C/C++动态检测内存错误利器 - ASan

C语言与CPP编程 今天

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ASan，即Address Sanitizer，是一个适用于c/c++程序的动态内存错误检测器，它由一个编译器检测模块（LLVM pass）和一个替换malloc函数的运行时库组成，在性能及检测内存错误方面都优于Valgrind，你值得拥有。

一 适用平台

在LLVM3.1版之后，ASan就是其的一个组成部分，所以所有适用LLVM的平台，且llvm版本大于3.1的，都可以适用ASan来检查c/c++内存错误。

对于gcc，则是4.8版本之后才加入ASan，但是ASan的完整功能则是要gcc版本在4.9.2以上。

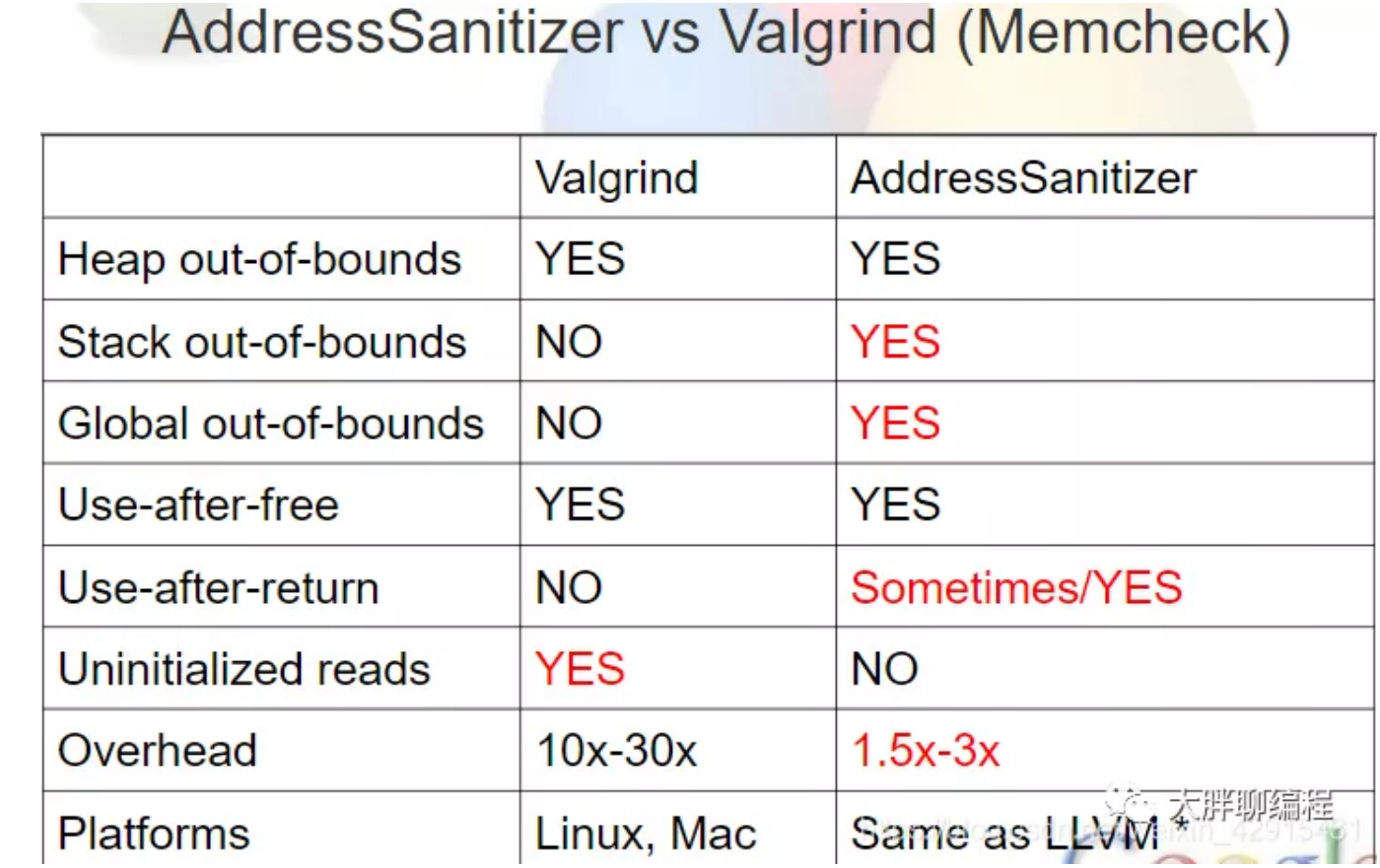
OS	x86	x86_64	ARM	ARM64	MIPS	MIPS64	PowerPC	PowerPC64
Linux	yes	yes			yes	yes	yes	yes
OS X	yes	yes						
iOS Simulator	yes	yes						
FreeBSD	yes	yes						
Android	yes	yes	yes	yes				

二 强大功能

ASan作为编译器内置功能，支持检测各种内存错误：

- 缓冲区溢出
  ① 堆内存溢出
  ② 栈上内存溢出
  ③ 全局区缓存溢出
- 悬空指针（引用）
  ① 使用释放后的堆上内存
  ② 使用返回的栈上内存
  ③ 使用退出作用域的变量
- 非法释放
  ① 重复释放
  ② 无效释放
- 内存泄漏
- 初始化顺序导致的问题

ASan和Valgrind对比如下图：



三 如何使用

1. 使用ASan时，只需gcc选项加上-fsanitize=address选项；
2. 如果想要在使用asan的时候获取更好的性能，可以加上O1或者更高的编译优化选项；
3. 想要在错误信息中让栈追溯信息更友好，可以加上-fno-omit-frame-pointer选项。
4. 本文针对linux x86-64平台，gcc编译器环境实验。

本文实验环境：

```
[root@yglocal ~]# lsb_release -a
LSB Version:    :core-4.1-amd64:core-4.1-noarch
Distributor ID: CentOS
Description:    CentOS Linux release 8.1.1911 (Core)
Release:        8.1.1911
Codename:       Core
[root@yglocal ~]# uname -r
4.18.0-147.el8.x86_64
```

```
[root@yglocal ~]# gcc --version
gcc (GCC) 8.3.1 20190507 (Red Hat 8.3.1-4)
Copyright (C) 2018 Free Software Foundation, Inc.
This is free software; see the source for copying conditions.  There is NO
warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE
```

在centos上使用ASan，编译会报如下错误（gcc 4.8.5）：

```
[root@localhost test]# gcc -g -O2 -fsanitize=address -fno-omit-frame-pointer
hello.c
/usr/bin/ld: cannot find /usr/lib64/libasan.so.0.0.0
collect2: error: ld returned 1 exit status
```

安装libasan即可：

```
[root@localhost test]# yum install libasan
```

注：ubuntu x86-64系统只需gcc版本高于4.8即可；但是在rhel/centos上使用ASan功能，除了gcc版本大于4.8之外，还需要安装libasan。

下面针对内存的几种c/c++常见内存错误，编写例子，看下ASan的检测输出情况：

1 堆缓冲区溢出

测试代码：

```
[root@yglocal asan_test]# vi heap_ovf_test.c

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
```

```
6
7
8  int main()
9  {
10         char *heap_buf = (char*)malloc(32*sizeof(char));
11         memcpy(heap_buf+30, "overflow", 8);    //在heap_buf的第30个字节开始，
12 拷贝8个字符
13
14         free(heap_buf);
15
16         return 0;
   }
```

编译并运行：

```
1  [root@yglocal asan_test]# gcc -fsanitize=address -fno-omit-frame-pointer -o
2  heap_ovf_test heap_ovf_test.c
3  [root@yglocal asan_test]# ./heap_ovf_test
4  =================================================================
5  ==40602==ERROR: AddressSanitizer: heap-buffer-overflow on address
6  0x603000000030 at pc 0x7f3de8f91a1d bp 0x7ffd4b4ebb60 sp 0x7ffd4b4eb308
7  WRITE of size 8 at 0x603000000030 thread T0
8      #0 0x7f3de8f91a1c  (/lib64/libasan.so.5+0x40a1c)
9      #1 0x400845 in main (/root/asan_test/heap_ovf_test+0x400845)
10     #2 0x7f3de8bb1872 in __libc_start_main (/lib64/libc.so.6+0x23872)
11     #3 0x40075d in _start (/root/asan_test/heap_ovf_test+0x40075d)
12
13 0x603000000030 is located 0 bytes to the right of 32-byte region
14 [0x603000000010,0x603000000030)
15 allocated by thread T0 here:
16     #0 0x7f3de9040ba8 in __interceptor_malloc (/lib64/libasan.so.5+0xefba8)
17     #1 0x400827 in main (/root/asan_test/heap_ovf_test+0x400827)
18     #2 0x7f3de8bb1872 in __libc_start_main (/lib64/libc.so.6+0x23872)
19
20 SUMMARY: AddressSanitizer: heap-buffer-overflow
21 (/lib64/libasan.so.5+0x40a1c)
22 Shadow bytes around the buggy address:
23   0x0c067fff7fb0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
24   0x0c067fff7fc0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

```
  0x0c067fff7fd0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0c067fff7fe0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0c067fff7ff0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
=>0x0c067fff8000: fa fa 00 00 00 00[fa]fa fa fa fa fa fa fa fa fa
  0x0c067fff8010: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8020: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8030: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8040: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8050: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
Shadow byte legend (one shadow byte represents 8 application bytes):
  Addressable:           00
  Partially addressable: 01 02 03 04 05 06 07
  Heap left redzone:       fa
  Freed heap region:       fd
  Stack left redzone:      f1
  Stack mid redzone:       f2
  Stack right redzone:     f3
  Stack after return:      f5
  Stack use after scope:   f8
  Global redzone:          f9
  Global init order:       f6
  Poisoned by user:        f7
  Container overflow:      fc
  Array cookie:            ac
  Intra object redzone:    bb
  ASan internal:           fe
  Left alloca redzone:     ca
  Right alloca redzone:    cb
==40602==ABORTING
[root@yglocal asan_test]#
```

可以看到asan报错：==40602==ERROR: AddressSanitizer: heap-buffer-overflow on address 0x603000000030 at xxxx,下面也列出了发生heap-buffer-overflow时的调用链及heap buffer在哪里申请的。

2 栈缓冲区溢出

测试代码：

```
[root@yglocal asan_test]# vi stack_ovf_test.c

#include <stdio.h>
#include <string.h>

int main()
{
        char stack_buf[4] = {0};
        strcpy(stack_buf, "1234");

        return 0;
}
```

编译并运行：

```
[root@yglocal asan_test]# ./stack_ovf_test
=================================================================
==38634==ERROR: AddressSanitizer: stack-buffer-overflow on address
0x7ffcf3d8b8d4 at pc 0x7f8714bbaa1d bp 0x7ffcf3d8b8a0 sp 0x7ffcf3d8b048
WRITE of size 5 at 0x7ffcf3d8b8d4 thread T0
    #0 0x7f8714bbaa1c  (/lib64/libasan.so.5+0x40a1c)
    #1 0x400949 in main (/root/asan_test/stack_ovf_test+0x400949)
    #2 0x7f87147da872 in __libc_start_main (/lib64/libc.so.6+0x23872)
    #3 0x4007cd in _start (/root/asan_test/stack_ovf_test+0x4007cd)

Address 0x7ffcf3d8b8d4 is located in stack of thread T0 at offset 36 in
frame
    #0 0x400895 in main (/root/asan_test/stack_ovf_test+0x400895)

  This frame has 1 object(s):
    [32, 36) 'stack_buf' <== Memory access at offset 36 overflows this
variable
HINT: this may be a false positive if your program uses some custom stack
unwind mechanism or swapcontext
      (longjmp and C++ exceptions *are* supported)
SUMMARY: AddressSanitizer: stack-buffer-overflow
(/lib64/libasan.so.5+0x40a1c)
Shadow bytes around the buggy address:
```

```
  0x10001e7a96c0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x10001e7a96d0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x10001e7a96e0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x10001e7a96f0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x10001e7a9700: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
=>0x10001e7a9710: 00 00 00 00 00 00 f1 f1 f1 f1[04]f2 f2 f2 f3 f3
  0x10001e7a9720: f3 f3 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x10001e7a9730: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x10001e7a9740: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x10001e7a9750: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x10001e7a9760: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
.....
```

可以看到asan报错：==38634==ERROR: AddressSanitizer: stack-buffer-overflow on address 0x7ffcf3d8b8d4 at xxx，发生stack buffer overflow时函数的调用链信息。

3 使用悬空指针

测试代码：

```
[root@yglocal asan_test]# vi dangling_pointer_test.c

#include <stdio.h>
#include <stdlib.h>
#include <string.h>

int main()
{
        char *p = (char*)malloc(32*sizeof(char));
        free(p);

        int a = p[1];

        return 0;
}
```

编译并运行：

```
[root@yglocal asan_test]# gcc -fsanitize=address -fno-omit-frame-pointer -o
dangling_pointer_test dangling_pointer_test.c
[root@yglocal asan_test]# ./dangling_pointer_test
=================================================================
==83532==ERROR: AddressSanitizer: heap-use-after-free on address
0x603000000011 at pc 0x0000004007c4 bp 0x7ffd7f562760 sp 0x7ffd7f562750
READ of size 1 at 0x603000000011 thread T0
    #0 0x4007c3 in main (/root/asan_test/dangling_pointer_test+0x4007c3)
    #1 0x7f56196cd872 in __libc_start_main (/lib64/libc.so.6+0x23872)
    #2 0x4006ad in _start (/root/asan_test/dangling_pointer_test+0x4006ad)

0x603000000011 is located 1 bytes inside of 32-byte region
[0x603000000010,0x603000000030)
freed by thread T0 here:
    #0 0x7f5619b5c7e0 in __interceptor_free (/lib64/libasan.so.5+0xef7e0)
    #1 0x400787 in main (/root/asan_test/dangling_pointer_test+0x400787)
    #2 0x7f56196cd872 in __libc_start_main (/lib64/libc.so.6+0x23872)

previously allocated by thread T0 here:
    #0 0x7f5619b5cba8 in __interceptor_malloc (/lib64/libasan.so.5+0xefba8)
    #1 0x400777 in main (/root/asan_test/dangling_pointer_test+0x400777)
    #2 0x7f56196cd872 in __libc_start_main (/lib64/libc.so.6+0x23872)

SUMMARY: AddressSanitizer: heap-use-after-free
(/root/asan_test/dangling_pointer_test+0x4007c3) in main
Shadow bytes around the buggy address:
  0x0c067fff7fb0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0c067fff7fc0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0c067fff7fd0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0c067fff7fe0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0c067fff7ff0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
=>0x0c067fff8000: fa fa[fd]fd fd fd fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8010: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8020: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8030: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8040: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8050: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
Shadow byte legend (one shadow byte represents 8 application bytes):
......
```

4 使用栈上返回的变量

```
[root@yglocal asan_test]# vi use-after-return.c

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
int *ptr;
void get_pointer()
{
        int local[10];
        ptr = &local[0];
        return;
}


int main()
{
        get_pointer();

        printf("%d\n", *ptr);

        return 0;
}
```

运行并编译：

```
[root@yglocal asan_test]# gcc -fsanitize=address -fno-omit-frame-pointer -o
use_after_return use-after-return.c
[root@yglocal asan_test]# ASAN_OPTIONS=detect_stack_use_after_return=1
./use_after_return
=================================================================
==108419==ERROR: AddressSanitizer: stack-use-after-return on address
0x7fa2de200020 at pc 0x0000004009a2 bp 0x7ffccaef23c0 sp 0x7ffccaef23b0
READ of size 4 at 0x7fa2de200020 thread T0
    #0 0x4009a1 in main (/root/asan_test/use_after_return+0x4009a1)
```

```
    #1 0x7fa2e264d872 in __libc_start_main (/lib64/libc.so.6+0x23872)
    #2 0x4007cd in _start (/root/asan_test/use_after_return+0x4007cd)

Address 0x7fa2de200020 is located in stack of thread T0 at offset 32 in
frame
    #0 0x400895 in get_pointer (/root/asan_test/use_after_return+0x400895)

  This frame has 1 object(s):
    [32, 72) 'local' <== Memory access at offset 32 is inside this variable
HINT: this may be a false positive if your program uses some custom stack
unwind mechanism or swapcontext
      (longjmp and C++ exceptions *are* supported)
SUMMARY: AddressSanitizer: stack-use-after-return
(/root/asan_test/use_after_return+0x4009a1) in main
Shadow bytes around the buggy address:
  0x0ff4dbc37fb0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0ff4dbc37fc0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0ff4dbc37fd0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0ff4dbc37fe0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0ff4dbc37ff0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
=>0x0ff4dbc38000: f5 f5 f5 f5[f5]f5 f5 f5 f5 f5 f5 f5 f5 f5 f5 f5
  0x0ff4dbc38010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0ff4dbc38020: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0ff4dbc38030: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0ff4dbc38040: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0ff4dbc38050: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
......
```

注：运行时，启用ASAN_OPTIONS=detect_stack_use_after_return=1标志，才能检测此种内存错误使用的情况。

5 使用退出作用域的变量

测试代码：

```
[root@yglocal asan_test]# vi use-after-scope.c

#include <stdio.h>
```

```c
#include <stdlib.h>
#include <string.h>

int main()
{
        int *p;
        {
                int num = 10;
                p = &num;
        }
        printf("%d/n", *p);

        return 0;
}
```

编译并运行：

```
[root@yglocal asan_test]# ./use-after-scope
=================================================================
==45490==ERROR: AddressSanitizer: stack-use-after-scope on address
0x7fffda668b50 at pc 0x0000004009ea bp 0x7fffda668b10 sp 0x7fffda668b00
READ of size 4 at 0x7fffda668b50 thread T0
    #0 0x4009e9 in main (/root/asan_test/use-after-scope+0x4009e9)
    #1 0x7fc2194ca872 in __libc_start_main (/lib64/libc.so.6+0x23872)
    #2 0x40082d in _start (/root/asan_test/use-after-scope+0x40082d)

Address 0x7fffda668b50 is located in stack of thread T0 at offset 32 in
frame
    #0 0x4008f5 in main (/root/asan_test/use-after-scope+0x4008f5)

  This frame has 1 object(s):
    [32, 36) 'num' <== Memory access at offset 32 is inside this variable
HINT: this may be a false positive if your program uses some custom stack
unwind mechanism or swapcontext
      (longjmp and C++ exceptions *are* supported)
SUMMARY: AddressSanitizer: stack-use-after-scope (/root/asan_test/use-
after-scope+0x4009e9) in main
Shadow bytes around the buggy address:
  0x10007b4c5110: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

```
  0x10007b4c5120: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x10007b4c5130: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x10007b4c5140: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x10007b4c5150: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
=>0x10007b4c5160: 00 00 00 00 00 00 f1 f1 f1 f1[f8]f2 f2 f2 f3 f3
  0x10007b4c5170: f3 f3 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x10007b4c5180: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x10007b4c5190: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x10007b4c51a0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x10007b4c51b0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
.....
[root@yglocal asan_test]#
```

6 重复释放

```
[root@yglocal asan_test]# vi invalid_free_test.c

#include <stdio.h>
#include <stdlib.h>

int main()
{
        char *p = (char*)malloc(32*sizeof(char));
        free(p);
        free(p);

        return 0;
}


```

运行并编译：

```
[root@yglocal asan_test]# gcc -fsanitize=address -fno-omit-frame-pointer -o
invalid_free_test invalid_free_test.c
[root@yglocal asan_test]# ./invalid_free_test
```

```
=================================================================
==116778==ERROR: AddressSanitizer: attempting double-free on 0x603000000010
in thread T0:
    #0 0x7fab036ca7e0 in __interceptor_free (/lib64/libasan.so.5+0xef7e0)
    #1 0x400743 in main (/root/asan_test/invalid_free_test+0x400743)
    #2 0x7fab0323b872 in __libc_start_main (/lib64/libc.so.6+0x23872)
    #3 0x40065d in _start (/root/asan_test/invalid_free_test+0x40065d)

0x603000000010 is located 0 bytes inside of 32-byte region
[0x603000000010,0x603000000030)
freed by thread T0 here:
    #0 0x7fab036ca7e0 in __interceptor_free (/lib64/libasan.so.5+0xef7e0)
    #1 0x400737 in main (/root/asan_test/invalid_free_test+0x400737)
    #2 0x7fab0323b872 in __libc_start_main (/lib64/libc.so.6+0x23872)

previously allocated by thread T0 here:
    #0 0x7fab036caba8 in __interceptor_malloc (/lib64/libasan.so.5+0xefba8)
    #1 0x400727 in main (/root/asan_test/invalid_free_test+0x400727)
    #2 0x7fab0323b872 in __libc_start_main (/lib64/libc.so.6+0x23872)

SUMMARY: AddressSanitizer: double-free (/lib64/libasan.so.5+0xef7e0) in
__interceptor_free
==116778==ABORTING
```

7 使用退出作用域的内存

测试代码：

```
[root@yglocal asan_test]# vi use-after-scope.c

#include <stdio.h>
#include <stdlib.h>

int main()
{
        int *p;
        {
                int num = 10;
```

```
                p = &num;
        }
        printf("%d/n", *p);

        return 0;
}
```

编译并运行：

```
[root@yglocal asan_test]# gcc -fsanitize=address -fno-omit-frame-pointer -o
use-after-scope use-after-scope.c
[root@yglocal asan_test]# ./use-after-scope
=================================================================
==118523==ERROR: AddressSanitizer: stack-use-after-scope on address
0x7ffd35fafc60 at pc 0x0000004009ea bp 0x7ffd35fafc20 sp 0x7ffd35fafc10
READ of size 4 at 0x7ffd35fafc60 thread T0
    #0 0x4009e9 in main (/root/asan_test/use-after-scope+0x4009e9)
    #1 0x7f6d2c4ce872 in __libc_start_main (/lib64/libc.so.6+0x23872)
    #2 0x40082d in _start (/root/asan_test/use-after-scope+0x40082d)

Address 0x7ffd35fafc60 is located in stack of thread T0 at offset 32 in
frame
    #0 0x4008f5 in main (/root/asan_test/use-after-scope+0x4008f5)

  This frame has 1 object(s):
    [32, 36) 'num' <== Memory access at offset 32 is inside this variable
HINT: this may be a false positive if your program uses some custom stack
unwind mechanism or swapcontext
      (longjmp and C++ exceptions *are* supported)
SUMMARY: AddressSanitizer: stack-use-after-scope (/root/asan_test/use-
after-scope+0x4009e9) in main
Shadow bytes around the buggy address:
  0x100026bedf30: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x100026bedf40: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x100026bedf50: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x100026bedf60: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x100026bedf70: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
=>0x100026bedf80: 00 00 00 00 00 00 00 00 f1 f1 f1 f1[f8]f2 f2 f2
  0x100026bedf90: f3 f3 f3 f3 00 00 00 00 00 00 00 00 00 00 00 00
```

```
  0x100026bedfa0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x100026bedfb0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x100026bedfc0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x100026bedfd0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
....
```

8 内存泄露检测

测试代码：

```
[root@yglocal asan_test]# vi memory_leak_test.c


#include <stdio.h>
#include <stdlib.h>
#include <string.h>

char* get_systeminfo()
{
        char *p_system = (char*)malloc(38*sizeof(char));
        strcpy(p_system, "Linux version 4.18.0-147.el8.x86_64");
        return p_system;
}

int main()
{
        printf("system info:%s", get_systeminfo());
        return 0;
}
```

编译并运行：

```
[root@yglocal asan_test]# gcc -fsanitize=address -fno-omit-frame-pointer -o
memory_leak_test memory_leak_test.c
[root@yglocal asan_test]# ASAN_OPTIONS=detect_leaks=1  ./memory_leak_test

=================================================================
```

```
==122316==ERROR: LeakSanitizer: detected memory leaks

Direct leak of 38 byte(s) in 1 object(s) allocated from:
    #0 0x7fde593f3ba8 in __interceptor_malloc (/lib64/libasan.so.5+0xefba8)
    #1 0x400827 in get_systeminfo
(/root/asan_test/memory_leak_test+0x400827)
    #2 0x400855 in main (/root/asan_test/memory_leak_test+0x400855)
    #3 0x7fde58f64872 in __libc_start_main (/lib64/libc.so.6+0x23872)

SUMMARY: AddressSanitizer: 38 byte(s) leaked in 1 allocation(s).
```

注：内存泄漏检测时，需带上ASAN_OPTIONS=detect_leaks=1参数启程序。

四 ASan输出格式优化

1 使用ASAN_OPTIONS参数启动程序

ASAN_OPTIONS='stack_trace_format="[frame=%n, function=%f, location=%S]"'参数启动程序

```
[root@yglocal asan_test]# ASAN_OPTIONS='stack_trace_format="[frame=%n,
function=%f, location=%S]"' ./heap_ovf_test
=================================================================
==31061==ERROR: AddressSanitizer: heap-use-after-free on address
0x603000000010 at pc 0x7f181e836796 bp 0x7ffd87d62c30 sp 0x7ffd87d623a8
READ of size 2 at 0x603000000010 thread T0
[frame=0, function=<null>, location=<null>]
[frame=1, function=__interceptor_vprintf, location=<null>]
[frame=2, function=__interceptor_printf, location=<null>]
[frame=3, function=main, location=<null>]
[frame=4, function=__libc_start_main, location=<null>]
[frame=5, function=_start, location=<null>]

0x603000000010 is located 0 bytes inside of 32-byte region
[0x603000000010,0x603000000030)
```

```
freed by thread T0 here:
[frame=0, function=__interceptor_free, location=<null>]
[frame=1, function=main, location=<null>]
[frame=2, function=__libc_start_main, location=<null>]

previously allocated by thread T0 here:
[frame=0, function=__interceptor_malloc, location=<null>]
[frame=1, function=main, location=<null>]
[frame=2, function=__libc_start_main, location=<null>]

SUMMARY: AddressSanitizer: heap-use-after-free
(/lib64/libasan.so.5+0x55795)
Shadow bytes around the buggy address:
  0x0c067fff7fb0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0c067fff7fc0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0c067fff7fd0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0c067fff7fe0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0c067fff7ff0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
=>0x0c067fff8000: fa fa[fd]fd fd fd fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8010: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8020: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8030: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8040: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8050: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
Shadow byte legend (one shadow byte represents 8 application bytes):
  Addressable:           00
  Partially addressable: 01 02 03 04 05 06 07
  Heap left redzone:       fa
  Freed heap region:       fd
  Stack left redzone:      f1
  Stack mid redzone:       f2
  Stack right redzone:     f3
  Stack after return:      f5
  Stack use after scope:   f8
  Global redzone:          f9
  Global init order:       f6
  Poisoned by user:        f7
  Container overflow:      fc
  Array cookie:            ac
  Intra object redzone:    bb
```

```
  ASan internal:           fe
  Left alloca redzone:     ca
  Right alloca redzone:    cb
==31061==ABORTING
```

2 使用asan_symbolize.py脚本

输出的调用链中信息更精确，可以对应到代码文件的具体某一行：

```
[root@yglocal asan_test]# gcc -fsanitize=address -fno-omit-frame-pointer -g
-o heap_ovf_test heap_ovf_test.c
[root@yglocal asan_test]# ./heap_ovf_test 2>&1 | ./asan_symbolize.py
=================================================================
==66336==ERROR: AddressSanitizer: heap-buffer-overflow on address
0x603000000030 at pc 0x7f0e8b19ea1d bp 0x7ffc0764d8a0 sp 0x7ffc0764d048
WRITE of size 8 at 0x603000000030 thread T0
    #0 0x7f0e8b19ea1c in __interceptor_strpbrk ??:?
    #1 0x400845 in main /root/asan_test/heap_ovf_test.c:9
    #1 0x7f0e8adbe872 in __libc_start_main ??:?
    #2 0x40075d in _start ??:?

0x603000000030 is located 0 bytes to the right of 32-byte region
[0x603000000010,0x603000000030)
allocated by thread T0 here:
    #0 0x7f0e8b24dba8 in malloc ??:?
    #1 0x400827 in main /root/asan_test/heap_ovf_test.c:8
    #1 0x7f0e8adbe872 in __libc_start_main ??:?

SUMMARY: AddressSanitizer: heap-buffer-overflow
(/lib64/libasan.so.5+0x40a1c)
Shadow bytes around the buggy address:
  0x0c067fff7fb0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0c067fff7fc0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0c067fff7fd0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0c067fff7fe0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x0c067fff7ff0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
=>0x0c067fff8000: fa fa 00 00 00 00[fa]fa fa fa fa fa fa fa fa fa
  0x0c067fff8010: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
```

```
  0x0c067fff8020: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8030: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8040: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x0c067fff8050: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
Shadow byte legend (one shadow byte represents 8 application bytes):
  Addressable:           00
  Partially addressable: 01 02 03 04 05 06 07
  Heap left redzone:       fa
  Freed heap region:       fd
  Stack left redzone:      f1
  Stack mid redzone:       f2
  Stack right redzone:     f3
  Stack after return:      f5
  Stack use after scope:   f8
  Global redzone:          f9
  Global init order:       f6
  Poisoned by user:        f7
  Container overflow:      fc
  Array cookie:            ac
  Intra object redzone:    bb
  ASan internal:           fe
  Left alloca redzone:     ca
  Right alloca redzone:    cb
==66336==ABORTING
```

五 更多配置参数

1 编译参数

2 运行时参数

查看看所有的运行时参数，可以用ASAN_OPTIONS=help=1启动程序，就会输出所有支持的参数标志：

```
[root@yglocal asan_test]# ASAN_OPTIONS=help=1 ./use-after-scope
Available flags for AddressSanitizer:
        ......
        debug
                - If set, prints some debugging information and does additiona
        check_initialization_order
               - If set, attempts to catch initialization order issues.
        replace_str
                - If set, uses custom wrappers and replacements for libc strin
        replace_intrin
                - If set, uses custom wrappers for memset/memcpy/memmove intri
        detect_stack_use_after_return
                - Enables stack-use-after-return checking at run-time.
        ......
                - Number of seconds to sleep after AddressSanitizer is initial
        check_malloc_usable_size
                - Allows the users to work around the bug in Nvidia drivers pr
        unmap_shadow_on_exit
                - If set, explicitly unmaps the (huge) shadow at exit.
        protect_shadow_gap
                - If set, mprotect the shadow gap
        print_stats
                - Print various statistics after printing an error message or
        print_legend
                - Print the legend for the shadow bytes.
        print_scariness
                - Print the scariness score. Experimental.
        ......
                - If true, ASan tweaks a bunch of other flags (quarantine, red
        detect_invalid_pointer_pairs
                - If >= 2, detect operations like <, <=, >, >= and - on invali
        detect_container_overflow
                - If true, honor the container overflow annotations. See https
        detect_odr_violation
```

```
35              - If >=2, detect violation of One-Definition-Rule (ODR); If ==
36      suppressions
37              - Suppressions file name.
38      halt_on_error
39              - Crash the program after printing the first error report (WAR
40      use_odr_indicator
41              - Use special ODR indicator symbol for ODR violation detectior
42      allocator_frees_and_returns_null_on_realloc_zero
43              - realloc(p, 0) is equivalent to free(p) by default (Same as t
44      verify_asan_link_order
45              - Check position of ASan runtime in library list (needs to be
46      symbolize
47              - If set, use the online symbolizer from common sanitizer runt
48      external_symbolizer_path
49              - Path to external symbolizer. If empty, the tool will search
50      allow_addr2line
51              - If set, allows online symbolizer to run addr2line binary to
52      strip_path_prefix
53              - Strips this prefix from file paths in error reports.
54      ......
```

更详细的使用可以查看参考链接相关页面。

参考链接：https://github.com/google/sanitizers/wiki/AddressSanitizer

--- EOF ---

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