An Introduction to x86 ASM

Malware Analysis Seminar

Meeting 1

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Registers

- General purpose
  - EAX, EBX, ECX, EDX
  - ESI, EDI (index registers, but used as general in 32-bit protected mode)
- Stack
  - EBP, ESP
- Instruction pointer
  - EIP
- Flags
  - EFLAGS
- Segment
  - CS, DS, SS, ES, FS, GS

Syntax

- General form:
  - *mnemonic operand(s)*

    movl %eax, %ebx

- Operands (0-3) may refer:
  - Registers
  - Memory
  - Immediate

Syntax (contd.)

- Register naming (AT&T is UNIX default)
    - **AT&T:** %eax
    - **Intel:** eax

- Source/Destination Ordering:
    - Load EBX with the value of EAX
    - **AT&T:** movl %eax, %ebx
    - **Intel:** mov ebx, eax

Constant value/immediate value format

- Load EAX with the address of the "C" variable boo
  - **AT&T:** movl $_boo, %eax
  - **Intel:** mov eax, _boo
  - Note that “_” works for static (global) variables only

- Now let's load ebx with 0xd00d:
  - **AT&T:** movl $0xd00d, %ebx
  - **Intel:** mov ebx, d00dh

Operator size specification

- You don't want make GAS to guess this wrong
  - **AT&T:** movw %ax, %bx
  - **Intel:** mov bx, ax

Referencing memory

- 32bit protected mode addressing
  - **AT&T:** immed32(basepointer,indexpointer,indexscale)
  - **Intel:** [basepointer + indexpointer*indexscale + immed32]
- A global C variable
  - **AT&T:** _booga
  - **Intel:** [_booga]
- Addressing what a register points to:
  - **AT&T:** (%eax)
  - **Intel:** [eax]

Referencing memory (contd.)

- Addressing a variable offset by a value in a register:
  - **AT&T:** _variable(%eax)
  - **Intel:** [eax + _variable]
- Addressing a value in an array of integers (scaling by 4):
  - **AT&T:** _array(,%eax,4)
  - **Intel:** [eax*4 + array]
- Offsets with immediate value
  - **C code:** *(p+1) where p is a char *
  - **AT&T:** 1(%eax) where eax has the value of p
  - **Intel:** [eax + 1]

Referencing memory (contd.)

- Addressing a particular char in an array of 8-character records
  - **EAX** holds the number of the record desired.
  - **EBX** has the wanted char's offset within the record.

  - **AT&T:** _array(%ebx,%eax,8)
  - **Intel:** [ebx + eax*8 + _array]

Arithmetic

- Integers:
  - Two's compliment:
  - Reverse bits, then add one (throw away carry)
    - Original value: 00111000 (+56)
    - Reverse bits: 11000111
    - Add 1: 11001000 (-56)
- Rules of arithmetic are preserved

	002C		44
+	FFFF	+	(- 1)
	002B		43

Carry and overflow

- Overflow
  - Set if the true result of the operation is too big to fit into the destination for signed arithmetic.
- Carry
  - Set if there is a carry in the msb of an addition or a borrow in the msb of a subtraction.
  - Can be used to detect overflow for unsigned arithmetic.

Extended precision arithmetic

- ADC

  operand1 = operand1 + carry flag + operand2

- SBB

  operand1 = operand1 - carry flag – operand2

- Sum of 64-bit integers in **EDX:EAX** and **EBX:ECX**

```
add eax, ecx ; add lower 32-bits
adc edx, ebx ; add upper 32-bits and carry
```

Control structures

- Control structures decide what to do based on comparisons of data
- **CMP** instruction
  - subtract operands
  - set EFLAGS
- **EFLAGS** register
  - ZF – zero flag
  - CF – carry flag
  - SF – sign flag

Control structures (contd.)

- **Unsigned:** cmp vleft, vright <=> vleft – vright
  - vleft = vright: ZF (1), CF (0)
  - vleft > vright: ZF (0), CF (0) – no borrow
  - vleft < vright: ZF (0), CF (1) – borrow
- **Signed:** cmp vleft, vright <=> vleft – vright
  - vleft = vright: ZF (1), CF (0)
  - vleft > vright: ZF (0), SF = CF
  - vleft < vright: ZF (0), SF != CF

Branch instructions

- JMP
  - Short:
    - One byte instruction!
    - But jumps only 128 bytes up or down
  - Near:
    - Jump anywere in a segment
    - 2-byte displacement: jump 32000 bytes
    - 4-byte displacement: jump anywhere in 32-bit mode
  - Far:
    - Jump across segments

Examples

```
if ( EAX == 0 )        cmp eax, 0   ; set flags (ZF set if eax - 0 = 0)
   EBX = 1;            jz thenblock ; if ZF is set branch to thenblock
else                   mov ebx, 2   ; ELSE part of IF
   EBX = 2;            jmp next     ; jump over THEN part of IF
                     thenblock:
                       mov ebx, 1   ; THEN part of IF
                     next:
```

Comparison instructions

- JE branches if vleft = vright
- JNE branches if vleft != vright
- JL, JNGE branches if vleft < vright
- JLE, JNG branches if vleft <= vright
- JG, JNLE branches if vleft > vright
- JGE, JNL branches if vleft >= vright

Loops

- LOOP
  - Decrements ECX, if ECX != 0 branches to label
- LOOPE, LOOPZ
  - Decrements ECX (FLAGS register is not modified), if ECX != 0 and ZF = 1, branches
- LOOPNE, LOOPNZ
  - Decrements ECX (FLAGS unchanged), if ECX != 0 and ZF = 0, branches

Loop example

```
sum = 0;
    for ( i=10; i >0; i-- )
        sum += i;
```

```
    mov eax, 0   ; eax is sum
    mov ecx, 10 ; ecx is i

loop_start:

    add eax, ecx
    loop loop_start
```

Stack

- SS
  - Specifies stack segment (usually same as data)
- ESP
  - Contains the address of the data that would be removed from the stack
- PUSH/POP
  - Insert/remove data on the stack
  - Subtract/add 4 to ESP

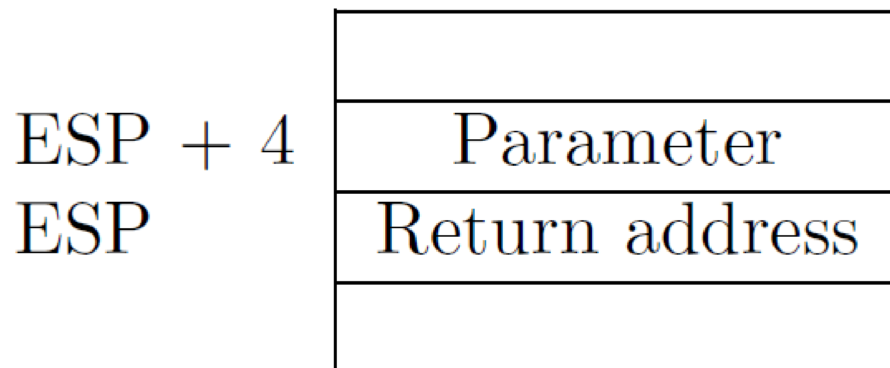
Call/return

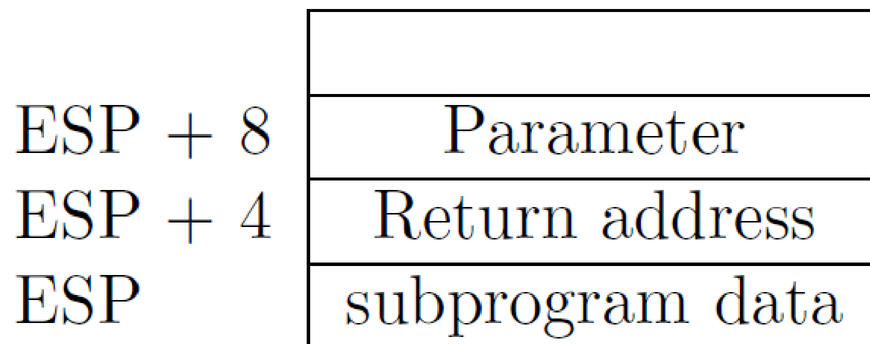
- CALL
  - Makes an unconditional jump to a subprogram and pushes the address of the next instruction on the stack
- RET
  - Pops off an address and jumps to that address

Calling conventions

- Goal: reentrant programs
  - Conventions differ from compiler, optimizations, etc.
- Call/return are used for function invocations
- Parameters passed on the stack
  - Pushed onto the stack before the CALL instruction

Stack bottom pointer





Initially parameter is

- [ESP + 4]

Later as the function pushes things on the stack it changes, e.g.

- [ESP + 8]

- Use dedicated register **EBP**

Prologue/epilogue

```
subprogram_label:
    push ebp          ; save original EBP value on stack
    mov ebp, esp      ; new EBP = ESP
; subprogram code
    pop ebp           ; restore original EBP value
    ret
```

- Example invocation

```
    push dword 1      ; pass 1 as parameter
    call fun
    add esp, 4        ; remove parameter from stack
```

Local variables

- Stored right after the saved EBP value in the stack
- Allocated by subtracting the number of bytes required from ESP

```
subprogram_label:
    push ebp                   ; save original EBP value on stack
    mov ebp, esp               ; new EBP = ESP
    sub esp, LOCAL_BYTES ; = # bytes needed by locals
; subprogram code
    mov esp, ebp               ; deallocate locals
    pop ebp                    ; restore original EBP value
    ret
```

Enter/leave

- ENTER
  - prologue code
- LEAVE
  - Epilogue

```
subprogram_label:
    enter LOCAL_BYTES, 0      ; = # bytes needed by locals
; subprogram code
    leave
    ret
```

Examples