Fight against 1-day exploits: Diffing Binaries vs Anti-diffing Binaries

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Jeongwook Oh works on eEye's flagship product called "Blink". He develops traffic analysis module that filters attacker's traffic. The analysis engine identifies protocol integrity violations by protocol parsing and lowers the chances of false positives and false negatives compared to traditional signature based IPS engines.
He's also interested in blocking ActiveX related attacks and made some special schemes to block ActiveX-based attacks without any false positives. The implementation was integrated to the company's product and used by the customers.
He runs Korean security mailing list called Bugtruck(not bugtraq).

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Introduction: The Problem

- Security patches are meant to fix security vulnerabilities.
  - fixing problems and protect computers and end users from risks.
- 1-day exploits
  - binary diffing technique can be used to identify the vulnerabilities
  - especially useful for Microsoft's binaries

Introduction: The Solution

- Purpose: making 1-day exploits difficult and time-consuming
  - Make binary differs' life harder
  - Severe code obfuscation is not an option
  - Need an efficient lightweight code obfuscation
- In-house tool to achieve this
  - Hondon(meaning Chaos)

Binary Diffing: Demo

- Just grab an idea what binary diffing is.
- We will show simple process of binary diffing.

Binary Diffing: The History

- BMAP: 10 years ago
- Halvar
  - Bindiff: Expensive commercial tool
  - Not affordable to most non-corporate researchers
- TODD
- eEye
- 2-3 free or opensource tools

Binary Diffing: BMAT(1999)

- Heavily depends on symbolic name matching
- Used mainly for Microsoft's binaries which symbol they have access to.
- Auxiliary method: 64bit hashing-based comparison for the blocks inside each procedure
  - hashing=multiple level of abstractions with opcode and operands

Binary Diffing: Automated Reverse Engineering(2004)

- Halvar at Blackhat 2004
- Signature of functions
  - signatures=number of nodes, edges and calls
- Isomorphic comparison between functions CG
  - A function is a node and calling relationship is an edge

Binary Diffing: Comparing binaries with graph isomorphism(2004)

- Todd Sabin
- Instructions graph's isomorphic matching
- Compares instructions not basic blocks
  - Very unique
- No POC ever released
  - Only testing datasheet released

Binary Diffing: Structural Comparison of Executable Objects(2004)

- Improved version of Halvar's Blackhat 2004 "Automated Reverse Engineering(2004)"[ARE] presentation[SCEO]

Binary Diffing: Graph-based comparison of Executable Objects(2005)

- Improved previous paper "Structural Comparison of Executable Objects(2004)"
- Heavily dependent on CFG generation from the binaries

The Tools: Sabre Security's bindiff(2004)

- Halvar
- A commercial binary diffing tool
- Based on his graph based function fingerprinting theory.

The Tools: IDACompare(2005)

- Based on signature scanning
- Used for porting malware analysis data
- Designed for around 500k file in size
  - Which is a small size

The Tools: eEye Binary Diffing Suite(2006)

- Internally used for Microsoft's Patch Tuesday patches analysis
- Patch analysis was the only way to obtain some secret information they don't release
  - You can use eye ball instead of binary diffing tools
  - Some of them has the talent
- The "DarunGrim" is one of the tools included and performs the main binary diffing analysis.

The Tools: Patchdiff2(2008)

- Made specifically for security patch or hotfix analysis
- Using checksum of graph call for signaturing
- Sounds like similar to bindiff

The Tools: DarunGrim2(2008)

- The improved version of eEye Binary Diffing Suite
- Using C++ instead of Python to overcome performance and memory footprint issues
- Will be Open-Sourced in few weeks

DarunGrim2: Algorithms

- The previous works in binary difference analysis were mainly concentrated on the graph structure analysis and graph isomorphism.
  - Intensive comparison of two graphs
  - dependency on the disassembler's CFG analysis capabilities
- **"Basic Block Fingerprint Hash Map"** is the way to overcome this limitation and to improve analysis result drastically.

Algorithms: Basic Block Fingerprint Hash Map

- Fingerprint hashing method is a main algorithm of DarunGrim2
  - Fingerprint of the block=extracted from instruction sequences
- Two fingerprint hash table for original binary and patched binary
- For each unique fingerprints from original binary
  - DarunGrim2 check if the patched binaries fingerprint hash table has matching entry.

Algorithms: Basic Block Fingerprint Hash Map

- Generating fingerprint for a basic block
  - Using IDA
- Overcoming Order Dependency
- Reducing Hash Collision
  - Merge multiple fingerprints from parent and children
- Determining matching functions
  - Count the number of matching basic blocks choose the pair that has highest matches
- Matching blocks inside function
  - After function match is determined, use locality.

Algorithms: Symbolic Names Matching

- Basic starting points for binary matching procedure
- Microsoft is generous enough to provide symbol files as soon as the patch is out

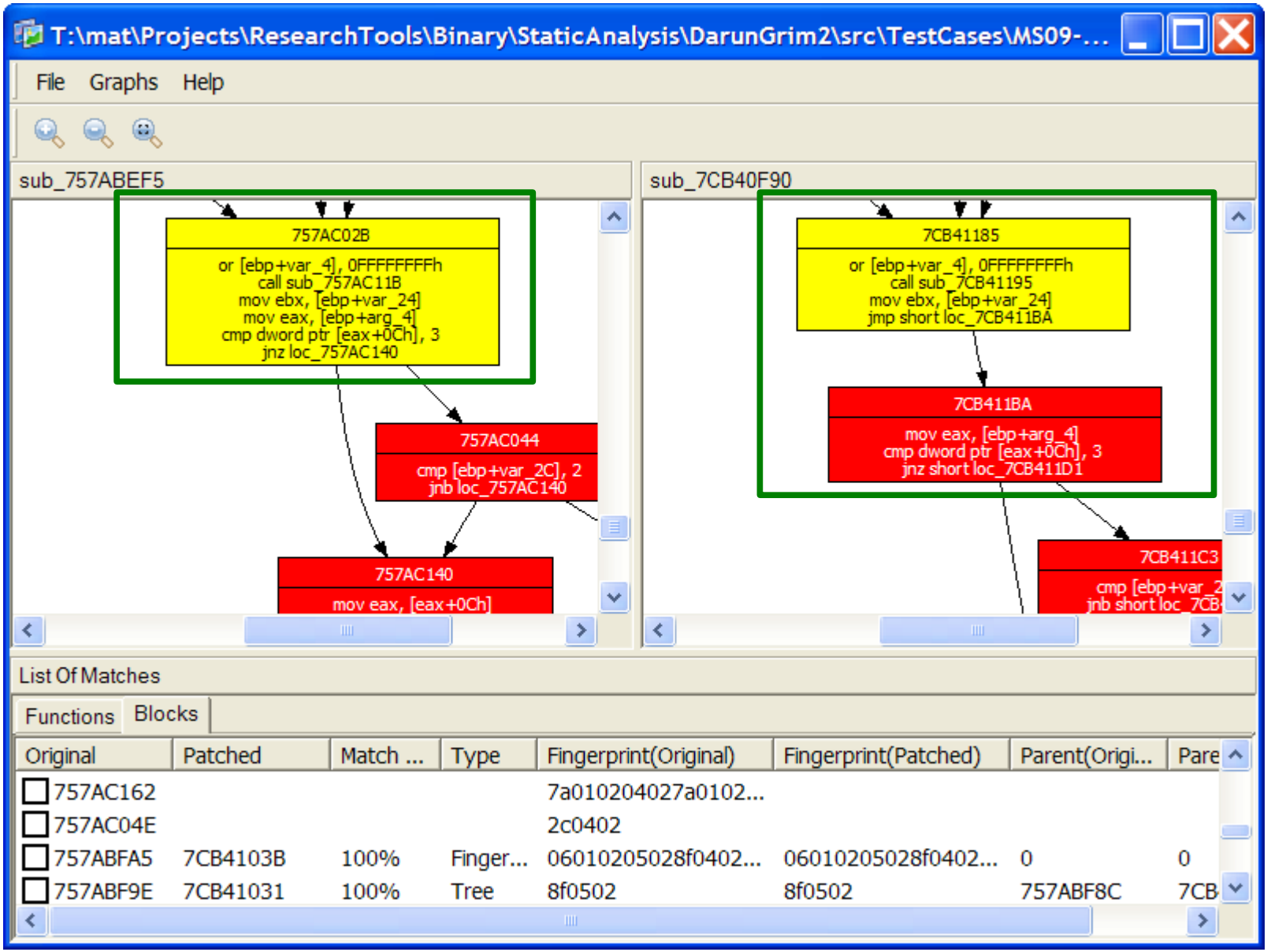
Algorithms: Structure Based Analysis

- Philosophy of divide and conquer
  - Similar to that of BMAT tool
- Calculating match rate
  - Compare fingerprint string using string match algorithm, same algorithm used in GNU diff(1)
  - Determines "Stop"(If match rate is under n%) or "Go"(If match rate is over n%).
- Need to recognize control flow Inversion
  - Todd's method: categorizing control flow

DarunGrim2: Real Life Issues

- Split Blocks
- Hot Patching
- Basic Blocks in Multiple Functions

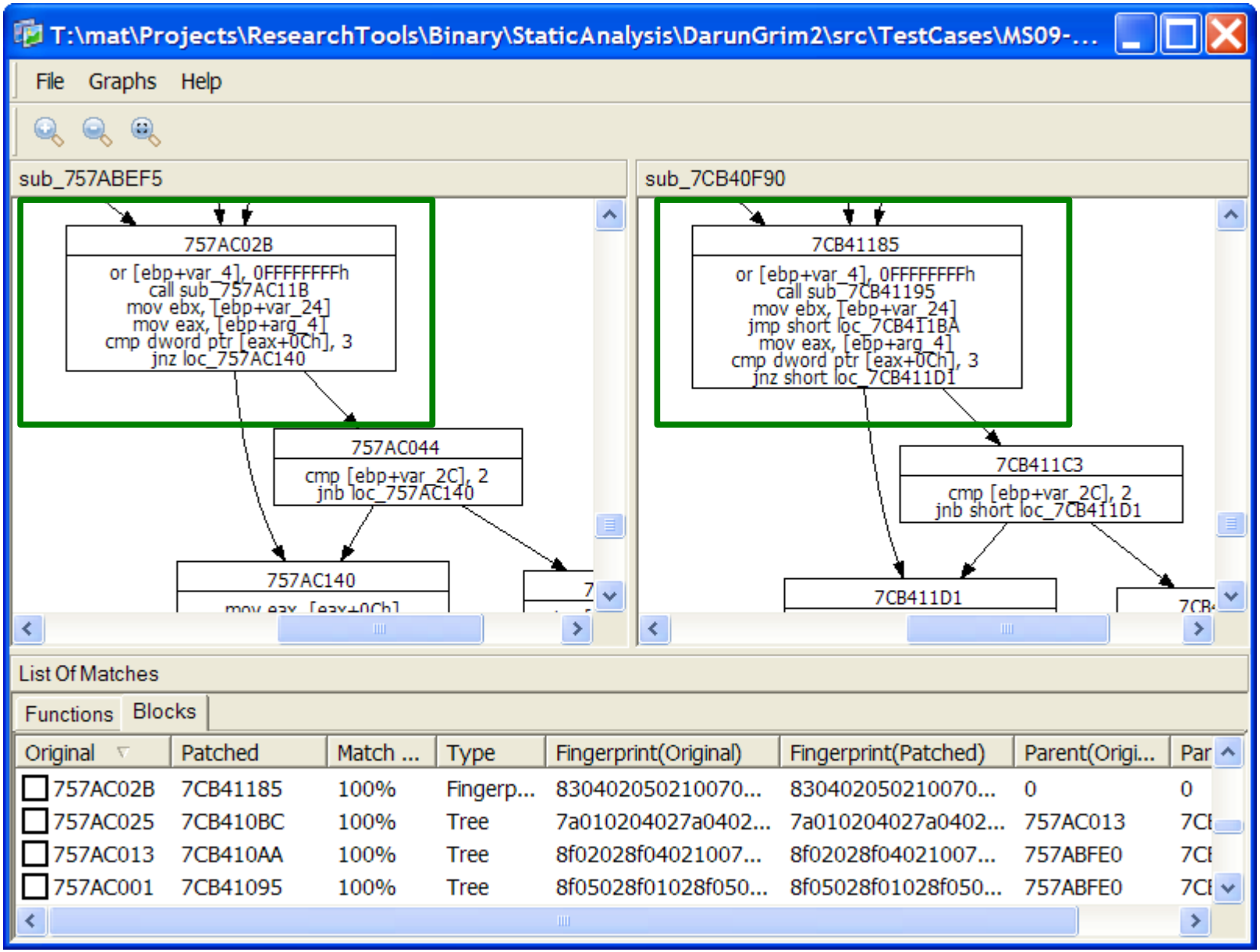
Real Life Issues: Split Blocks



Real Life Issues: Split Blocks

- "The block who has one child and the child of the block has only one parent in CFG."
- The split blocks tend to make CFG broken
  - The matching process incomplete.
- Need to merge split blocks

Real Life Issues: Split Blocks



Real Life Issues: Hot Patching

```
.text:765D1E9C ; int __stdcall sub_765D1E9C(unsigned __int8
*NetworkAddr,int)
.text:765D1E9C sub_765D1E9C    proc near
.text:765D1E9C                 mov     eax, eax
.text:765D1E9E
.text:765D1E9E ; __stdcall W32TimeGetNetlogonServiceBits(x, x)
.text:765D1E9E _W32TimeGetNetlogonServiceBits@8:
.text:765D1E9E                 push    ebp
.text:765D1E9F                 mov     ebp, esp
.text:765D1EA1                 push    0FFFFFFFFh
.text:765D1EA3                 push    offset dword_765D1F80
```

- Solution: Just ignore any hot patching preamble
- Pattern: mov RegA,RegA at the start of a function

Real Life Issues: Basic Blocks in Multiple Functions

- Usually one basic block belongs to one function
- There are some cases that one basic block can be part of multiple functions.
  - For example: Windows kernel
- The limitation with IDA
  - One function for one basic block

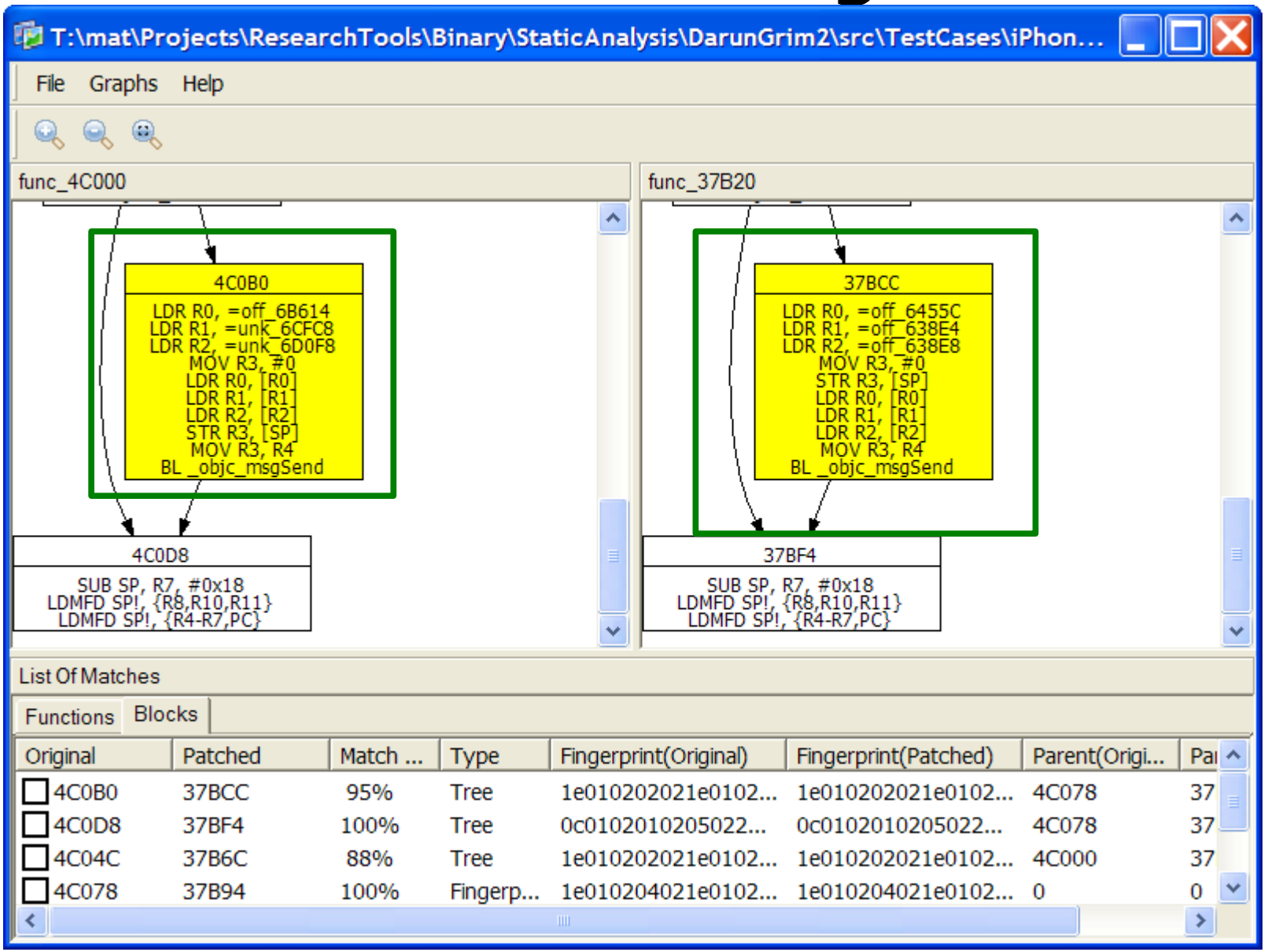
Real Life Issues: Basic Blocks in Multiple Functions

- Perform additional custom CFG analysis
  - Doesn't totally rely on IDA's CFG analysis
- Design data structure to make it possible for
  - a basic block can belong to multiple functions.

Real Life Issues: Instruction Reordering

- During ARM binaries diffing experiments
  - we found that there are a lot of instruction reordering happen over each releases.
  - Binary differ is confused a lot and mark all the same blocks as being different

Real Life Issues: Instruction Reordering



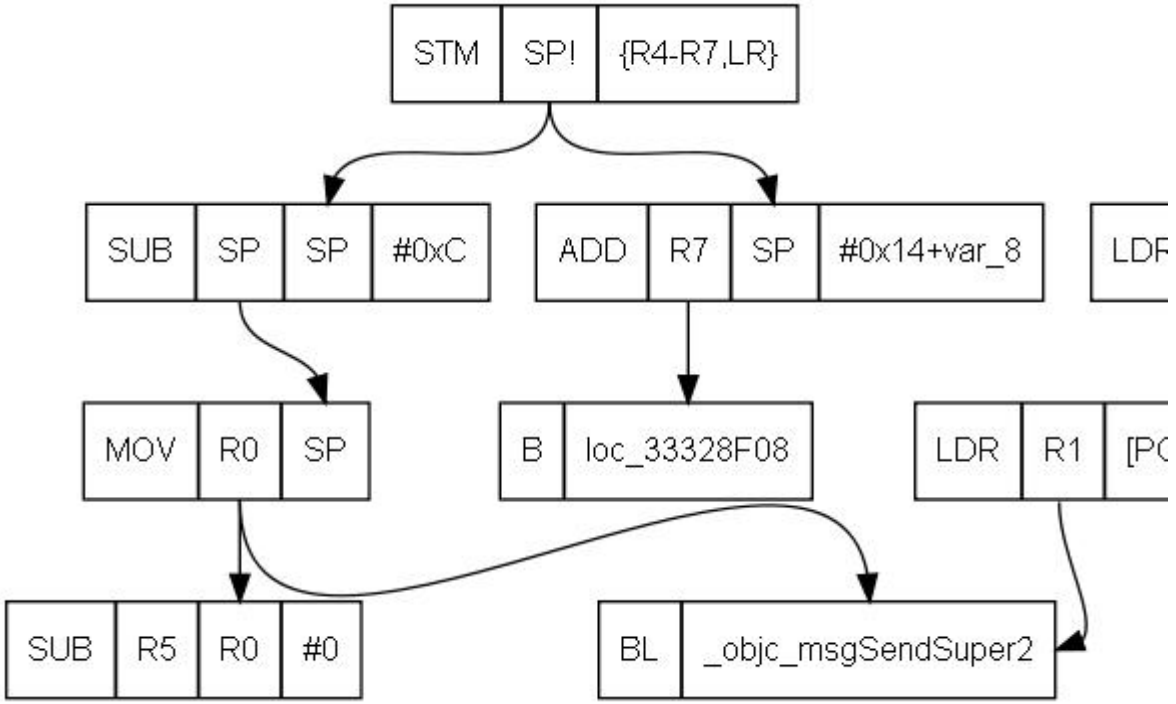
Real Life Issues: Instruction Reordering

Original	***Patched***

STMFD SP!, {R4-R7,LR}
ADD R7, SP, #0x14+var_8
LDR R3, =(off_3AFD9AAC - 0x32FF9A80)
SUB SP, SP, #0xC
LDR R1, =(off_3AFD86B8 - 0x32FF9A88)
LDR R3, [PC,R3]
STR R0, [SP,#0x20+var_20]
LDR R1, [PC,R1] ; "initWithPath:"
MOV R0, SP
MOV R6, R2
STR R3, [SP,#0x20+var_1C]
BL _objc_msgSendSuper2
SUBS R5, R0, #0
BEQ loc_32FF9B84
	STMFD SP!, {R4-R7,LR}
	ADD R7, SP, #0x14+var_8
	SUB SP, SP, #0xC
	LDR R3, =(off_3B2CF6C8 - 0x33328E08)
	LDR R1, =(off_3B2CDE70 - 0x33328E10)
	STR R0, [SP,#0x20+var_20]
	LDR R3, [PC,R3]
	MOV R0, SP
	LDR R1, [PC,R1] ; "initWithPath:"
	MOV R6, R2
	STR R3, [SP,#0x20+var_1C]
	BL _objc_msgSendSuper2
	SUBS R5, R0, #0
	BEQ loc_33328F08

Real Life Issues: Instruction Reordering

Generate Data flow graph and serialize each node



Real Life Issues: Instruction Reordering

Original

```
STMFD   SP!, {R4-R7,LR}
ADD     R7, SP, #0x14+var_8
LDR     R3, =(off_3AFD
0x32FF9A80)
SUB     SP, SP, #0xC
LDR     R1, =(off_3AFD
0x32FF9A88)
LDR     R3, [PC,R3]
STR     R0, [SP,#0x20+
LDR     R1, [PC,R1]
MOV     R0, SP
MOV     R6, R2
STR     R3, [SP,#0x20+
BL      _objc_msgSend
SUBS    R5, R0, #0
BEQ     loc_32FF9B84
```

Patched

```
STMFD   SP!, {R4-R7,LR}
ADD     R7, SP, #0x14+var_8
```

Original

```
STMFD   SP!, {R4-R7,LR}
ADD     R7, SP, #0x14+var_8
SUB     SP, SP, #0xC
BEQ     loc_32FF9B84
MOV     R0, SP
SUBS    R5, R0, #0
STR     R0, [SP,#0x20+var_20]
LDR     R3, =(off_3AFD9AAC -
0x32FF9A80)
LDR     R3, [PC,R3]
STR     R3, [SP,#0x20+var_1C]
LDR     R1, =(off_3AFD86B8 -
0x32FF9A88)
LDR     R1, [PC,R1]     ;
"initWithPath:"
BL      _objc_msgSendSuper2
MOV     R6, R2
```

Patched

```
STMFD   SP!, {R4-R7,LR}
ADD     R7, SP, #0x14+var_8
SUB     SP, SP, #0xC
BEQ     loc_33328F08
MOV     R0, SP
SUBS    R5, R0, #0
STR     R0, [SP,#0x20+var_20]
LDR     R3, =(off_3B2CF6C8 -
0x33328E08)
LDR     R3, [PC,R3]
STR     R3, [SP,#0x20+var_1C]
LDR     R1, =(off_3B2CDE70 -
0x33328E10)
LDR     R1, [PC,R1]     ;
"initWithPath:"
BL      _objc_msgSendSuper2
MOV     R6, R2
```

Examples

Microsoft's Binaries
Non-Microsoft's Binaries
Malwares

Gathering Binaries

- Each vendors patch pages
  - Use MS patches pages
- Need to archive binary files for future patch releases
  - SortExecutables.exe: Sort PE binaries according to the version information.
  - <Company Name>\<File Name>\<Version Name>

Gathering Binaries: SortExecutables

- You can make your own archive of binaries in more organized way

```
T:\PROJECTS\BINARIES\WINDOWS XP\MICROSOFT CORPORATION\MSHTML
├─6.00.2600.0000 (xpclient.010817-1148)
├─6.00.2800.1528
├─6.00.2800.1561
├─6.00.2800.1562
├─6.00.2900.2180 (xpsp_sp2_rtm.040803-2158)
├─6.00.2900.2604 (xpsp.041130-1728)
├─6.00.2900.2604 (xpsp_sp2_gdr.041130-1729)
├─6.00.2900.3020 (xpsp_sp2_gdr.061023-0214)
├─6.00.2900.3492 (xpsp_sp2_qfe.081212-1622)
├─6.00.2900.5512 (xpsp.080413-2105)
├─6.00.2900.5659 (xpsp_sp3_gdr.080819-1237)
├─6.00.2900.5659 (xpsp_sp3_qfe.080819-1352)
├─6.00.2900.5694 (xpsp_sp3_qfe.081015-1409)
├─6.00.2900.5726 (xpsp_sp3_gdr.081212-1450)
├─6.00.2900.5726 (xpsp_sp3_qfe.081212-1451)
├─7.00.6000.16788 (vista_gdr.081211-1619)
├─7.00.6000.16809 (vista_gdr.090114-1504)
└─8.00.6001.18702 (longhorn_ie8_rtm(wmbla).090308-0339)
```

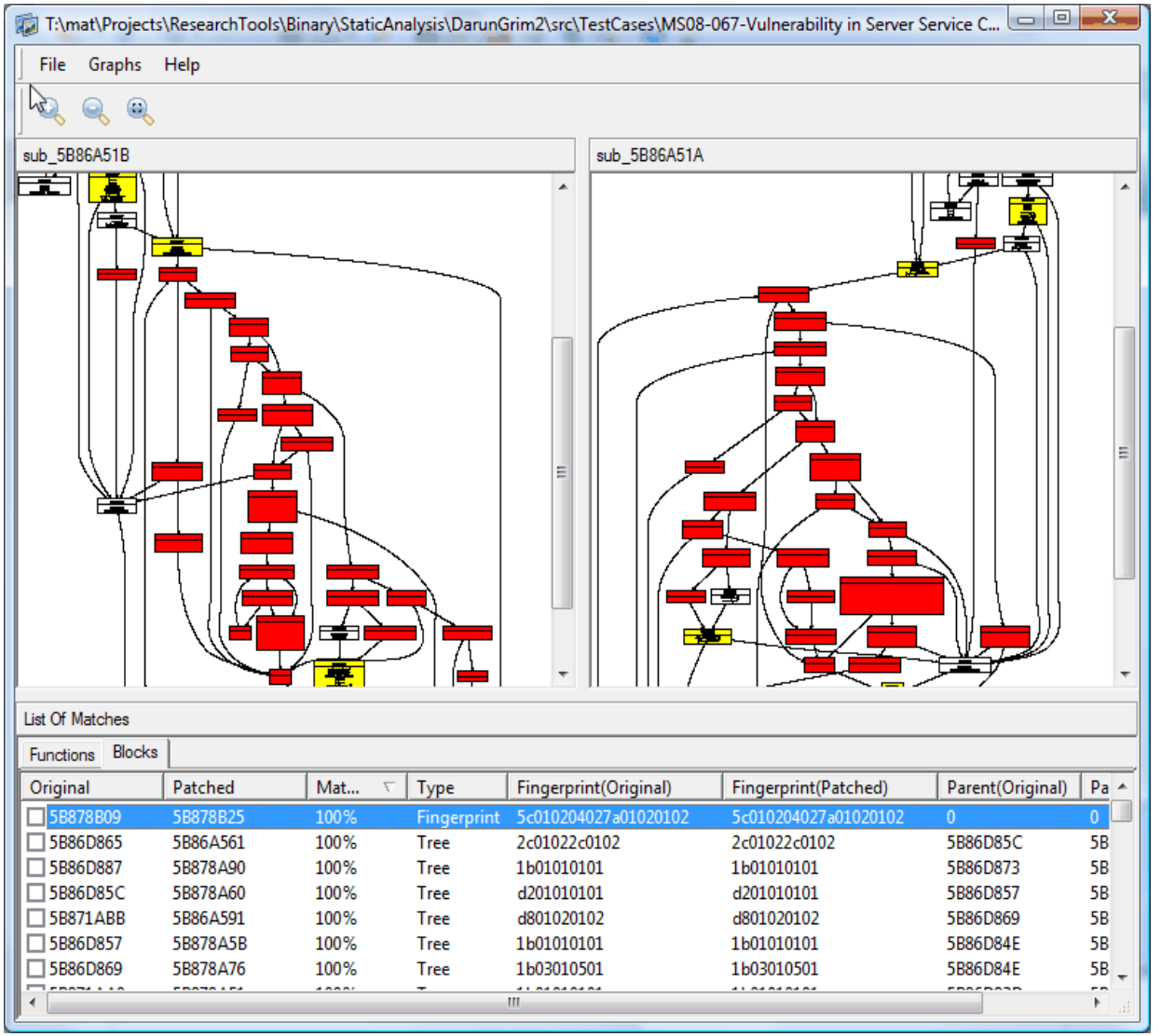
Performing Diffing

- Using DarunGrim2.exe and Two IDA sessions
  - First launch DarunGrim2.exe
  - Launch two IDA sessions
  - First run DarunGrim2 plugin from the original binary
  - Secondly run DarunGrim2 plugin from the patched binary
- Using DarunGrim2C.exe command line tool
  - Handy
  - Batch-able
  - Quick

The infamous MS08-067(which was exploited by Conficker)

- Conficker worm exploited this vulnerability to propagate through internal network.
- Easy target for binary diffing: only 2 functions changed.
- One is a change in calling convention.
- The other is the function that has the vulnerability

The infamous MS08-067(which was exploited by Conficker)



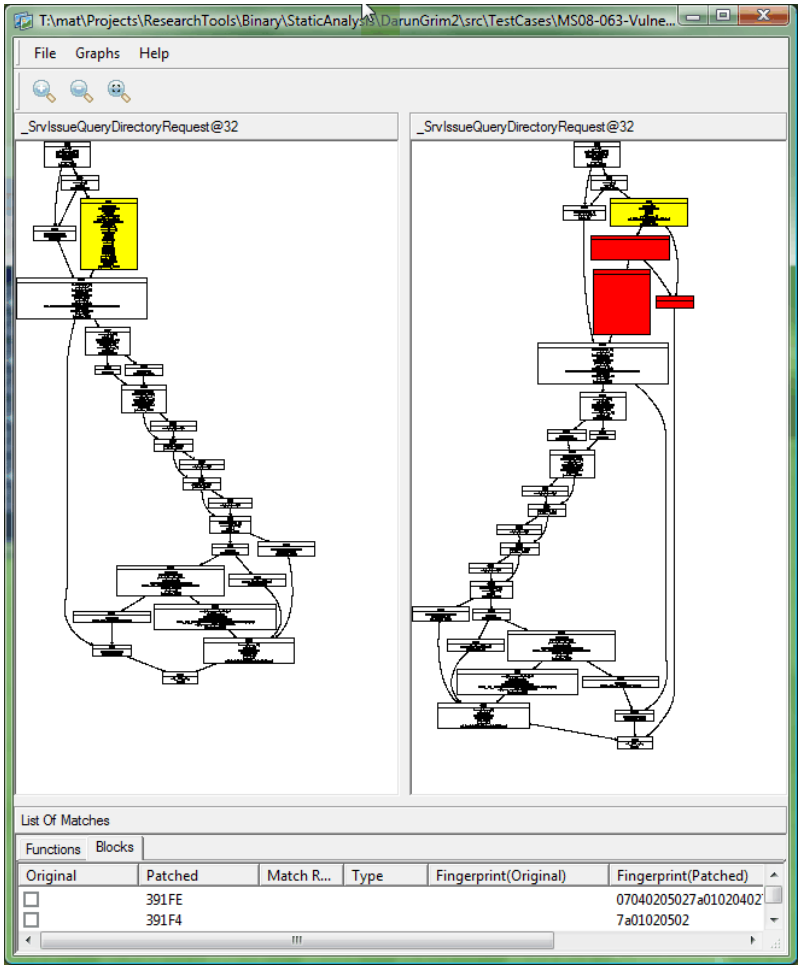
MS08-063: DarunGrim2 vs bindiff

Modified Functions

Original	Unmat...	Patched	Unmat...	Different	Matched	M...
_SrvCompleteRfcbClose@4	0	_SrvCompleteRfcbClose@4	1	3	18	90%
@SrvRestartRawReceive@4	0	@SrvRestartRawReceive@4	1	5	25	90%
_SrvIssueQueryDirectoryRequest@32	0	_SrvIssueQueryDirectoryRequest@32	2	1	23	94%
func_1D0E4	0	func_1CD48	0	1	11	95%
@SrvFsdRestartPrepareRawMdlWrite...	0	@SrvFsdRestartPrepareRawMdlWrite@4	3	1	43	95%
_SrvRequestOplock@12	0	_SrvRequestOplock@12	0	2	40	97%
_GenerateOpen2Response@8	0	_GenerateOpen2Response@8	0	1	57	99%

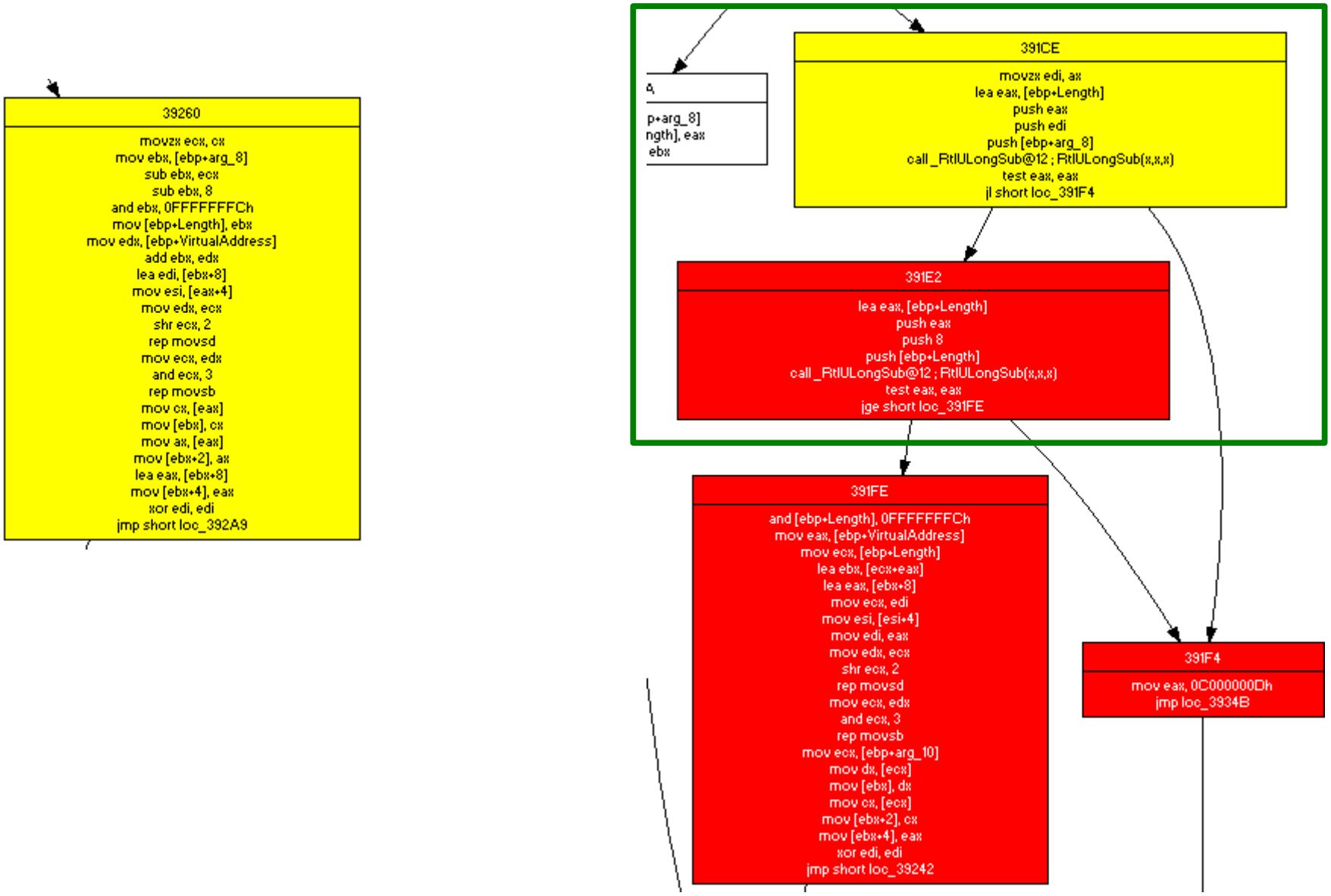
MS08-063: DarunGrim2 vs bindiff

_SrvIssueQueryDirectoryRequest@32



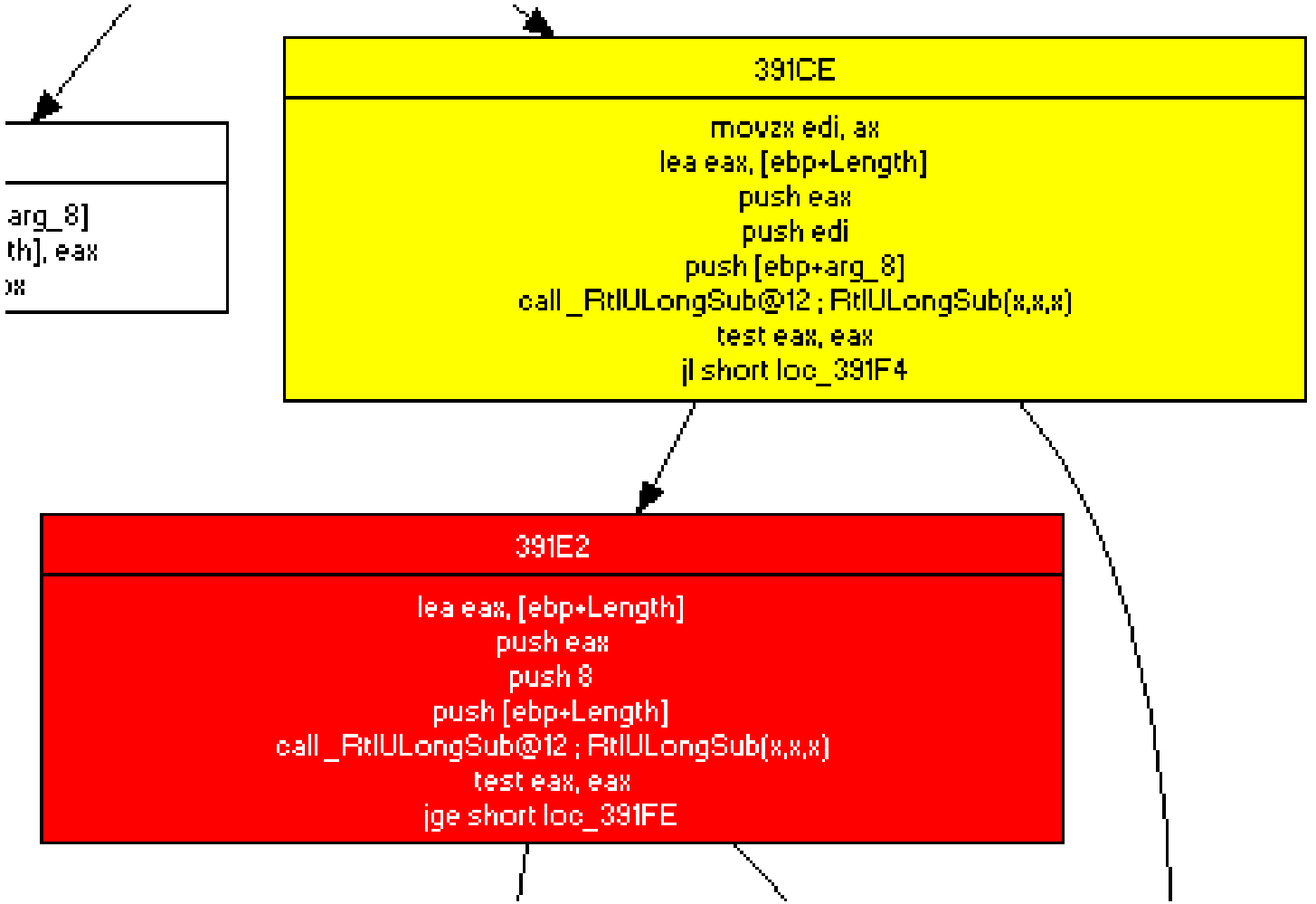
MS08-063: DarunGrim2 vs bindiff

Patched Blocks



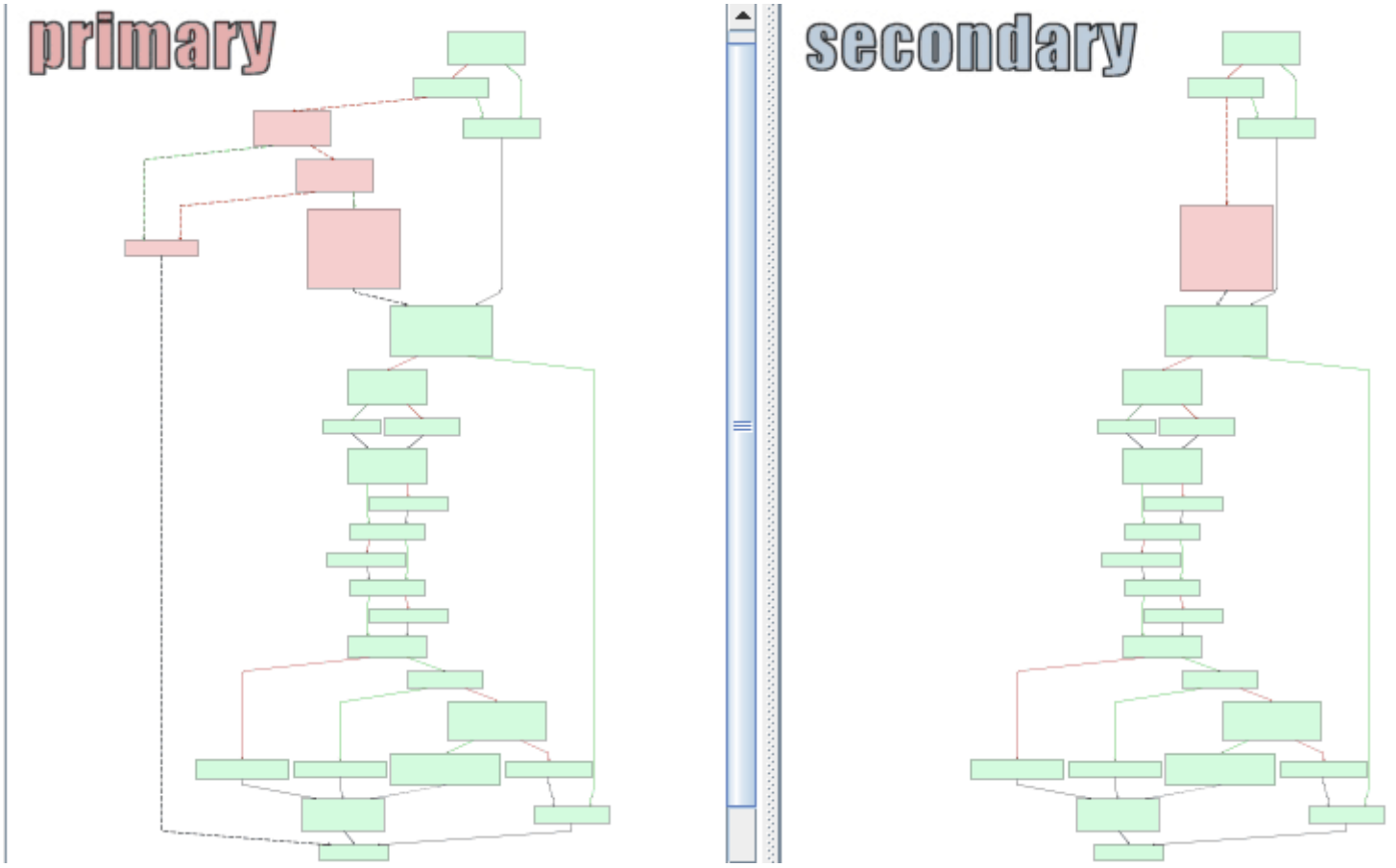
MS08-063: DarunGrim2 vs bindiff

Patched Blocks



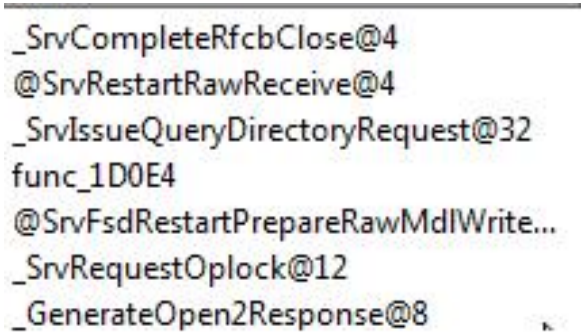
MS08-063: DarunGrim2 vs bindiff

Bindiff Results



MS08-063: DarunGrim2 vs bindiff

False Negatives



VS

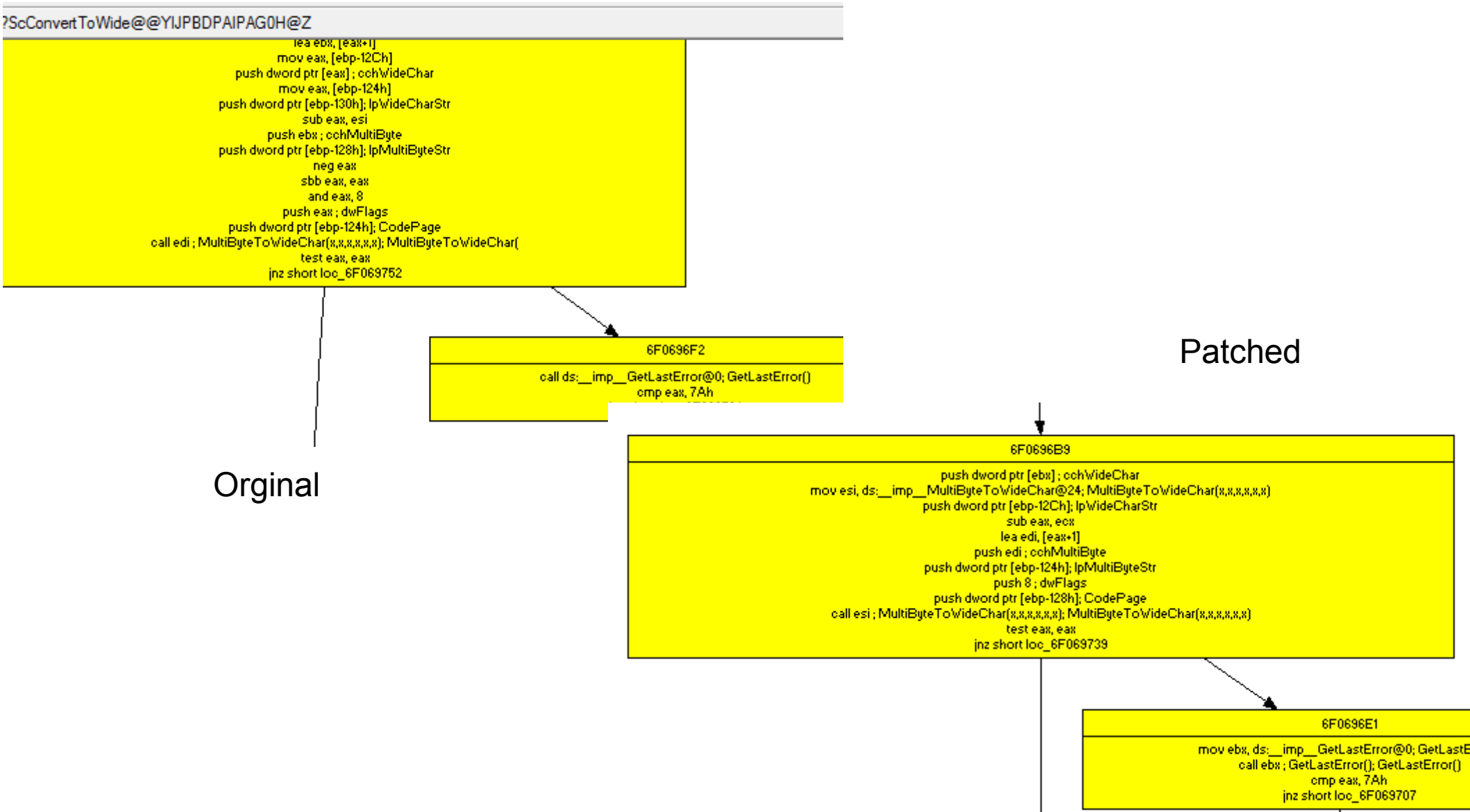
SrvFsdRestartPrepareRawMdlWrite
SrvIssueQueryDirectoryRequest
SrvRestartRawReceive

7 VS 3

MS09-020: WebDav case

Patched Function looks almost same

?ScConvertToWide@@YIJPBD... 0 ?ScConvertToWide@@YIJPBDPA... 0 10 16 80%



MS09-020: WebDav case

Flags has changed

Original

```
lea ebx, [eax+1]
mov eax, [ebp-12Ch]
push dword ptr [eax] ; cchWideChar
mov eax, [ebp-124h]
push dword ptr [ebp-130h]; lpWideCharStr
sub eax, esi
push ebx ; cchMultiByte
push dword ptr [ebp-128h]; lpMultiByteStr
neg eax
sbb eax, eax
and eax, 8
push eax ; dwFlags
push dword ptr [ebp-124h]; CodePage
call edi ; MultiByteToWideChar(x,x,x,x,x,x); MultiByteToWideChar(
```

Patched

```
push dword ptr [ebx] ; cchWideChar
mov esi, ds:__imp__MultiByteToWideChar@24; MultiByteToWideChar(x,x,x,x,x,x)
push dword ptr [ebp-12Ch]; lpWideCharStr
sub eax, ecx
lea edi, [eax+1]
push edi ; cchMultiByte
push dword ptr [ebp-124h]; lpMultiByteStr
push 8 ; dwFlags
push dword ptr [ebp-128h]; CodePage
call esi ; MultiByteToWideChar(x,x,x,x,x,x); MultiByteToWideChar(x,x,x,x,x,x)
```

MS09-020: WebDav case

What does flag 8 mean?

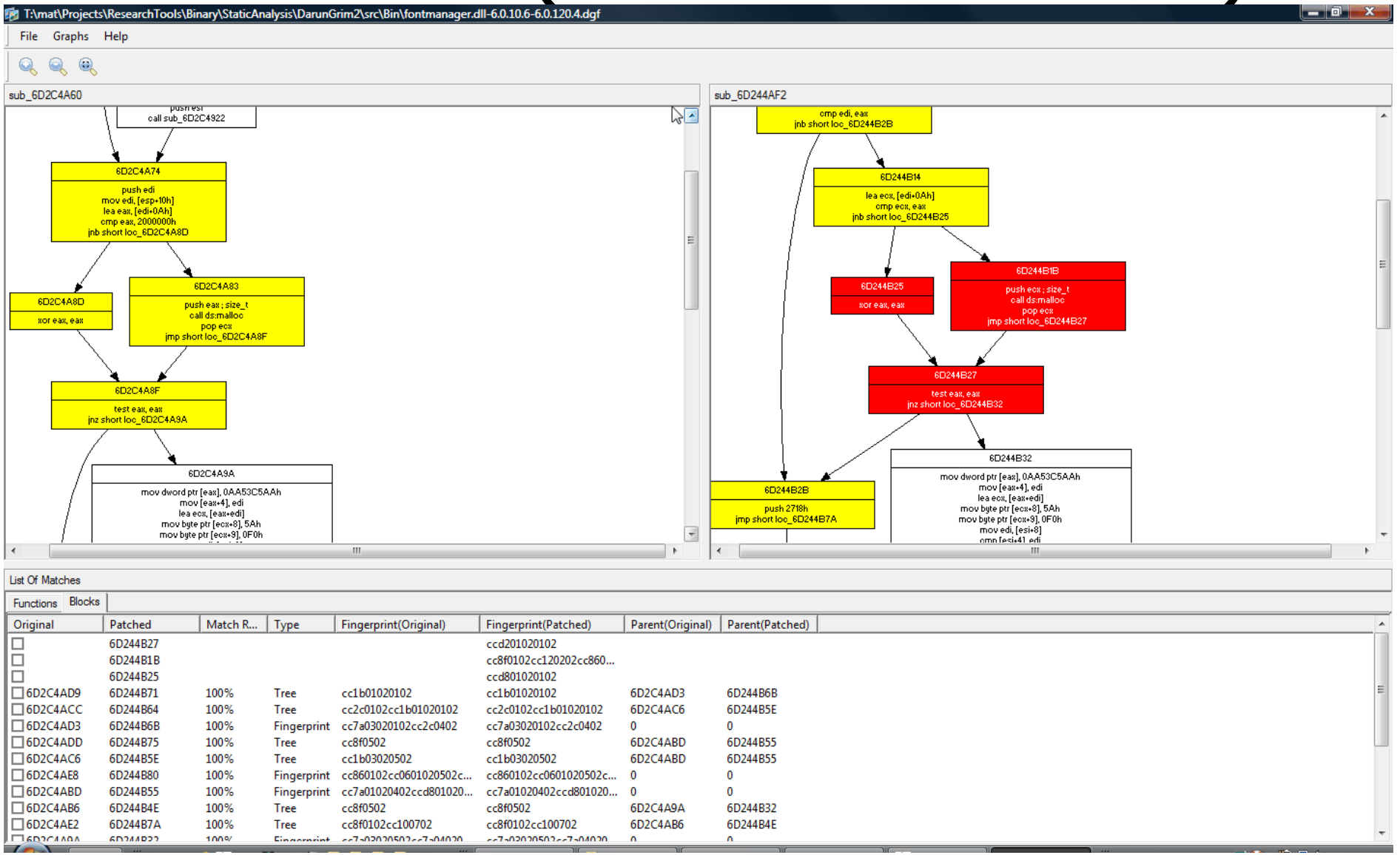
MSDN(http://msdn.microsoft.com/en-us/library/dd319072(VS.85).aspx) declares like following:

MB_ERR_INVALID_CHARS Windows Vista and later: The function does not drop illegal code points if the application does not set this flag.
Windows 2000 Service Pack 4, Windows XP: Fail if an invalid input character is encountered. ***If this flag is not set, the function silently drops illegal code points.*** A call to GetLastError returns ERROR_NO_UNICODE_TRANSLATION.

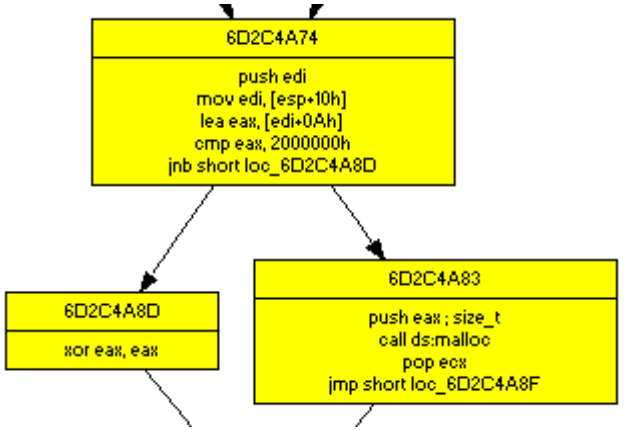
MS09-020: WebDav case Broken UTF8 Heuristics?

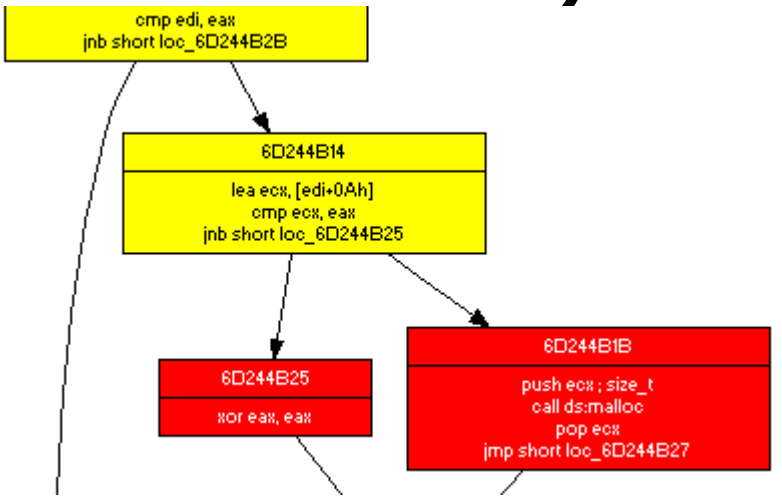
```
6F0695EA mov     esi, 0FDE9h
,,,,
6F069641 call    ?FIsUTF8Url@@YIHPBD@Z ;
FIsUTF8Url(char const *)
6F069646 test    eax, eax
if(!eax)
{
        6F0695C3 xor     edi, edi
        6F06964A mov     [ebp-124h], edi
}else
{
        6F069650 cmp     [ebp-124h], esi
}
,,,
6F0696C9 mov     eax, [ebp-124h]
6F0696D5 sub     eax, esi
6F0696DE neg     eax
6F0696E0 sbb     eax, eax
6F0696E2 and     eax, 8
```

JRE Font Manager Buffer Overflow(Sun Alert 254571)



JRE Font Manager Buffer Overflow(Sun Alert 254571)





Original

```
.text:6D2C4A75          mov     edi, [esp+10h]
.text:6D2C4A79          lea     eax, [edi+0Ah]
.text:6D2C4A7C          cmp     eax, 2000000h
.text:6D2C4A81          jnb     short loc_6D2C4A8D
.text:6D2C4A83          push    eax             ; size_t
.text:6D2C4A84          call    ds:malloc
```

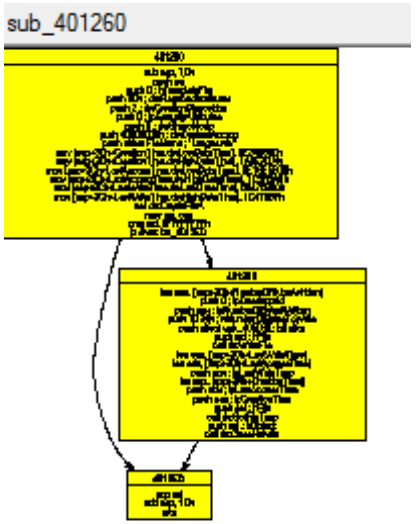
Patched

```
.text:6D244B06          push    edi
.text:6D244B07          mov     edi, [esp+10h]
.text:6D244B0B          mov     eax, 2000000h
.text:6D244B10          cmp     edi, eax
.text:6D244B12          jnb     short loc_6D244B2B
.text:6D244B14          lea     ecx, [edi+0Ah]
.text:6D244B17          cmp     ecx, eax
.text:6D244B19          jnb     short loc_6D244B25
.text:6D244B1B          push    ecx             ; size_t
.text:6D244B1C          call    ds:malloc
```

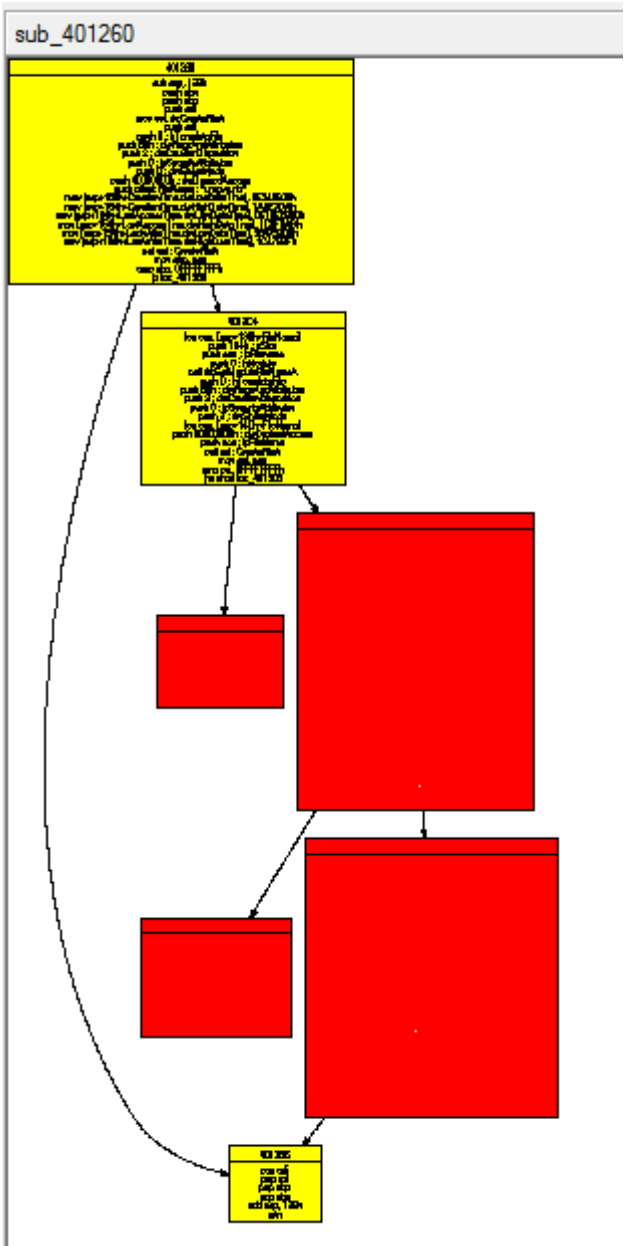
Malwares: 4th of July DDOS Attack

- On this 4th of July a DDOS attack was fired against some of US government and corporate sites.
  - It had very limited impact against the targets
- For some reason they changed their targets to South Korean government and major news sites.
  - This time it made a huge success and the targets were almost unreachable during the attack period(3 days).
  - During the time few variants of malware samples were collected.

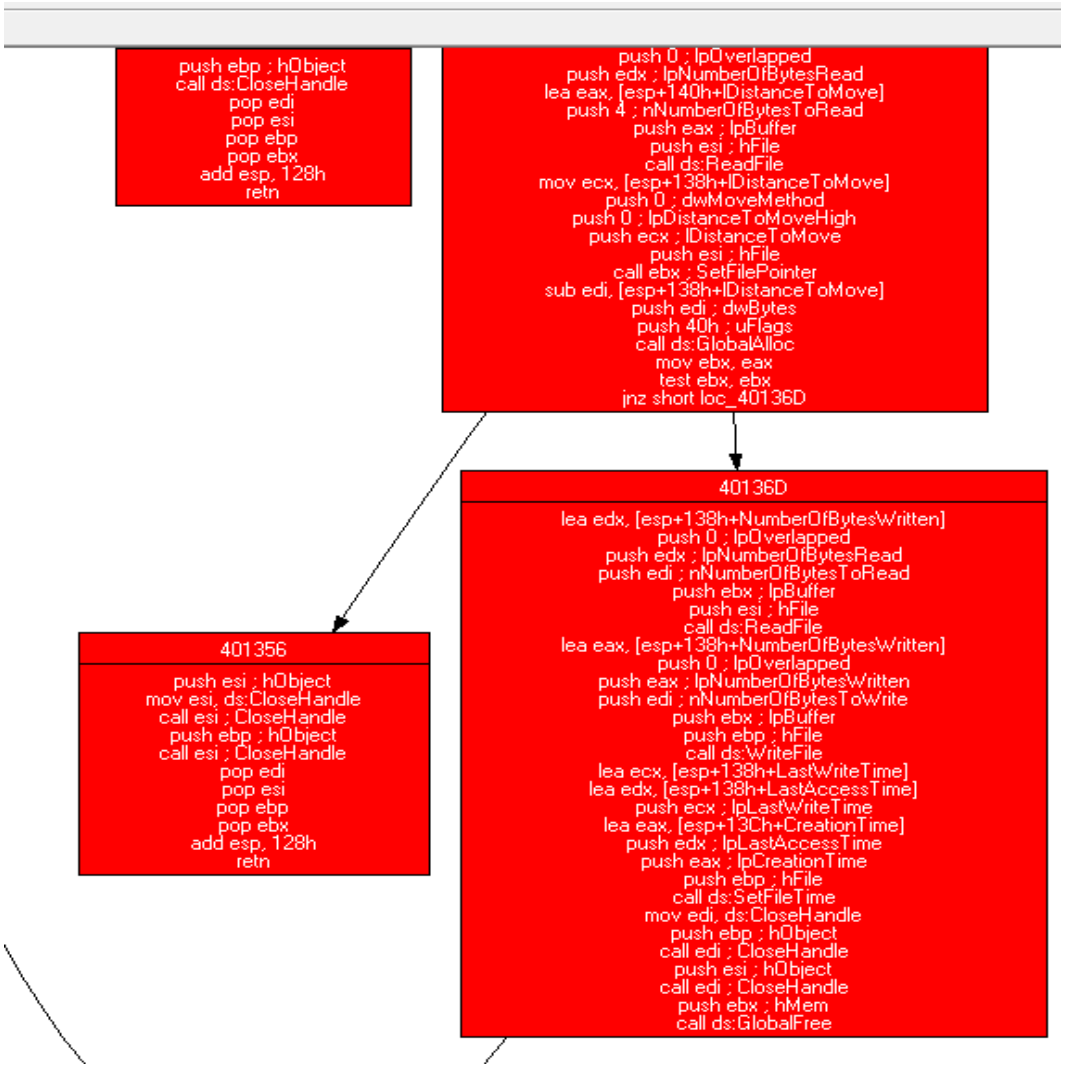
Malwares: 4th of July DDOS Attack: Comparison of variants



vs



Malwares: 4th of July DDOS Attack



- This is the routines that saves new attack targets.
- From the binary this part was the only modification.
- It can save a lot of time for the malware analysists.

Anti-Binary Diffing

- Symbol Mangling
- Reordering and replacing instructions
- CFG Altering
  - Call that never returns
  - Sharing Basic Blocks
  - Use multiple heads for a function
- CG Altering
  - Use proxy call

Anti Binary Diffing Tool: Hondon

- Hondon= 혼돈 = 混沌 = Chaos
  - A state that can't be divided and defined.
- Don't do extensive code obfuscation that can affect performance
  - Just make the codes not disassemble-able easily.
  - Disassemblableness is not a mandatory feature for a legitimate binary.
  - Usually make IDA's the function recognition fail

Anti Binary Diffing Tool: Hondon

- Implements CFG altering
  - Minor CFG altering breaks IDA
- Tested under 5.0 and 5.5.
  - 5.0 is broken severely
  - 5.5 is much better, but is still very confused with function recognition
- Hondon works as IDA plugin
  - In real world it should be implemented as a part of compiler(like Visual C++ or gcc).
  - Use binary rewriting to generate obfuscated binary

Hondon: Demo

Check if how IDA can be confused.

Conclusion

- The 1-day exploit threat is real
  - Someone finds vulnerabilities fixed silently
  - Bugs tend to aggregate and many times around where bugs were found
  - Some fixes are incomplete and someone can find those facts and can exploit the conditions
- "Hondon" attacks binary-differs weak points
  - Dependency on disassemblers for CFG and CG

DarunGrim2 and Hondon

http://www.darungrim.org

- All the source code and latest binaries will be uploaded within 2 weeks

Questions?