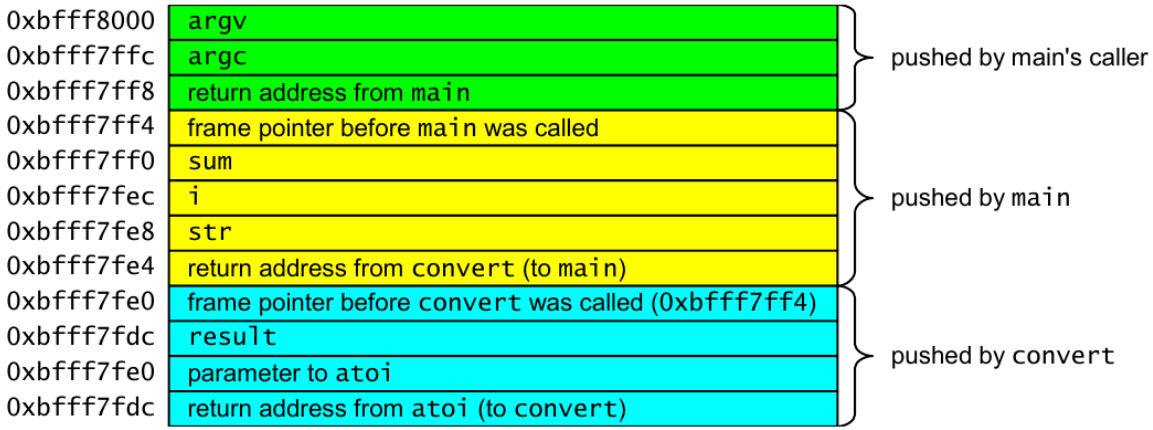
- The stack is composed of frames
- Frames are pushed on the stack as a consequence of function calls (function prologue)
- The address of the current frame is stored in the Frame Pointer (FP) register
  - On Intel architectures `%ebp` is used
- Each frame contains
  - The function's actual parameters
  - The return address to jump to at the end of the function
  - The pointer to the previous frame
  - Function's local variables
- Compiler optimization may eliminate stack frames

Frames & Func call II


```
int convert(char *str) {
    int result = atoi(str); return result;
}
int main(int argc, char **argv) {
    int i, sum;
    for (i = 0; i < argc; i++) sum += convert(
        argv[i]);
    printf("sum=%d\n", sum); return 0;
}
```



Function prologue

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- Before calling a function the caller prepares the parameters by either setting specific registers or by pushing them on the stack
- The prologue of the called function
  - Pushes the current base pointer on the stack
  - Sets the base pointer to be the current stack pointer
  - Moves the stack pointer onward to make room for local variables

```
push %ebp
mov %esp, %ebp
sub $n, %esp
```

Function Epilogue

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- The epilogue of the called function
  - Saves the results (if any) in the `%eax` register
  - Stores the base pointer into the stack pointer (deletes the current stack frame)
  - Pops a value from the stack, restoring the saved base pointer
  - Executes a `ret`
- The second and third operations are equivalent to the `LEAVE` opcode

Example

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```
void function (char *str) {
    char buffer[8];
    strcpy(buffer, str);
    return;
}
```

```
main:
    sub $0x4,%esp
    movl $0x8048560,(%esp)
    call 0x8048444 <function>
    ...

function:
    push %ebp
    mov %esp, %ebp
    sub $0x10, %esp
    ...
    leave
```

A Program's Life

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- Design
- Development, usually in a high-level language
- Compilation/translation into binary form (object form) by a compiler or assembler
- Programs in interpreted languages are translated into an intermediate format
- Execution by a process
- Termination

Objects

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- Object files include applications and libraries
- Object files in general contain:
  - The code, in binary format
  - Relocation information about things that need to be fixed once the code and the data are loaded into memory
  - Information about the symbols defined by the object file and the symbols that are imported from different objects
  - Optionally, debugging information

Linking

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- Linking is the process of resolving references that a program has to external objects (variables, functions)
- Static linking is performed at compile-time
- Dynamic linking is performed at run-time

The ELF File Format I

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- The Executable and Linkable Format (ELF) is one of the most used binary object formats
- ELF files are of three types
  - relocatable: need to be fixed by the linker before being executed
  - executable: ready for execution (all symbols have been resolved with the exception of those related to shared libs)
  - shared objects: shared libraries with the appropriate linking information

The ELF File Format II

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- A program is seen as a collection of segments by the loader and as a collection of sections by the compiler/linker
- A segment is usually made of several sections
- The segment structure is defined in the Program Header Table
- The section structure is defined in the Section Header Table

Process Structure

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- Environment/Argument section
  - Used for environment data
  - Used for the command line data
- Stack section
  - Used for local parameters
  - Used for saving the processor status
- Heap section
  - Used for dynamically allocated data
- Data section (Static/global vars)
  - Initialized variables (.data)
  - Uninitialized variables (.bss)
- Code/Text section (.text)
  - Usually marked read-only
  - Modifications causes segfaults

PLT and GOT

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- When a shared library function is called by a program the address called is an entry in the Procedure Linking Table (PLT)
- The address contains an indirect jump to the addresses contained in variables stored in the Global Offset Table
- The first time a function is called, the GOT address is a jump back to the PLT, where the code to invoke the linker is called
- The linker does its magic and updates the GOT entry, so next time the function is called it can be directly invoked
- The PLT is read-only, but the GOT is not...
  - By overwriting the contents of a GOT entry it is possible to jump to arbitrary locations

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The examples and slides

https://github.com/seshagiriprabhu/CTF-Workshop-day-3

Inspired by

Application and Network Security course offered by Dr. Herbert Bos at VU, Amsterdam.

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Questions ?

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