HITB GSEC

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Recreating an iOS 0-day jailbreak out of Apple's security patches

August, 2019

Who Am I?

Stefan Esser

- working in IT Security since 1998
- started with runtime encryption / decryption
- moved on to linux daemon security
- then did a lot of work in PHP and Web Application Security
- finally moved on in 2010 to iOS and Mac Security

Motivation

- the release of iOS 12.1.4 fixed vulnerabilities used in the wild
- we only know because of a tweet from someone at Google P0
- neither Apple nor Google officially described the incident
- no official description of the vulnerabilities from those who found it
- 3rd parties had to use patch diffing to figure it out

- Of course Google Project 0 dumped a lot of info literally YESTERDAY :P

Agenda

- Introduction
- Diffing the kernel for CVE-2019-7287
- Diffing user land for CVE-2019-7286
- Exploitation roadmap for CVE-2019-7287
- Exploitation roadmap for CVE-2019-7286
- Conclusion

Introduction

Security Content of iOS 12.1.4

- Apple released iOS 12.1.4 on February 7th 2019
- in response to a serious FaceTime vulnerability
- vulnerability in FaceTime got a lot of media attention
- initiator of a group call could force recipient to answer

Security Content of iOS 12.1.4 (II)

- … but security updated contained two more vulnerability fixes [1]

Foundation

Available for: iPhone 5s and later, iPad Air and later, and iPod touch 6th generation

Impact: An application may be able to gain elevated privileges

Description: A memory corruption issue was addressed with improved input validation.

CVE-2019-7286: an anonymous researcher, Clement Lecigne of Google Threat Analysis Group, Ian Beer of Google Project Zero, and Samuel Groß of Google Project Zero

IOKit

Available for: iPhone 5s and later, iPad Air and later, and iPod touch 6th generation

Impact: An application may be able to execute arbitrary code with kernel privileges

Description: A memory corruption issue was addressed with improved input validation.

CVE-2019-7287: an anonymous researcher, Clement Lecigne of Google Threat Analysis Group, Ian Beer of Google Project Zero, and Samuel Groß of Google Project Zero

And then Google Project 0 chimed in

- one day after release a tweet from @benhawkes of Google’s P0 appeared [2]
- apparently Google had knowledge of both flaws being exploited in the wild

Any more info?

- Aside from Ben Hawkes' tweet there was no further information
- This raised a lot of questions among researchers like
  - How did Google find an iOS 0-day in the wild
  - Who was attacked? Google itself? Or their customers?
  - What exactly hides behind CVE-2019-7286 and CVE-2019-7287?
  - Was the attack hidden in some app?
    (because both vulnerabilities seems to be LPE/sandbox escape only)
  - Why did Google keep silent considering iOS 0-days are not often found
  - Will we ever get samples?

GOOGLE dumped a full description yesterday[3]

Any more info? (II)

- most of these questions are still unanswered
- only bit of more info was given within a tweet of another Google researcher
- apparently the two vulnerabilities were combined with an already fixed browser bug
- furthermore it was said that Google were simply too busy to do a write up

- tweet was lost in ocean of twitter

GOOGLE dumped a full description yesterday[3]

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References

- [1] About Security Content of iOS 12.1.4
  https://support.apple.com/en-sg/HT209520
- [2] Tweet by @benhawkes
  https://twitter.com/benhawkes/status/1093581737924259840
- [3] A very deep dive into iOS Exploit chains found in the wild
  https://googleprojectzero.blogspot.com/2019/08/a-very-deep-dive-into-ios-exploit.html
- [4] In-the-wild iOS Exploit Chain 4
  https://googleprojectzero.blogspot.com/2019/08/in-wild-ios-exploit-chain-4.html

Diffing the kernel for CVE-2019-7287

CVE-2019-7287

- Information released by Apple is short and misleading

```
IOKit
Available for: iPhone 5s and later, iPad Air and later, and iPod touch 6th generation
Impact: An application may be able to execute arbitrary code with kernel privileges
Description: A memory corruption issue was addressed with improved input validation.
CVE-2019-7287: an anonymous researcher, Clement Lecigne of Google Threat Analysis
Group, Ian Beer of Google Project Zero, and Samuel Groß of Google Project Zero
```

- we only learn that it is a memory corruption
- affected component is said to be IOKit
- IOKit is a part of the iOS kernel that is responsible for device drivers
  (however further analysis will reveal that this is misleading)

Preparing the Kernels

- In order to analyse Apple's patch we first need to grab a copy of the two kernels
- download IPSW files for iOS 12.1.3 and 12.1.4 via links from TheiPhoneWiki **[1]**
- unzip the kernelcache files
- use Xerub's IMG4LIB **[2]** to extract the macho kernels
- load both kernels into different IDA sessions
- use Lumina **[3]** and other scripts to fill the databases with symbols
- perform as many steps as possible to cleanup the disassemblies

Diffing the Kernels

- with both kernels being prepared and symbolised we can now use Diaphora **[4]**
- diffing will take a long while and is best performed overnight
- to speed up diffing we could limit diff to only affected area
- problem is we don’t really know what is affected
- Apple listed IOKit as affected but limiting to main kernel did not get us results

Diffing the Kernels (II)

- when you diff whole kernel you run into several problems
  - lots of unclean disassembly
  - many more functions
  - many more false matches
- so diffing result will be incomplete and harder to interpret

Finding the affected Component (I)

- Diaphora result was hard to read
- However after a while we found a candidate that could be the culprit **[5]**

```
__int64 __fastcall ProvInfoIOKitUserClient::ucGetEncryptedSeedSegment(__int64 a1, unsigned int *a2, __int64 a3,
{
  __int64 v8; // x19
  char *v9; // x0
  __int64 v10; // x0
  __int64 v12; // [xsp+0h] [xbp-20h]

  if ( !a2 )
  {
    v8 = 0xE00002C2LL;
    v9 = "[ProvInfoIOKitUserClient::ucGetEncryptedSeedSegment] Error: null pointer for input structure\n";
    goto LABEL_7;
  }
  if ( a2[30] >= 0x41 )
  {
    v8 = 0xE00002C2LL;
    v9 = "[ProvInfoIOKitUserClient::ucGetEncryptedSeedSegment] Error: bad input structure lengths\n";
LABEL_7:
    IOLog(v9, v12);
    return v8;
  }
  v10 = (*(__int64 (__fastcall **)(_QWORD, _QWORD, _QWORD, char *, __int64, char *))(**(_QWORD **)(a1 + 216) +
          *(_QWORD *)(a1 + 216),
          *a2,
          *((unsigned __int16 *)a2 + 2),
          (char *)a2 + 6,
          a3,
          (char *)a2 + 54);
  v8 = v10;
  if ( (_DWORD)v10 )
  {
    v12 = v10;
    v9 = "[ProvInfoIOKitUserClient::ucGetEncryptedSeedSegment] ProvInfoIOKit::getEncryptedSeedSegment returned
    goto LABEL_7;
  }
  return v8;
```

Finding the affected Component (II)

- Diaphora found us a newly inserted size check
- in method ucGetEncryptedSeedSegment of object called ProvInfo**IOKit**UserClient
- this could be why Apple mentioned the affected area as IOKit
- however this code is not in the main kernel but in driver **ProvInfoIOKit**

```
__int64 __fastcall ProvInfoIOKitUserClient::ucGetEncryptedSeedSegment(__int64 a1, unsigned int *a2, __int64 a3,
{
  __int64 v8; // x19
  char *v9; // x0
  __int64 v10; // x0
  __int64 v12; // [xsp+0h] [xbp-20h]

  if ( !a2 )
  {
    v8 = 0xE00002C2LL;
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    goto LABEL_7;
  }
  if ( a2[30] >= 0x41 )
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    v8 = 0xE00002C2LL;
    v9 = "[ProvInfoIOKitUserClient::ucGetEncryptedSeedSegment] Error: bad input structure lengths\n";
LABEL_7:
    IOLog(v9, v12);
    return v8;
  }
  v10 = (*(__int64 (__fastcall **)(_QWORD, _QWORD, _QWORD, char *, __int64, char *))(**(_QWORD **)(a1 + 216) +
          *(_QWORD *)(a1 + 216),
          *a2,
          *((unsigned __int16 *)a2 + 2),
          (char *)a2 + 6,
          a3,
          (char *)a2 + 54);
  v8 = v10;
  if ( (_DWORD)v10 )
  {
    v12 = v10;
    v9 = "[ProvInfoIOKitUserClient::ucGetEncryptedSeedSegment] ProvInfoIOKit::getEncryptedSeedSegment returned
    goto LABEL_7;
  }
  return v8;
```

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Analysing ProvInfoIOKit

- Purpose of **ProvInfoIOKit** was unknown
- Google search for this string revealed no additional information
- driver not accessible from container sandbox or mobile safari
- only sandbox profiles allowing access are

  - **findmydeviced**
  - **mobileactivationd**
  - **identityserviced**

Analysing ProvInfoIOKit (II)

- object **ProvInfoIOKitUserClient** is user space interface of driver
- further research revealed that affected method is an external method of driver
- In total 6 external methods are supported by that object

  - **ucGenerateSeed** (obfuscated name: fpXqy2dxjQo7)
  - **ucGenerateInFieldSeed** (obfuscated name: afpHseTGo8s)
  - **ucExchangeWithHoover** (obfuscated name: AEWpRs)
  - **ucGetEntcryptedSeedSegment**
  - **ucEncryptSUInfo**
  - **ucEncryptWithWrapperKey**

The Surprise !!! (I)

- Check of other external methods revealed two more new size checks

```
__int64 __fastcall ProvInfoIOKitUserClient::ucEncryptSUInfo(__int64 a1, __int64 a2, size_t a3, __int64 a4, __i
{
  size_t v8; // x20
  unsigned int *v9; // x19
  __int64 v10; // x21
  size_t v11; // x2
  __int64 v12; // x19
  char *v13; // x0
  __int64 v14; // x0
  __int64 v16; // [xsp+0h] [xbp-30h]

  v8 = a3;
  v9 = (unsigned int *)a2;
  v10 = a1;
  if ( !a2 || !a3 )
  {
    v12 = 0xE00002C2LL;
    v13 = "[ProvInfoIOKitUserClient::ucEncryptSUInfo] Error: null pointer for input parameter\n";
    goto LABEL_8;
  }
  v11 = *(unsigned int *)(a2 + 2004);
  if ( (unsigned int)v11 >= 0x7D1 )
  {
    v12 = 0xE00002C2LL;
    v13 = "[ProvInfoIOKitUserClient::ucEncryptSUInfo] Error: bad input structure length\n";
LABEL_8:
    IOLog(v13, v16);
    return v12;
  }
  memmove((void *)(v8 + 4), (const void *)(a2 + 4), v11);
  *(_DWORD *)(v8 + 2004) = v9[501];
  v14 = (*(__int64 (__fastcall **)(_QWORD, _QWORD, size_t))(**(_QWORD **)(v10 + 216) + 1368LL))(
          *(_QWORD *)(v10 + 216),
          *v9,
```

The Surprise !!! (II)

- Check of other external methods revealed two more new size checks

```
__int64 __fastcall ProvInfoIOKitUserClient::ucEncryptWithWrappedKey(__int64 a1, unsigned int *a2, size_t a3, _
{
  _DWORD *v8; // x19
  unsigned int *v9; // x20
  __int64 v10; // x21
  size_t v11; // x2
  __int64 v12; // x19
  char *v13; // x0
  __int64 v15; // x0

  v8 = (_DWORD *)a3;
  v9 = a2;
  v10 = a1;
  if ( !a2 || !a3 )
  {
    v12 = 0xE00002C2LL;
    v13 = "[ProvInfoIOKitUserClient::ucEncryptWithWrappedKey] bad pointer for input or output structure\n";
    goto LABEL_7;
  }
  v11 = a2[17];
  if ( (unsigned int)v11 > 0x40 || a2[34] >= 0x41 )
  {
    v12 = 0xE00002C2LL;
    v13 = "[ProvInfoIOKitUserClient::ucEncryptWithWrappedKey] bad input structure length\n";
LABEL_7:
    IOLog(v13);
    return v12;
  }
  memmove(v8 + 1, a2 + 1, v11);
  v8[17] = v9[17];
  memmove(v8 + 18, v9 + 18, v9[34]);
  v8[34] = v9[34];
  v15 = (*(__int64 (__fastcall **)(_QWORD, _QWORD, _DWORD *, _QWORD, _DWORD *))(**(_QWORD **)(v10 + 216) + 137
          *(_QWORD *)(v10 + 216),
```

Controlled memmove length

- two methods **ucEncryptSUInfo** and **ucEncryptWithWrapperKey** are better targets
- newly introduced size check is just before size is used in a memmove
- the size for memmove is taken out of the incoming mach message
- and an arbitrary memory block is moved into the out message

```
  {
  v11 = a2[17];
  if ( (unsigned int)v11 > 0x40 || a2[34] >= 0x41 )
  {
    v12 = 0xE00002C2LL;
    v13 = "[ProvInfoIOKitUserClient::ucEncryptWithWrappedKey] bad input structure length\n";
LABEL_7:
    IOLog(v13);
    return v12;
  }
  memmove(v8 + 1, a2 + 1, v11);
  v8[17] = v9[17];
  memmove(v8 + 18, v9 + 18, v9[34]);
  v8[34] = v9[34];
```

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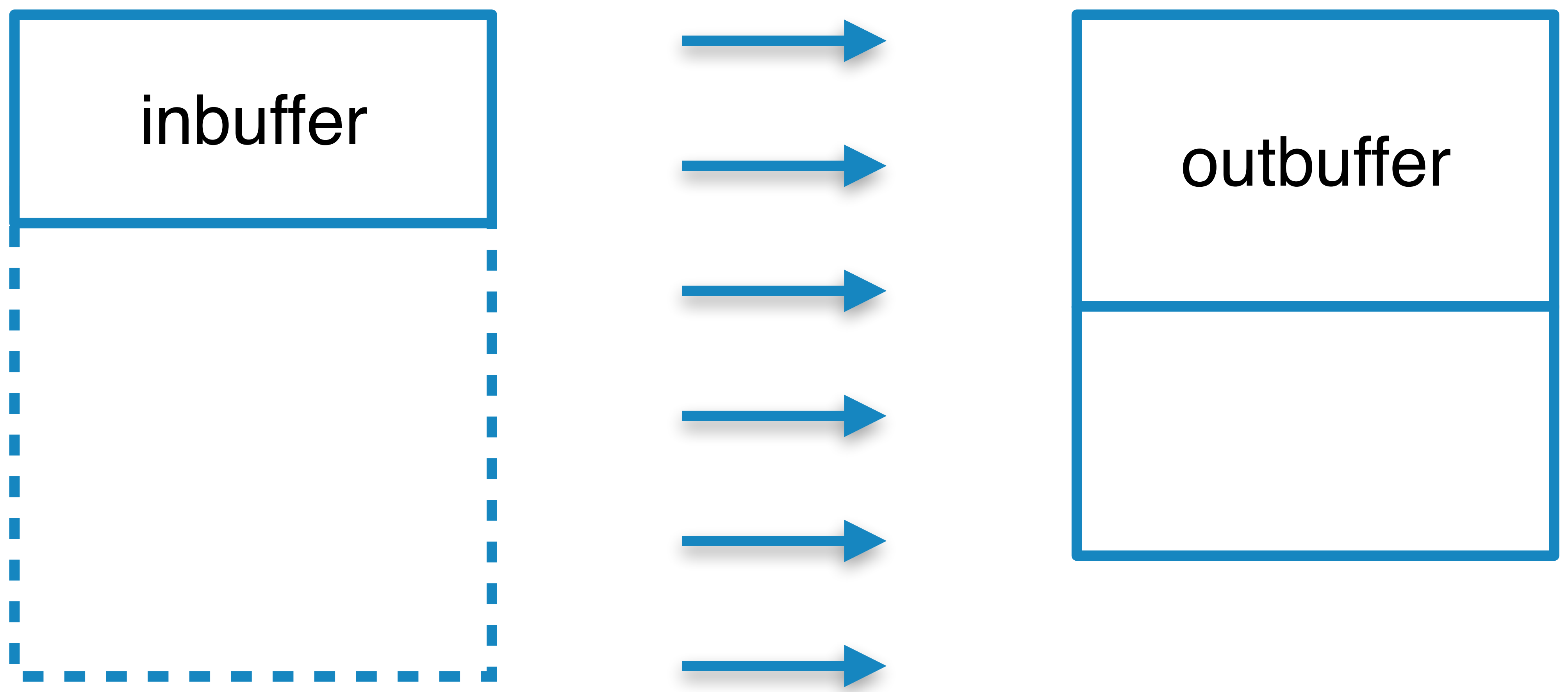
Controlled memmove length

- two methods **ucEncryptSUInfo** and **ucEncryptWithWrapperKey** are better targets
- newly introduced size check is just before size is used in a memmove
- the size for memmove is taken out of the incoming mach message
- and an arbitrary memory block is moved into the out message



References

- [1] TheiPhoneWiki Firmware Page
  https://www.theiphonewiki.com/wiki/Firmware/iPhone/12.x
- [2] Xerub's IMG4LIB
  https://github.com/xerub/img4lib
- [3] Hexray's iOS Kernel Lumina Support
  https://www.hex-rays.com/products/ida/7.2/the_mac_rundown/the_mac_rundown.shtml
- [4] Diaphora
  https://github.com/joxeankoret/diaphora
- [5] Antid0te Research into CVE-2019-7287
  https://www.antid0te.com/blog/19-02-23-ios-kernel-cve-2019-7287-memory-corruption-vulnerability.html

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Diffing user land for CVE-2019-7286

ZecOps Writeups

- a company called ZecOps performed similar research on the user land part
- they released a write up about it **[1]**
- the following section uses some content from their write up

CVE-2019-7286

- Information released by Apple is short and **again** misleading

```
Foundation
Available for: iPhone 5s and later, iPad Air and later, and iPod touch 6th generation
Impact: An application may be able to gain elevated privileges
Description: A memory corruption issue was addressed with improved input validation.
CVE-2019-7286: an anonymous researcher, Clement Lecigne of Google Threat Analysis
Group, Ian Beer of Google Project Zero, and Samuel Groß of Google Project Zero
```

- we only learn that it is some form of memory corruption
- affected component is said to be Foundation
- this hints the vulnerability is located in Foundation.framework
  (however further analysis will reveal that this is misleading)

Diffing the Framework (I)

- on iOS all builtin frameworks are located in the dyldsharedcache file
- this gigantic file is very hard to work with with most tools
- IDA has meanwhile acceptable support for it
- with a clear diffing target the diff can be performed a lot faster

Diffing the Framework (II)

- unfortunately diffing the Foundation.framework does not reveal any security fixes
- at this point other targets should be diffed
- next obvious choice is CoreFoundation.framework
- the Diaphora result for this diff reveals changes in CFPrefsDaemon

Name	Address 2	Name 2	Ratio	BBlocks 1	BBlocks 2
-[CFPrefsDaemon h...	00101854	-[CFPrefsDaemon handleMultiMessage:replyHandler:]	0.980	43	41
-[CFPrefsDaemon h...	0010021c	-[CFPrefsDaemon handleMessage:fromPeer:replyHandler:]	0.940	22	22
___49-[CFPrefsDae...	00101c34	___49-[CFPrefsDaemon handleMultiMessage:replyHandler:]_block_invoke_2	0.890	3	1
-[CFPrefsDaemon h...	001016f8	-[CFPrefsDaemon handleFlushSourceForDomainMessage:replyHandler:]	0.880	6	4
___39-[CFPrefsDae...	0010218c	___39-[CFPrefsDaemon initWithRole:testMode:]_block_invoke_3	0.670	4	2

Image source ZecOps

Finding the Vulnerability

- Unfortunately the last CoreFoundation source code on is 4 years old
- that old version does not seem to contain the CFPrefsDaemon code
- furthermore a quick google search did not reveal a copy of the code either
- however **ZecOps** has performed a manual decompilation of the code in question

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Decompiled code (by ZecOps)

```
@implementation CFPrefsDaemon
-(void)handleMultiMessage:(xpc_object_t)xpc_dict replyHandler:(Callback)replyHandler
{
  // ...
  CFPrefMessagesArr = xpc_dictionary_get_value(xpc_dict, "CFPreferencesMessages");
  // ...
  xpc_array_count = xpc_array_get_count(CFPrefMessagesArr);
  xpc_buffer = (__int64*)__CFAllocateObjectArray(xpc_array_count);
  //...
  for( counter = 0; xpc_array_count != counter; counter++)
  {
    xpc_buffer[counter] = xpc_array_get_value(CFPrefMessagesArr, counter); // This method does not
  }
  for( counter = 0; xpc_array_count != loop_counter ; counter++)
  {
    xpc_element = xpc_buffer[counter];
    xpc_buffer[counter] = 0;           //patch fix
    if ( xpc_get_type(xpc_element) == &_xpc_type_dictionary )
    {
      [self handleMessage_fromPeer_replyHandler: xpc_element fromPeer: xpc_connection replyHandler
          if (xpc_element) // patch fix
        {
            xpc_object_t result = xpc_retain(xpc_element);
            xpc_buffer[counter] = result;
          }
        }];
    }
    if ( !xpc_buffer[counter] )                //patch fix
      xpc_buffer[counter] = xpc_null_create(); //patch fix
  }
  //...
  array_from_xpc_buffer = xpc_array_create(xpc_buffer, xpc_array_count);
  xpc_dictionary_set_value(dict_response, "CFPreferencesMessages", array_from_xpc_buffer);
  xpc_release(array_from_xpc_buffer);
  for( counter = 0; xpc_array_count != counter ; counter++)
  {
    current_element = xpc_buffer[counter];
    if (xpc_get_type(current_element) != &_xpc_type_null )
        xpc_release(current_element); // first free. Double free will occur when the array CFPref
  }
  // ...
}
```

Finding the Vulnerability (II)

- In their research **ZecOps** has identified the vulnerability as a reference counting issue that leads to a double free
- The issue is in one of the XPC handling functions and therefore triggered via an XPC message
- The vulnerability is summarised as follows:
  - the code loops through the array **CFPreferencesMessages**
  - each element is copied into a buffer without increasing references
  - callback handlers are supposed to retain the object
  - a crafted XPC message can skip the callback
  - In this case the object is missing a reference

```
poc_dict = {
  "CFPreferencesOperation" = 5,
  "CFPreferencesMessages" = [
    {
     "CFPreferencesOperation": 4
    }
  ]
}
```

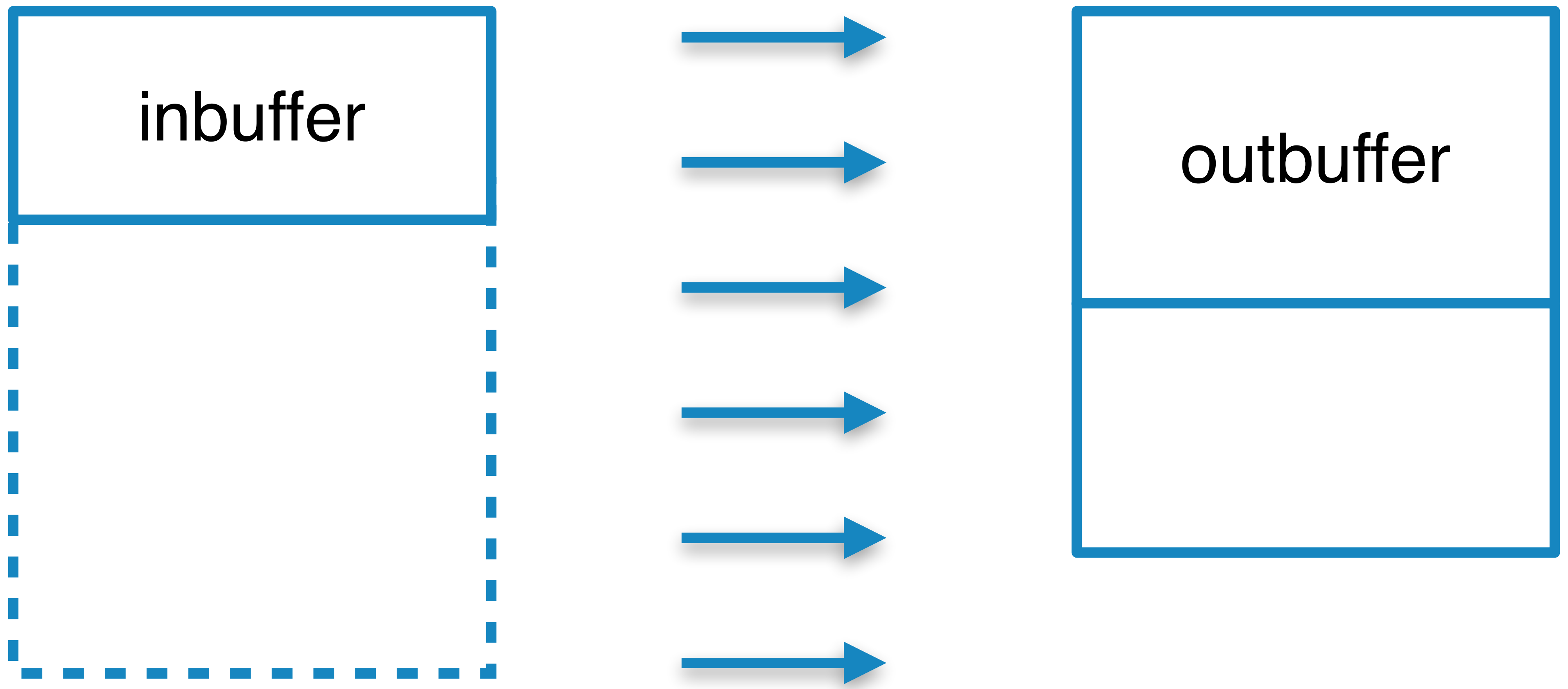

References

- [1] Analysis and Reproduction of iOS/OSX Vulnerability: CVE-2019-7286 https://blog.zecops.com/vulnerabilities/analysis-and-reproduction-of-cve-2019-7286/

Exploitation roadmap for CVE-2019-7287

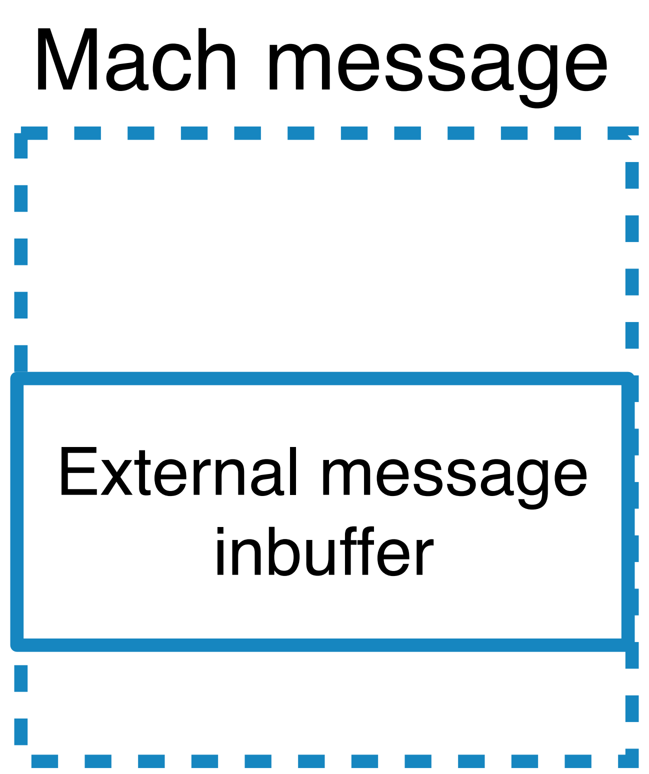
What kind of vulnerability do we have again?

- we control length of memmove when calling two external methods
- we can copy whatever is behind the input buffer
- overwrite what is behind the outputbuffer



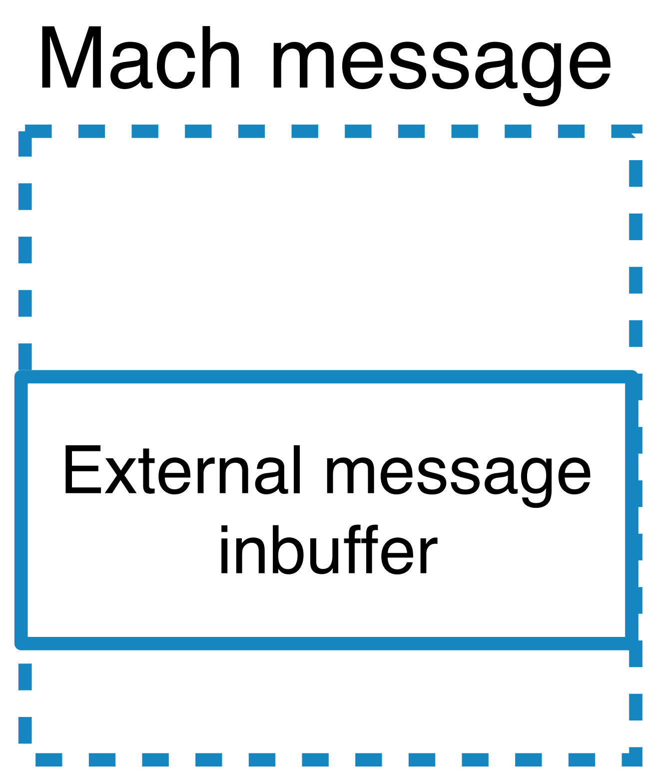
Where is our input buffer?

- external method is called internally via mach message
- input buffer is inbound in that mach message
- kernel “compresses” message according to parameter length
- position on heap depends on length



Where is our input buffer?

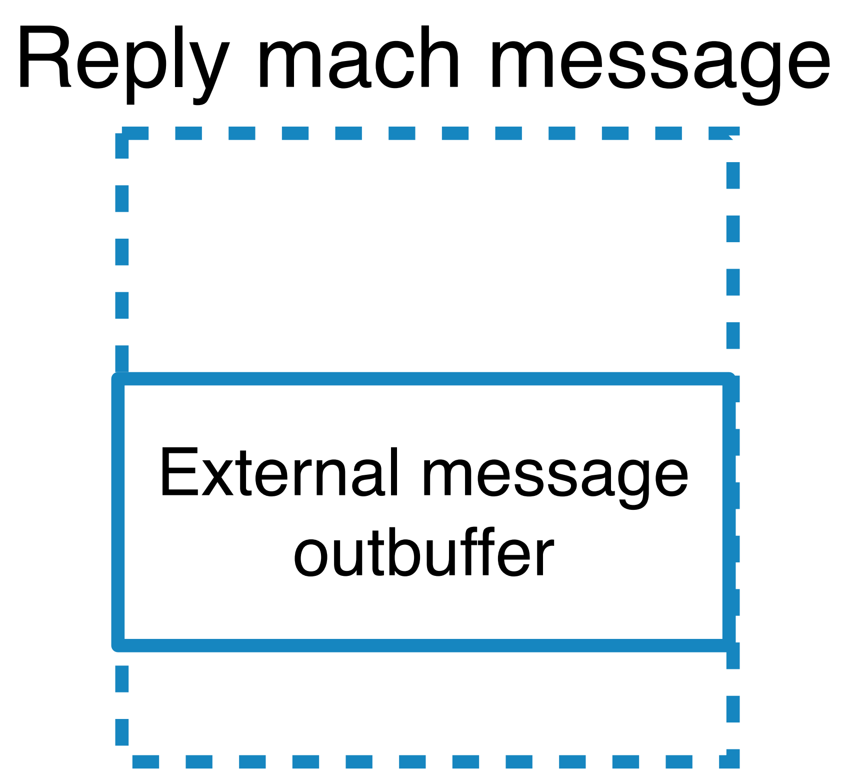
- **ucEncryptSUInfo**
  - 0x7d8 param length
  - message in kalloc.4096 zone
- **ucEncryptWithWrapperKey**
  - 0x8c param length
  - message in kalloc.512 zone



- buffer is in kalloc memory
- attacker can choose what zone is more convenient

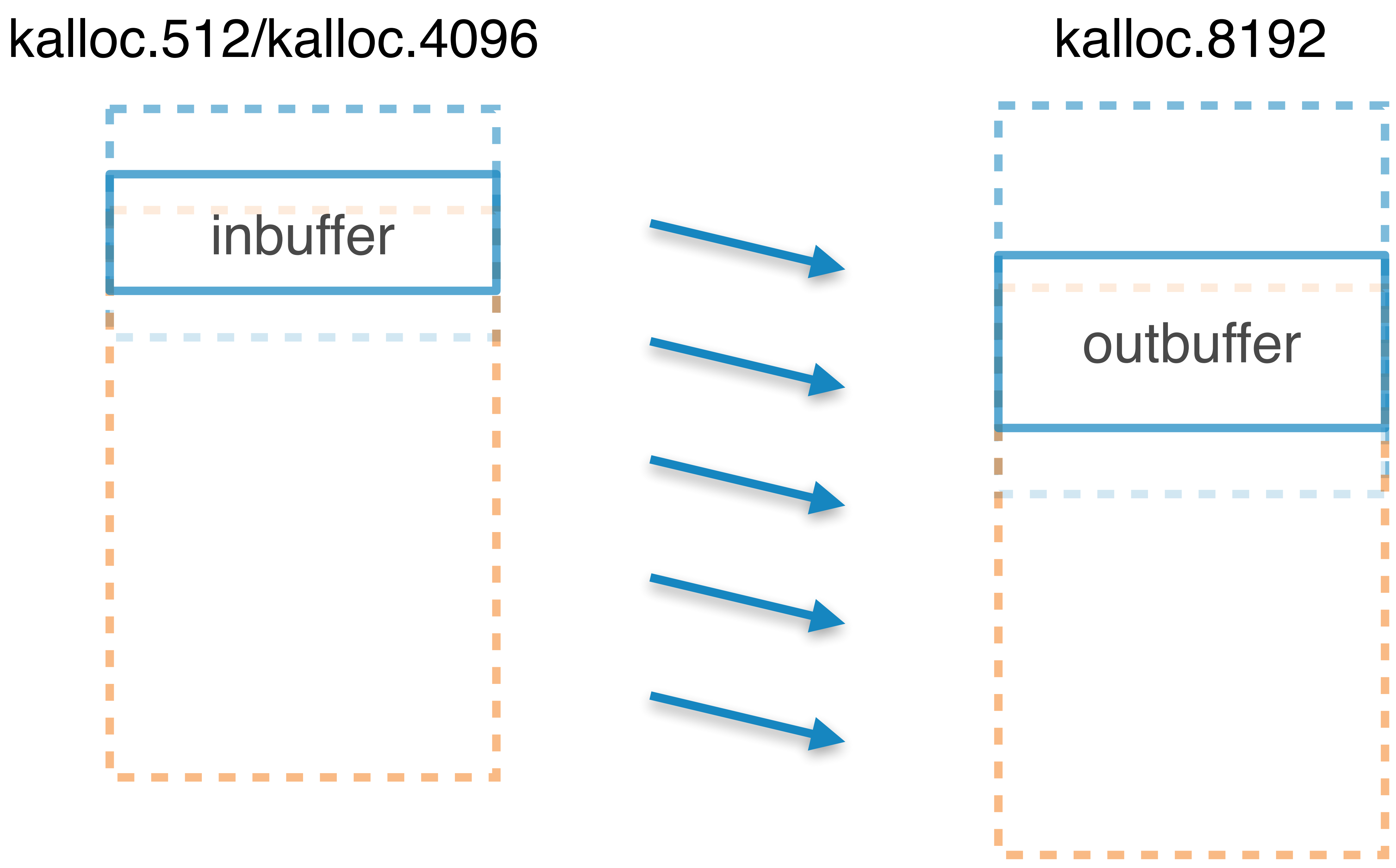
Where is our output buffer?

- external method is called internally via mach message
- output buffer is inbound in the reply mach message
- reply message is in kalloc.8192 zone



What kind of vulnerability do we have again?

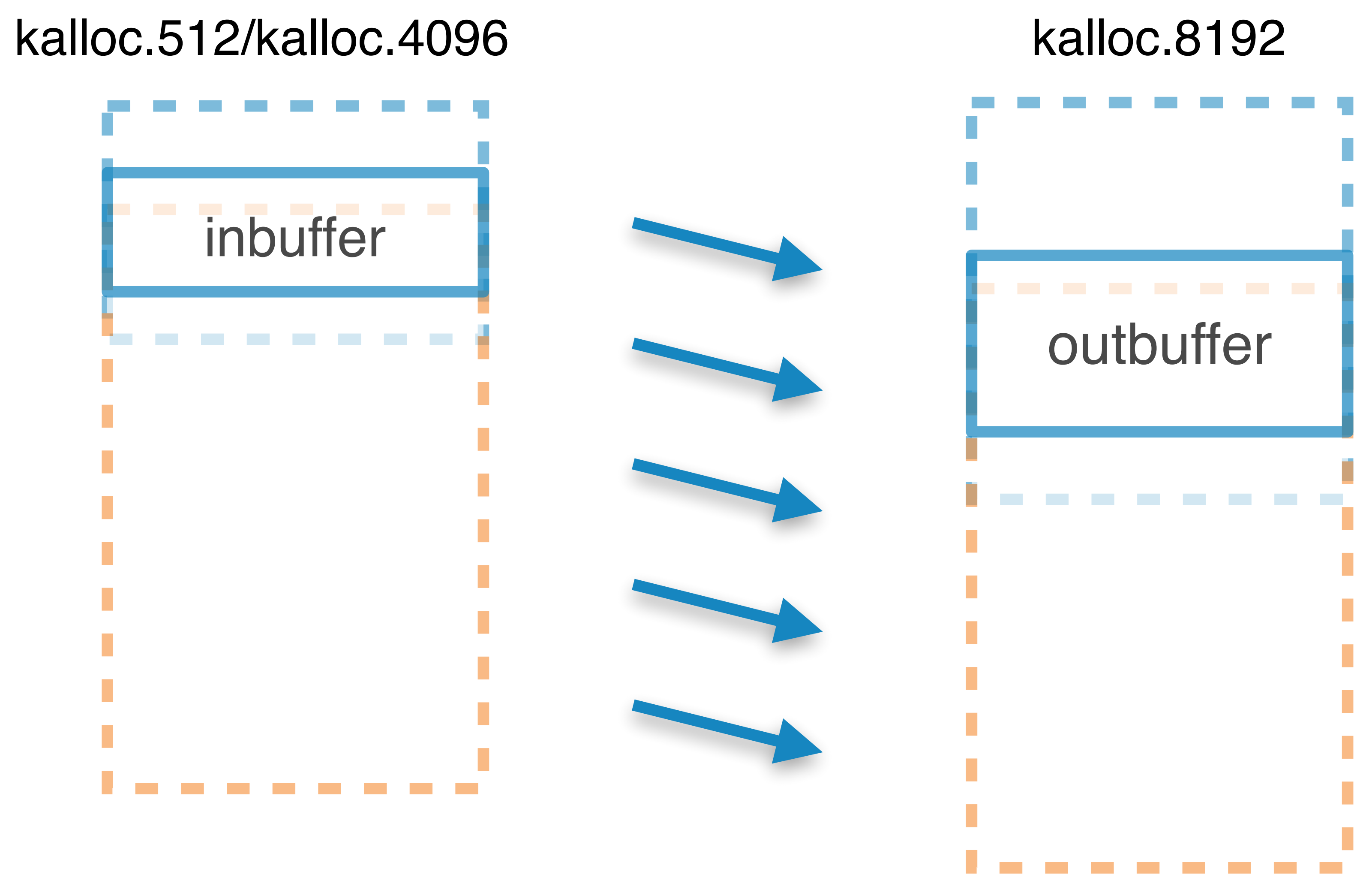
- source and destination are on different kalloc.X zone
- attacker can freely choose smaller or larger source zone



How to exploit?

- basically just a matter of heap feng shui
- and choosing what data to overwrite with what
- usually target is to somehow end up with a kernel task port

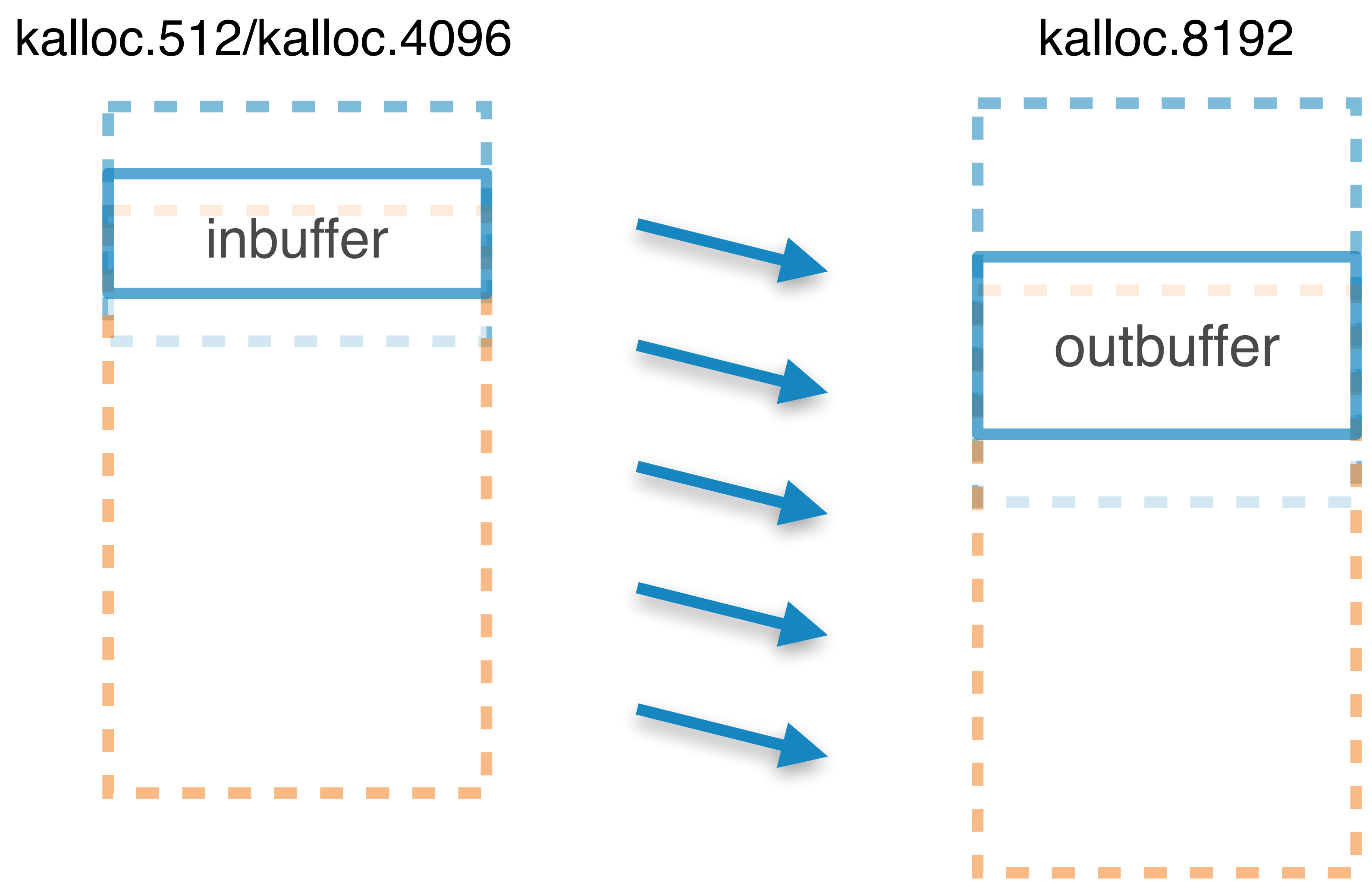
- possible heap feng shui techniques
    - vm_map_copy_t **[1]**
    - OOL_PORTS_DESCRIPTOR **[2]**
    - OSUnserializeXML / OSUnserializeBinary **[3]**
    - OSUnserializeXML via IOSurface **[4]**
    - pre-loaded mach messages for ports **[5]**
    - ...



How to exploit? (pre iPhone 7 devices)

- on old devices immediate game-over as demonstrated at CanSecWest 2017 **[2]**

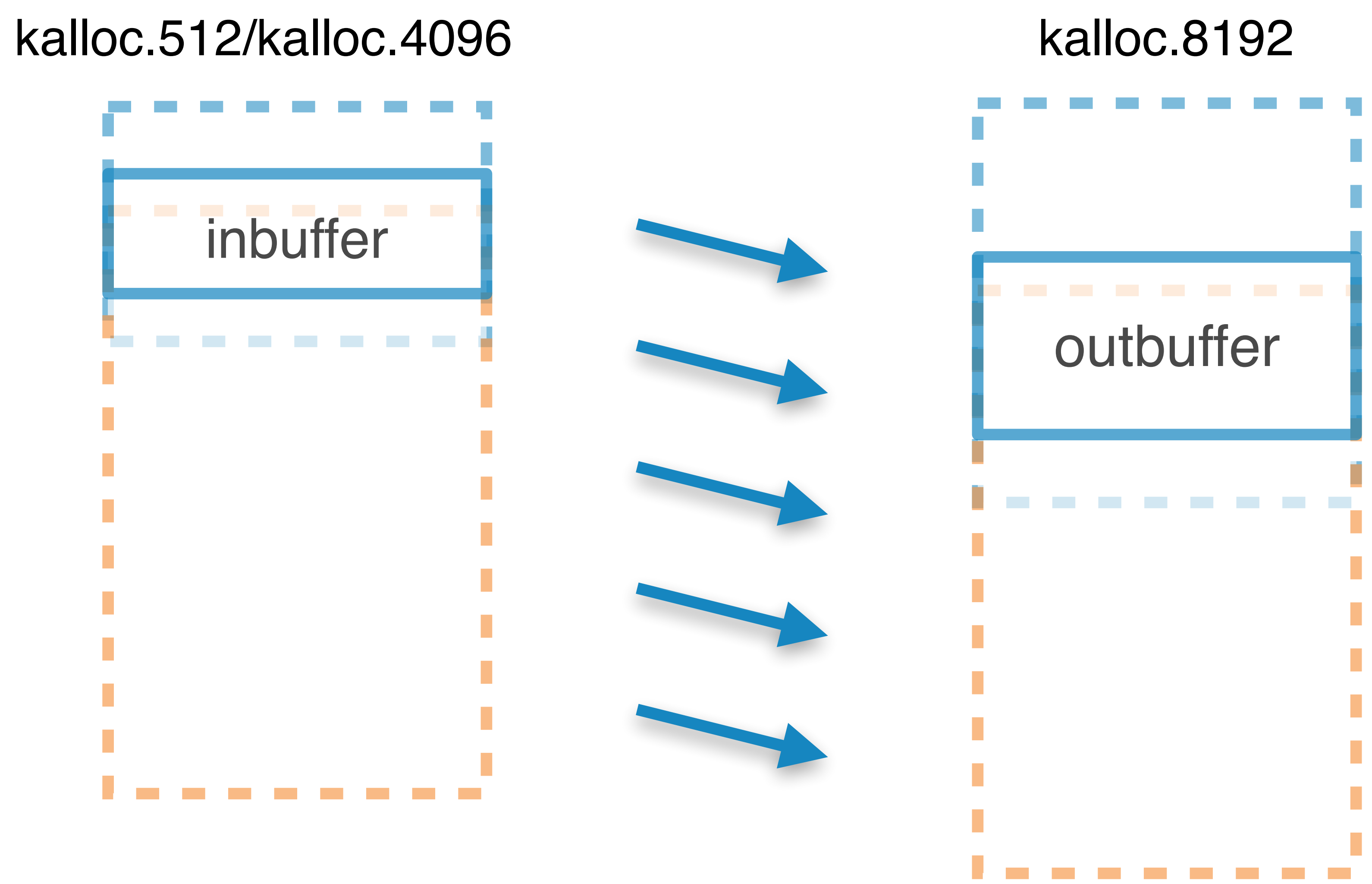
- use **vm_map_copy_t** to put user land pointers behind input buffer
- Use **OOL_PORTS_DESCRIPTOR** to put port pointers behind output buffer
- trigger exploit and use known code
    - CLOCK_PORT
    - TASK_PORT
    - KERNEL_TASK_PORT



How to exploit? (post iPhone 7 devices)

- on new devices exploitation is naturally harder
- however this vulnerability allows a lot of different things

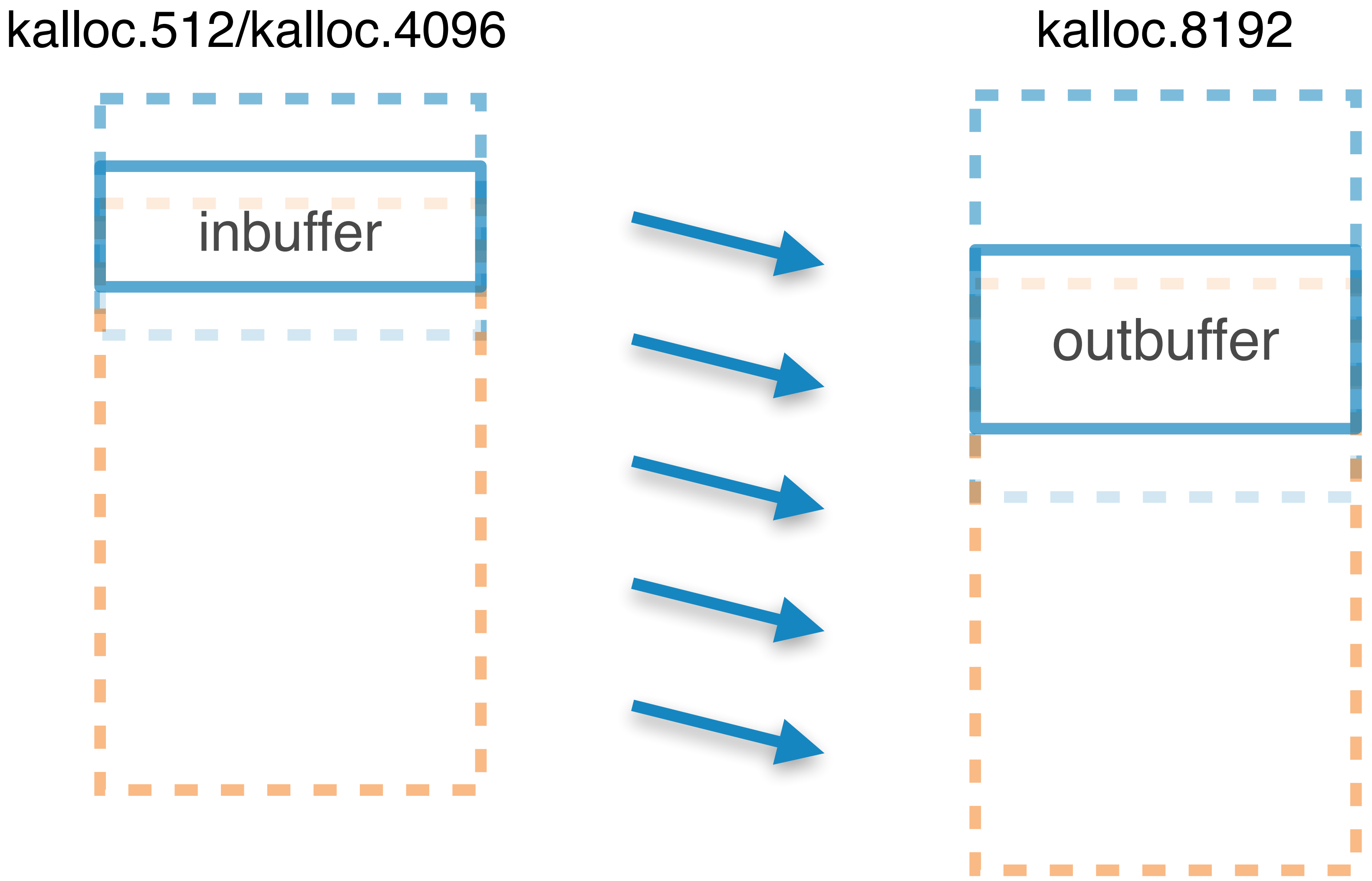
- **Example 1:**
  - Use **vm_map_copy_t** or **IOSurface** method in output buffer zone
  - after memmove content is moved into areas that we can read back
  - arbitrary kernel memory info leak (self locate, break KASLR)



How to exploit? (post iPhone 7 devices)

- on new devices exploitation is naturally harder
- however this vulnerability allows a lot of different things

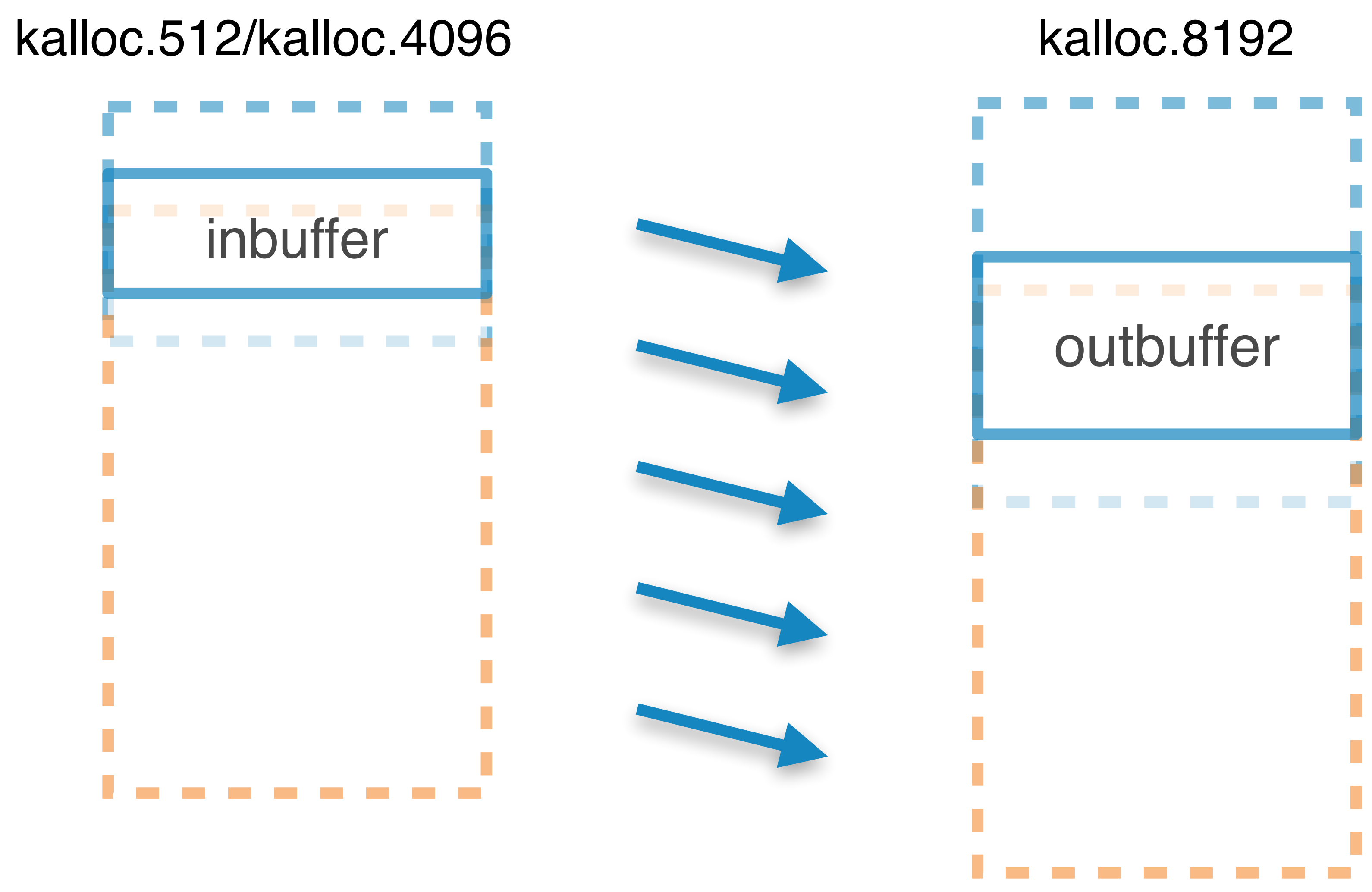
- **Example 2:**
  - Use **vm_map_copy_t** in input zone to put arbitrary data behind us
  - turns our memmove into a “bufferoverflow”
  - use exploitation technique from extract_recipe for outbuffer side



How to exploit? (post iPhone 7 devices)

- on new devices exploitation is naturally harder
- however this vulnerability allows a lot of different things

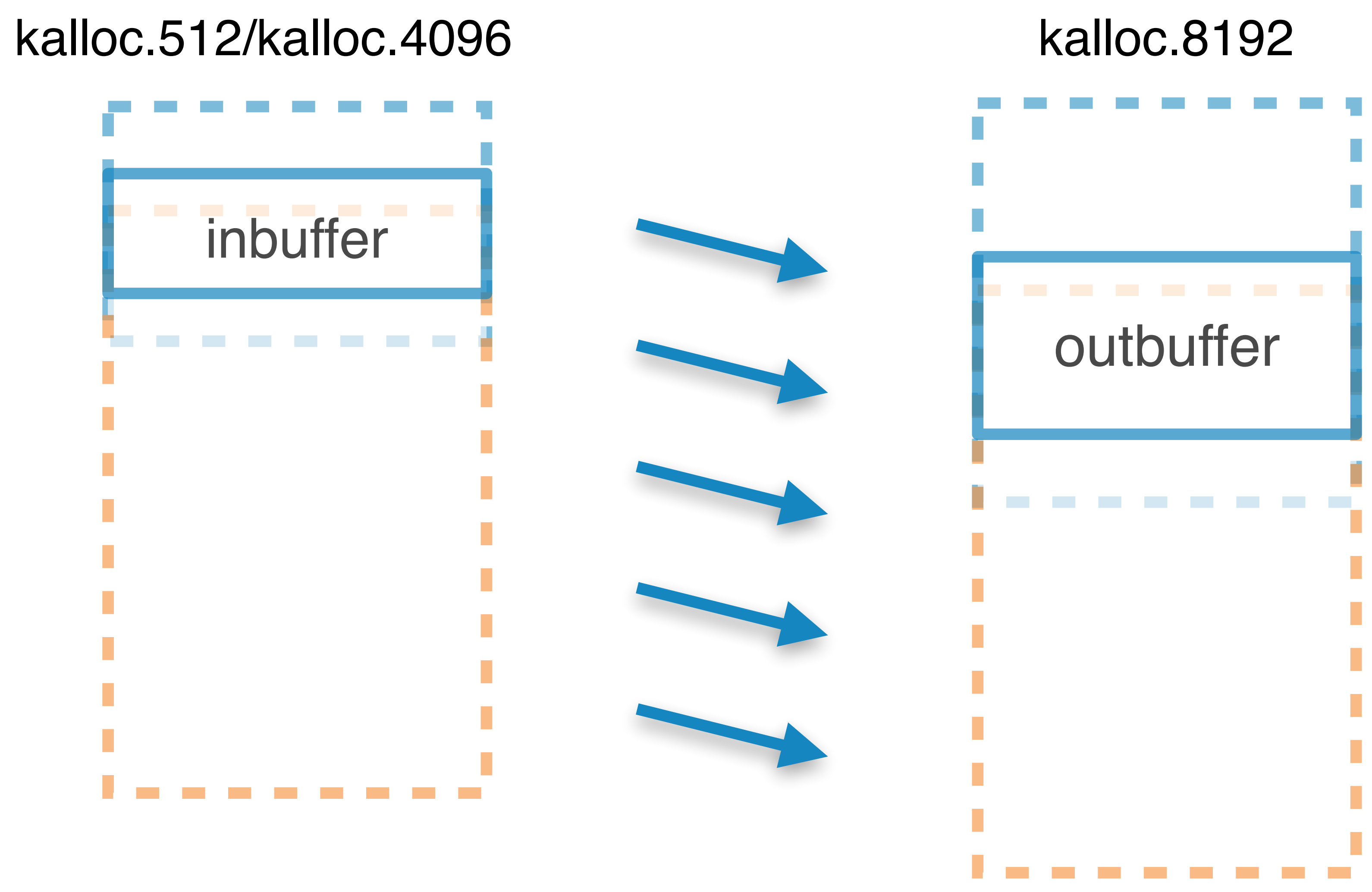
- **Example 3:**
  - Use **OOL_PORTS_DESCRIPTOR** in input and output zone
  - copies pointers to legal ports in output buffer
  - after receiving input zone heap feng shui messages all those pointers are dangling



How to exploit? (post iPhone 7 devices)

- on new devices exploitation is naturally harder
- however this vulnerability allows a lot of different things

- **Example 4:**
  - Use **vm_map_copy_t** in input zone to put arbitrary data into behind us
  - turns our memmove into a “bufferoverflow”
  - create many many kernel ports to have them next to output buffer
  - use vulnerability to (partially) overwrite ports



References

- [1] iOS 6 Kernel Security
  http://conference.hackinthebox.org/hitbsecconf2012kul/materials/D1T2%20-%20Mark%20Dowd%20&%20Tarjei%20Mandt%20-%20iOS6%20Security.pdf
- [2] Port(al) to the iOS Core
  https://www.slideshare.net/i0n1c/cansecwest-2017-portal-to-the-ios-core
- [3] iOS Kernel Heap Armageddon
  https://media.blackhat.com/bh-us-12/Briefings/Esser/BH_US_12_Esser_iOS_Kernel_Heap_Armageddon_WP.pdf
- [4] Rotten Apples Vulnerability Heaven in the iOS Sandbox
  https://www.blackhat.com/docs/eu-17/materials/eu-17-Donenfeld-Rooten-Apples-Vulnerability-Heaven-In-The-IOS-Sandbox.pdf
- [5] Ian Beer Slidedeck - link and title missing

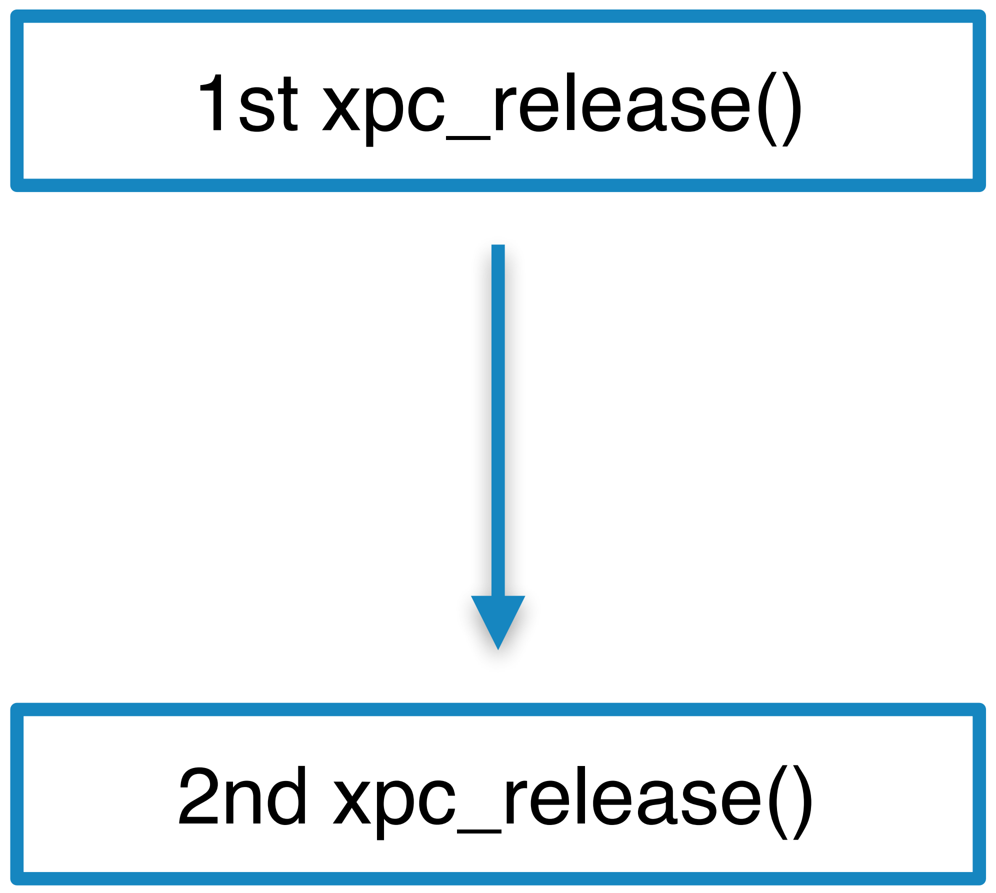
Exploitation roadmap for CVE-2019-7286

ZecOps Writeups

- ZecOps also analysed the exploitation of this bug and wrote a write up **[1]**
- they released POC code
- their POC code does not have actual payload
- the POC does not do exactly what the blog post describes
- it does not actually work on iOS device (didn’t test on Mac)
- wrong addresses and heapspray that kills the device

What kind of vulnerability do we have again?

- reference counting vulnerability that leads to double xpc_release()
- happens in same XPC request without interruption
- no control of memory in the XPC request in between



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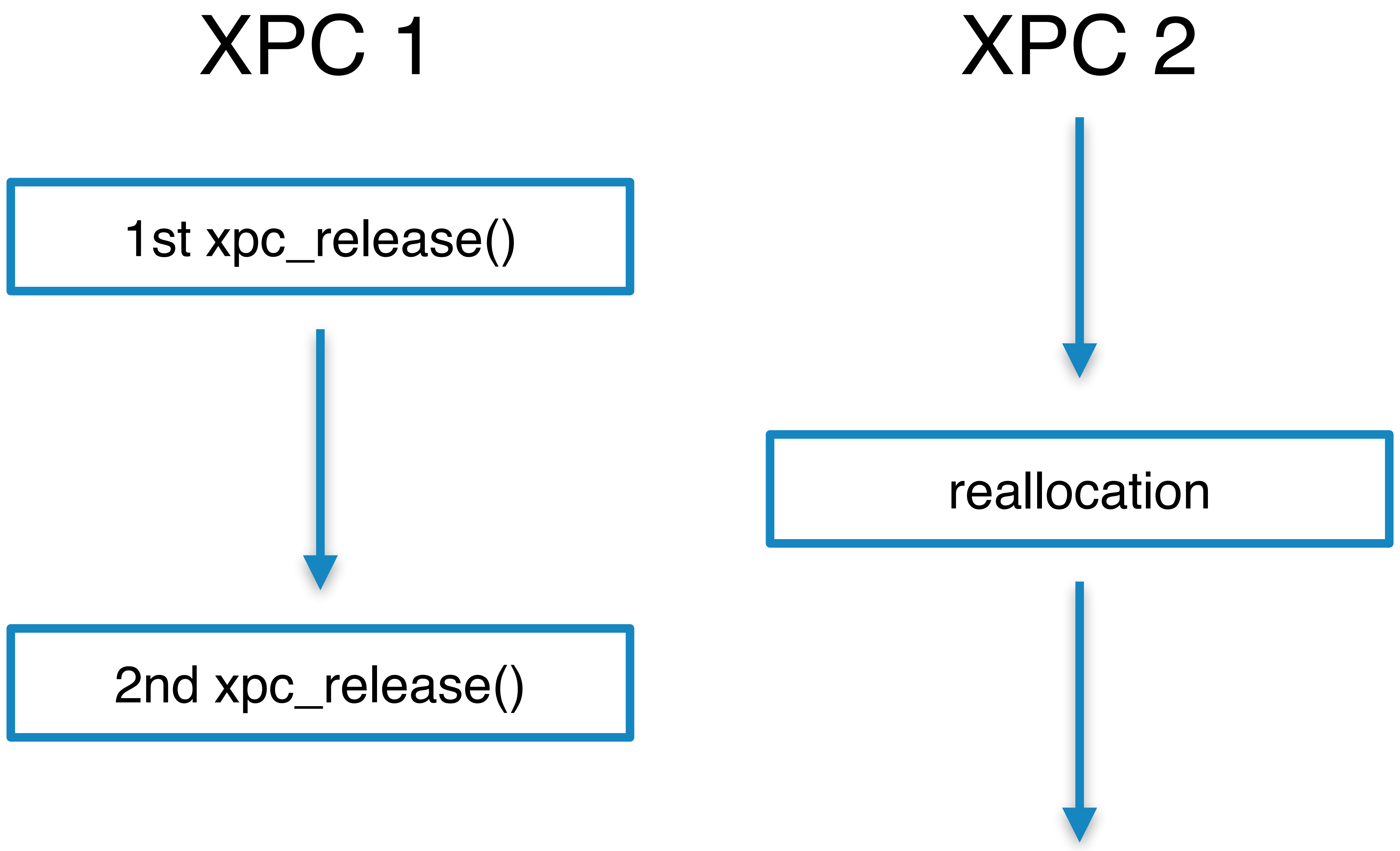
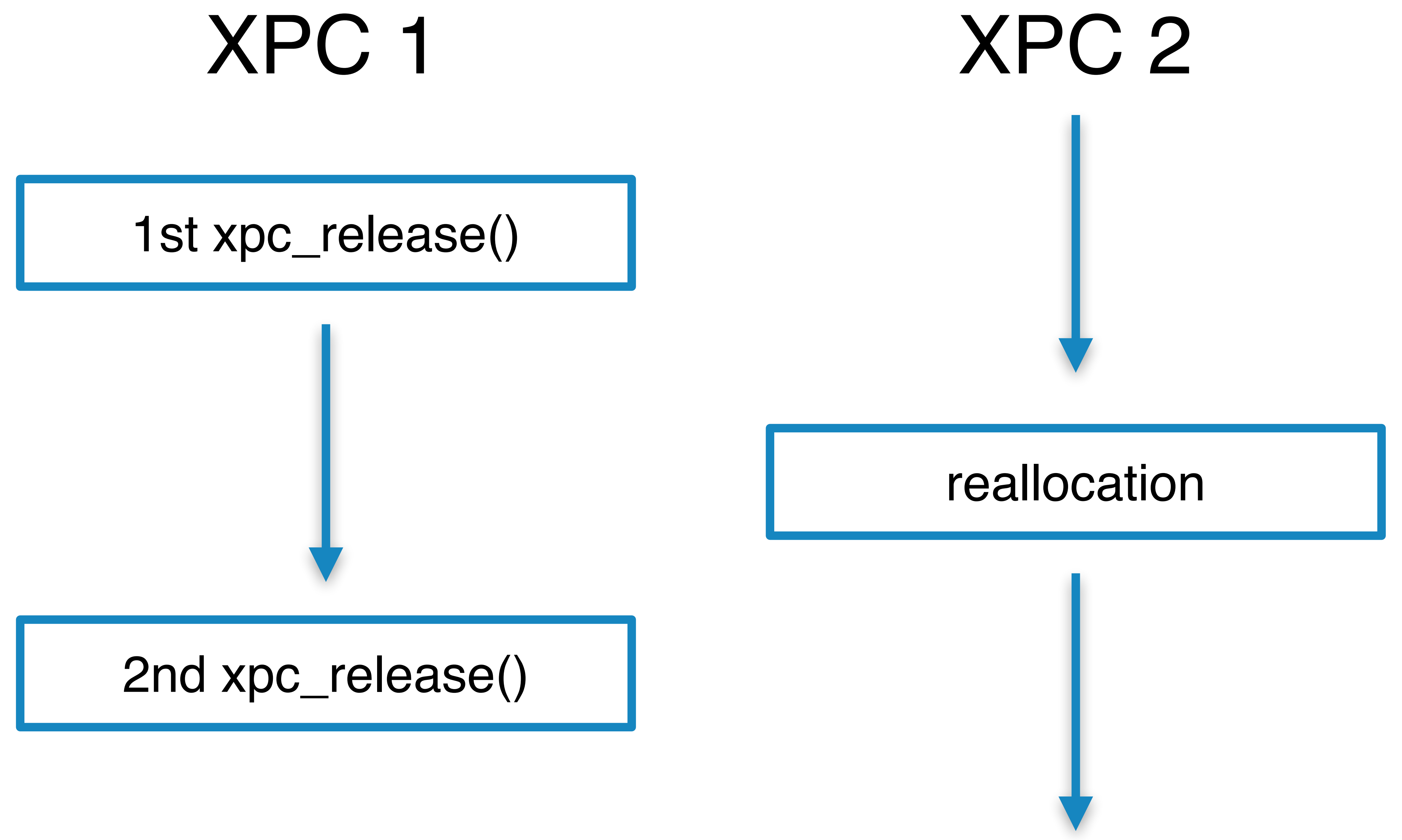
How to exploit?

- need to race the double free
    - How to fill memory (in between frees)?
    - How to increase race window?



How to fill memory (in between frees)?

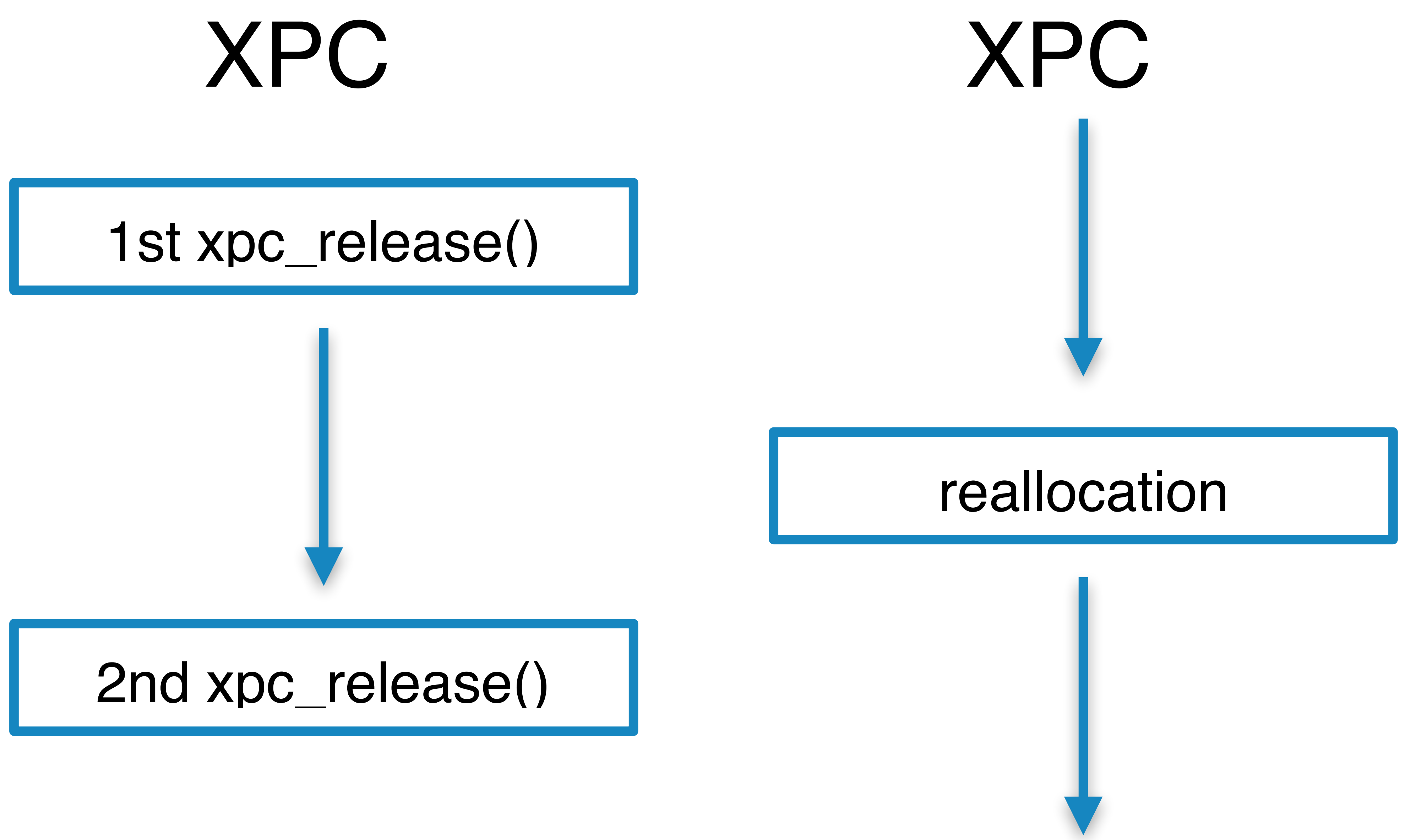
- need to create a second thread in daemon
- easiest done by doing another XPC connection
- then need to do XPC heap spraying **[2]**
  - sending arbitrary XPC arrays



How to increase race window?

- time between the two frees depends on XPC data
- first free happens in loop over an array **CFPreferencesMessages**
- we can increase race window by adding many values to the array

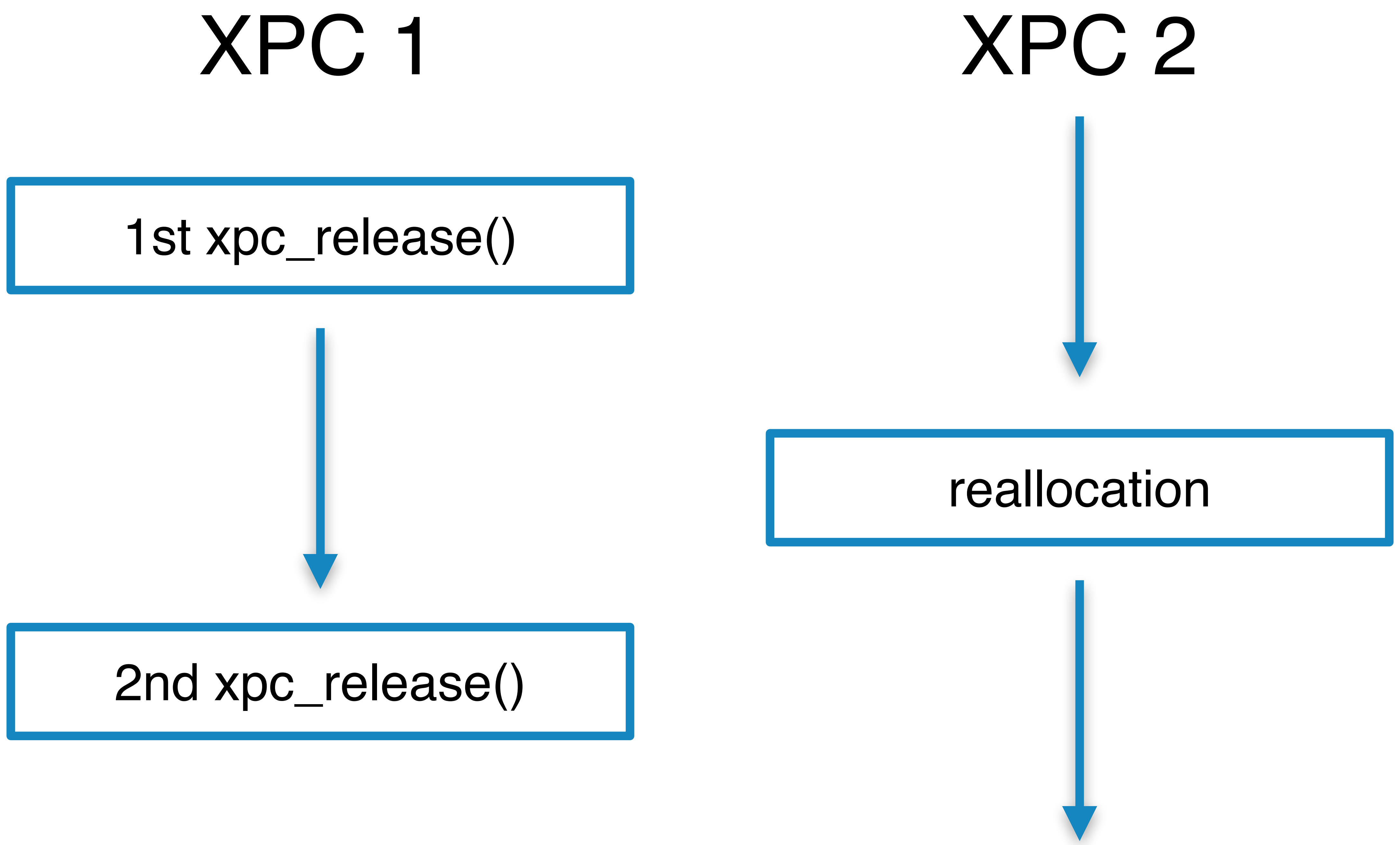
```
for( counter = 0; xpc_array_count != counter ; counter++)
{
   current_element = xpc_buffer[counter];
   if (xpc_get_type(current_element) != &_xpc_type_null )
     xpc_release(current_element);
}
```



What to fill memory with?

- what should we use to replace the freed object with?
- exploitation technique is based on Phrack article by nemo **[3]**
- need control over first 8 bytes for ISA pointer
- need control over length (0xc0)
- xpc_string is using strdup()
- also can be used many times

- BUT NULL bytes
- POC gives up at this point



How it really worked?

- Google has released on 29th August a description of what really happened **[6]**
- the exploit is using similar ideas but is different
- not going to copy and paste it here
- just go read blog that seems to be excellent

Exploit flow

The exploit strategy here is to reallocate the `free`'d `xpc_dictionary` in the gap between the `xpc_release` when destroying the `sub_messages` and the `xpc_release` of the outer request message. They do this by using four threads, running in parallel. Threads `A`, `B` and `C` start up and wait for a global variable to be set to `1`. When that happens they each try `100` times to send the following `XPC` message to the service:

```
{ "CFPreferencesOperation": 5,
  "CFPreferencesMessages" : [10'000 * xpc_data_spray] }
```

where `xpc_data_spray` is a `448`-byte `xpc_data` buffer filled with the qword value `0x118080000`. This is the target address to which they will try to heapspray. They are hoping that the contents of one of these `xpc_data`'s 448-byte backing buffers will overlap with the `free`'d `xpc_dictionary`, completely filling the memory with the heapspray address.

As we saw in `[CFPrefsDaemon handleMultiMessage:replyHandler]` this is not a valid `multiMessage`; the `CFPreferencesMessage` array may only contain dictionaries or NULLs. Nevertheless, it will take some time for all these `xpc_data` objects to be created, `handleMultiMessage` to run, fail and the `xpc_data` objects to be destroyed. They are hoping that with three threads trying this in parallel this replacement strategy will be good enough.

Trigger message

The bug will be triggered by a sub-message with an operation key mapping to a handler which doesn't invoke its reply block. They chose operation `4`, handled by `handleFlushSourceForDomainMessage`. The trigger message looks like this:

```
{ "CFPreferencesOperation": 5
  "CFPreferencesMessages" :
    [
      8000 * (op_1_dict, second_op_5_dict),
      150 * (second_op_5_dict, op_4_dict, op_4_dict, op_4_dict),
      third_op_5_dict
    ]
}
```

where the sub-message dictionaries are:

```
op_1_dict = {
```

Unlimited Tries!

- **cfprefsd** is a LaunchDaemon/Agent
- this means it will be respawned on crash
- while crashing it is noisy we have unlimited tries

- was the original exploit so noisy so that Google noticed?

What todo with ROP?

- **dyld_shared_cache** makes address of all ROP gadgets known to local attackers
- we can create arbitrary ROP programs
- once you can ROP inside **cfprefsd** what can you do?

    - steal its task port to "remote control" it **[4] [5]**
    - open a driver connection and steal that instead
    - ...

References

- [1] CVE-2019-7286 Part II: Gaining PC Control
  https://blog.zecops.com/vulnerabilities/exploit-of-cve-2019-7286/
- [2] Auditing and Exploiting Apple IPC
  https://thecyberwire.com/events/docs/IanBeer_JSS_Slides.pdf
- [3] Modern Objective-C Exploitation Techniques
  http://phrack.org/issues/69/9.html#article
- [4] An introduction to exploiting userspace race conditions on iOS
  https://bazad.github.io/2018/11/introduction-userspace-race-conditions-ios/
- [5] Bypassing platform binary restrictions with task_threads()
  https://bazad.github.io/2018/10/bypassing-platform-binary-task-threads/
- [6] In-the-wild iOS Exploit Chain 4
  https://googleprojectzero.blogspot.com/2019/08/in-wild-ios-exploit-chain-4.html

Conclusion

Conclusion (I)

- both vulnerabilities could be reversed with just a bit of Diaphora
- kernel vulnerability easy to spot from diff
- user space vulnerability took more time to spot because it is more complex
- but this gets easier the more often you do this in code you know
- there are people who do this every day and get paid for just that

- doesn’t really stop attackers for long

Conclusion (II)

- after understanding the vulnerability simple POC exploits can be done fast
- full exploitation takes naturally longer
- the kernel bug felt easier to exploit than the user land bug (more powerful)
- also there is plenty of source code available for iOS kernel exploits
- parts could be cut and pasted

Where is the code?

- The code will show up in the next days on GitHub
  - https://github.com/Antid0teCom
- Keep updated about the release and other things via Twitter
  - https://twitter.com/antid0tecom
- Consider signing up for one of our upcoming trainings
  - https://www.antid0te.com/stories/training.html

Questions ?

www.antid0te.com