Full System Emulation: Achieving Successful Automated Dynamic Analysis of Evasive Malware

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Lastline, Inc.

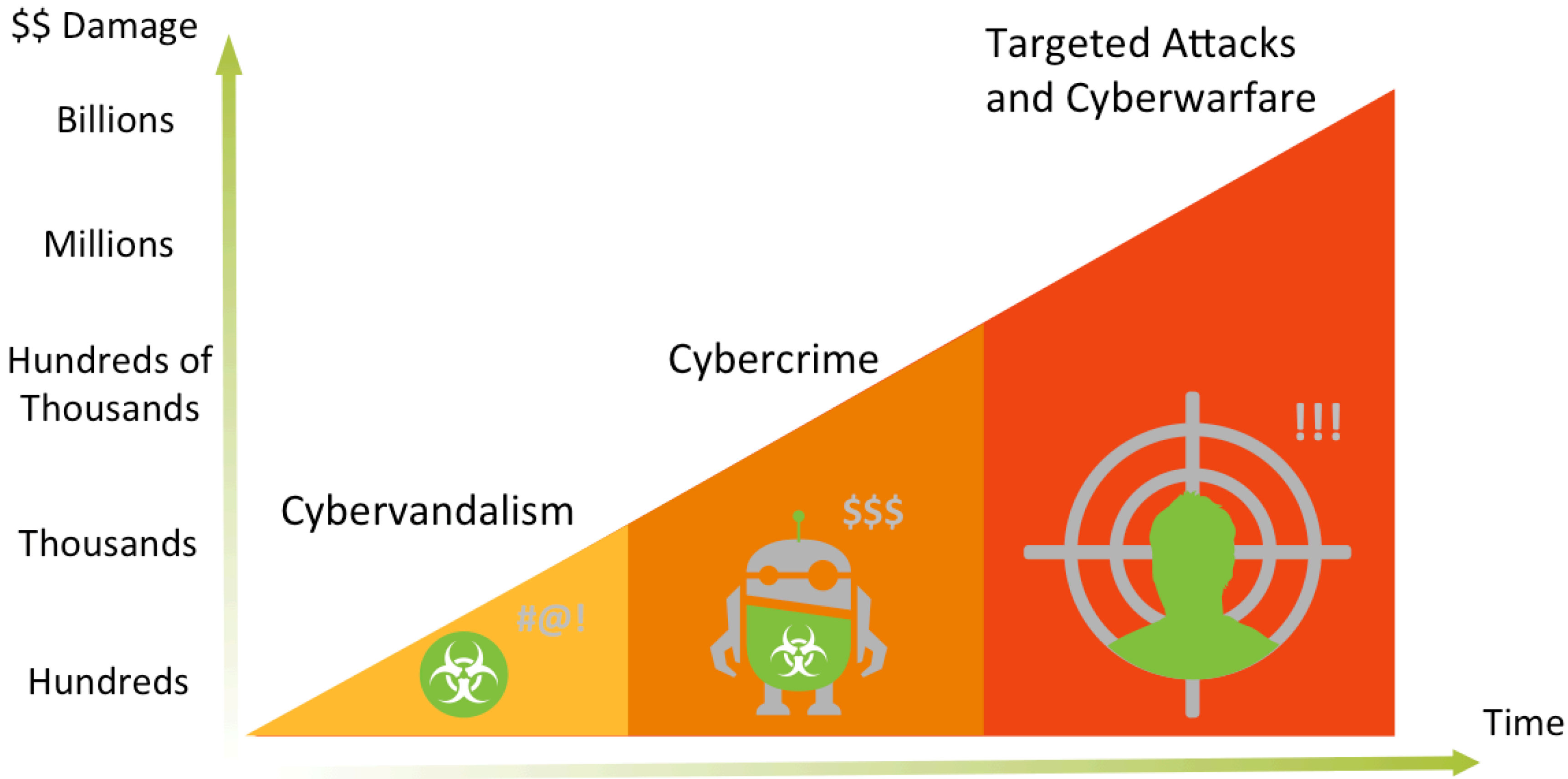
Who am I?

- Co-founder and Chief Scientist at Lastline, Inc.
  - Lastline offers protection against zero-day threats and advanced malware
  - effort to commercialize our research
- Professor in Computer Science at UC Santa Barbara (on leave)
  - many systems security papers in academic conferences
  - started malware research in about 2004
  - built and released practical systems (Anubis, Wepawet, …)

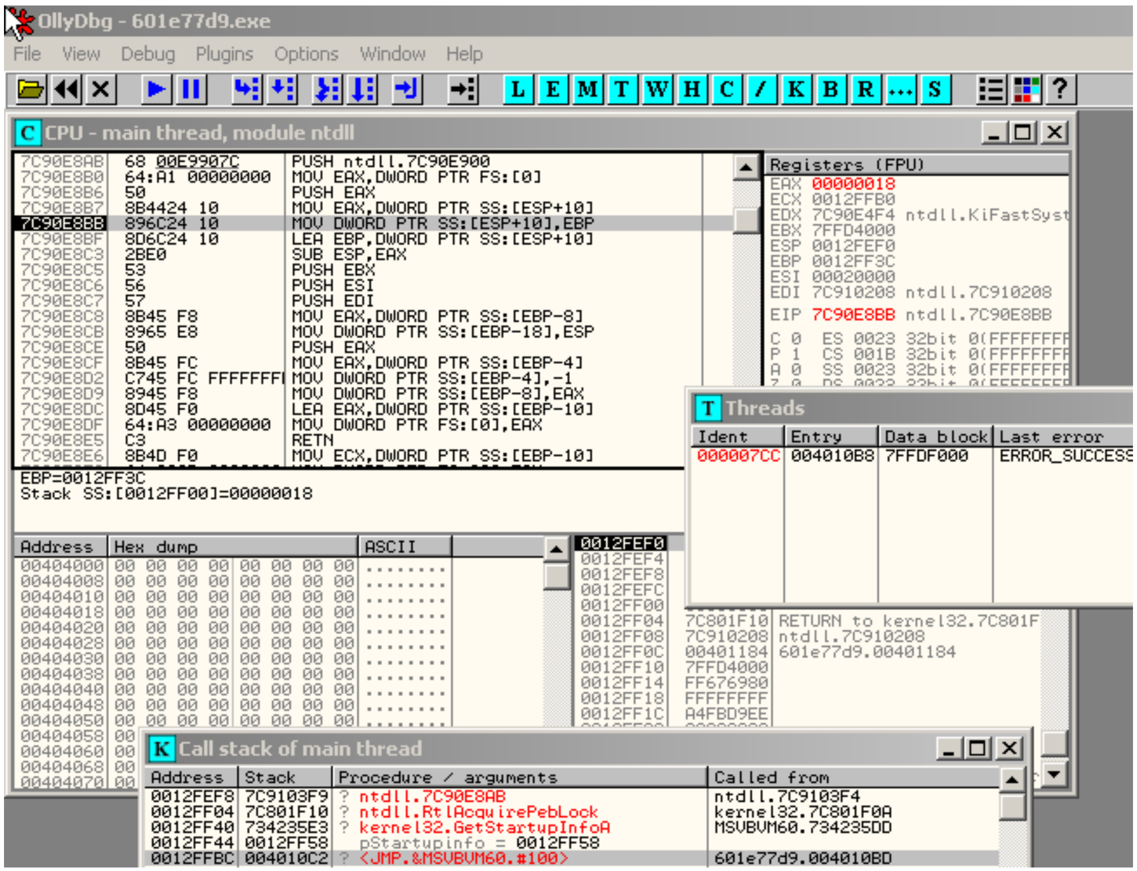
What are we talking about?

- Automated malware analysis
  - how can we implement dynamic malware analysis systems
- Evasion as a significant threat to automated analysis
  - detect analysis environment
  - detect analysis system
  - avoid being seen by automated analysis
- Improvements to analysis systems
  - automate defenses against classes of evasion approaches

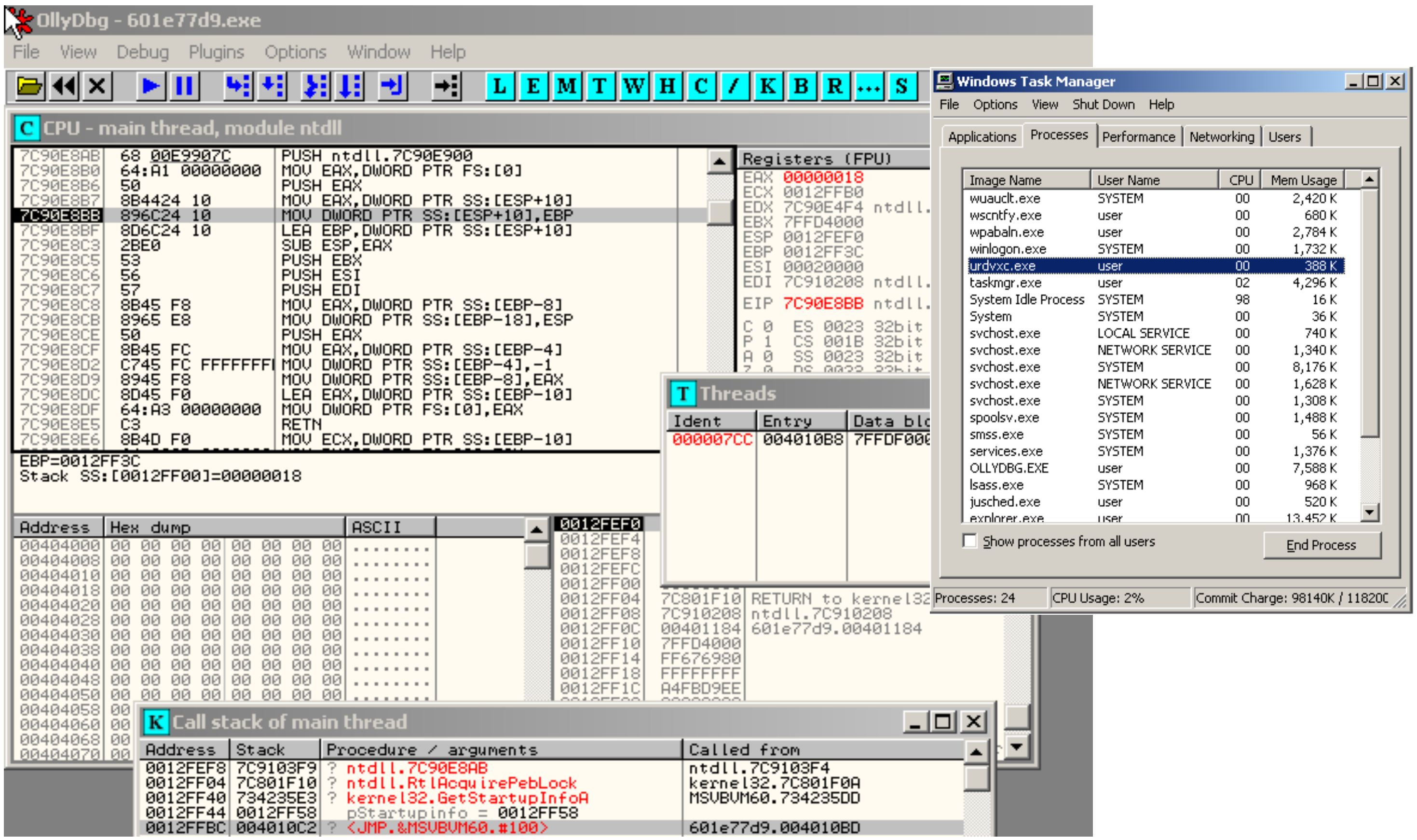
Evolution of Malware



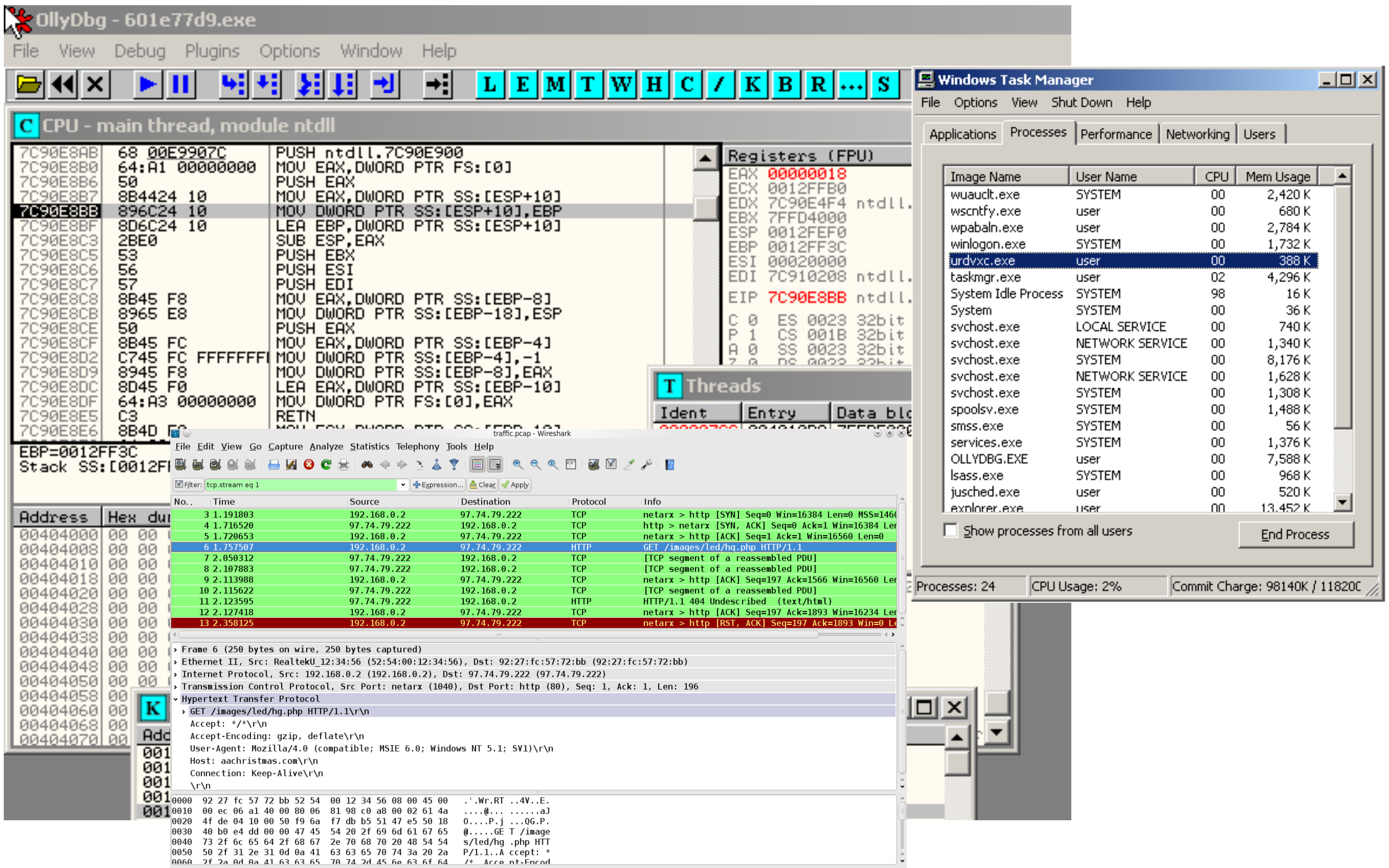
Malware Analysis



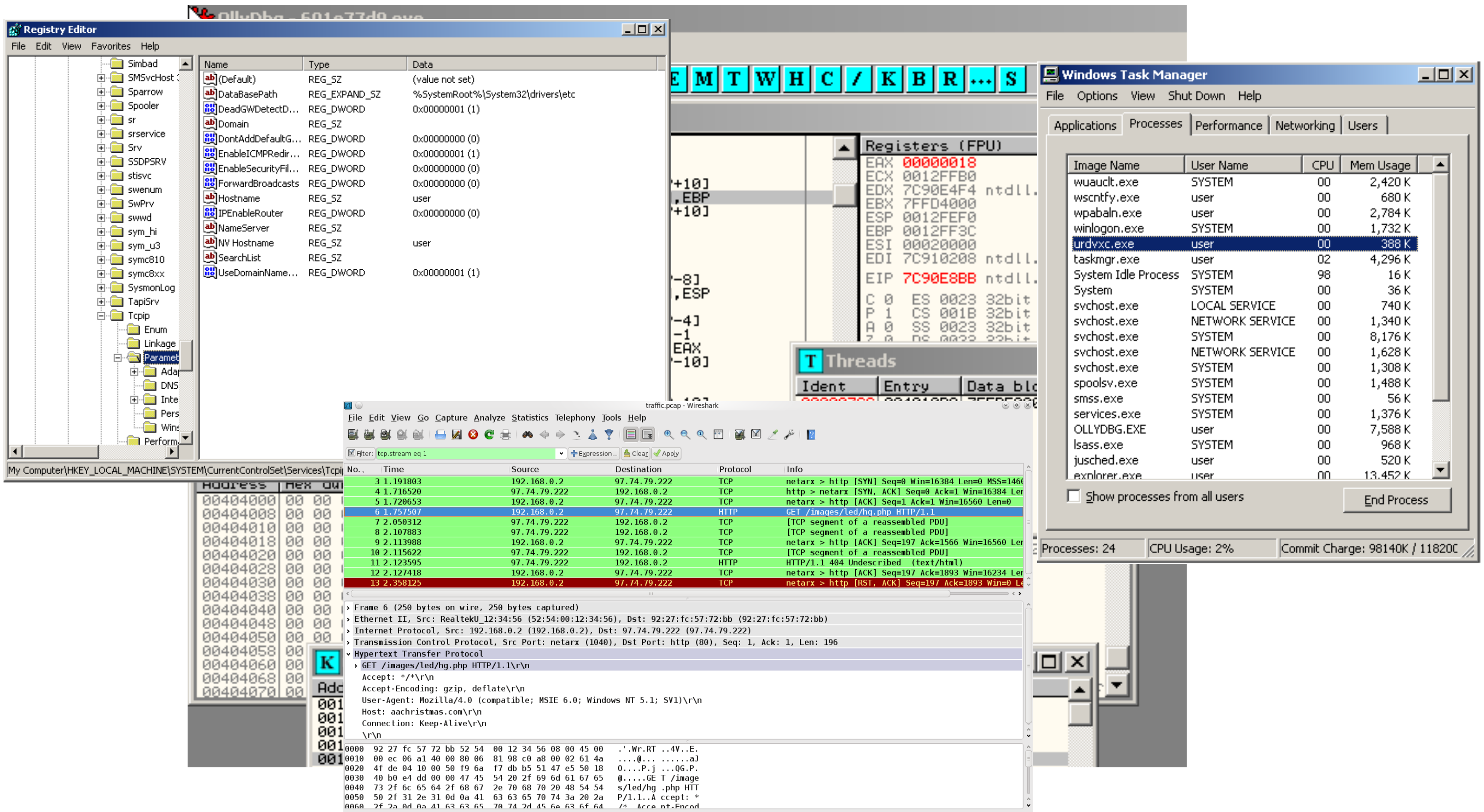
Malware Analysis



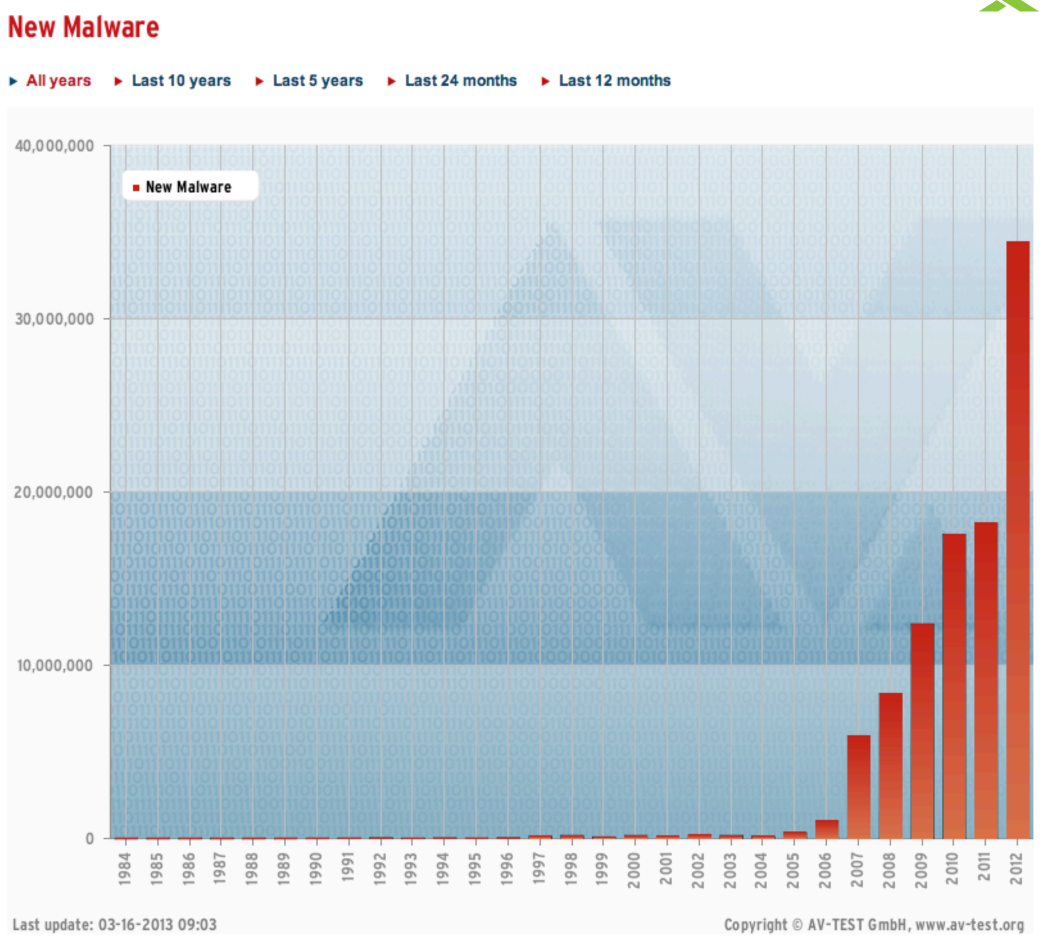
Malware Analysis



Malware Analysis



There is a lot of malware out there …



Automated Malware Analysis

- Aka sandbox
- Automation is great!
  - analysts do not need to look at each sample by hand (debugger)
  - only way to stem flood of samples and get scalability
  - can handle zero day threats (signature-less defense)
- Implemented as instrumented execution environment
  - run program and observe its activity
  - make determination whether code is malicious or not

What do we want to monitor?

1. Persistent changes to the operating system, network traffic
   - a file was written, some data was exchanged over the network

What do we want to monitor?

1. Persistent changes to the operating system, network traffic
   - a file was written, some data was exchanged over the network

- Can be done with post hoc monitoring of file system and external capturing of network traffic
  - easy to implement
  - allow malware to run on bare metal and unmodified OS (stealthy)
  - quite poor visibility (no temporary effects, sequence of actions, memory snapshots, data flows, …)

What do we want to monitor?

2. Interactions between the program (malware) and the environment (operating system)

```
open c:\sample.exe
read c:\secret.exe
write c:\tmp\a.txt
net: 192.168.0.1
-> evil.com:80
delete c:\tmp\a.txt
write c:\sample.exe
```

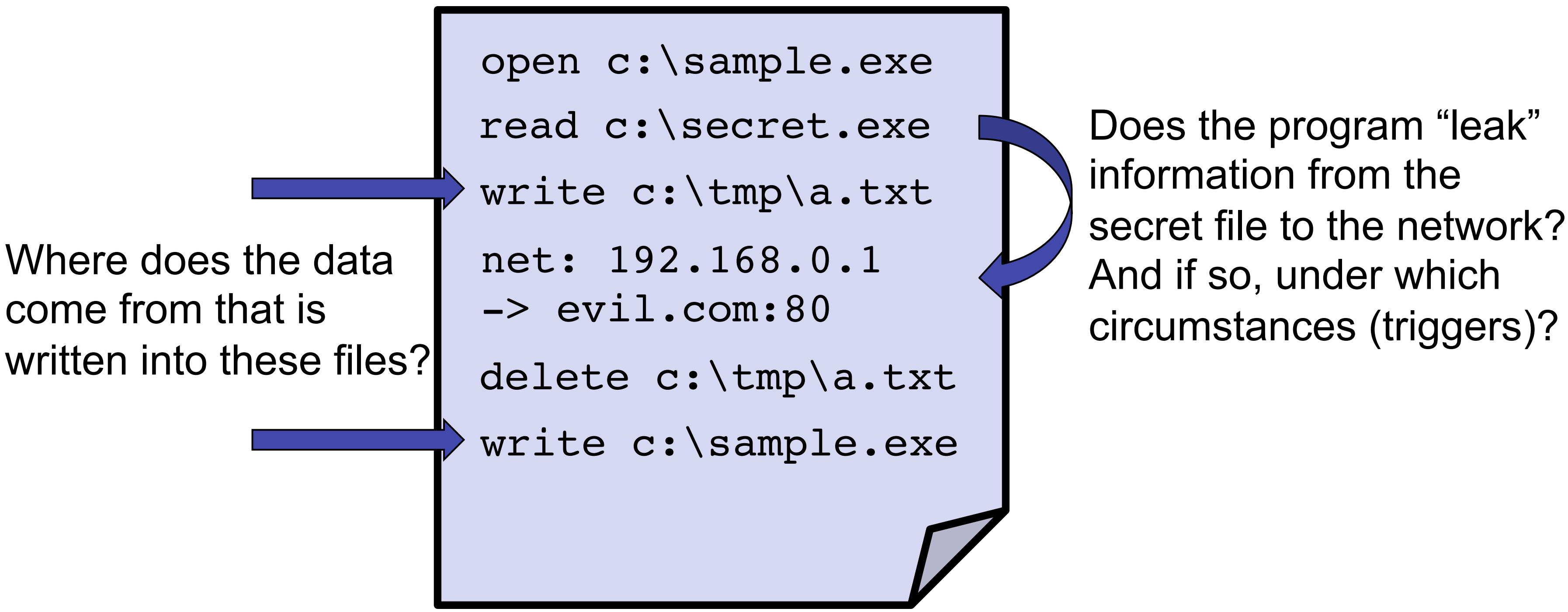
What do we want to monitor?

2. Interactions between the program (malware) and the environment (operating system)

- Can be done by instrumenting the operating system or libraries (install system call or library call hooks)
  - typically done by running modified OS image inside virtual machines, used by many (most) vendors
  - can see temporary effects, sequence of operations, more details
  - very limited visibility into program operations (instructions)
  - limited visibility of memory (where does data value come from?)

What do we want to monitor?

3. Details of the program execution (how does the program process certain inputs, how are outputs produced, which checks are done)?



What do we want to monitor?

3. Details of the program execution (how does the program process certain inputs, how are outputs produced, which checks are done)?

- Can be implemented through process emulation (CPU instructions + some Windows API calls) or a debugger
  – provides single instruction visibility
  – can potentially detect triggers and *data flows*
  – poor fidelity (**some** Windows API calls)
  – very slow and easy to detect (debugger)
  – produces a lot of data, so analysis must be able to leverage it

What do we want to monitor?

4. Details of the program execution while maintaining good fidelity?

What do we want to monitor?

4. Details of the program execution while maintaining good fidelity?

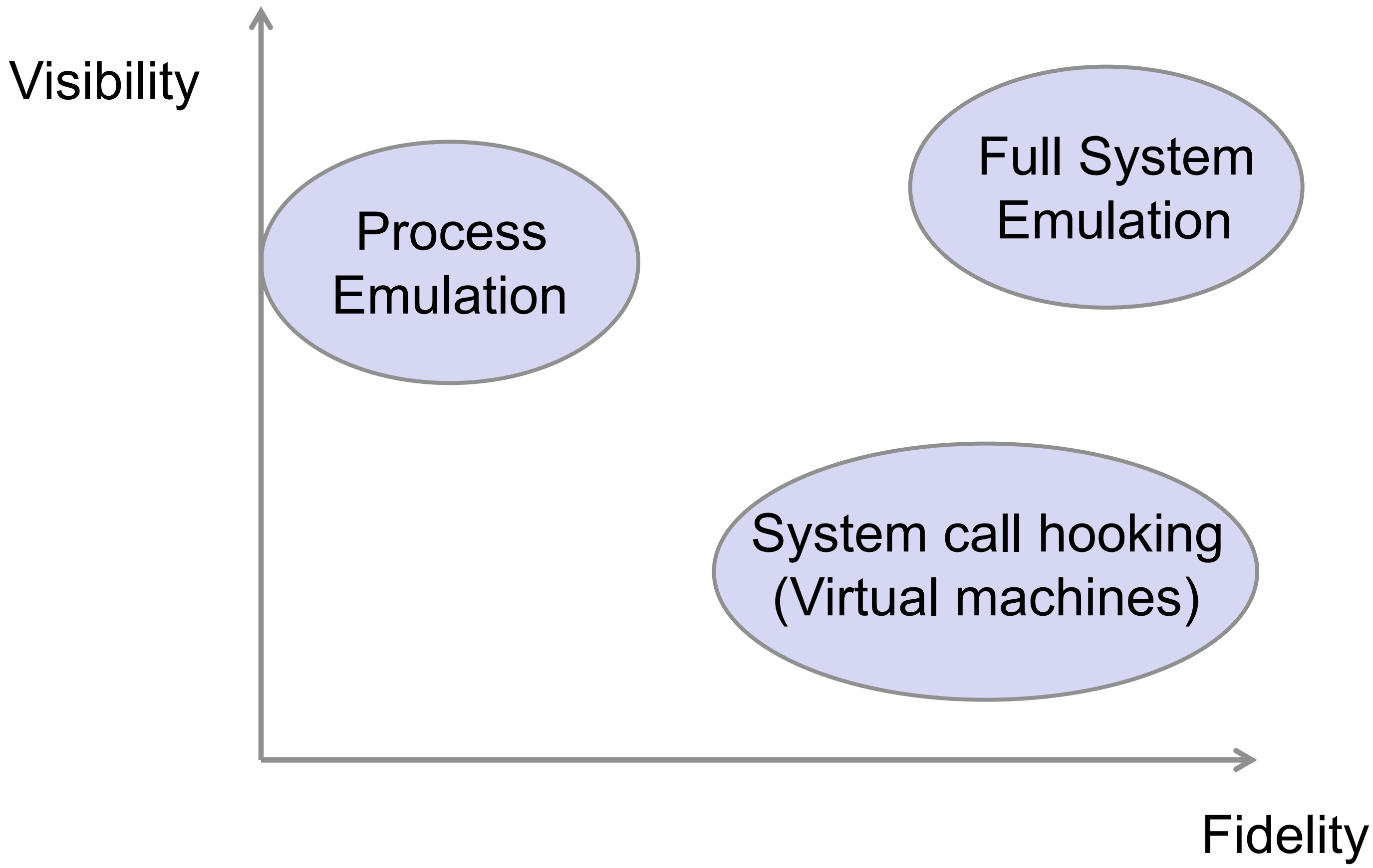
- Can be implemented through full system emulation (running a real OS on top of emulated hardware – CPU / memory)
  - provides single instruction visibility
  - can detect triggers and data flows
  - much better fidelity (real Windows)
  - not as fast as native execution (or VM), but pretty fast
  - produces a lot of data, so analysis must be able to leverage it

VM Approach versus CPU Emulation

```
[redacted]
callq   0x100070478        ; symbol stub for: _open
[redacted]
callq   0x1000704b4        ; symbol stub for: _read
[redacted]
callq   0x1000702b6        ; symbol stub for: _close
[redacted]
```

```
cmpl    $0x0c,%ebx
je      0x10000f21e
xorl    %esi,%esi
movq    %r15,%rdi
xorl    %eax,%eax
callq   0x100070478        ; symbol stub for: _open
movl    %eax,%r12d
testl   %eax,%eax
js      0x10000f21e
leaq    0xffffff70(%rbp),%rcx
movq    %rcx,0xfffffec0(%rbp)
movl    $0x00000050,%edx
movq    %rcx,%rsi
movl    %eax,%edi
callq   0x1000704b4        ; symbol stub for: _read
movq    %rax,%r13
movl    %eax,%r14d
movl    %r12d,%edi
callq   0x1000702b6        ; symbol stub for: _close
cmpl    $0x02,%r13d
jle     0x10000f21e
```

Dynamic Analysis Approaches



Our Automated Malware Analysis

Anubis: *ANalyzing Unknown BInarieS* (university project)

and its successor (which was built from scratch)

llama: *LastLine Advanced Malware Analysis*

- based on full system emulation
- can see every instruction!
- monitors system activity from the outside (stealthier)
- runs real operating system
  - requires mechanisms to handle semantic gap
- general platform on which additional components can be built

Visibility Does Matter

- See more types of behavior
  - which connection is used to leak sensitive data
    - allows automated detection of C&C channels
  - how does the malware process inputs from C&C channels
    - enumeration of C&C commands (and malware functionality)
  - insights into keyloggers (often passive in sandbox)
  - take memory snapshots after decryption for forensic analysis

- Combat evasion
  - detect triggers
  - bypass stalling code
  - much more about this later …

Detecting Keyloggers

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- Software-based keyloggers
  - `SetWindowsHook`: intercepts events from the system, such as keyboard and mouse activity
  - `GetAsyncKeyState` or `GetKeyState`
- User simulation module that triggers actions likely to be monitored by keyloggers
  - Type on keyboard
  - Insert special data values (e.g., “valid” credit card numbers, passwords, email addresses, etc.)
- Track sensitive data and how it is used by the malware

Detecting Keyloggers

Threat Level

The file was found to be **malicious** at 2014-05-09 01:38:35.

Risk Assessment

Maliciousness score: **100/100**
Risk estimate: High Risk - Malicious behavior detected

Malicious Activity Summary

Type	Description
Autostart	Registering for autostart using the Windows start menu
Evasion	Possibly stalling against analysis environment (loop)
File	Modifying executable in user-shared data directory
Signature	Identified trojan code
Steal	Keystroke logging capabilities
Stealth	Creating executables masquerading system files
Stealth	Deleting the sample after execution

Detecting Keyloggers

− Analysis Subject 2

MD5	21f8b9d9a6fa3a0cd3a3f0644636bf09
SHA1	0392f25130ce88fdee482b771e38a3eaae90f3e2
Command Line	"C:\ProgramData\Microsoft\Windows\Start Menu\Programs\Startup\spoolsv.exe" C:\Users\ ...\chewbacca.exe
File Type	PE executable, application, 32-bit
File Size (bytes)	5,224,645
Analysis Reason	Process started

+ Libraries
+ File System Activity
+ Registry Activity
+ Network Activity
+ Process Interactions

− Keyboard Monitoring

Keylogging

Content Type	Content
Credit Card	[illegible]-1100-9326
Password	grafsndv
Social Security Number	[illegible]-06-6413
Username	Username omitted from public report

Supporting Static Analysis

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- Recognize interesting points in time during the analysis of a malware
  - a sensitive system call has been executed
  - malware has unpacked itself
- Take a snapshot of the process memory and annotate interesting regions
- Import snapshot into IDA Pro (together with the annotations) for manual analysis

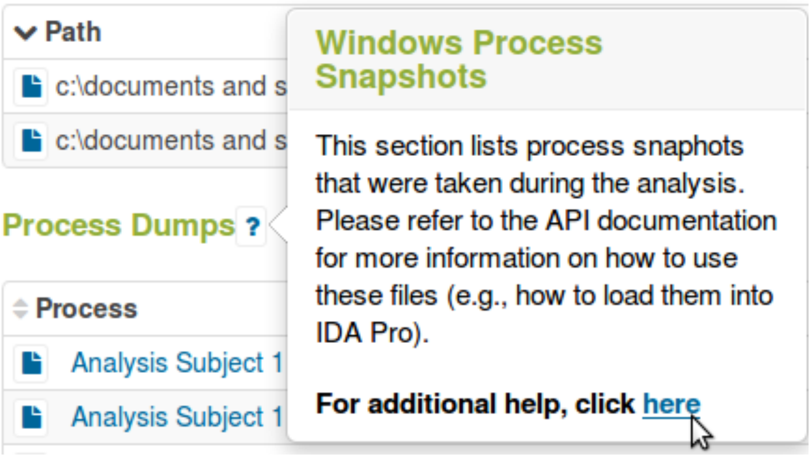
https://user.lastline.com/malscape#/task/f7b5c2293e574d069e0a48bcd7691b16

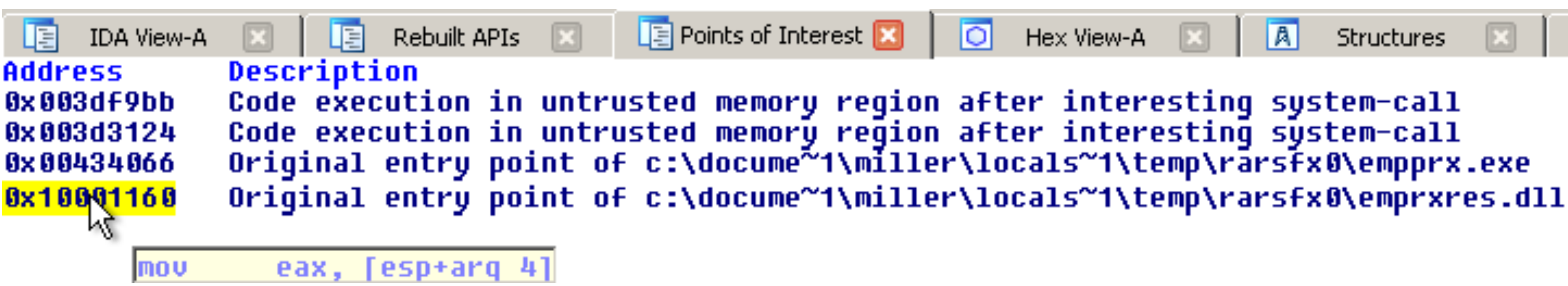
Supporting Static Analysis

Process Dumps ?

Process	Timestamp	Dump Type	Snapshot Reason
Analysis Subject 1	17 s	Process Dump	Observed API function invocation from untrusted memory regi…
Analysis Subject 1	20 s	Process Dump	Observed API function invocation from untrusted memory regi…
Analysis Subject 1	296 s	Process Dump	Analysis terminated
Analysis Subject 2	22 s	Process Dump	Observed code execution in memory region allocated by untr…
Analysis Subject 2	22 s	Process Dump	Observed code execution in memory region allocated by untr…
Analysis Subject 2	297 s	Process Dump	Analysis terminated
Analysis Subject 3	27 s	Process Dump	Observed code execution in memory region allocated by untr…
Analysis Subject 3	28 s	Process Dump	Observed API function invocation from untrusted memory regi…
Analysis Subject 3	30 s	Process Dump	Process terminated
Analysis Subject 4	30 s	Process Dump	Observed code execution in memory region allocated by untr…
Analysis Subject 4	30 s	Process Dump	Observed code execution in memory region allocated by untr…
Analysis Subject 4	39 s	Process Dump	Observed API function invocation from untrusted memory regi…
Analysis Subject 6	42 s	Process Dump	Observed code execution in memory region allocated by untr…
Analysis Subject 6	42 s	Process Dump	Observed code execution in memory region allocated by untr…
Analysis Subject 6	297 s	Process Dump	Analysis terminated

Supporting Static Analysis





Evasion

- Malware authors are not sleeping
  - they got the news that sandboxes are all the rage now
  - since the code is executed, malware authors have options ..

- Evasion
  - develop code that exhibits no malicious behavior in sandbox, but that infects the intended target
  - can be achieved in various ways

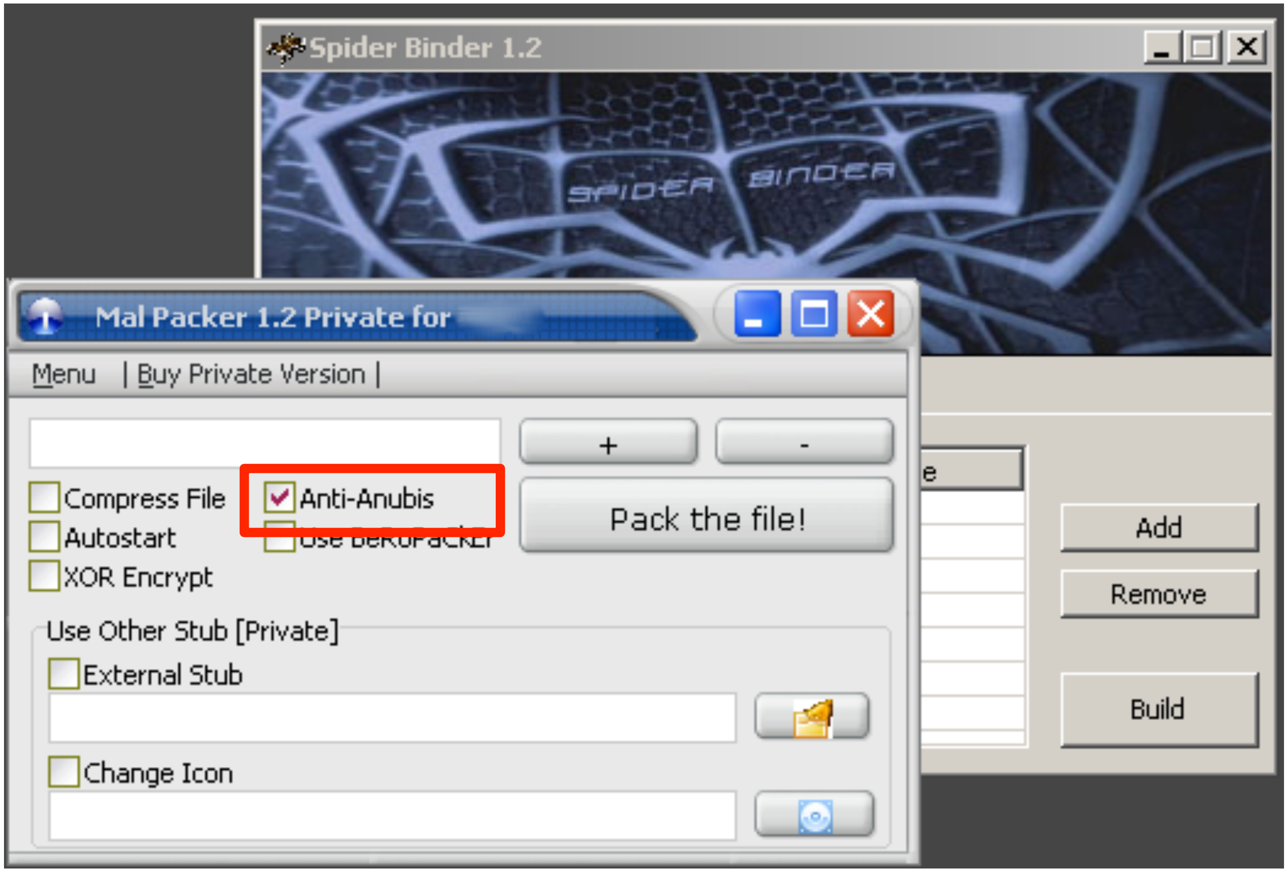
Evasion

- Malware can detect underlying runtime environment
  - differences between virtualized and bare metal environment
  - checks based on system (CPU) features
  - artifacts in the operating system

- Malware can detect signs of specific analysis environments
  - checks based on operating system artifacts (files, processes, …)

- Malware can avoid being analyzed
  - tricks in making code run that analysis system does not see
  - wait until someone does something
  - time out analysis before any interesting behaviors are revealed
  - simple sleeps, but more sophisticated implementations possible

Evasion


Spider Binder 1.2
SPIDER BINDER
Add
Remove
Build
Mal Packer 1.2 Private for
Menu | Buy Private Version |
+
-
Compress File
Anti-Anubis
Autostart
XOR Encrypt
Pack the file!
Use Other Stub [Private]
External Stub
Change Icon

Evasion


PXCrypter 1.1 Fully undetected
PXCrypter 1.1 build 231
Crypter 1.1
Input Filename:
Browse
Change Icon
Icon Filename:
Browse
Adv Settings
Anti Virtualization (Microsoft VPC,VMware,VirtualBox)
Anti Debug (Ollydbg,Soft-Ice,IDA,Generic Debuggers)
Anti SandBoxie/ThreatExpert
Anti SandBoxes (Norman,Anubis,CW,Generic Sandboxes)
Melt on exit
Start Hidden (Without GUI)
Try to Unpack the Executable before Crypting
UPX Packing Mode
Automatic (Recommended)
Overlay Detection/Processing
Automatic (Recommended)
Injection Target
Default Self (Recommended)
Delay
0
Seconds
Build
Private Version for Current Customers

Evasion

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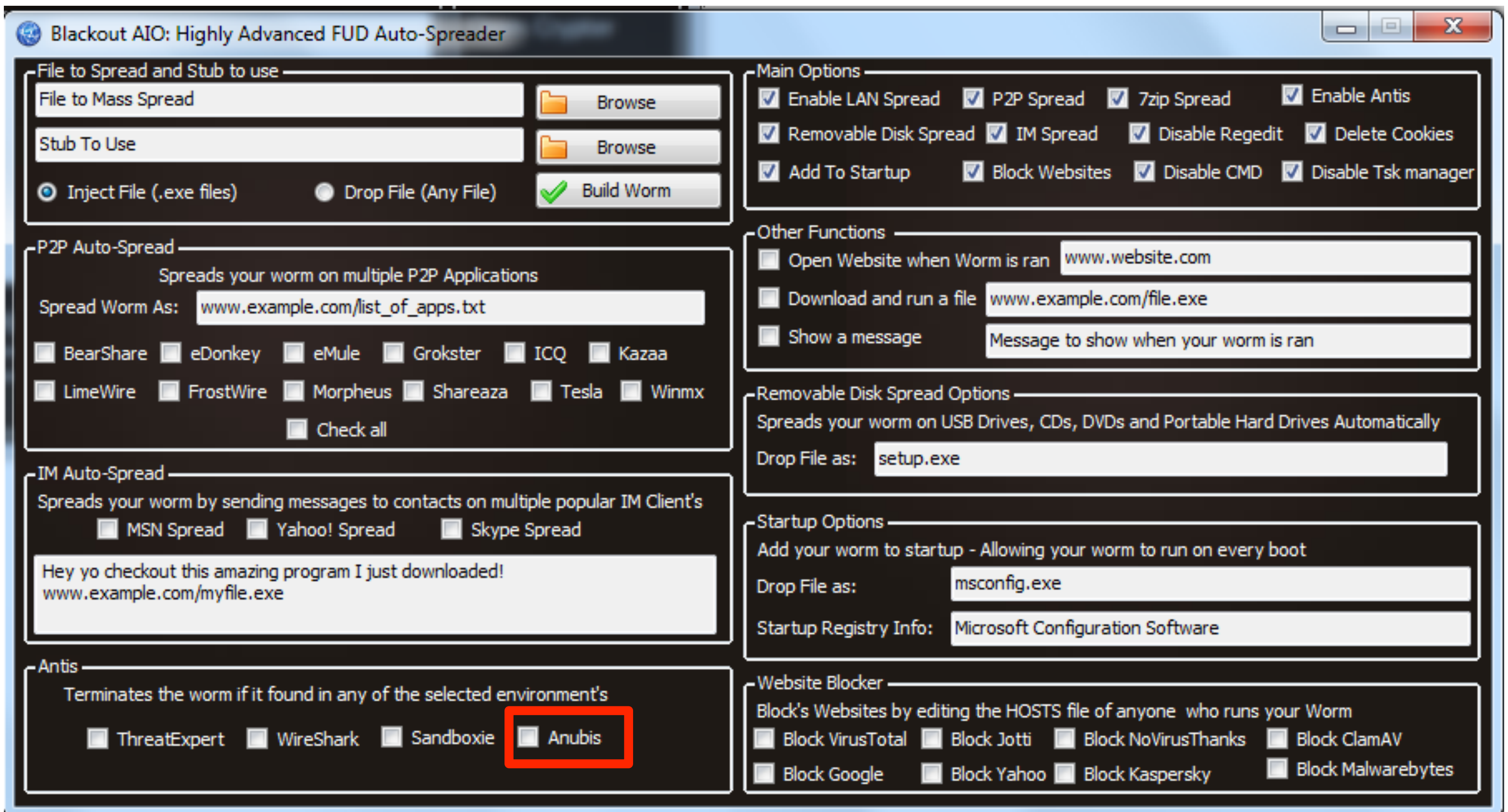

Detect Runtime Environment

- Insufficient support from hardware for virtualization
  - J. Robin and C. Irvine: Analysis of the Intel Pentium's Ability to Support a Secure Virtual Machine Monitor; Usenix Security Symposium, 2000
  - famous RedPill code snippet

Joanna Rutkowska

Swallowing the Red Pill is more or less equivalent to the following code (returns non zero when in Matrix):

```
int swallow_redpill () {
  unsigned char m[2+4], rpill[] = "\x0f\x01\x0d\x00\x00\x00\x00\xc3";
  *((unsigned*)&rpill[3]) = (unsigned)m;
  ((void(*)())&rpill)();
  return (m[5]>0xd0) ? 1 : 0;
}
```

Detect Runtime Environment

- Insufficient support from hardware for virtualization
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  - famous RedPill code snippet

- hardware assisted virtualization (Intel-VT and AMD-V) helps
- but systems can still be detected due to timing differences

Detect Runtime Environment

- CPU bugs or unfaithful emulation
  - invalid opcode exception, incorrect debug exception, …
  - later automated in: R. Paleari, L. Martignoni, G. Roglia, D. Bruschi: A fistful of red-pills: How to automatically generate procedures to detect CPU emulators; Usenix Workshop on Offensive Technologies (WOOT), 2009
  - recently, we have seen malware make use of (obscure) math instructions

- The question is … can malware really assume that a generic virtual machine implies an automated malware analysis system?

Detect Analysis Engine

- Check Windows XP Product ID

  `HKLM\SOFTWARE\Microsoft\Windows NT\CurrentVersion\ProductID`

- Check for specific user name, process names, hard disk names

  `HKLM\SYSTEM\CURRENTCONTROLSET\SERVICES\DISK\ENUM`

- Check for unexpected loaded DLLs or Mutex names

- Check for color of background pixel

- Check of presence of 3-button mouse, keyboard layout, …

Detect Analysis Engine

```
.text:00401E37
.text:00401E39 loc_401E39:                             ; CODE XREF: .text:00401DCC↑j
.text:00401E39                                         ; .text:00401DC3↑j
.text:00401E39                 mov     eax, [ebp-270h]
.text:00401E3F
.text:00401E3F loc_401E3F:                             ; CODE XREF: .text:00401DD1↑j
.text:00401E3F                 mov     [ebp-170h], eax
.text:00401E45
.text:00401E45 loc_401E45:                             ; CODE XREF: .text:00401E2B↑j
.text:00401E45                 push    dword ptr [ebp-16Ch]
.text:00401E4B                 call    dword ptr [ebp-34h]
.text:00401E4E                 cmp     dword ptr [ebp-170h], 'awmv' ;
.text:00401E4E                                         ; search known sandboxes'
.text:00401E4E                                         ; substring in registry key value
.text:00401E4E                                         ; vbox
.text:00401E4E                                         ; qemu
.text:00401E4E                                         ; vmwa
.text:00401E58                 jz      short loc_401E95
.text:00401E5A                 cmp     dword ptr [ebp-170h], 'xobv'
.text:00401E64                 jz      short loc_401E95
.text:00401E66                 cmp     dword ptr [ebp-170h], 'umeq'
.text:00401E70                 jz      short loc_401E95
.text:00401E72
.text:00401E72 loc_401E72:                             ; CODE XREF: .text:00401D55↑j
.text:00401E72                                         ; .text:00401D6D↑j ...
.text:00401E72                 rdtsc
```

Detect Analysis Engine

Detect Analysis Engine


```
if( (snd = FindWindow("SandboxieControlWndClass", NULL)) ){
  return true; // Detected Sandboxie.
} else if( (pch = strstr (str,"sample")) || (user == "andy") || (user == "Andy") ){
  return true; // Detected Anubis sandbox.
} else if( (exeName == "C:\file.exe") ){
  return true; // Detected Sunbelt sandbox.
} else if( (user == "currentuser") || (user == "Currentuser") ){
  return true; // Detected Norman Sandbox.
} else if( (user == "Schmidti") || (user == "schmidti") ){
  return true; // Detected CW Sandbox.
} else if( (snd = FindWindow("Afx:400000:0", NULL)) ){
  return true; // Detected WinJail Sandbox.
} else {
  return false;
}
```

Avoid Monitoring

- Open window and wait for user to click
  - or, as recently discovered by our competitor, click multiple times ;-)
- Only do bad things after system reboots
  - system could catch the fact that malware tried to make itself persistent
- Only run before / after specific dates
- Code execution after initial call to `NtTerminateProcess`
- Bypass in-process hooks (e.g., of library functions)

Avoid Monitoring

```
SYSTEMTIME SystemTime;

DisableThreadLibraryCalls(hdll);
GetSystemTime(&SystemTime);
result = SystemTime.wMonth;
if (SystemTime.wDay + 100 * (SystemTime.wMonth + 100 * (unsigned int)SystemTime.wYear)
    >= 20120101)
{
  uint8_t* pmain_image = (uint8_t*)GetModuleHandleA(0);
  IMAGE_DOS_HEADER *pdos_header = (IMAGE_DOS_HEADER*)pmain_image;
  IMAGE_NT_HEADERS *pnt_header = \
      (IMAGE_NT_HEADERS*)(pdos_header->e_lfanew + pmain_image);
  uint8_t* entryPoint = pmain_image + pnt_header->OptionalHeader.AddressOfEntryPoint;
  result = VirtualProtect(entryPoint, 0x10u, 0x40u, &flOldProtect);

  if (result)
  {
    entryPoint[0] = 0xE9;
    entryPoint[1] = (uint8_t)((uint8_t *)loadShellCode - entryPoint - 5);
    entryPoint[2] = (uint8_t)(((uint8_t *)loadShellCode - entryPoint - 5) >> 8);
    entryPoint[3] = (uint8_t)(((uint8_t *)loadShellCode - entryPoint - 5) >> 16);
    entryPoint[4] = (uint8_t)(((uint8_t *)loadShellCode - entryPoint - 5) >> 24);
    result = VirtualProtect((LPVOID)entryPoint, 0x10u, flOldProtect, &flOldProtect);
  }
```

Avoid Monitoring

Code execution after initial call to `NtTerminateProcess`

```
ExitProcess(IN UINT uExitCode)
{
    BASE_API_MESSAGE ApiMessage;
    PBASE_EXIT_PROCESS ExitProcessRequest = &ApiMessage.Data.ExitProcessRequest;

    ASSERT(!BaseRunningInServerProcess);

    _SEH2_TRY
    {
        /* Acquire the PEB lock */
        RtlAcquirePebLock();

        /* Kill all the threads */
        NtTerminateProcess(NULL, 0);

        /* Unload all DLLs */
        LdrShutdownProcess();

        /* Notify Base Server of process termination */
        ExitProcessRequest->uExitCode = uExitCode;
        CsrClientCallServer((PCSR_API_MESSAGE)&ApiMessage,
                            NULL,
                            CSR_CREATE_API_NUMBER(BASESRV_SERVERDLL_INDEX, BasepExitProcess),
                            sizeof(BASE_EXIT_PROCESS));

        /* Now do it again */
        NtTerminateProcess(NtCurrentProcess(), uExitCode);
```

Stop monitoring here (→ `NtTerminateProcess(NULL, 0);`)

Interesting stuff happens here … (→ `LdrShutdownProcess();`)

Avoid Monitoring

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Bypass in-process hooks (e.g., of library functions)

```
Address     Pointer
7FF90000   7FF80560
      7FF80560     8>MOV EDI,EDI   <- copied from 77DDEFFC
      7FF80562   - E>JMP ADVAPI32.77DDEFFE
```

jump to second instruction of library function

```
AdjustTokenPrivlages
77DDEFFC >   8>MOV EDI,EDI     <- start
77DDEFFE     5>PUSH EBP
77DDEFFF     8>MOV EBP,ESP
77DDF001     5>PUSH ESI
77DDF002     F>PUSH DWORD PTR SS:[EBP+1C]
77DDF005     F>PUSH DWORD PTR SS:[EBP+18]
77DDF008     F>PUSH DWORD PTR SS:[EBP+14]
77DDF00B     F>PUSH DWORD PTR SS:[EBP+10]
77DDF00E     F>PUSH DWORD PTR SS:[EBP+C]
77DDF011     F>PUSH DWORD PTR SS:[EBP+8]
77DDF014     F>CALL DWORD PTR DS:[<&ntdll.NtAdjustPrivi>; ntdll.ZwAdjustPrivilegesToken
```

Avoid Monitoring

- Sleep for a while (analysis systems have time-outs)
  - typically, a few minutes will do this
- Anti-sleep-acceleration
  - some sandboxes skip long sleeps, but malware authors have figured that out …
- “Sleep” in a smarter way (stalling code)

Avoid Monitoring

Anti-sleep-acceleration

– introduce a race condition that involves sleeping

•Sample creates two threads

1. `sleep()` + `NtTerminateProcess`
2. copies and restarts program

– if `ZwDelayExecution` gets patched, `NtTerminateProcess` executes before second thread is done

•Another variation

1. `sleep()` + `DeleteFileW(`<name>.bat`)`
2. start <name>.bat file

Avoid Monitoring

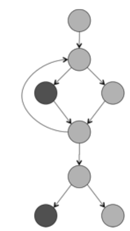
```
unsigned count, tick;

void helper() {
  tick = GetTickCount();
  tick++;
  tick++;
  tick = GetTickCount();
}

void delay() {
  count=0x1;
  do {
    helper();
    count++;
  } while (count!=0xe4e1c1);
}
```

Figure 1. Stalling code found in real-world malware (W32.DelfInj)

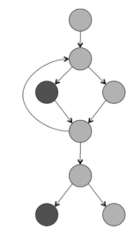
Real host - A few milliseconds
Anubis - Ten hours

What can we do about evasion?

- One key evasive technique relies on checking for specific values in the environment (triggers)
  - we can randomize these values, if we know about them
  - we can detect (and bypass) triggers automatically



- Another key technique relies on timing out the sandbox
  - we can automatically profile code execution and recognize stalling



Bypassing Triggers

- Idea
  - explore multiple execution paths of executable under test
  - exploration is driven by monitoring how program uses certain inputs
  - system should also provide information under which circumstances a certain action is triggered

- Approach
  - track “interesting” input when it is read by the program
  - whenever a control flow decision is encountered that uses such input, two possible paths can be followed
  - save snapshot of current process and continue along first branch
  - later, revert back to stored snapshot and explore alternative branch

Bypassing Triggers

- Tracking input
  - we already know how to do this (tainting)

- Snapshots
  - we know how to find control flow decision points (branches)
  - snapshots are generated by saving the content of the process' virtual address space (of course, only used parts)
  - restoring works by overwriting current address space with stored image

- Explore alternative branch
  - restore process memory image
  - set the tainted operand (register or memory location) to a value that reverts branch condition
  - let the process continue to run

Bypassing Triggers

- Unfortunately, it is not that easy
  - when only rewriting the operand of the branch, process state can become inconsistent
  - input value might have been copied or used in previous calculations

```
x = read_input();
y = 2*x + 1;
check(y);
print(“x = %d, x”);
....

void check(int magic) {
    if (magic != 47)
        exit();
}
```

Bypassing Triggers

- Unfortunately, it is not that easy
  - when only rewriting the operand of the branch, process state can become inconsistent
  - input value might have been copied or used in previous calculations

x = 0

```
x = read_input();
y = 2*x + 1;
check(y);
print("x = %d, x");
....

void check(int magic) {
    if (magic != 47)
        exit();
}
```

Bypassing Triggers

- Unfortunately, it is not that easy
  - when only rewriting the operand of the branch, process state can become inconsistent
  - input value might have been copied or used in previous calculations

x = 0

```
x = read_input();
y = 2*x + 1;
check(y);
print("x = %d, x");
....

void check(int magic) {
    if (magic != 47)
        exit();
}
```

Bypassing Triggers

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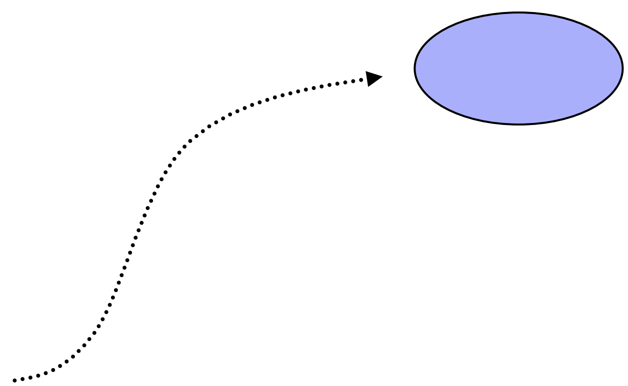

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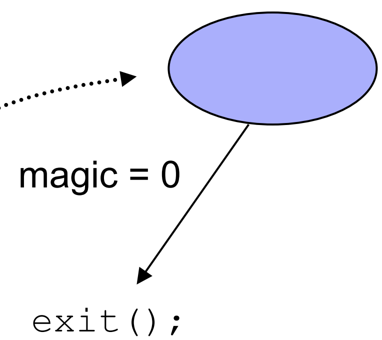

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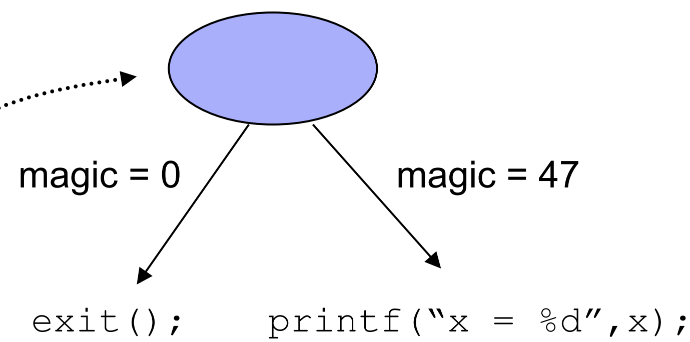

This prints x = 0 !

We have to remember that y depends on x, and that magic depends on y.

Bypassing Triggers

- Tracking of input must be extended
  - whenever a tainted value is copied to a new location, we must remember this relationship
  - whenever a tainted value is used as input in a calculation, we must remember the relationship between the input and the result

- Constraint set
  - for every operation on tainted data, a constraint is added that captures relationship between input operands and result
  - currently, we only model linear relationships
  - can be used to perform consistent memory updates when exploring alternative paths
  - provides immediate information about condition under which path is selected

Bypassing Triggers

- Constraint set

```
x = read_input();
y = 2*x + 1;
check(y);
print(“x = %d, x”);
....


void check(int magic) {
    if (magic != 47)
       exit();
}
```

Bypassing Triggers

- Constraint set

x = 0

```
x = read_input();
y = 2*x + 1;
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x == input

y == 2*x + 1

magic == y

Bypassing Triggers

- Constraint set

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magic == 47

Bypassing Triggers

- Constraint set

x = 0

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x = read_input();
y = 2*x + 1;
check(y);
print("x = %d, x");
....


void check(int magic) {
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}
```

x == input

y == 2*x + 1

magic == y

magic == 47

solve for alternative branch

y == magic == 47
x == input == 23

Now, print outputs “x = 23”

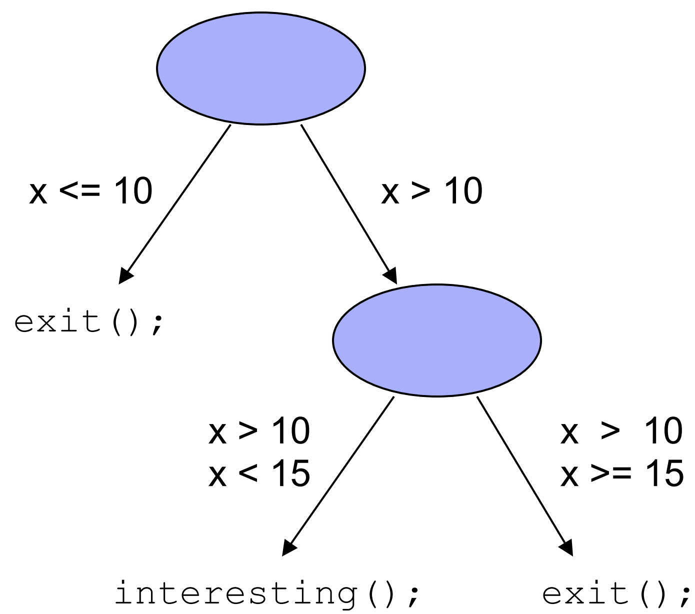
Bypassing Triggers

- Path constraints
  - capture effects of conditional branch operations on tainted variables
  - added to constraint set for certain path

```
x = read_input();

if (x > 10)
  if (x < 15)
    interesting();

exit();
```



Bypassing Triggers

- 308 malicious executables
  - large variety of viruses, worms, bots, Trojan horses, …

Interesting input sources	
Check for Internet connectivity	20
Check for mutex object	116
Check for existence of file	79
Check for registry entry	74
Read current time	134
Read from file	106
Read from network	134

Additional code coverage	
none	136
0% - 10%	21
10% - 50%	71
50% - 200%	37
> 200%	43

Additional code is likely for error handling

Relevant behavior:
time-triggers
filename checks
bot commands

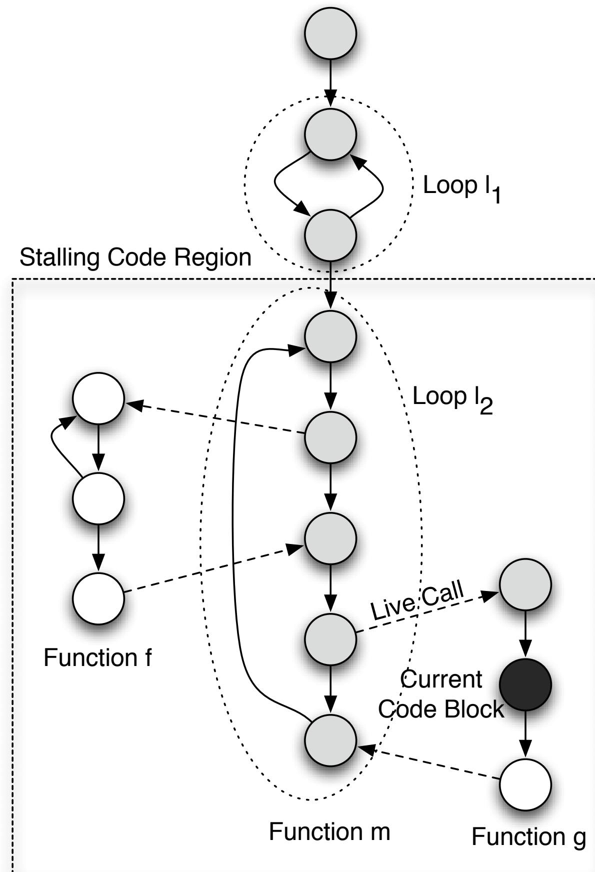
Combating Evasion

- Mitigate stalling loops
  1. detect that program does not make progress
  2. passive mode
     - find loop that is currently executing
     - reduce logging for this loop (until exit)
  3. active mode
     - when reduced logging is not sufficient
     - actively interrupt loop

- Progress checks
  – based on system calls
    too many failures, too few, always the same, …

Passive Mode

- Finding code blocks (white list) for which logging should be reduced
  - build dynamic control flow graph
  - run loop detection algorithm
  - identify live blocks and call edges
  - identify first (closest) *active* loop (loop still in progress)
  - mark all regions reachable from this loop



Active Mode

- Interrupt loop
  - find conditional jump that leads out of white-listed region
  - simply invert it the next time control flow passes by
- Problem
  - program might later use variables that were written by loop but that do not have the proper value and fail
- Solution
  - mark all memory locations (variables) written by loop body
  - dynamically track all variables that are marked (taint analysis)
  - whenever program uses such variable, extract slice that computes this value, run it, and plug in proper value into original execution

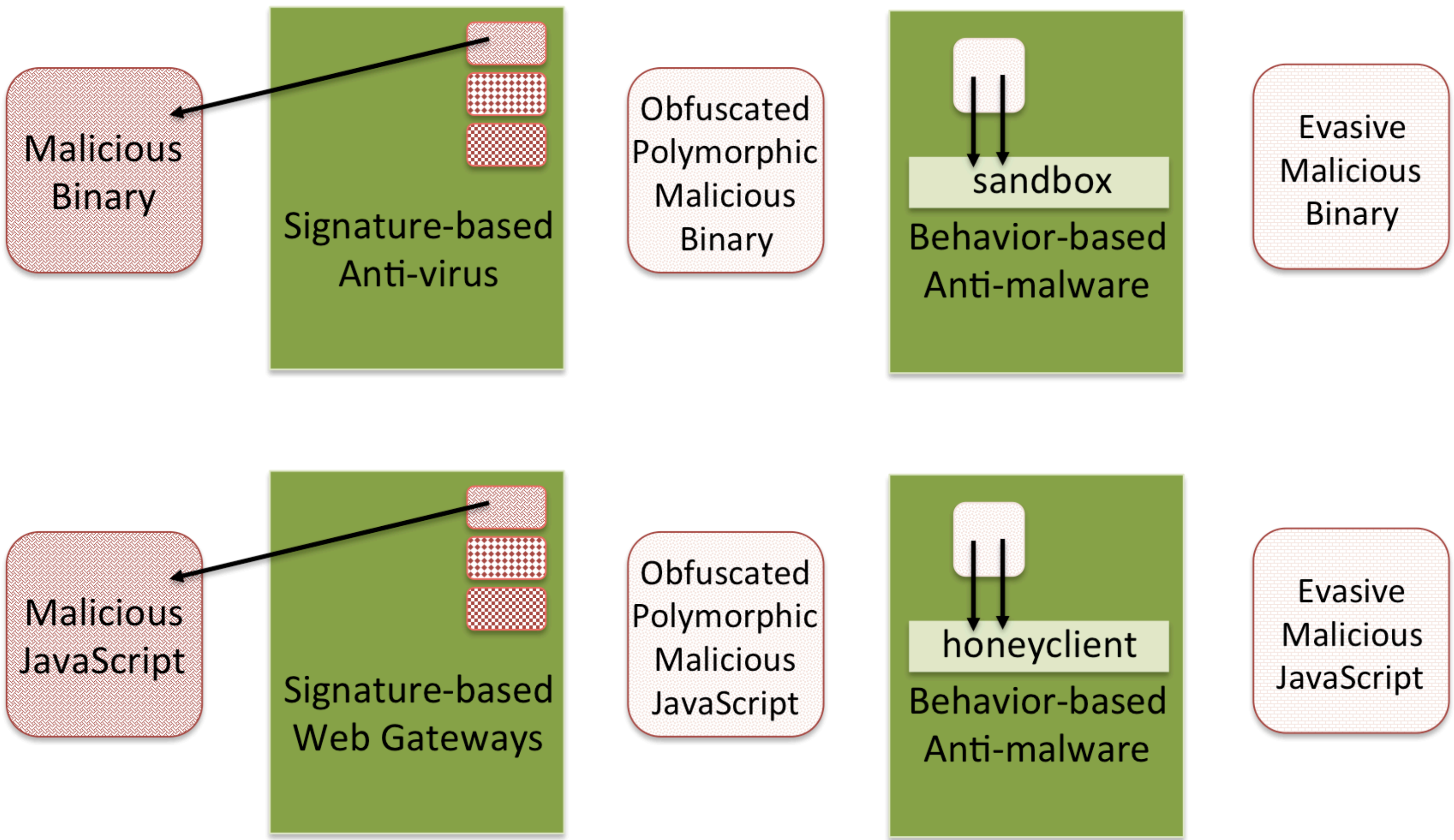
Experimental Results

Description	# samples	%	# AV families
base run	29,102	–	1329
stalling	9,826	33.8%	620
loop found	6,237	21.4%	425

- 1,525 / 6,237 stalling samples reveal additional behavior
- At least 543 had obvious signs of malicious (deliberate) stalling

Description	Passive			Active		
	# samples	%	# AV families	# samples	%	# AV families
Runs total	3,770	–	319	2,467	–	231
Added behavior (any activity)	1,003	26.6%	119	549	22.3%	105
- Added file activity	949	25.2%	113	359	14.6%	79
- Added network activity	444	11.8%	52	108	4.4%	31
- Added GUI activity	24	0.6%	15	260	10.5%	51
- Added process activity	499	13.2%	55	90	3.6%	41
- Added registry activity	561	14.9%	82	184	7.5%	52
- Exception cases	21	0.6%	13	273	11.1%	48
Ignored (possibly random) activity	1,447	38.4%	128	276	11.2%	72
- Exception cases	0	0.0%	0	82	3.3%	27
No new behavior	1,320	35.0%	225	1,642	66.6%	174
- Exception cases	0	0.0%	0	277	11.2%	63

Evasion in a Broader Context



Conclusions

- Visibility and fidelity are two critical factors when building successful dynamic analysis systems
  - full system emulation is a great point in the design spectrum
- Automated analysis of malicious code faces number of challenges
  - evasion is one critical challenge
- We shouldn't simply give up; it is possible to address many evasion techniques in very general ways

THANK YOU!

For more information visit **www.lastline.com**
or contact us at **info@lastline.com.**