Memento

Learning Secrets from Process Footprints[3]

Suman Jana Vitaly Shmatikov

CAP6135 Malware & Software Vulnerability Analysis

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under
Prof. Cliff Zou[1]

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Dept. of EECS

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About Paper

- Authors - Suman Jana , Vitaly Shmatikov. UT - Austin.
- IEEE Symposium on Security and Privacy 2012.
- Best Student Paper Award.
- Partly funded by NSF grants.
- Demo - side channel attack.

Outline

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Introduction

- Memento[1] -

Introduction
Terminology

- Side Channel Attack.
  - [P] Timing(CPU, mem), Power Analysis(SPA,DPA), Acoustic Cryptanalysis , Differential Fault, Data Remanence.[2]
- Secrets - Webpage Identity, Finer grained information.
- Process Footprint - DRS/WS/RSS.
- [P]

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PS C:\Users\Sid> get-process chrome

Handles  NPM(K)    PM(K)      WS(K) VM(M)   CPU(s)     Id ProcessName
-------  ------    -----      ----- -----   ------     -- -----------
    167      33    81844      66392   270     4.98    380 chrome
    162      34    62176      49672   241     4.85   3536 chrome
    161      28    52988      40256   216     2.57   4040 chrome
   1610     101   130828     190828   489 2,684.47   6040 chrome
    163      34    57264      45744   230     4.63   6964 chrome
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Why Do It ?

- Symptom of larger problem. Illusion of harmlessness (System isolation mechanisms).
- OS mechanisms increasingly leveraged.
  - Android, Network Daemons,Chrome, IE.
- Related Work. Fails with non-deterministic programs (ESP not required).
  - Zhang,Wang[4] . */proc* ↔ ESP, Keystroke sniffing.
  - Dawn Song [5] . Timing analysis on SSH.
- Different Attack model. *Network* Attacker vs *Local* Attacker.

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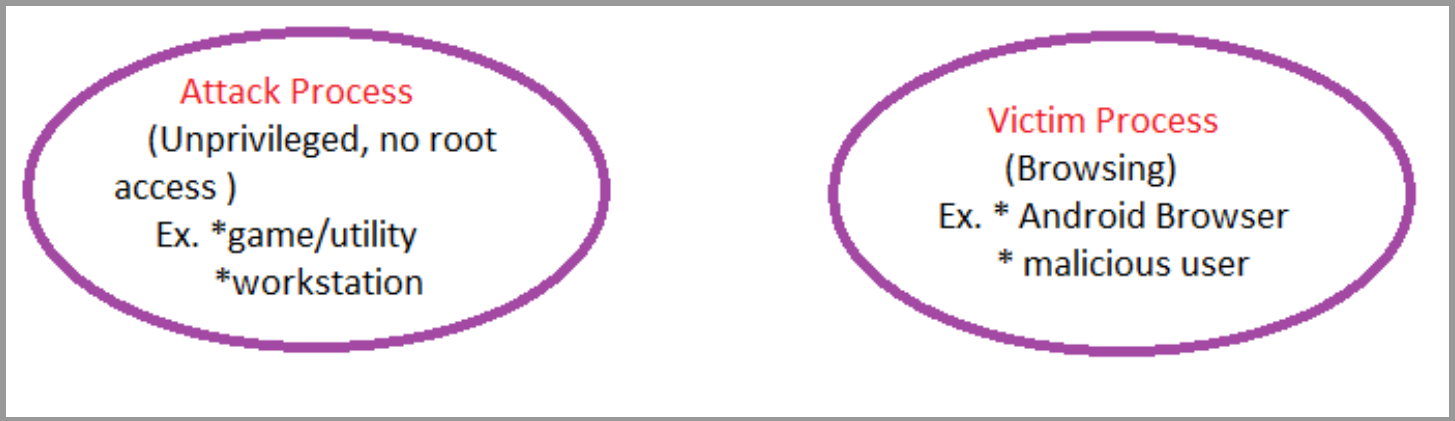
MUST.. KEEP .. EYes .. op..zzz..

Attack Overview

- 2 Processes in parallel on same host as different users.



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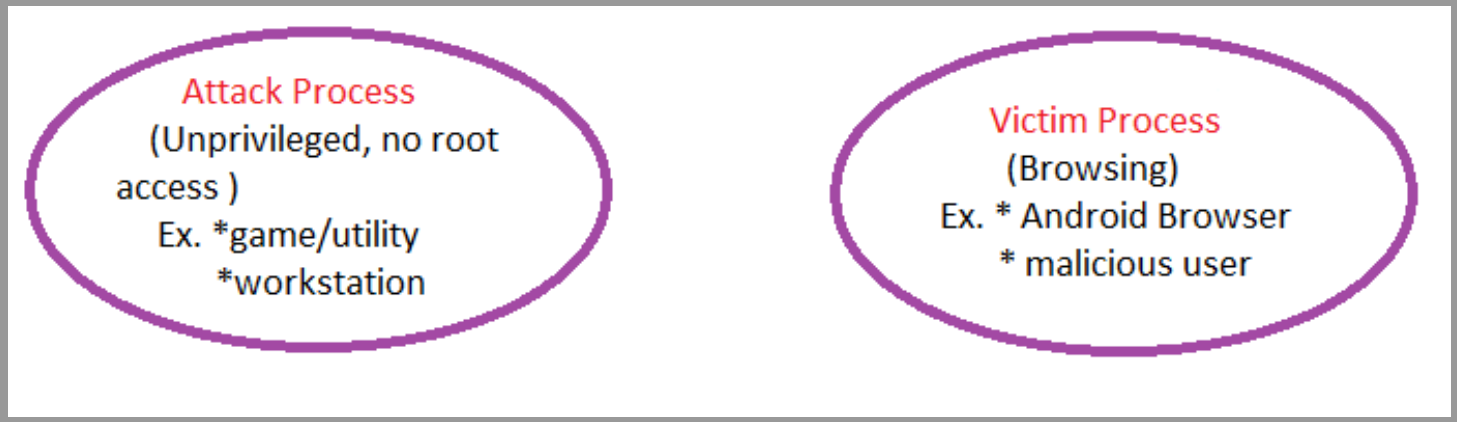
- 

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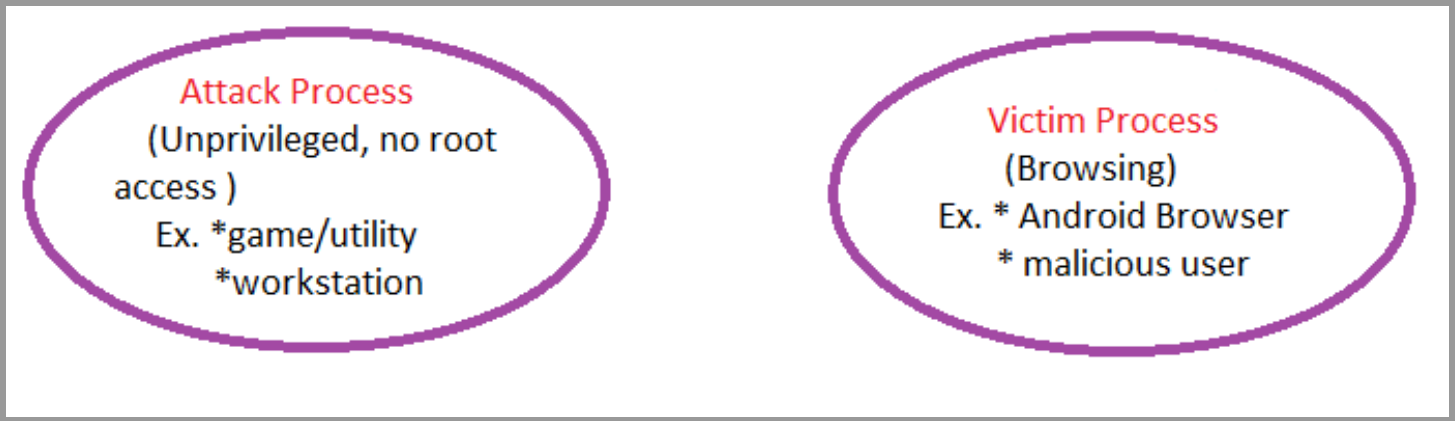

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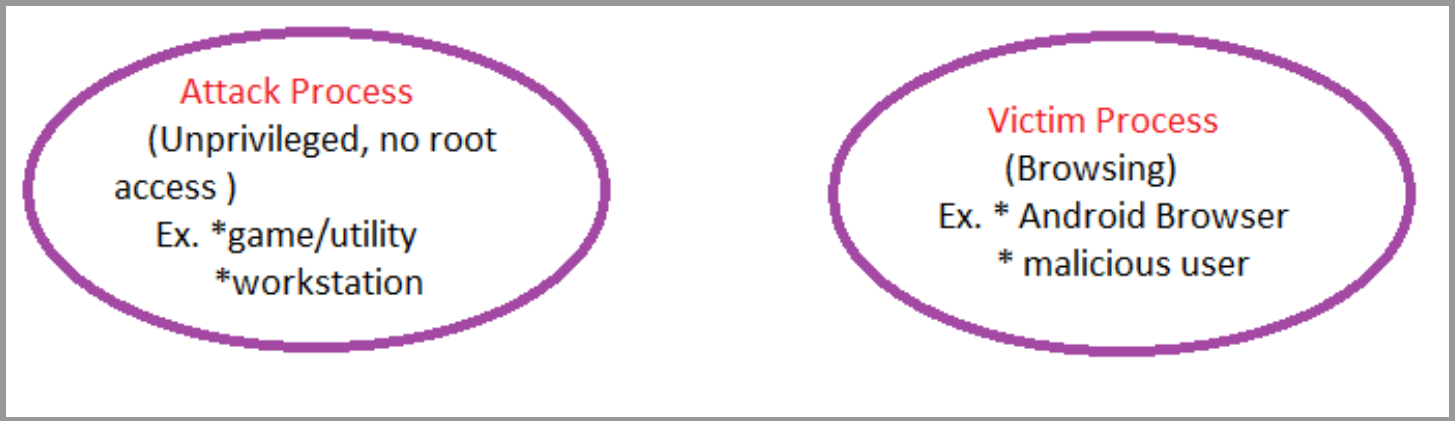

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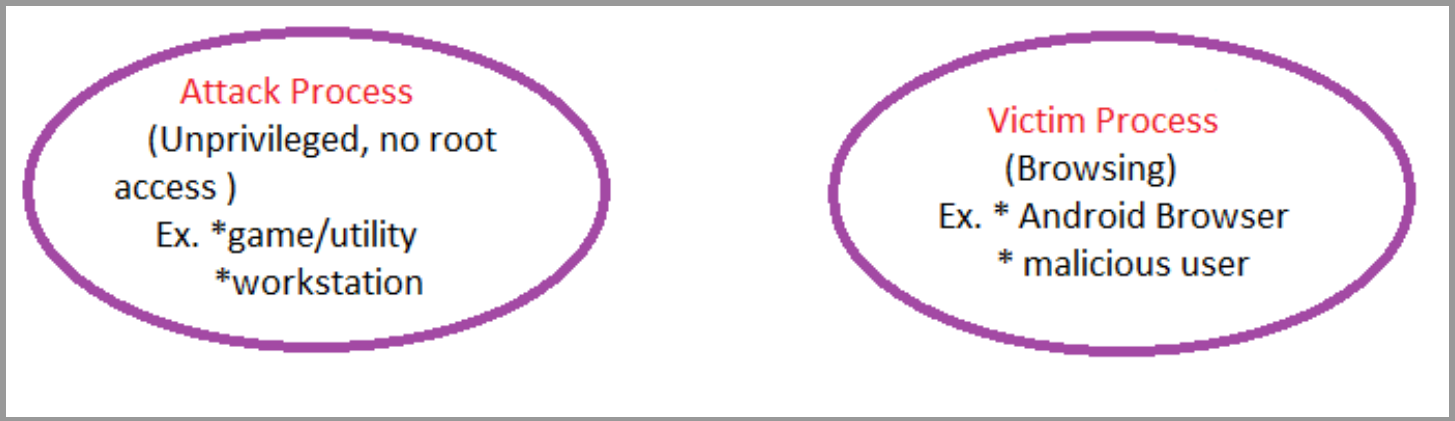

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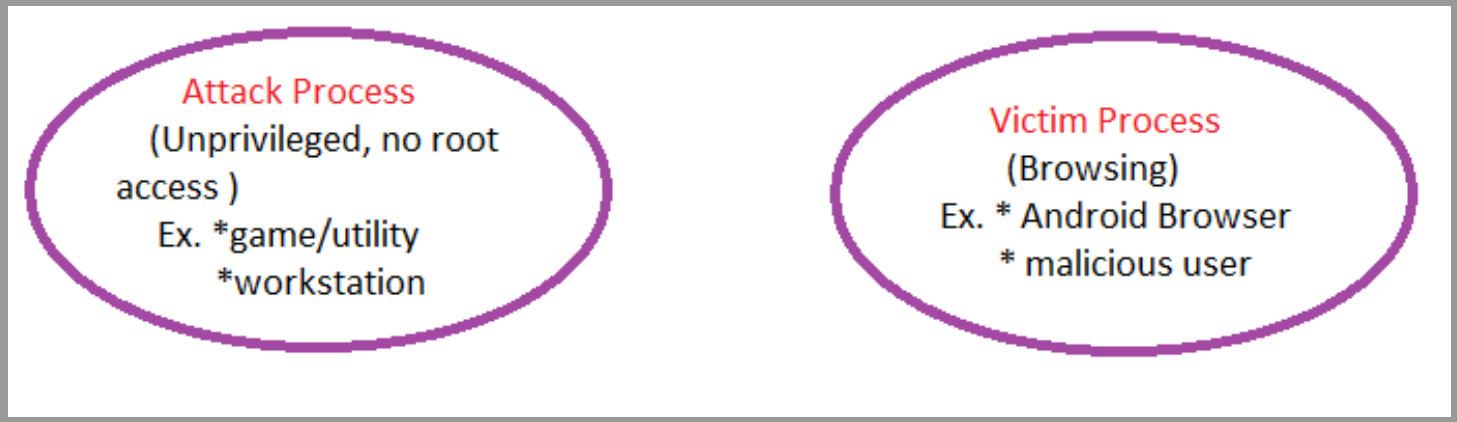
- 

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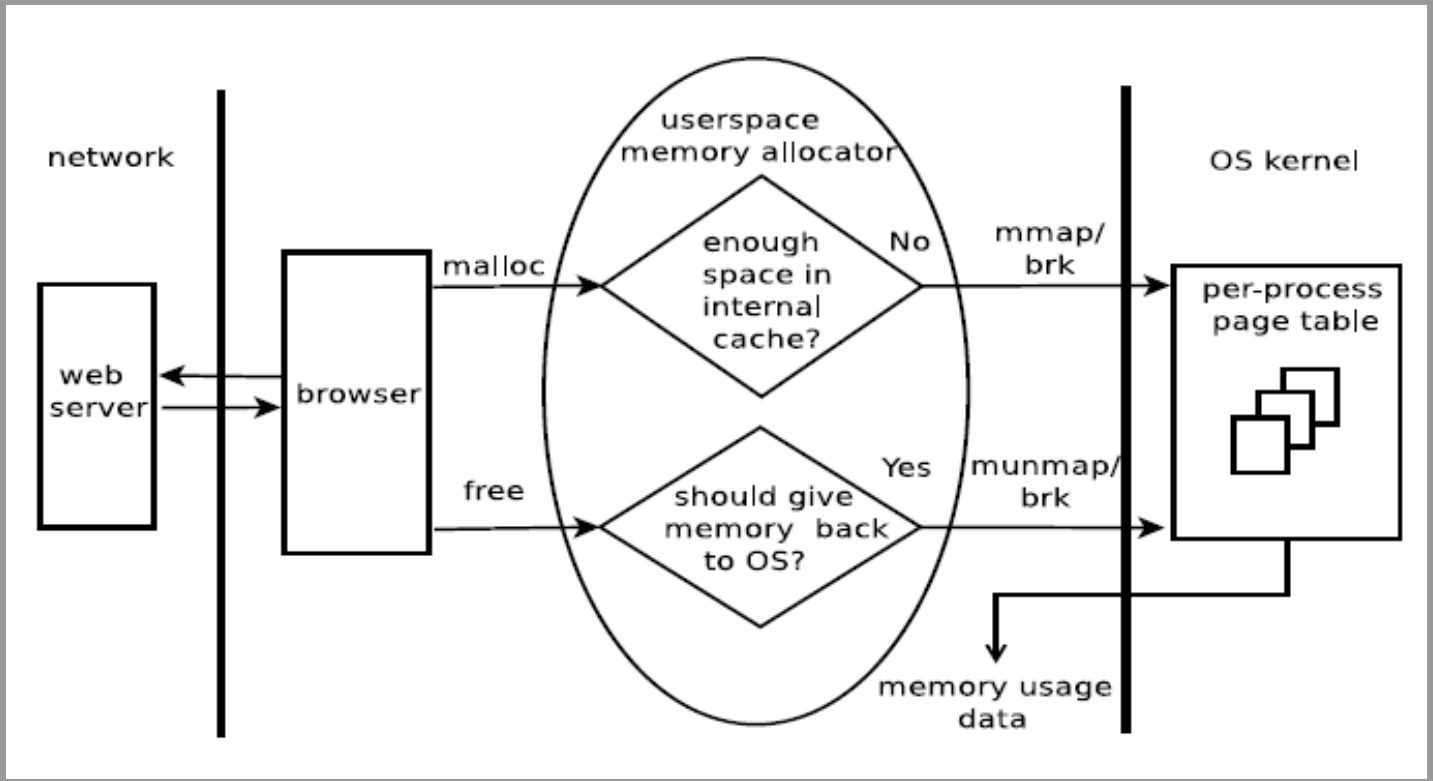
Outline

life, the universe and everything ? 42 .

Attack Details

Browser Mem Management

- Different browsers,different allocators(jemalloc,tcmalloc, etc ...).



- Allocator optimization & behaviour , *Sensitivity*.
- Not directly translated,Varies, Memprint, Noise.

Attack Details

When it works ?

- Diversity.
- Stability.
- Which process to monitor?
  - Monolithic browsers.
  - Micro Kernel browsers.
- Network attacks.

Outline

progress bar at the top says 50%. YES!!

Experimental Setup

- Browsers - Chrome,Firefox,Android
- OS - Windows,Linux,Android.
- Memory Signature gathering by automated scripts.
- ALEXA top 100,000 websites.
- **Memprint** statistics collected.
  - DRS change recorded using PID.
  - Scaled to 100,000 webpages , attacker pauses victim .
  - *FixSched*, *Attack*.
- Plugins,addons,extensions alter in predictable ways.Offset calculated or blocker used.

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maybe if I start clapping early .. hel stop ?

Results
Verification

- False + , False -.
- Distinguishability .
  - wrt fixed ambiguity sets.
  - distinguishability $= (\mu - \sigma) - (\mu_{false} + \sigma_{false})$
  - positive or negative ? ◂ Statistics
- Recognizability
  - true positive rate.Not every page produces a match.
  - Fixsched and Attack visited 5-15 times.
  - Threshhold = highest $J(sig_p, memprint(visittoambiguitypage))$.
  - ◂ Statistics
- Factors affecting accuracy of measurement.(method,concurrent workload,measurement rate,variations).

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wonder if I have anterograde amnesia ?...

Extensions of Attack

Advanced Attacks

- Variations.
- Web Sessions.
- Similar memprint disambiguation.

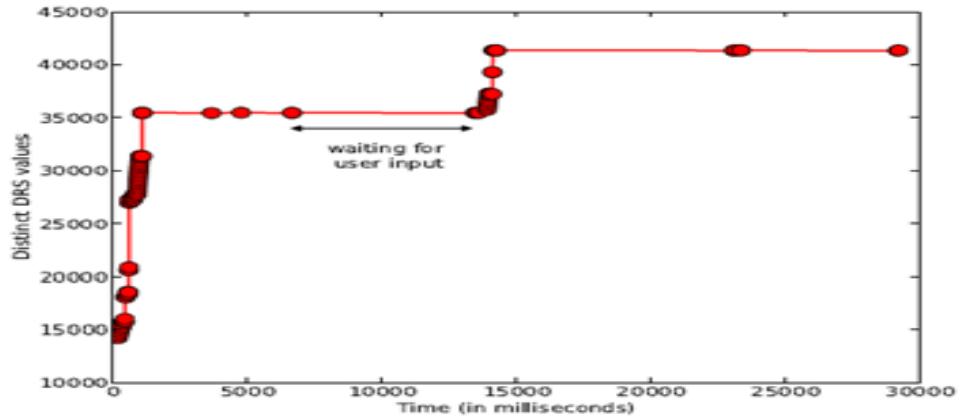

Figure 19. Evolution of the Firefox memory footprint during a Google search session.

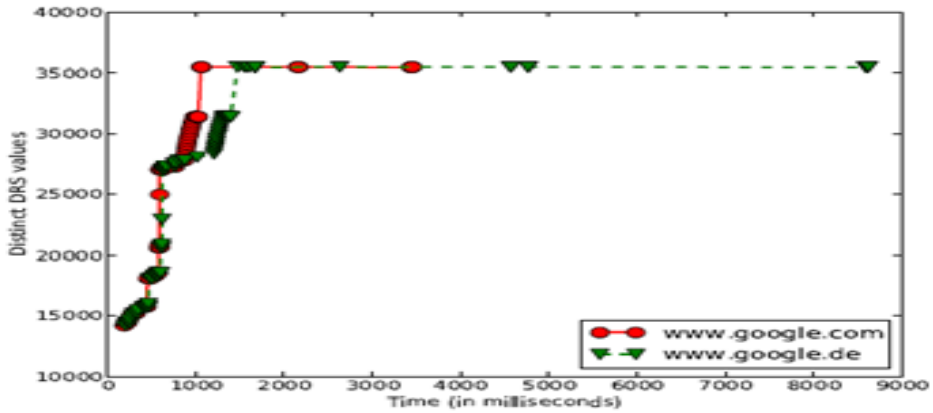

Figure 23. Evolution of the Firefox memory footprint when loading google.com and google.de (US-based browser).

[3] *Fig.*19, 23

Extensions of Attack
CPU Scheduling Stats

- ESP, keystroke timing relation.[4]
- $top - ltm1$,context switches,*schedstat*,Android
- Use this to differentiate.

[3] $Fig.5, TableV$

INTER-KEYSTROKE TIMINGS IN MILLISECONDS: KEYLOGGER VS. STATUS MEASUREMENTS (ANDROID).

Timings	MMS app		bash	
	True	Measured	True	Measured
1	445	449	256	256
2	399	399	320	320
3	176	176	165	175
4	236	240	393	391
5	175	173	255	256

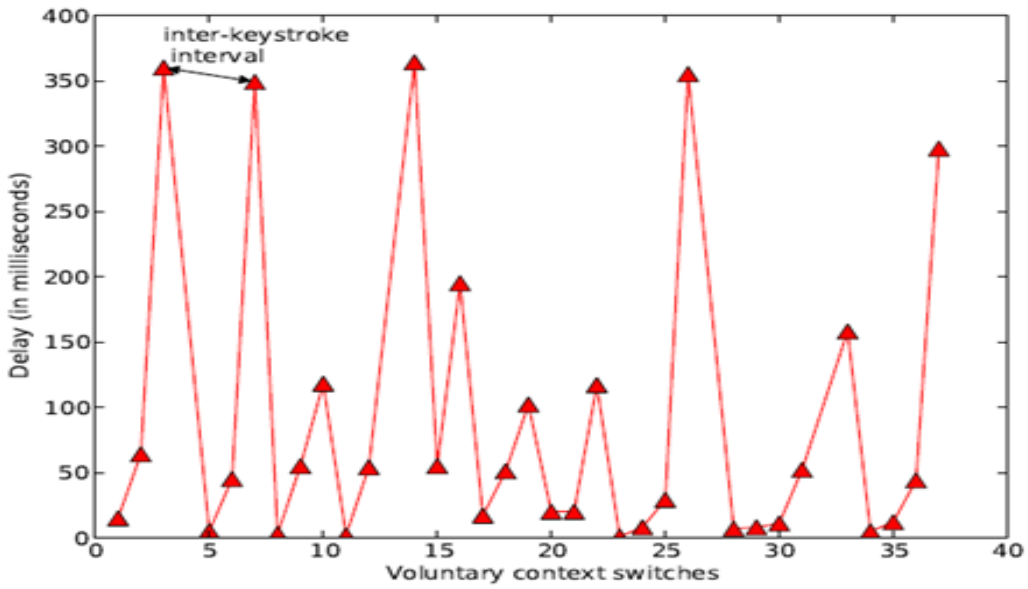

Figure 25. Context-switch delays (LIME in Android).

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hmm. 8 's my new fav number.

Defenses

- Changing the OS.
  - Not a OS specific attack.
  - Can be calculated.
  - Designers must cooperate.
- Changing the application.
  - Browser defenses (network,proxy,incognito etc ...) dont work.
  - Reduce app↔OS correlation.
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  - Memory usage abstraction.
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[P]Presenter's Notes

Pros

- Novel side-channel attack.(Elaborate,complete).
- Proved Hypothesis.
- Structured,well written and precise.

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Cons

- Elaborate attack, result is identity.
- Complexity.
  - Space - $\mathcal{O}(nmw)$.
  - Time - $\mathcal{O}(n^2)$.
- Solutions not concrete.
  - Asynchronous CPUs.
  - blinding.
- Combination with other side-channel attacks.
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[1] `http://www.imdb.com/title/tt0209144/`

[2] `www.wikipedia.com`

[3] Jana,Suman and Shmatikov,Vitaly, *Memento: Learning Secrets from Process Footprints* in IEEE symposium,2012.

[4] K. Zhang and X. Wang. *Peeping Tom in the neighborhood: Keystroke eavesdropping on multi-user systems.* In USENIX Security, 2009.

[5] D. Song, D. Wagner, and X. Tian. Timing analysis of keystrokes and timing attacks on SSH. In USENIX Security, 2001.

Don't **forget** to watch.

QUESTIONS ?

Size of Target's Mem Footprint

- Only info needed is mem size.
- Most OS's have no restriction on this.
  - Different OS

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Windows
    PDH Library
    cmdlets , get-process(wss,host stats)
Linux
    DRS field in /proc/<pid>/statm
    Data(mmap) + heap(brk) + code(stack)
    mm→total_vm - shared_vm
Android
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Building Signature Database

- Create *Attack Signatures* , Build Database.
  - Visit w pages n times.
  - Calculate **memprint** $= (E, e)$,
  - E =int footprint size.(DRS,6th field of proc), e =frequency.
- Comparison of memprints.
  - $((E, e_1)\epsilon m_1) \wedge ((E, e_2)\epsilon m_2) \implies (E, min(e_1, e_2))\epsilon m_1 \cap m_2$
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Perform Attack

Attack memprint is matched against signature database.

Algorithm 1 Main steps of the matching algorithm

Input: Signature database D, attack memprint s_m
Output: Matched page or no match

for each page p in D **do**
  for each signature sig_p for page p in D **do**
    if $J(s_m, sig_p) > threshold$ **then**
      Return matched page p
    end if
  end for
end for
Return no match

◂ Overview

Allocators

```
valgrind \
--smc-check=all --trace-children=yes
--tool=massif \
--pages-as-heap=yes --detailed-freq=1
--threshold=0.5 \
--alloc-fn=mmap \
--alloc-fn=syscall \
--alloc-fn=pages_map \
--alloc-fn=chunk_alloc \
--alloc-fn=arena_run_alloc \
--alloc-fn=arena_bin_malloc_hard \
--alloc-fn=malloc \
--alloc-fn=realloc \
--alloc-fn='operator new(unsigned lon
--alloc-fn=huge_malloc \
--alloc-fn=posix_memalign \
--alloc-fn=moz_xmalloc \
--alloc-fn=JS_ArenaAllocate \
--alloc-fn=PL_ArenaAllocate \
--alloc-fn=NS_Alloc_P \
--alloc-fn=NS_Realloc_P \
--alloc-fn='XPConnectGCChunkAllocator
--alloc-fn='PickChunk(JSRuntime*)' \
--alloc-fn='RefillFinalizableFreeList
--alloc-fn=sqlite3MemMalloc \
--alloc-fn=mallocWithAlarm \
--alloc-fn=sqlite3Malloc \
<insert-firefox-command-here>
```

◂ Attack Details

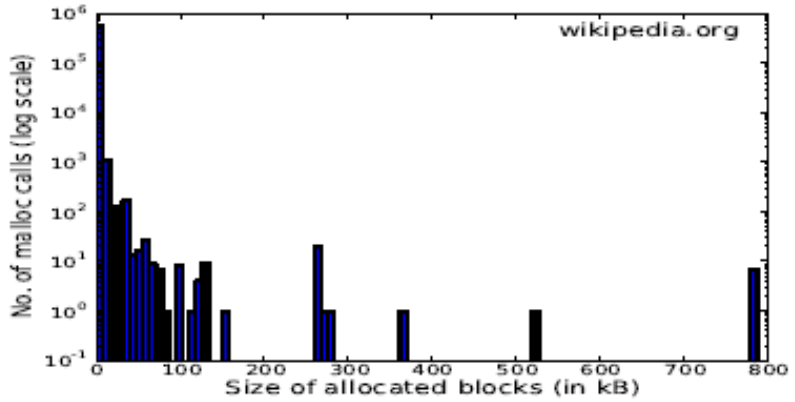
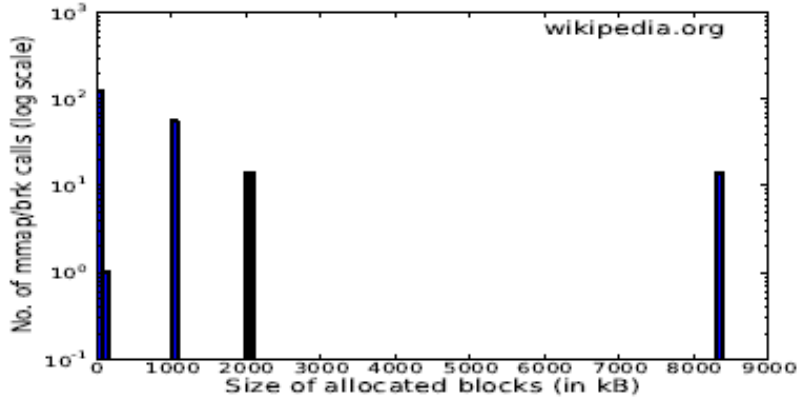


Figure 2. Firefox: Distribution of malloc'd block sizes.



Distinguishability

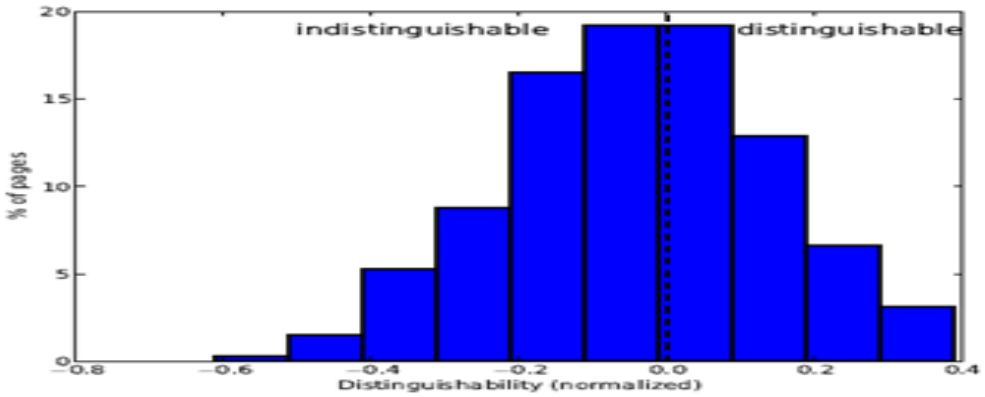


Figure 7. Chrome: Distinguishability of 1,000 random pages, 100,000-page ambiguity set (FixSched measurement). 43% of sites are distinguishable.

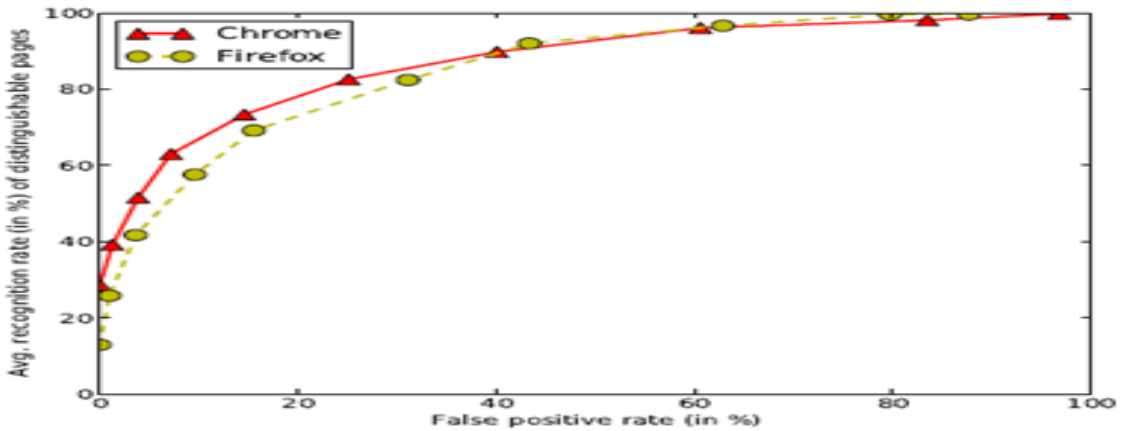


Figure 11. Chrome and Firefox: Average recognition rate vs. false positive rate for 1,000 pages, 10 visits each, with a 20,000-page (Chrome) and 10,000-page (Firefox) ambiguity set (FixSched measurement).

◂ Verification

Recognizability

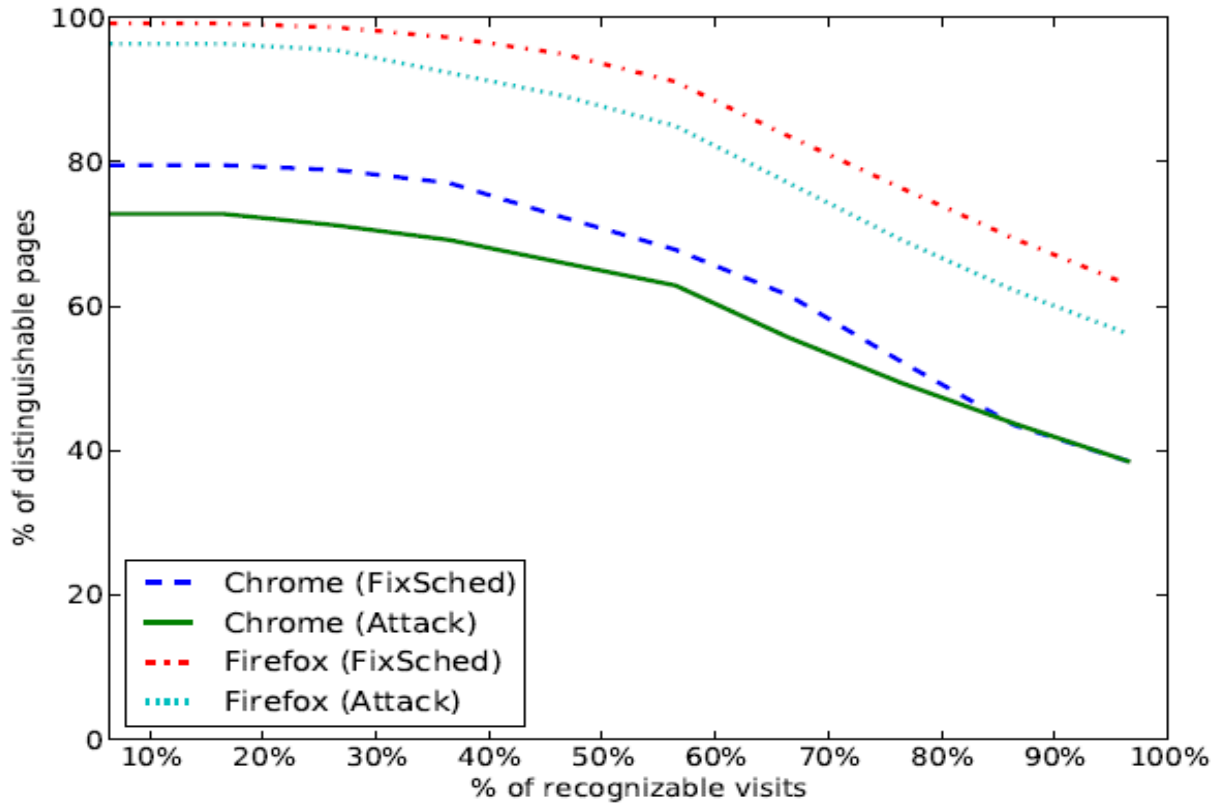


Figure 14. Chrome and Firefox: Recognizability of 100 random distinguishable pages (Attack and FixSched measurements). No false positives.

◂ Verification