Accurate, Low Cost and Instrumentation-Free Security Audit Logging for Windows

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ILLINOIS

Motivation

- Forward/Backward Tracing from Detected Anomalies
- Abnormal Causal Dependencies between Applications
- Track Information Flow

Windows ETW

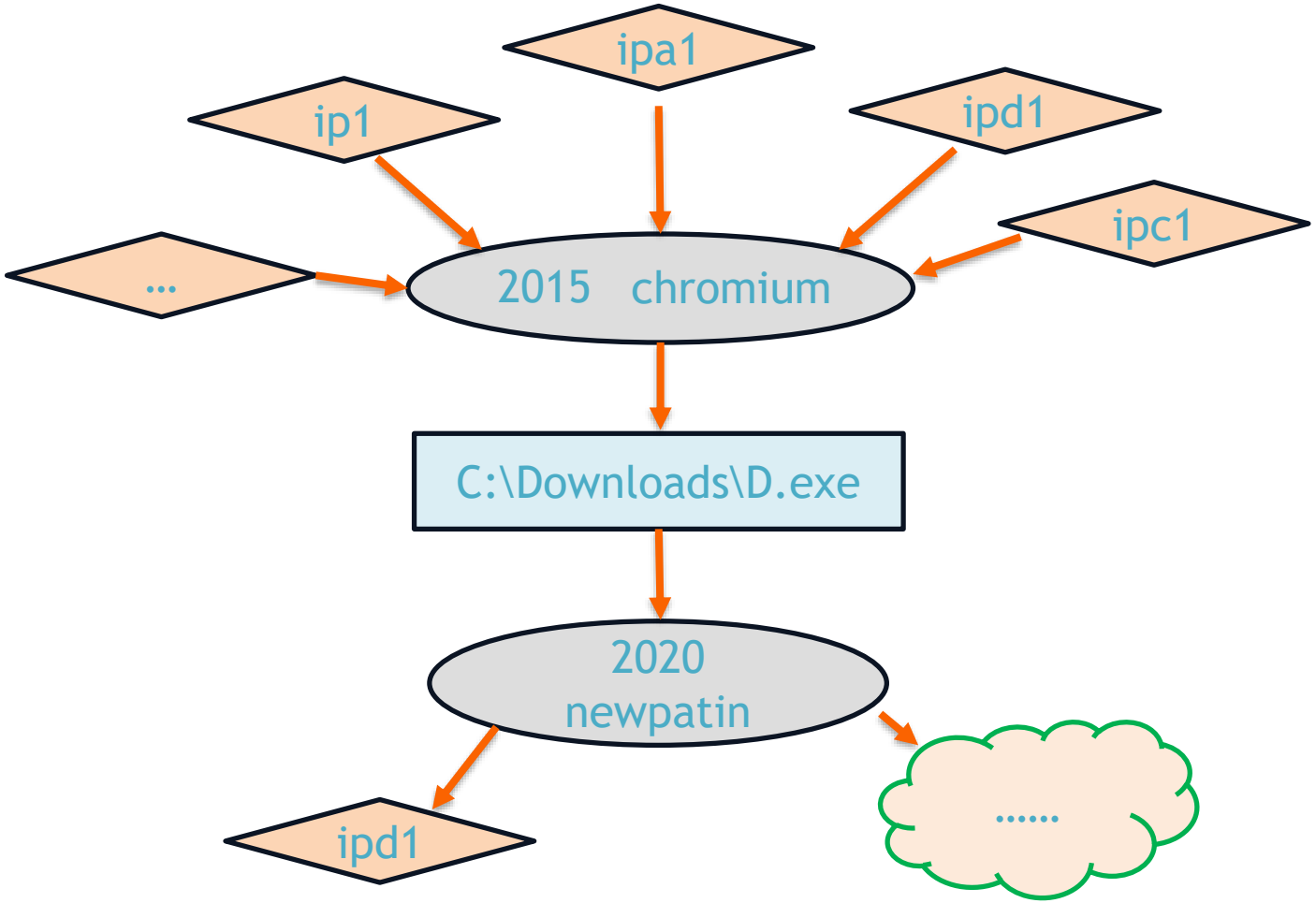
Event(TimeStamp,Processor)

- Event Type
  - FileRead etc.
- Event specific
  - FileObject, IOFlags etc.
- Process ID, Thread ID etc.
- Stack

Stack

1. TurboDispatchJumpAddressEnd+0x690@wow64cpu.dll
2. …
3. winnt_get_connection+0x4b@libhttpd.dll
4. worker_main+0x27@libhttpd.dll
5. …
6. RtlInitializeExceptionChain+0x36@ntdll.dll

Provenance Graphs



Execution Partitioning

- Parse Log File into Execution Units (Event Loops)
- Remove Intra-Unit Dependencies
- Output Events causally related to Input Events in same Unit
- Reduces Complexity and Overhead of Provenance Graphs

Methodology

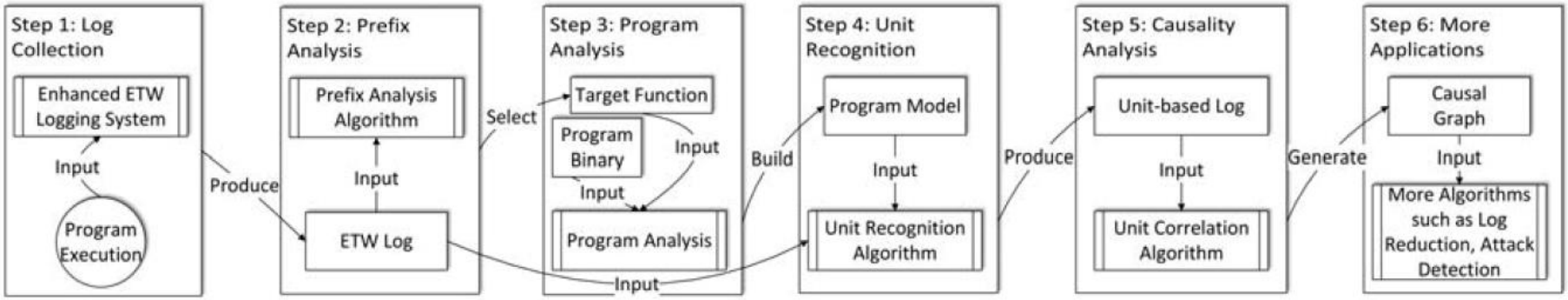


Figure 2: Approach Overview.

Log Collection

- ETW Collects Execution Log for Commonly used Applications
- Extend ETW to record Memory Operations (Clipboard Buffer)

```
Timestamp:      0x20462fbd1fb                    (1)
EventType:      WinsockTcpIpReceive
-Event Detailes-------------------------------------
TransferSize:   8000                             (2)
-Process--------------------------------------------
Process:        3112 httpd.exe                   (3)
Thread:         3948 msvcrt.dll!endthreadex+0x29
-Stack Trace----------------------------------------
  ...(Library and kernel functions)              (4)
  libapr-1.dll!apr_socket_recv+0x42
  ...(Application functions)
  libhttpd.dll!worker_main+0x9c
  ...(Kernel functions)
```

Prefix Analysis

- Identify *Target Function*, which contains Event Processing Loop
- Execution: Prologue, Event Handling Phase, Epilogue
- Prologue and Epilogue same between Executions

Prefix Analysis

```
1.  void main() {
2.      init();
3.      while(True) {
4.          read_cmd();
5.          if (cmd == FileDownload) {
6.              if(file ready) {
7.                  fd = open_file(file_name);
8.                  if(open fails)
9.                      errmsg_continue(MSG2);
10.                 buf = memory_allocation(size);
11.                 while(transfer not done) {
12.                     read_file(fd, buf);
13.                 write-data(socket, buf);
14.                 }
15.                 memory_free(buf);
16.                 close_file(fd);
17.             } else
18.                 errmsg_continuemsg(socket, MSG3);
19.         } else if(cmd ==...) { ... }
20.     }// end while
21.     server_exit();
22. }
```

```
SocketRead:   windows_runtime->main->read_cmd->...
FileOpen:     windows_runtime->main->open_file->...
FileRead:     windows_runtime->main->read_file->...
SocketWrite:  windows_runtime->main->write_data->...
FileClose:    windows_runtime->main->close_file->...
```

Model Construction

- Identify Event Handling Loop from PCs in Event Handling Logs
- Represent Possible Sequences of Function Calls in Loop by Regular Expression
- Recursively Disassembles Callee Functions until reaches sufficiently Informative Model
- Use ETW Logs if Binary too Complex

Model Construction

```
1.  void main() {
2.      init();
3.      while(True) {
4.  F1:     read_cmd();
5.          if (cmd == FileDownload) {
6.              if(file ready) {
7.  F2:             fd = open_file(file_name);
8.                  if(open fails)
9.  F3:                 errmsg_continue(MSG2);
10.                 buf = memory_allocation(size);
11.                 while(transfer not done) {
12. F4:                 read_file(fd, buf);
13. F5:                 write_data(socket, buf);
14.                 }
15.                 memory_free(buf);
16. F6:             close_file(fd);
17.             } else
18. F7:             errmsg_continuemsg(socket, MSG3);
19.         } else if(cmd ==...) { ... }
20.     }// end while
21.     server_exit();
22. }
```

Model(3-20)$

=F1•Model(5-20)$

=F1•(Model(6-18) | …)$

=F1•((Model(7-16) | F7)| …)$

=F1•((F2•Model(8-16) | F7)| …)$

=F1•((F2•([F3] •Model(11-16))|F7)|…)$

=F1•((F2•([F3] •(Model(11-14)•F6))|F7)|…)$

=F1•((F2•([F3] •((F4•F5)*•F6))|F7)|…)$

Log Partitioning

- Separate Logs by Process ID
- When end of sequence is reached, begin parsing another unit
- Can remove library functions which never lead to syscalls
- Always parse longest possible subsequence of events as unit

Dependency Analysis

- Construct Causality Graph between Units and System Objects
- Output Events are only dependent on Input Events of the same Unit
- Prune Dependency-Free Objects
- Prune Repeated Reads/Writes

Evaluation

- ETW Log overhead of ~10-18% for high workload
- Around ~0.4-2.5% overhead for normal workload

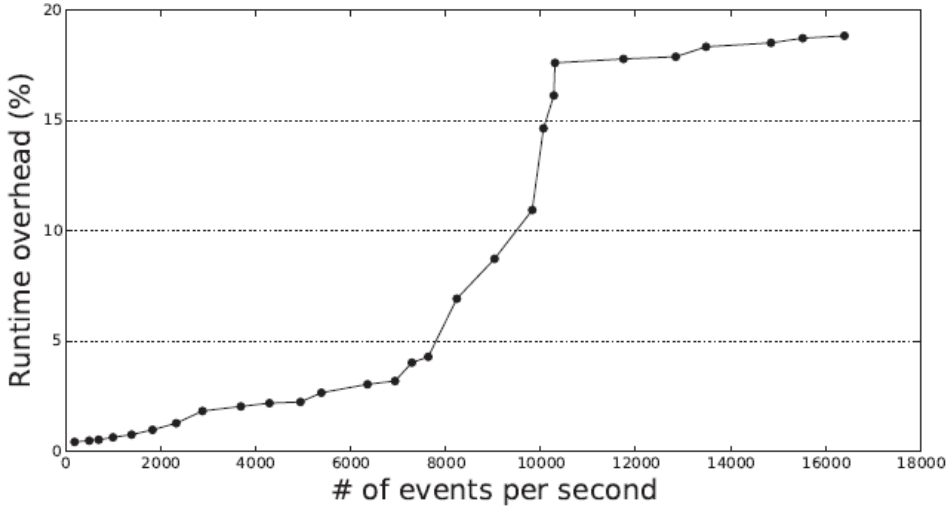


Figure 8: Event Tracing Overhead.

Evaluation

Application	# of Events / Ratio				# of Units		# of Events per unit	
	Original	Dependency-free	Redundant	Final	Original	Final	Original	Final
TextTransfer	316	310 / 98.10%	0 / 0.00%	6 / 1.90%	2	2	158.00	3
Chromium	102,206	61,193 / 59.87%	36,834 / 36.04%	4,179 / 4.09%	255	248	400.81	16.85
DrawTool	15,438	13,382 / 86.68%	1,982 / 12.84%	74 / 0.48%	11	11	1,403.45	6.73
NetFTP	10,621	8,909 / 83.88%	1,132 / 10.66%	580 / 5.46%	8	8	1,327.63	72.5
AdvancedFTP	1,615	1,161 / 71.89%	411 / 25.45%	43 / 2.66%	3	3	538.33	14.3
Apache httpd	37,171	27,035 / 72.73%	8,084 / 21.75%	2,052 / 5.52%	46	46	808.07	44.61
IE	29,969	12,983 / 43.32%	14,711 / 49.09%	2,275 / 7.59%	10	10	2,996.90	227.5
Paint	7,085	6,772 / 95.58%	235 / 3.32%	78 / 1.10%	28	28	253.04	2.78
Notepad	11,704	8,506 / 72.68%	3,168 / 27.07%	30 / 0.26%	6	6	1,950.67	5.00
Notepad++	5,516	4,976 / 90.21%	404 / 7.32%	136 / 2.47%	9	9	612.89	15.11
SimpleHTTP	779	559 / 71.76%	180 / 23.11%	40 / 5.13%	13	13	59.92	3.08
Sublime Text	30,372	24,419 / 80.40%	5,637 / 18.56%	316 / 1.04%	11	11	2,761.09	28.73

Table 3: Effectiveness of Log Reduction.

Evaluation

Scenario	# of events			# of nodes			# of edges			Correctness	
	Before	After	Ratio	Original	Unit	GC	Original	Unit	GC	Backward	Forward
Mis-configured server	986,563	85,042	8.62%	173	10	10	204	10	10	-	Match
Phishing attack	523,385	44,593	8.52%	573	21	21	693	32	32	Match	Match
Information leak	1,947,485	260,857	13.39%	10,222	11	11	20,532	10	10	Match	Match
Spyware	1,284,748	102,523	7.98%	9,282	9	9	11,244	8	8	Match	Match

Table 4: Attack scenarios summary with original log and reduced log.

Recap

- Especially useful for Network Services
- 12X – 95X Space Reduction with Garbage Collection

Discussion

- Assumptions (Limitations) of the Paper
- Other Program Analysis Techniques to improve Model
- Other Applications of this Methodology

Comments

- Causal Relationships between Units (e.g. Browsers)
  - Attackers Distribute Effects across Units
- Attackers Use Temporary Files (Dependency-Free Objects)
- Evaluated Performance, but not Effectiveness in Analysis
- Extensive use of Heuristics