Identifying and Analyzing Pointer Misuses for Sophisticated Memory-corruption Exploit Diagnosis

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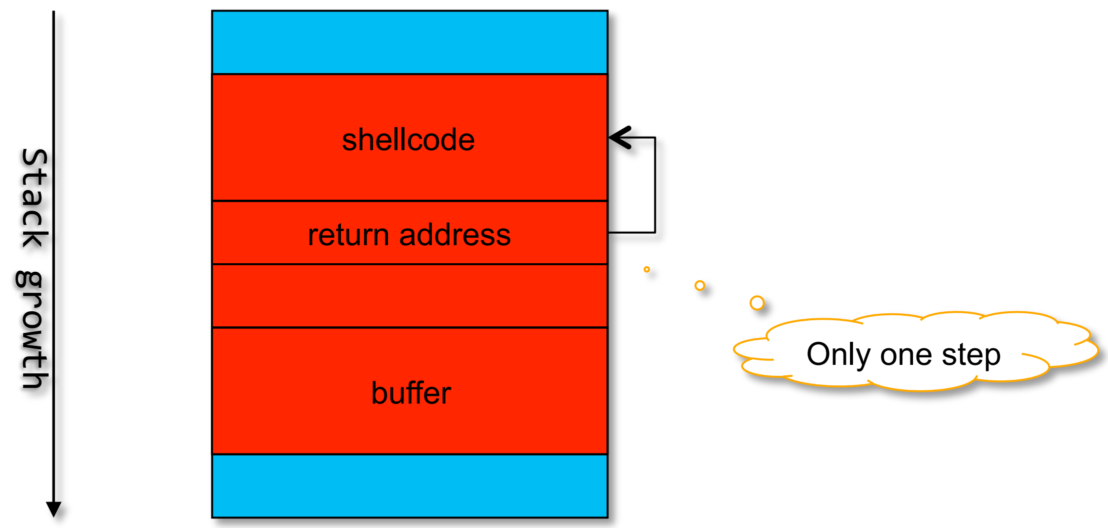
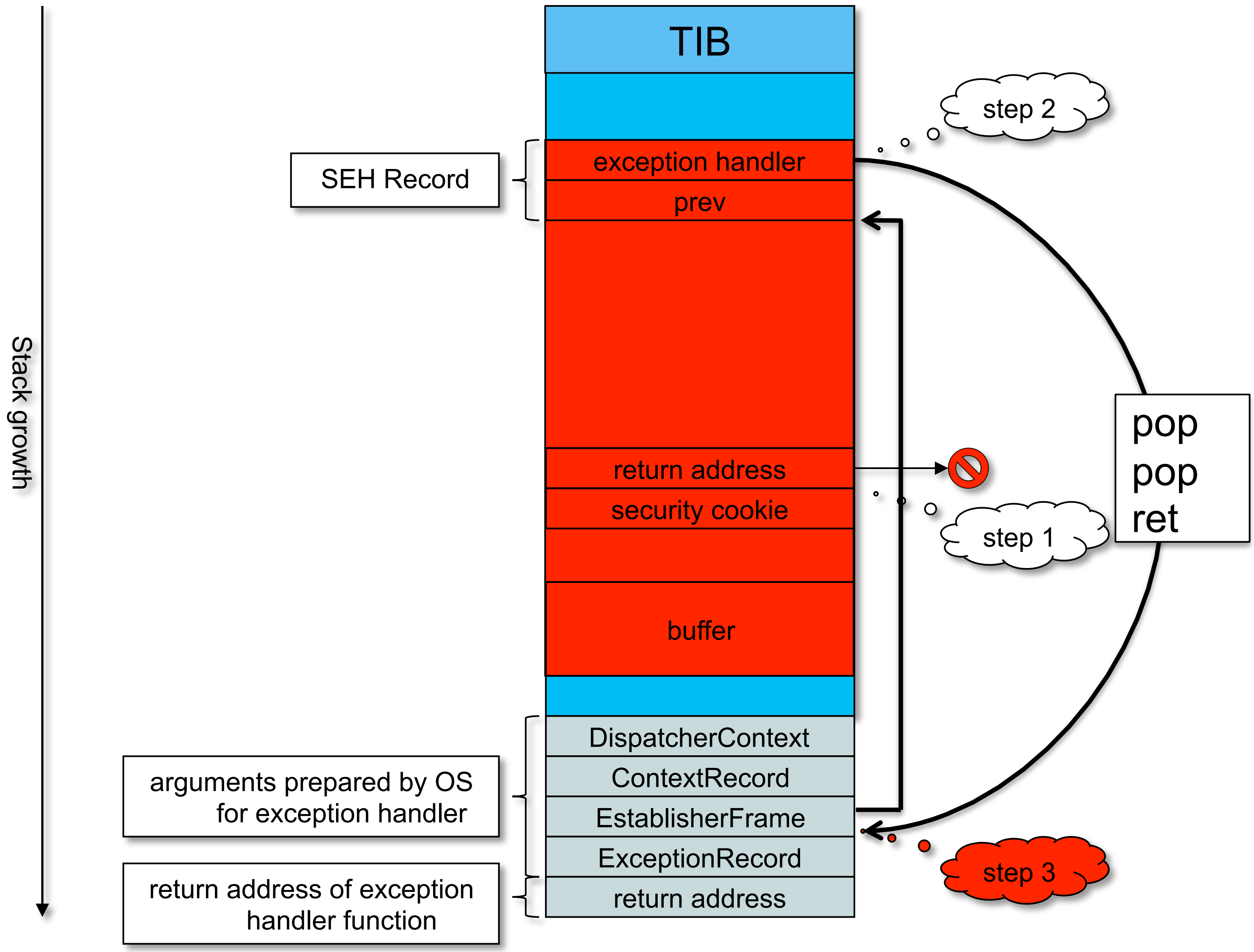
Simple Stack Buffer Overflow

- An attacker overwrites vulnerable function return address, which points to shellcode on stack.



- These single step attacks don't work anymore thanks to:
  - ASLR, DEP, NX, etc.

Exploiting SEH Mechanism



Insights

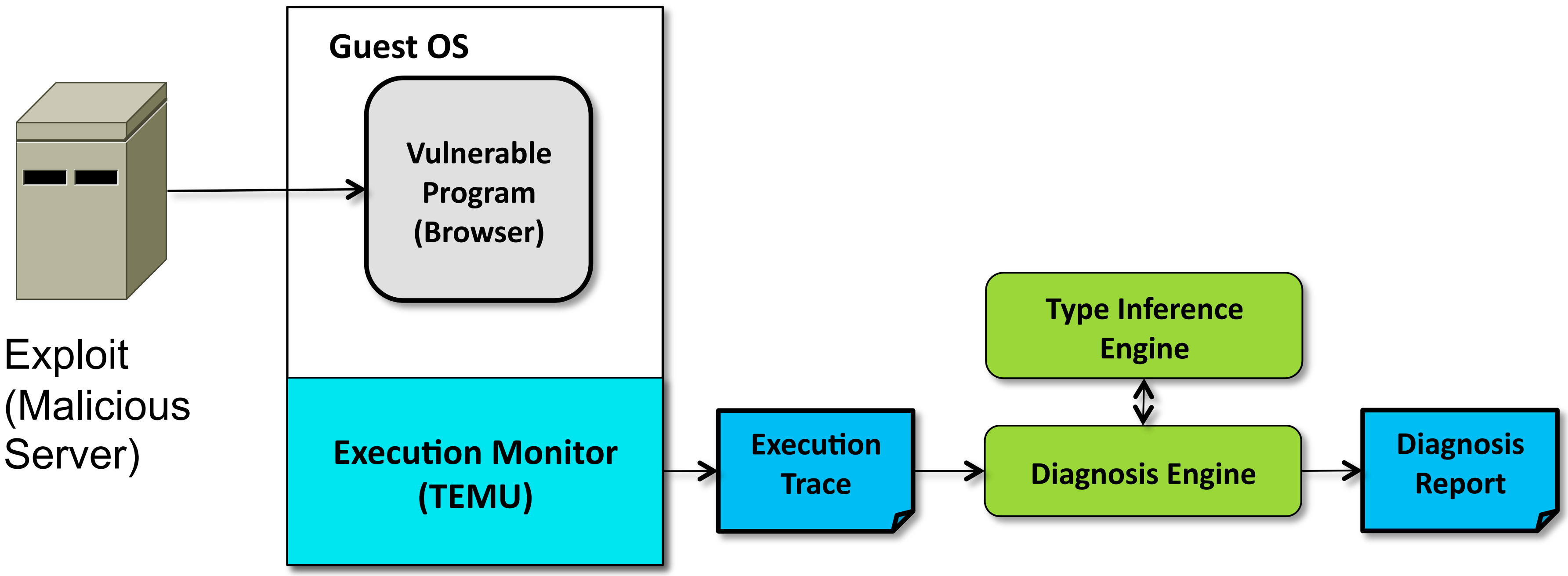
- Recent attacks employ **multiple steps**.
- **Pointer misuse** is very prominent in sophisticated attacks.
- Key steps constitute pointer misuses.

Our Goal:
Diagnosing pointer misuses in a multi-step attack.

Pointerscope – Attack Diagnosis Engine

- **Type System** tailored to diagnose pointer misuse.
- **Eager type inference** system to detect pointer misuses.
- Provide **big picture** of the misuse through *key steps* graph.

Overview

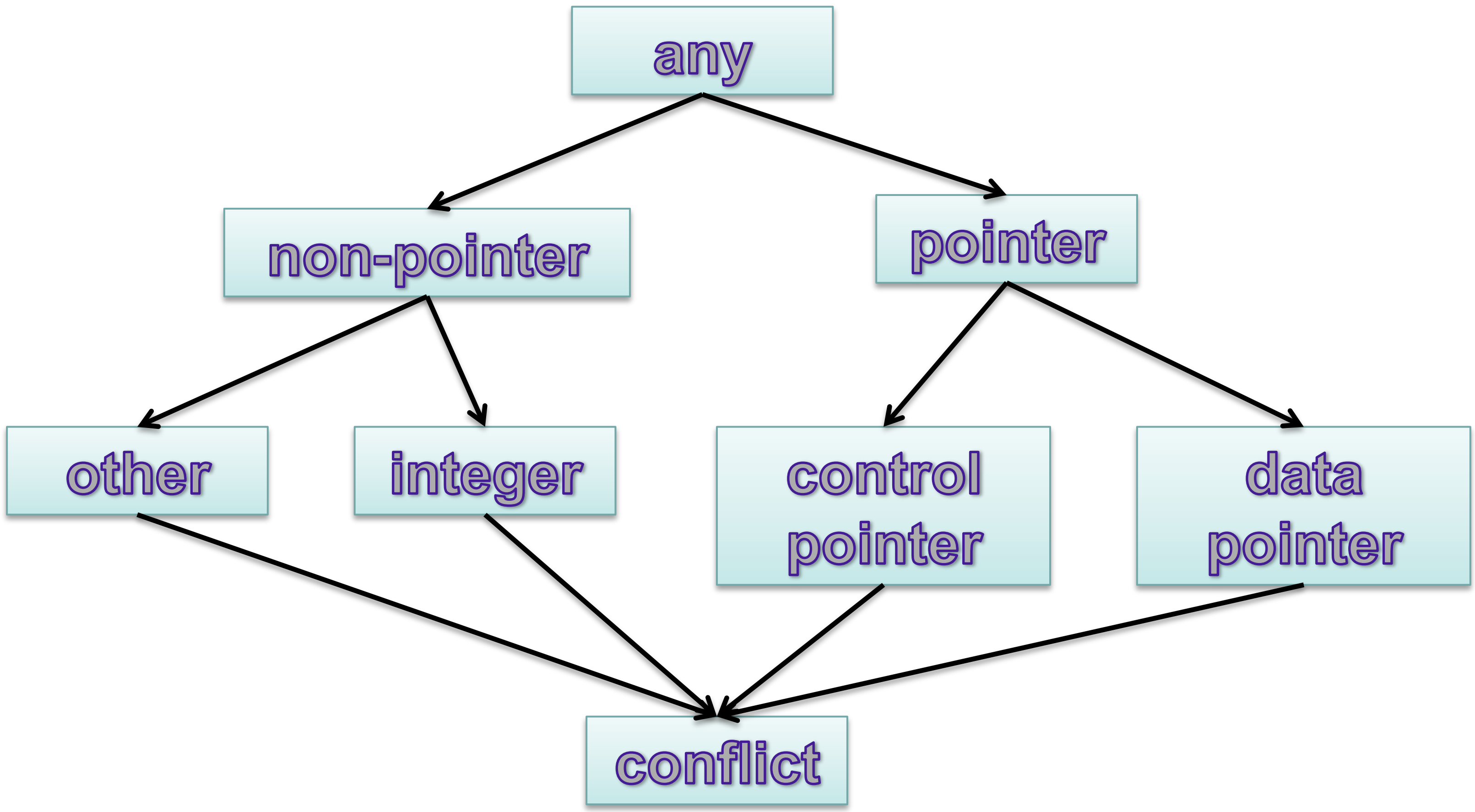


Exploit
(Malicious
Server)
Guest OS
Vulnerable
Program
(Browser)
Execution Monitor
(TEMU)
Execution
Trace
Type Inference
Engine
Diagnosis Engine
Diagnosis
Report

Variable And Variable Type

- A variable is a memory location or a register.
- Simple primitive variable types:
  - Integer
  - Control Pointer (or code pointer)
  - Data Pointer
  - Other. (The rest of the types)

Type Lattice



Eager Dynamic Type Inference

- Type Propagation:
  - mov %eax, %ebx
    - Inference: eax and ebx have same type
- Type Constraints:
  - call %eax
    - Inference: %eax contains Control Pointer

Example – Type Inference

{eax, ebx} : **ANY**	mov %eax, %ebx
{eax, ebx, ecx} : **ANY**	mov %ebx, %ecx
ecx is an INT {eax, ebx, ecx}: **Integer**	imul $0x05, %ecx, %ecx
{eax, ebx, ecx, edx} : **Integer**	mov %ecx, %edx
Used as a pointer. **Conflict**	call *%ecx

Harder than it seems!

Challenges

- X86 supports base-index with displacement – Problem: Compilers don't follow convention.

```
movl $0x8(%eax,%edx), %ecx
```

address = displacement + base register + index register

Solution: Register closest to result is the base.

Challenges… contd.

- Individual instructions not always lead to accurate type inferences.
  - Eg:

```
not %ebp
or  $0x3,%ebp
not %ebp
```

⇔

```
and $0xfffffffc,%ebp
```

  - Solution: recognizing the common patterns and treat them as special cases

Challenges… contd.

- LEA designed to load effective address, but often used in arithmetic.

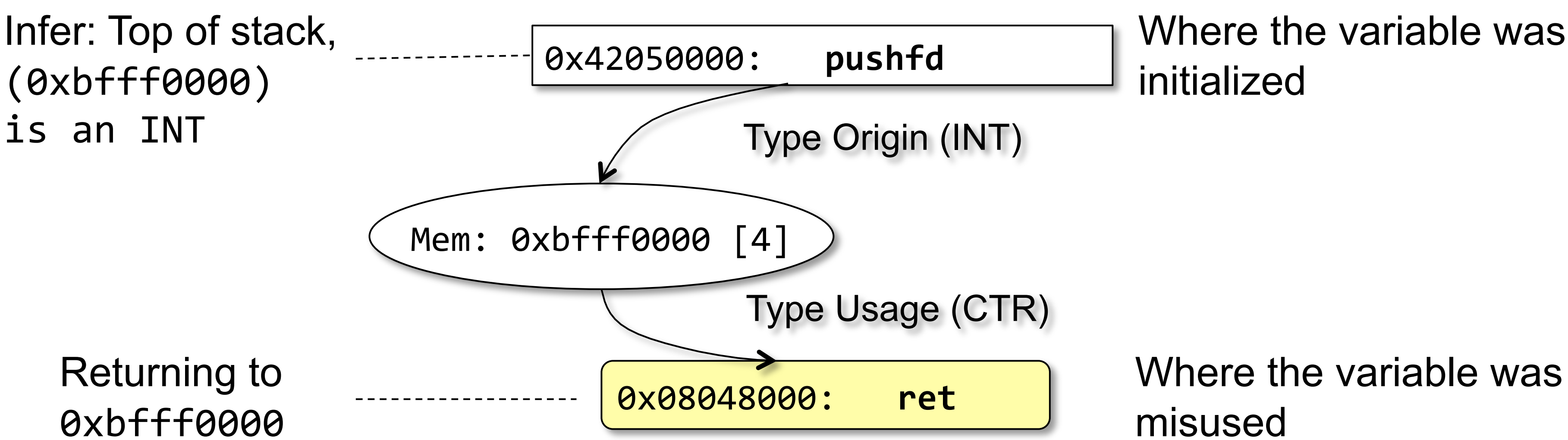
lea $0x8(%eax,%edx,4), %ecx	⇨	%ecx＝%eax＋%edx×4＋$0x8

Solution: Treat lea as an arithmetic operation.

Challenges…

- More challenges discussed in the paper!

Key Steps Graph – Example



Evaluation

- Implementation
  - Execution monitor on TEMU.
  - 3.6K lines of C code.
- Experimental setup
  - Evaluated against real world exploits from Metasploit framework.

Summary of Effectiveness

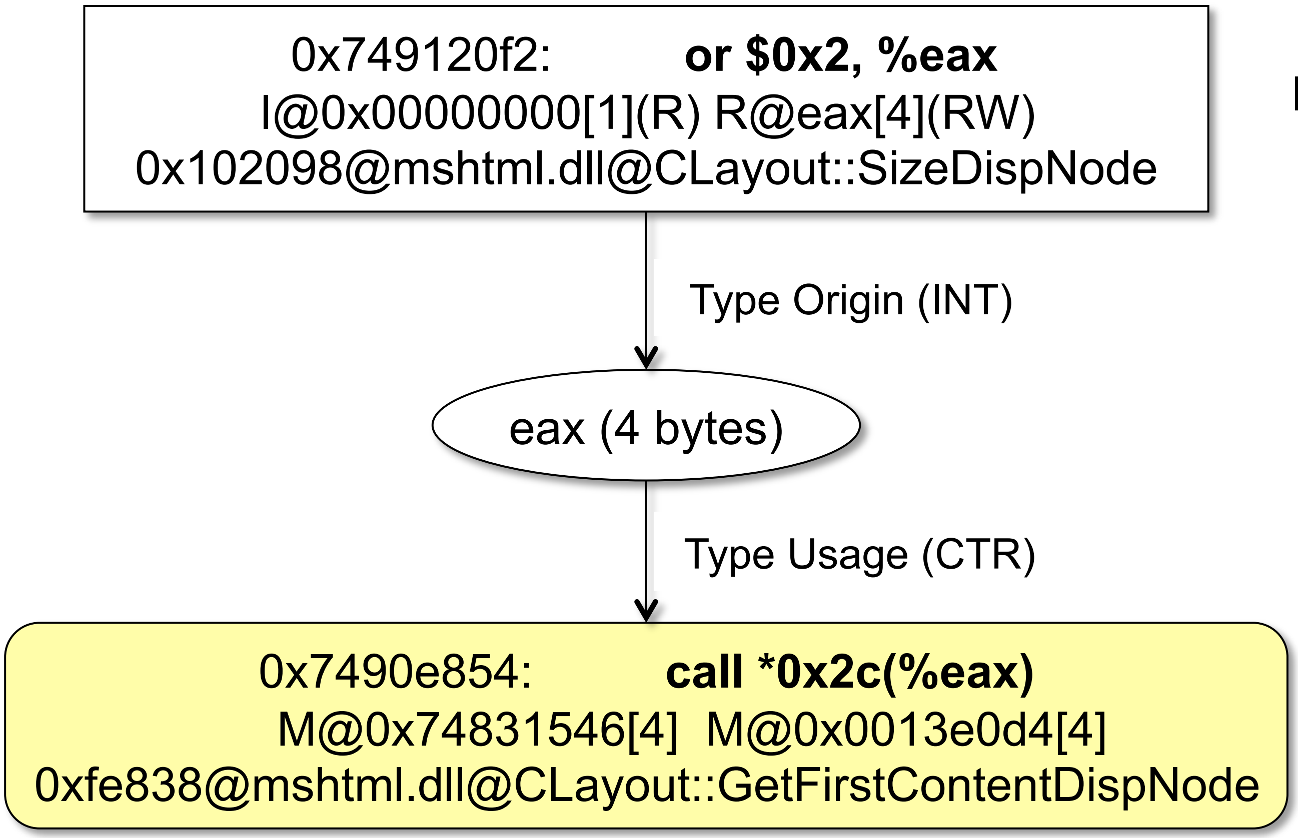
CVE	Attack Technique	Runtime*	Pointer Misuses	Trace Size	Slice Size
CVE-2010-0249	Uninitialized memory; heap spray	18m23s, 8m30s	11	307,987,560	48,404,242
CVE-2009-3672	Incorrect variable initialization; heap-spray	3m10s, 31s	2	22,759,299	955,325
CVE-2009-0075	Uninitialized memory; heap spray	25m, 21m16s	6	411,323,083	44,792,770
CVE-2006-0295	Heap overflow; heap spray	3m5s, 1s	3	808,392	34,883
CVE-2006-1016	Stack overflow; SEH exploit	4m59s, 1m33s	3	64,355,691	1,334,253
CVE-2006-4777	Integer overflow; heap spray	1m45s, 40s	3	2,632,241	1,669,751
CVE-2006-1359	Incorrect variable initialization; heap spray	11m58s, 13s	2	8,336,193	29,520
CVE-2010-3333	Stack overflow vulnerability; SEH exploit	18m53s, 7m24s	1	236,331,307	814,305
CVE-2010-3962	Incorrect variable initialization; heap spray	10m36, 15s	2	9,281,019	78,704

*Time taken to generate trace, time taken to generate key steps

Case Study: CVE-2009-3672

- This is a real world exploit for vulnerable version of IE Browser
- This attack is caused by a vulnerability in the class `CDispNode`'s member function `SetExpandedClipRect`

The First Type Conflict

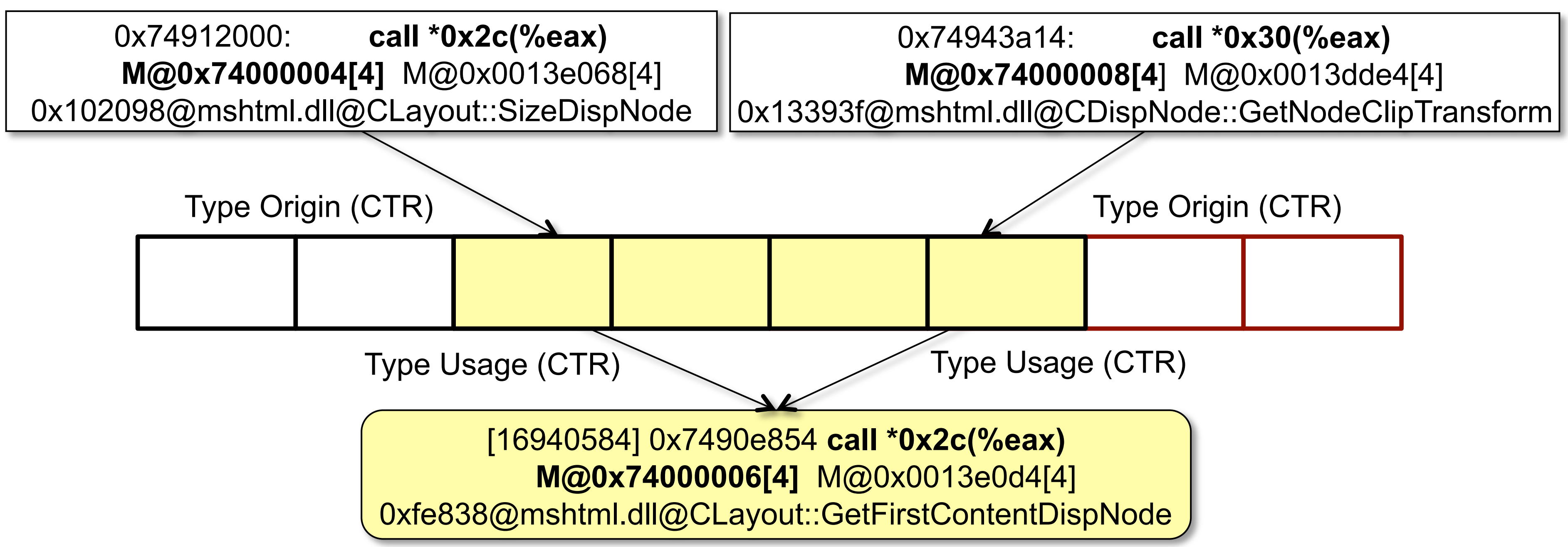


Infer: Integer

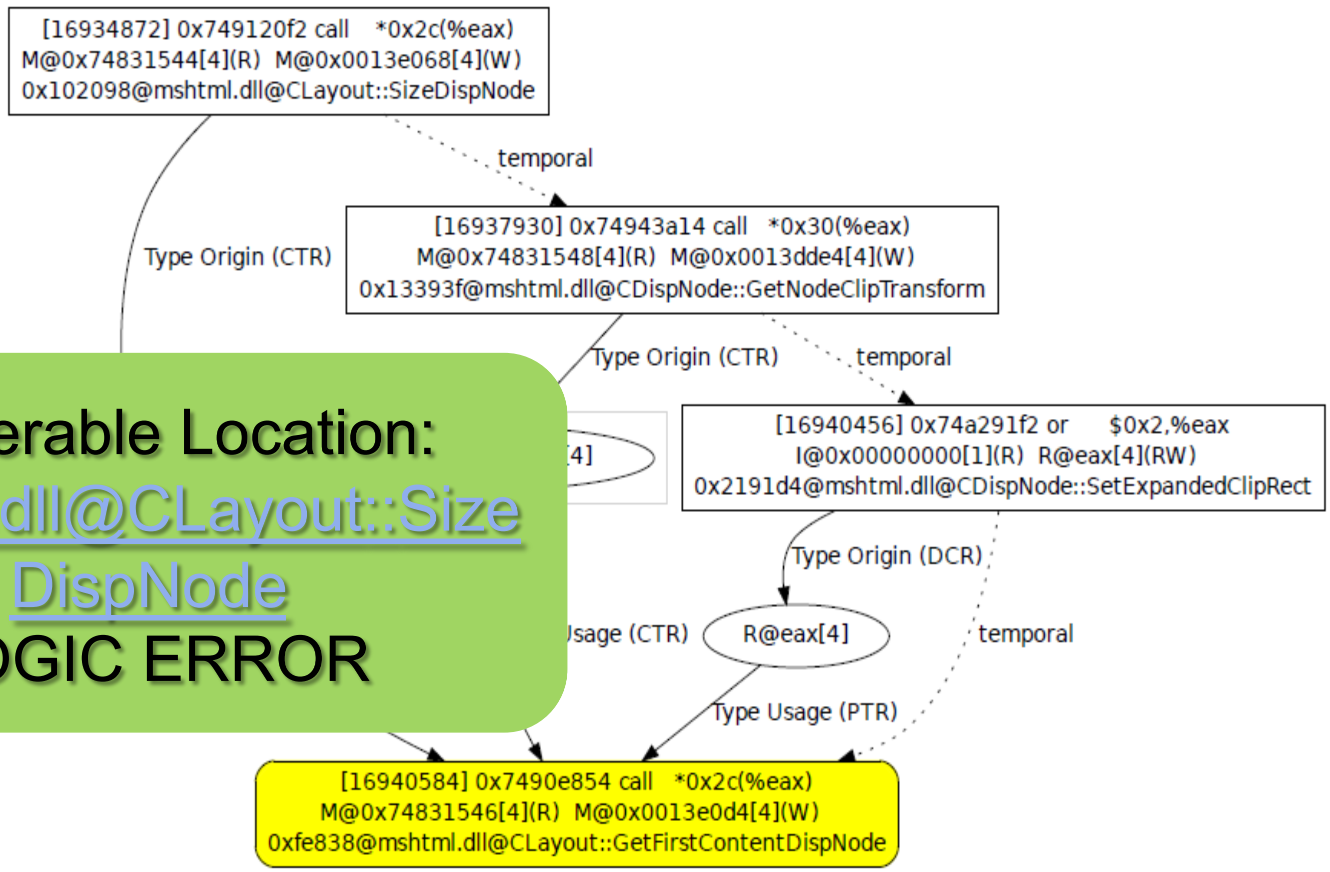
or $0x2, %eax

Used as Control Ptr Violation

The Second Type Conflict



Final Result



Vulnerable Location:
mshtml.dll@CLayout::SizeDispNode
LOGIC ERROR

Reducing False Positives

- What makes it hard?
  - Compiler optimizations
  - Code obfuscation – even by proprietary code.

- Note: Our goal is NOT to eliminate False Positives.

Related Work

- Attack Diagnosis Techniques
  - BackTracker [King, et. al, SOSP'03], Dynamic Taint Analysis [Newsome, et. al, NDSS'05]
- Type and Data Structure recovery from binary
  - Rewards [Zin, et.al, NDSS'10], Howard [Slowinska, NDSS'11], Tie [Lee, et.al, NDSS'11]
- Defense and evasion techniques
  - CFI [Abadi, et.al, CCS'05], DFI [Castro, et.al, OSDI'06], WIT [Akritidis, et.al, IEEE S&P'08]

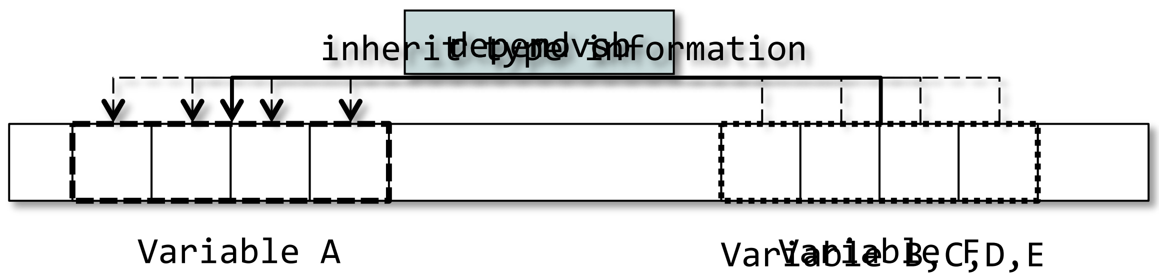
Conclusion

- We define a **pointer centric type system** to track pointers.
- We design a **type inference system** to detect pointer misuses.
- We **generate the key steps graph** to identify key steps.
- We evaluate our work by testing our system on real-world exploits from metasploit.

Questions?

Challenges… contd.

- Handling memory copy operations
  - Memory copy operations may break the integrity of variables



Solution: Aggregation.

Case Study: SEH Attack