USENIX SECURITY '23

ON THE FEASIBILITY OF MALWARE UNPACKING VIA HARDWARE-ASSISTED LOOP PROFILING

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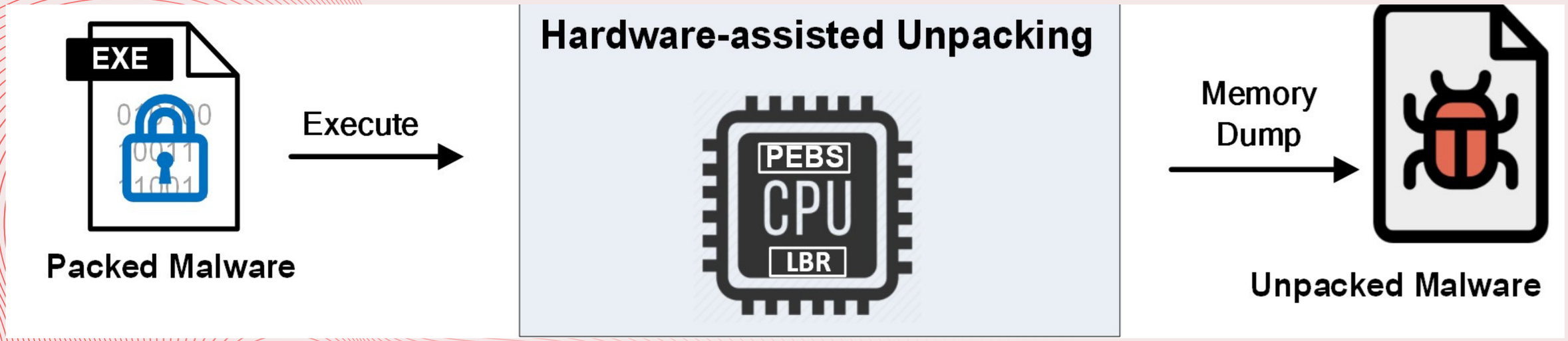
About This Presentation

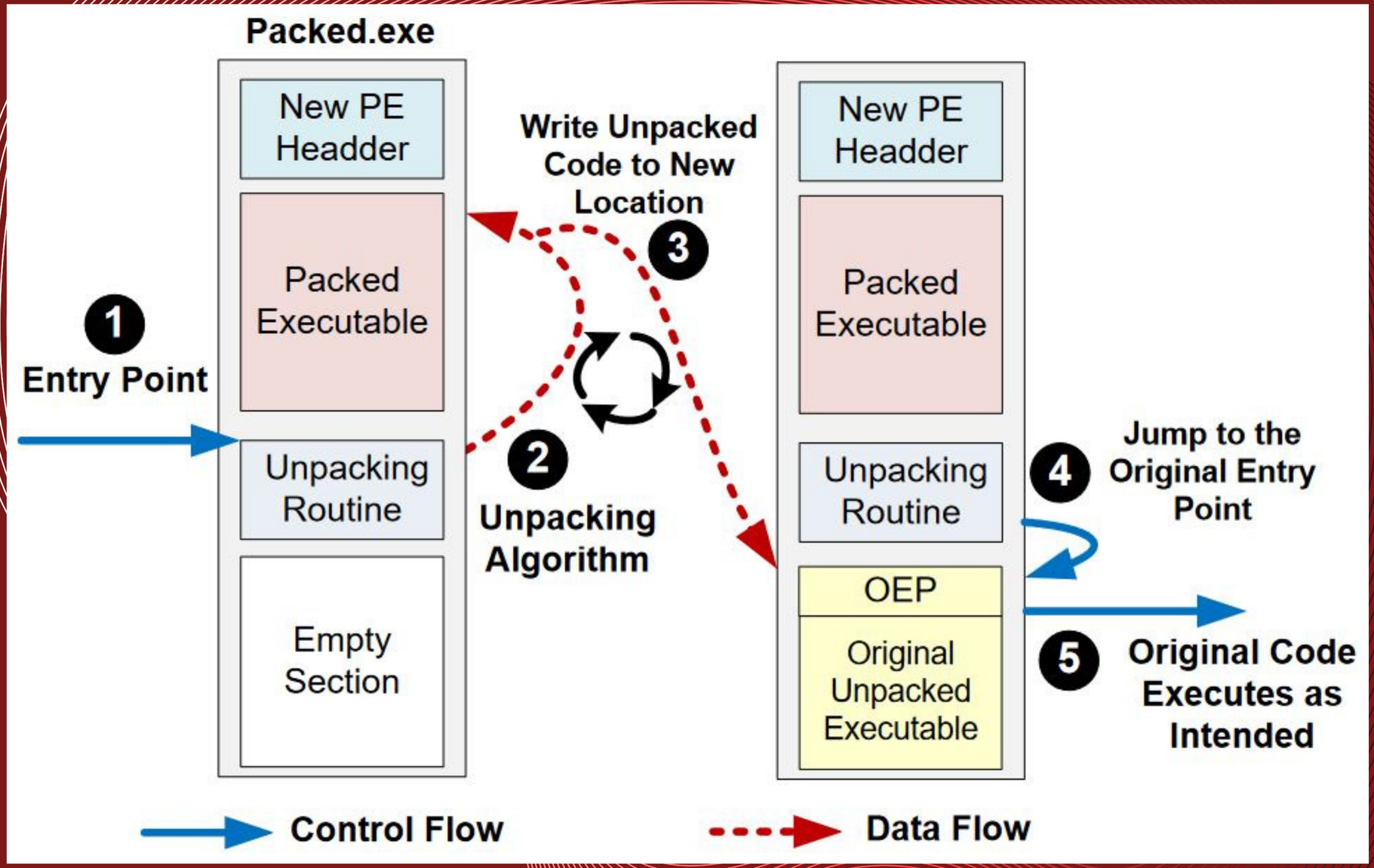
- Loop HPC
- Loop–Centric Profiling
- Hardware Performance Counters
- Unpacking Malware
- Resilience, Consistent, and Effective



A Bit of Background Knowledge....

Unpacking/Packing can use	**93–99% OF THE CPU**
Most malware is packed	~80% AND RISING
HPCs are non-deterministic in nature	ADDRESSED IN ONLY 10% OF HPC RESEARCH

The Unpacking Process



Hardware Performance Counters

Special registers found in the CPU

100s exist within a processor

37 Candidate events for our study

Non-Deterministic

The Semantic Gap critiscism

Non-Determinism Can Happen In HPCs By...

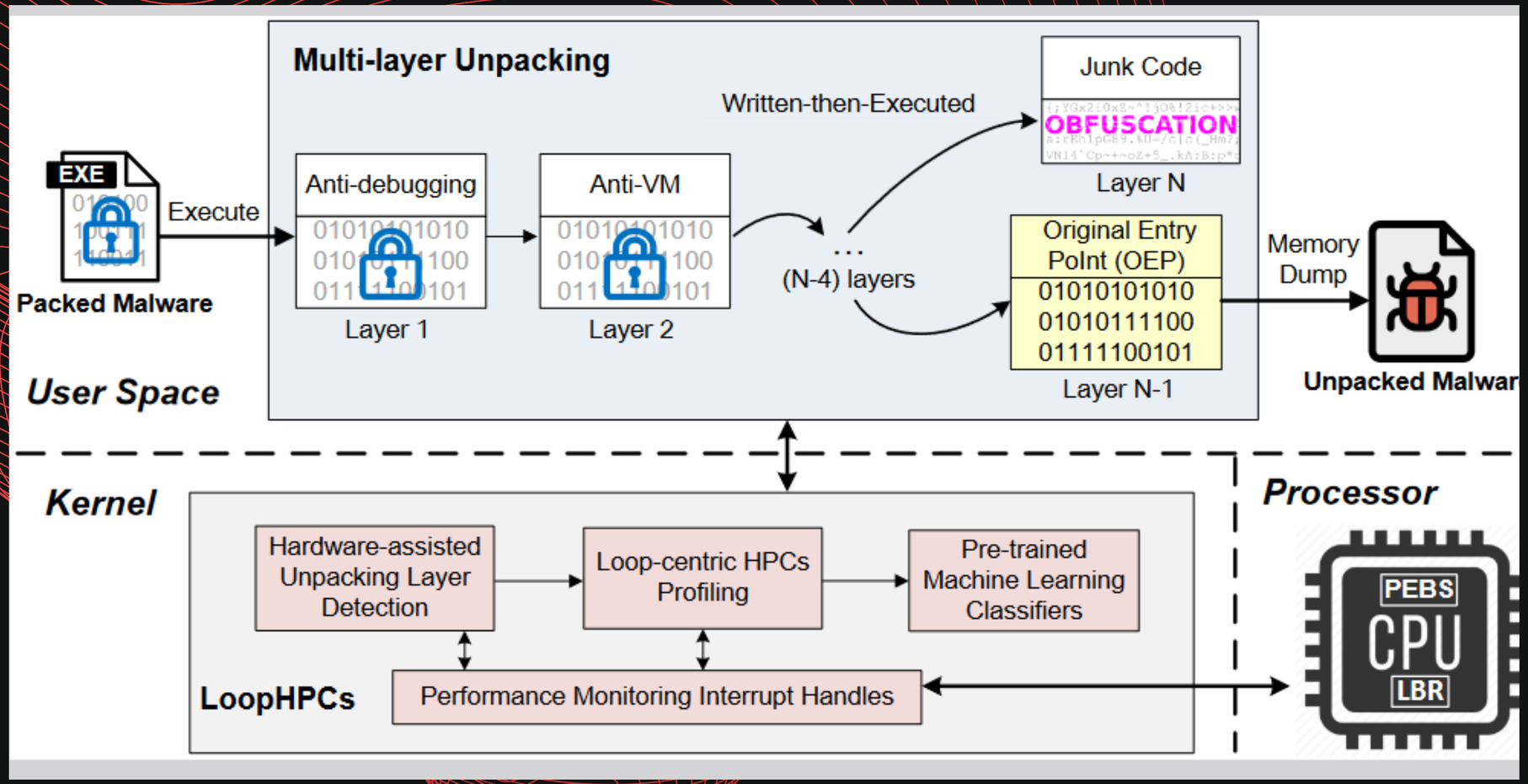
- Multiplexing
- Multi-Cores
- Interrupt Skid
- Multi Processes
- Page Faults

Interrupt Skid vs. Effect of LoopHPC

```
void multiply_matrices()
{
 1:  for (int i = 0; i < 10; i++) {
 2:     for (int j = 0; j < 10; j++) {
 3:        float sum = 0.0;
 4:        for (int k = 0; k < 10; k++) {
 5:           temp =matrix_a[i][k] * matrix_b[k][j];
 6:            sum = sum + temp;      }
 7:        matrix_r[i][j] = sum;  } } }
```

	Interrupt Skid Impact		Loop-centric HPCs Profiling	
	Expected Value	Observed Value	Expected Value	Observed Value
Line 4		764	2000	1999
Line 5	2000	152		
Line 6		1083		
Line 7		1		1

LoopHPC


Multi-layer Unpacking
Written-then-Executed
Junk Code
OBFUSCATION
Layer N
EXE
Execute
Anti-debugging
Anti-VM
Packed Malware
Layer 1
Layer 2
(N-4) layers
Original Entry PoInt (OEP)
01010101010
01010111100
01111100101
Layer N-1
Memory Dump
Unpacked Malwar
User Space
Kernel
Processor
Hardware-assisted Unpacking Layer Detection
Loop-centric HPCs Profiling
Pre-trained Machine Learning Classifiers
LoopHPCs
Performance Monitoring Interrupt Handles
PEBS
CPU
LBR

"Hot Loops"

UPX

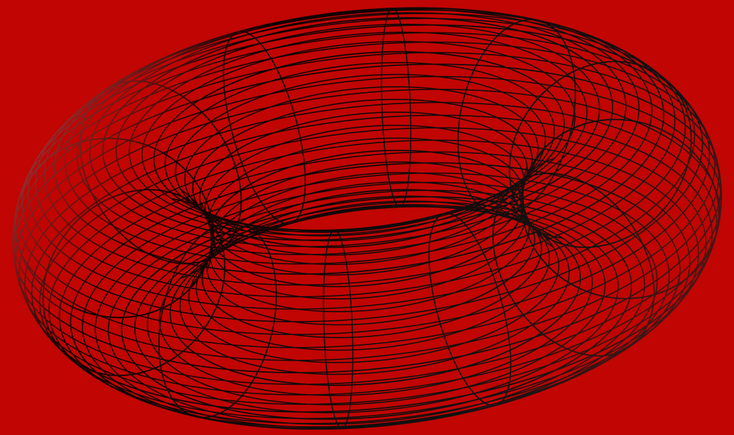
```
loop:
  dec   esi
  mov   eax, ebx
  mov   ecx, esi
  shr   eax, cl
  and   eax, 0x1
  ...
  test  esi, esi
  jne   loop
```

(a) Compression Packer

tElock

```
loop:
  ...
  rol   byte  ptr  [ebx+ecx], 0x5
  add   byte  ptr  [ebx+ecx], cl
  xor   byte  ptr  [ebx+ecx], 0x67
  inc   byte  ptr  [ebx+ecx]
  dec   ecx
  jnle  loop
```

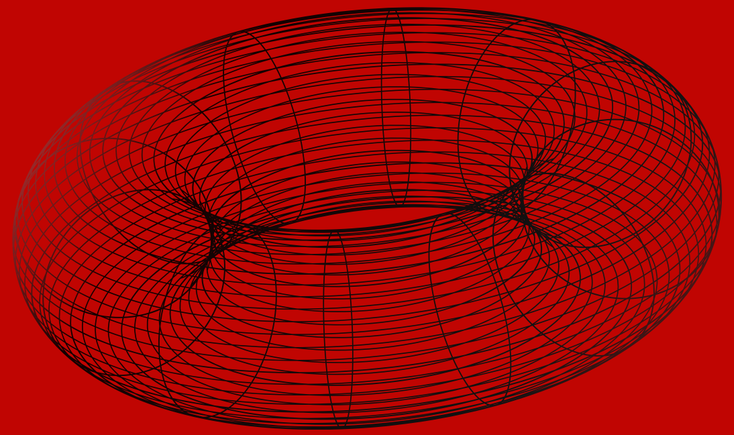
(b) Encryption Packer



hot loop examples in an unpacking routine

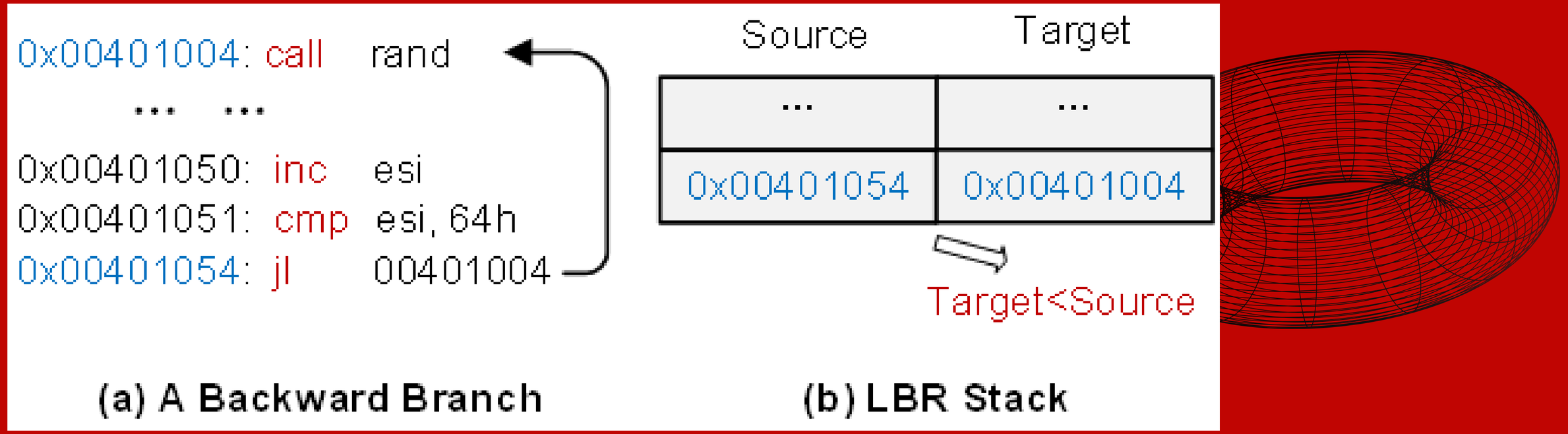
"Hot Loops"

Sample	# of Max Iterations	Inst (%)	Cycle (%)
UPX	3,359,627	99%	99%
Enigma	432,110	95%	98%
Yoda's Protector	920,837	97%	98%
Obsidium	698,330	90%	94%
SoftwarePassport	3,145,470	91%	93%
Pelock	3,451,282	97%	98%
Telock	945,821	99%	98%
Pespin	418,183	92%	97%
Armadillo	3,361,391	93%	97%
ACProtect	918,139	92%	99%



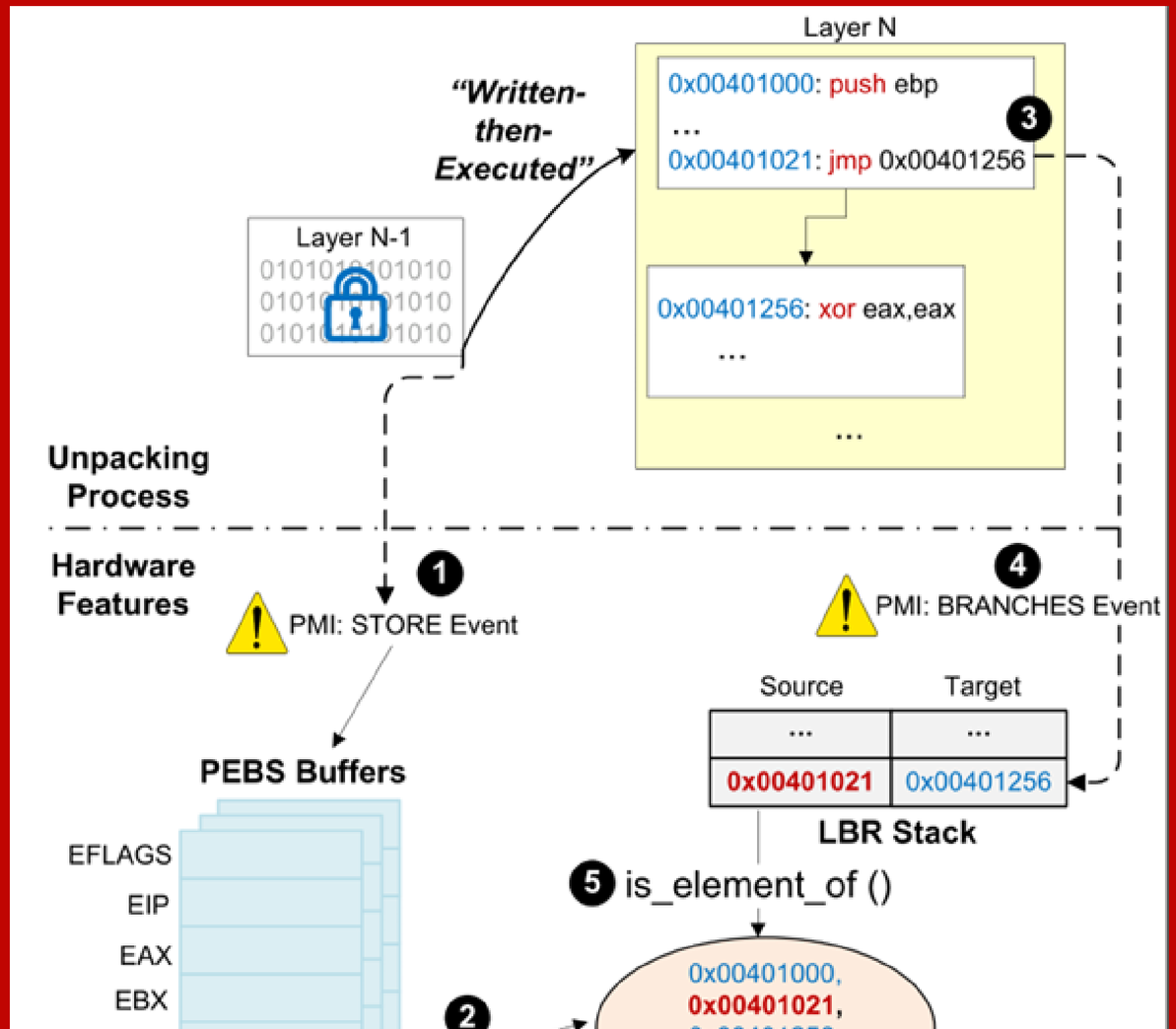
# of iterations per packer

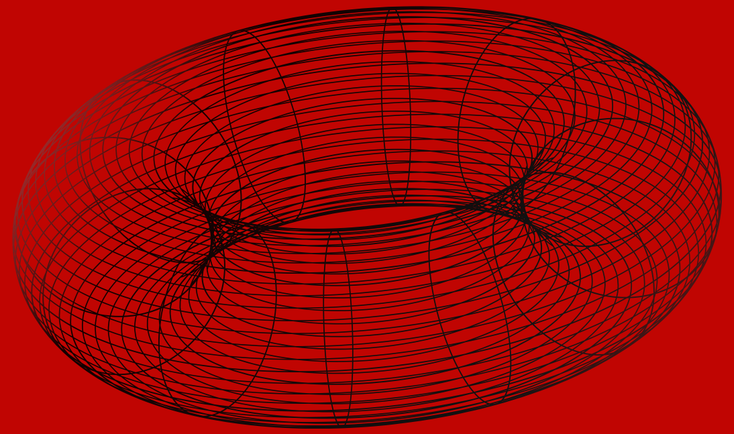
How To Detect A Loop



an example of loop detection using LBR

How To Detect Unpacking Layers



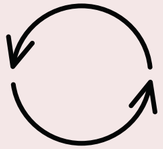


capture unpacking layers via PEBS and LBR

Determining Original Code

STEP # 1

Define the sum of loop centric HPCs values



STEP # 2

Use the loop layers classified as original code or not

STEP # 3

Train & Test 5 ML Classifiers

Evaluation

29 off the shelf packers

CAPE, Olly, Arancino

100% success rate in study

Large scale evalution on 74,938 wild malware

96.5% success rate on wild malware

Smaller samples do not reveal hotloops

Possible Attacks

DETECTION ATTACK

TIME BASED ATTACK

HIDING HOTLOOP

MIMICRY ATTACK

FAKE HOT LOOP

Have Questions? Connect with us..

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Thank you!