DIGITAL FORENSICS RESEARCH CONFERENCE

A Study on the Evolution of Kernel Data Types Used in Memory Forensics and Their Dependency on Compilation Options

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About OS Profiles

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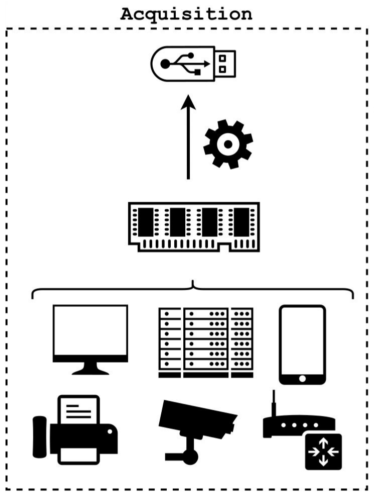
- Acquisition: copy RAM content to a non-volatile storage



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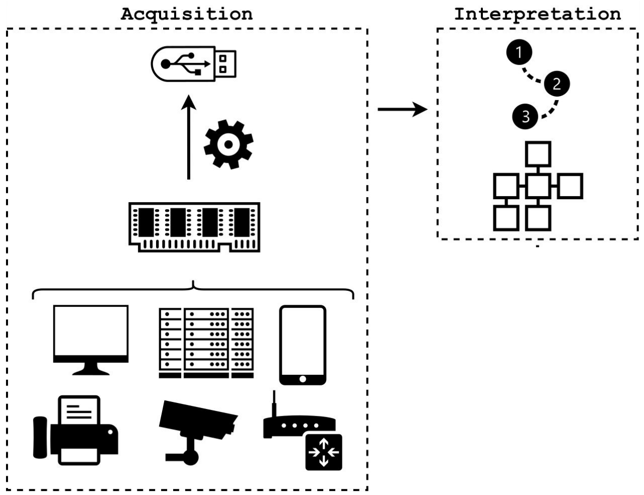

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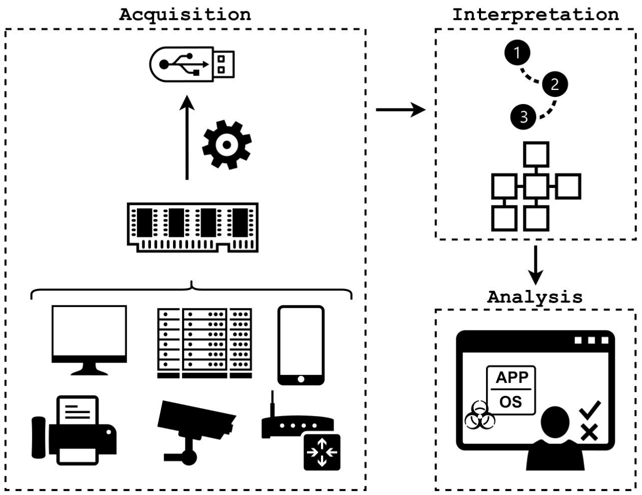

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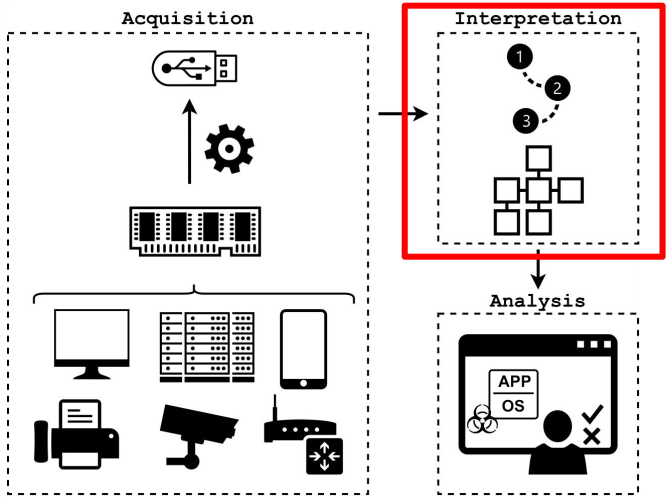

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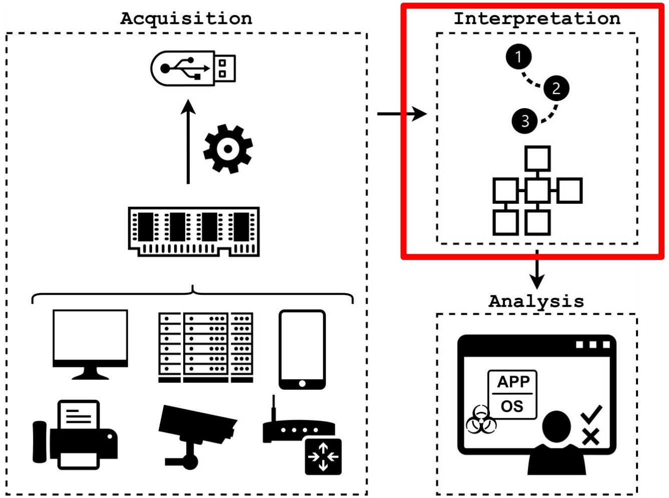

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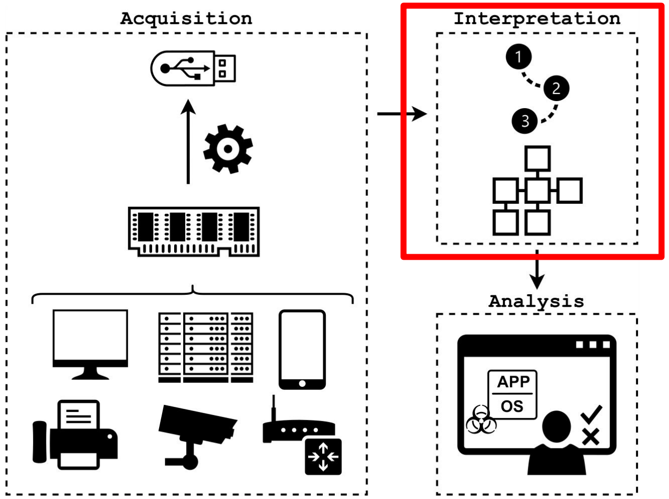

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- different OS versions and/or kernel configurations **require different profiles**

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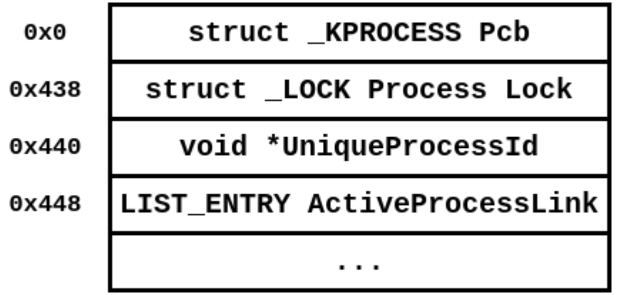

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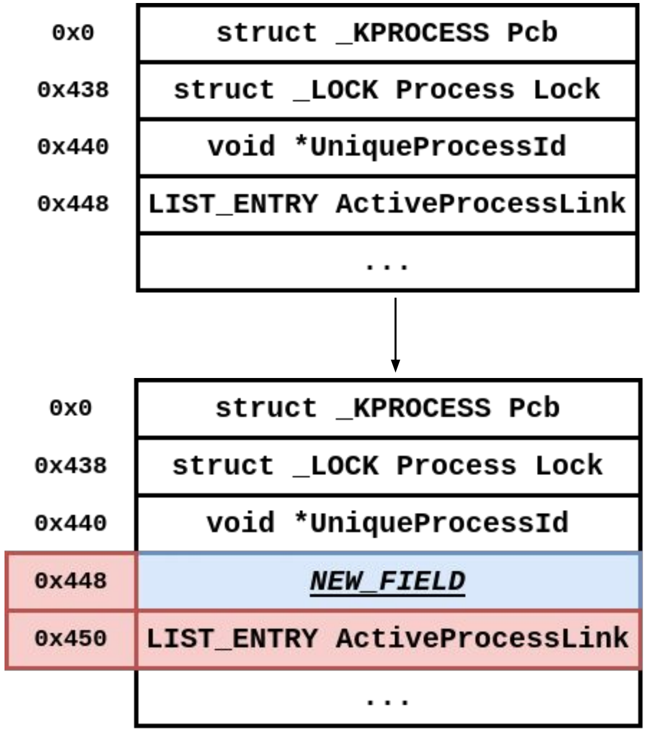

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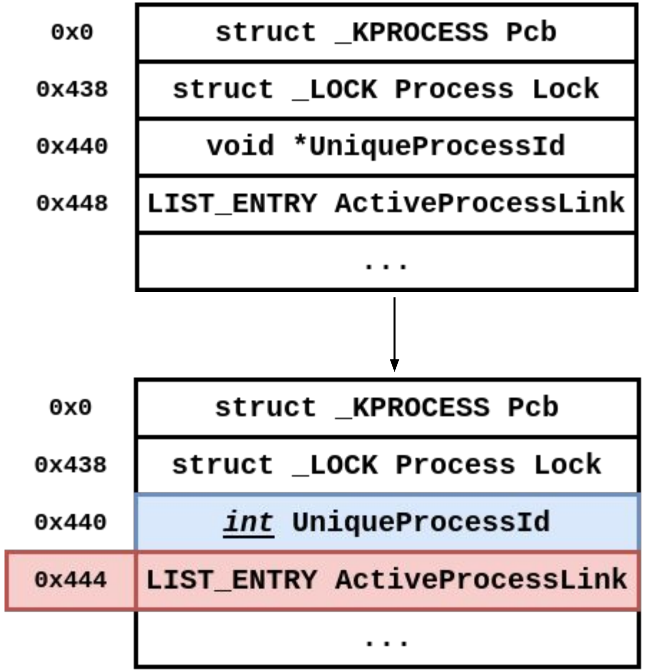

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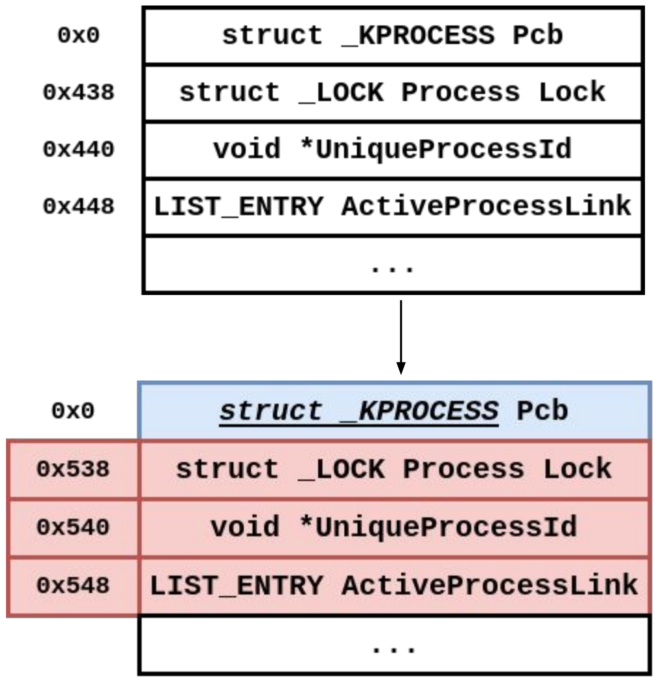

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- Kernel compiled with different options (Linux only)

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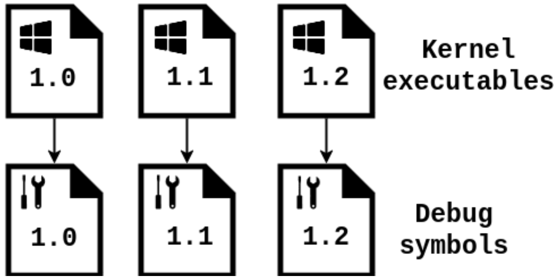

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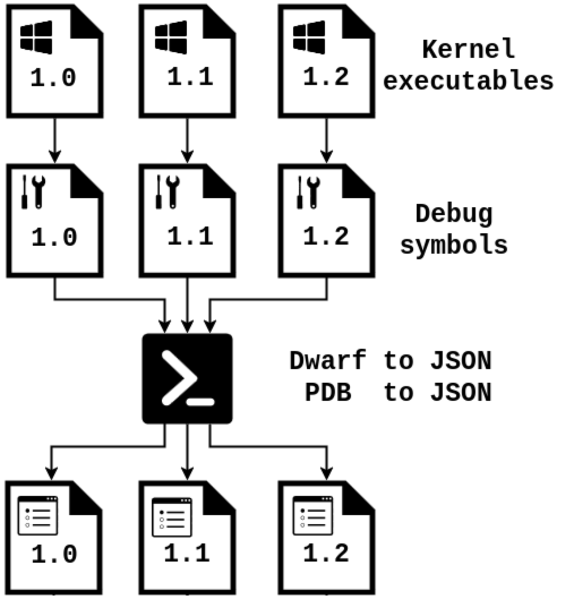

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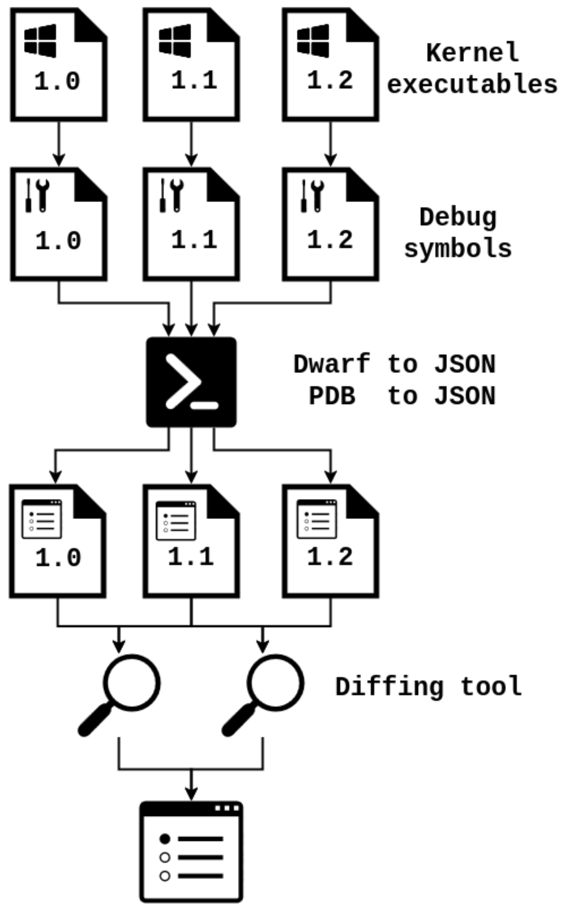

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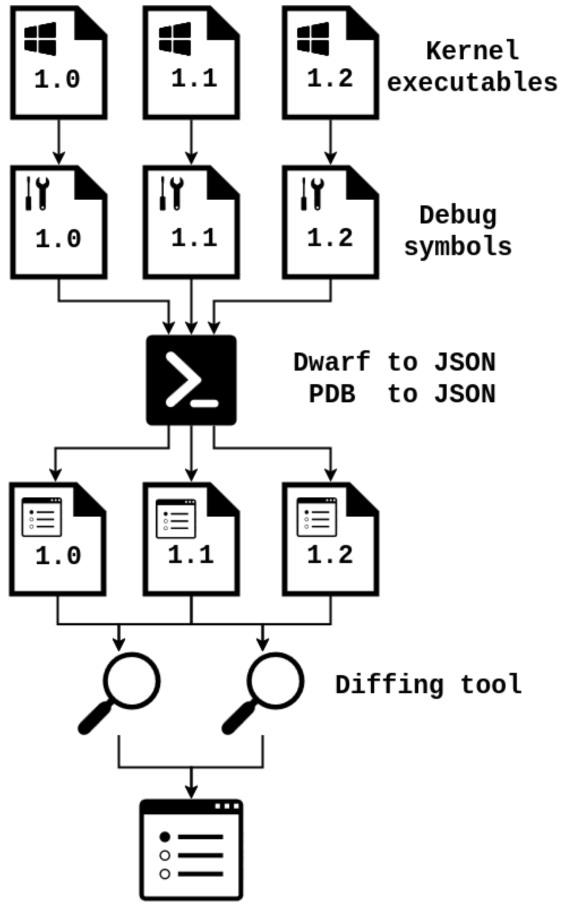
5. Collect and analyze
   - Add/removed struct/unions
   - Add/removed fields
   - Change in embedded structs
   - Change in field offset
   - Change in global variables location



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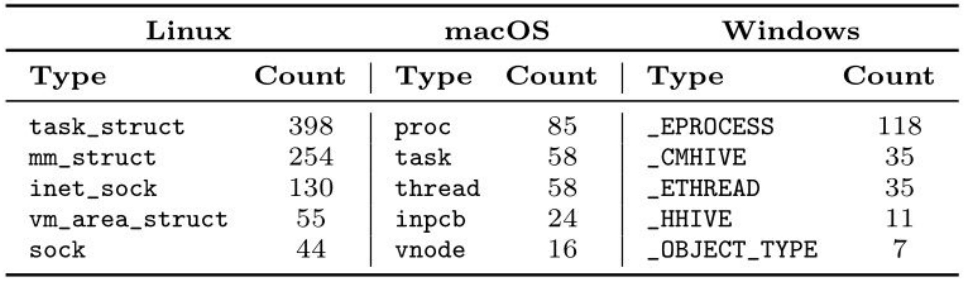

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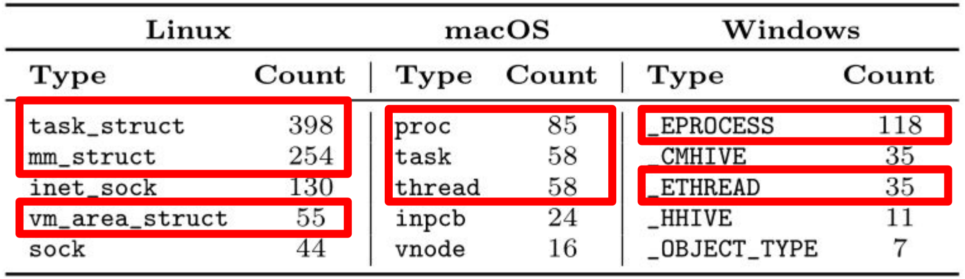

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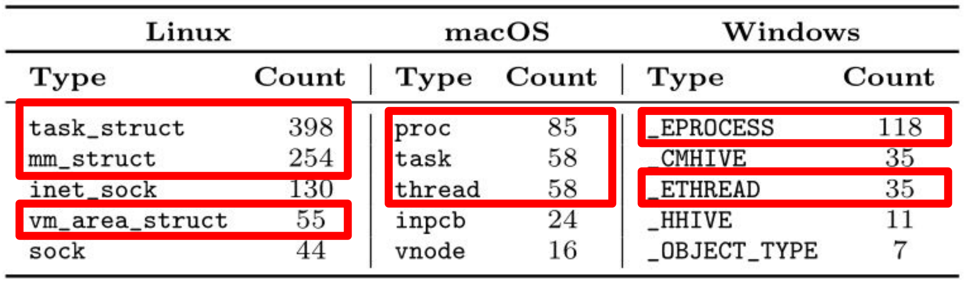

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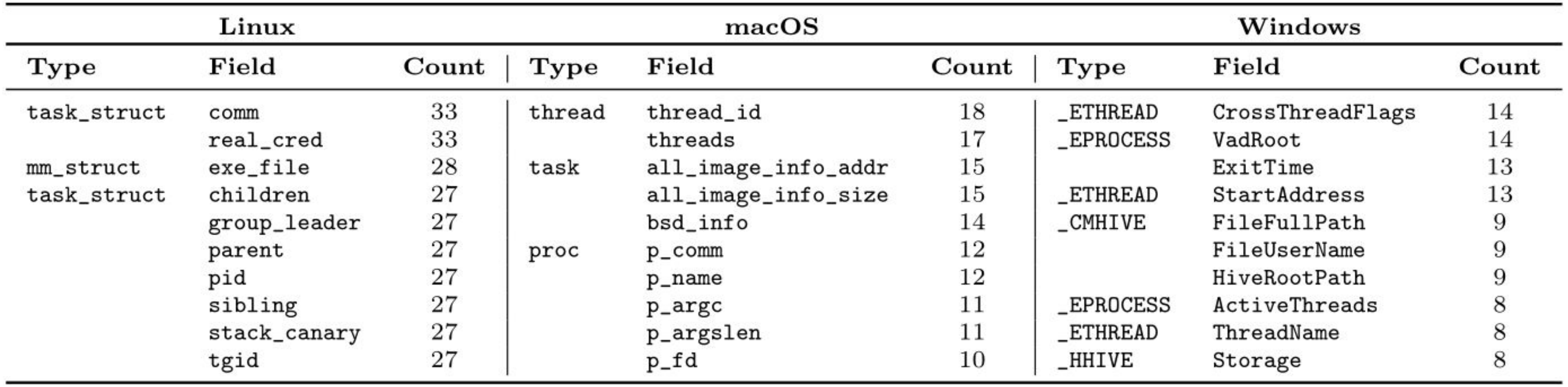

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mm_struct	exe_file	28	task	all_image_info_addr	15		ExitTime	13
task_struct	children	27		all_image_info_size	15	_ETHREAD	StartAddress	13
	group_leader	27		bsd_info	14	_CMHIVE	FileFullPath	9
	parent	27	proc	p_comm	12		FileUserName	9
	pid	27		p_name	12		HiveRootPath	9
	sibling	27		p_argc	11	_EPROCESS	ActiveThreads	8
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- Other affected plugins:
  - <u>**macOS**</u> ⇒ **lsof, listraw**
  - <u>**Windows**</u> ⇒ all **Registry plugins**

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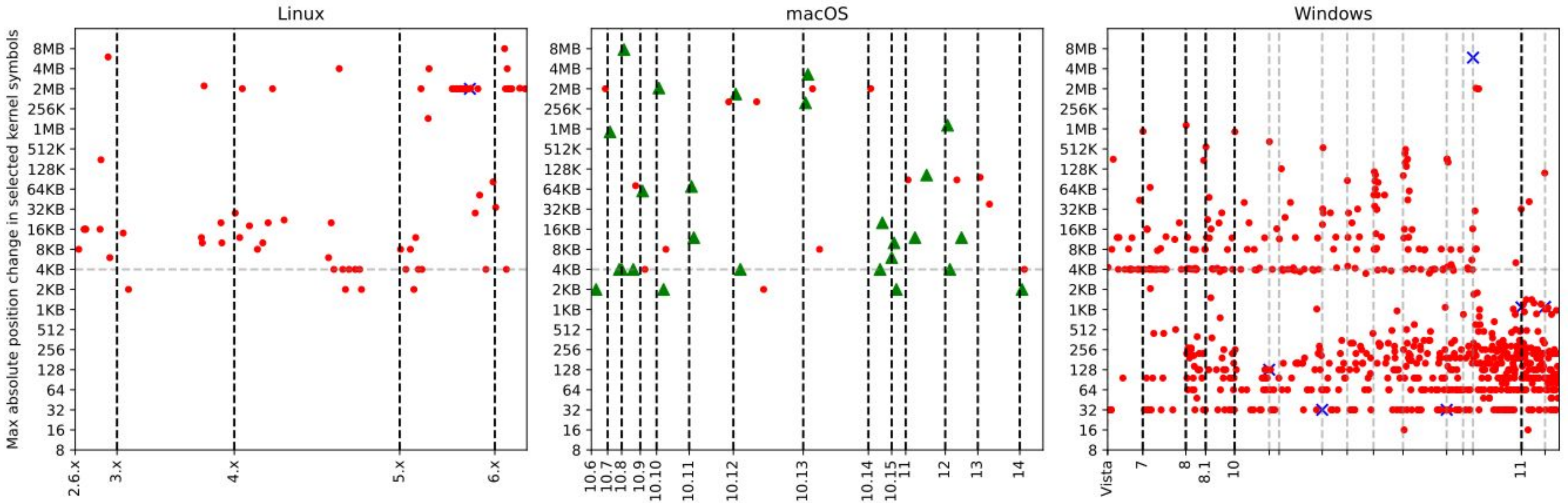

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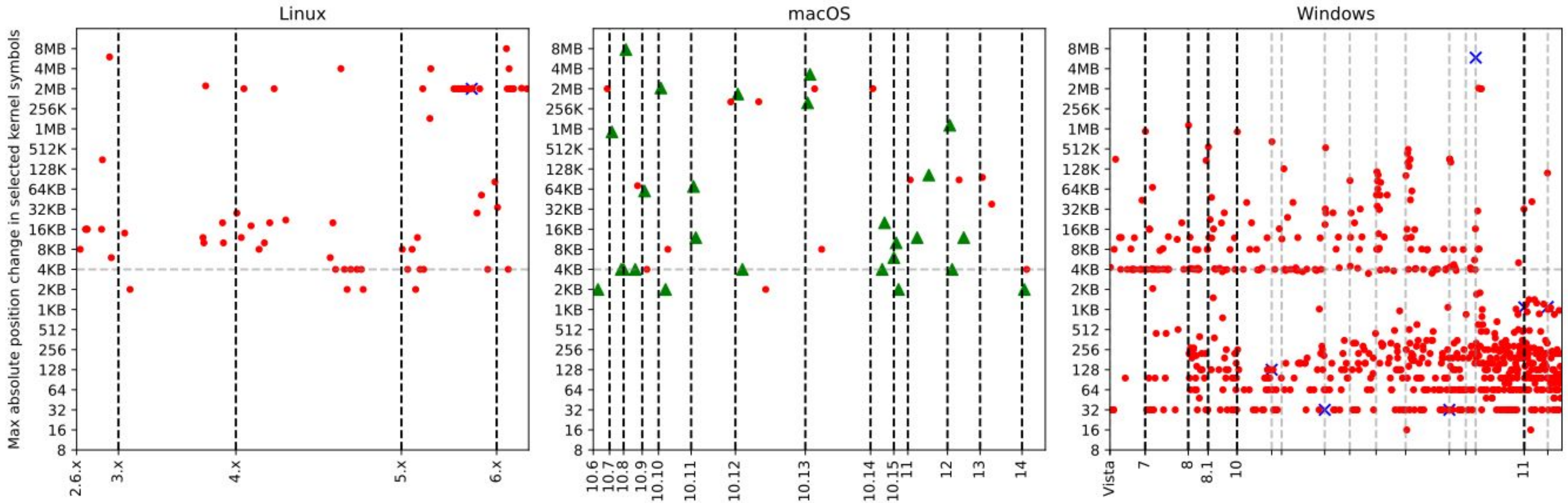

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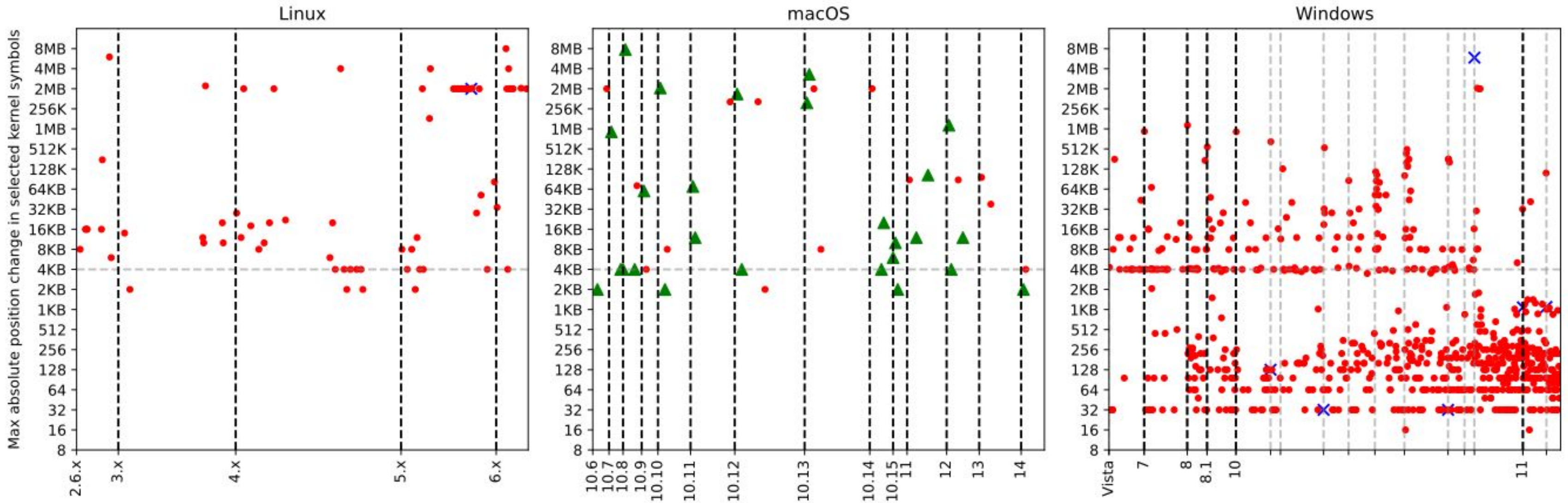

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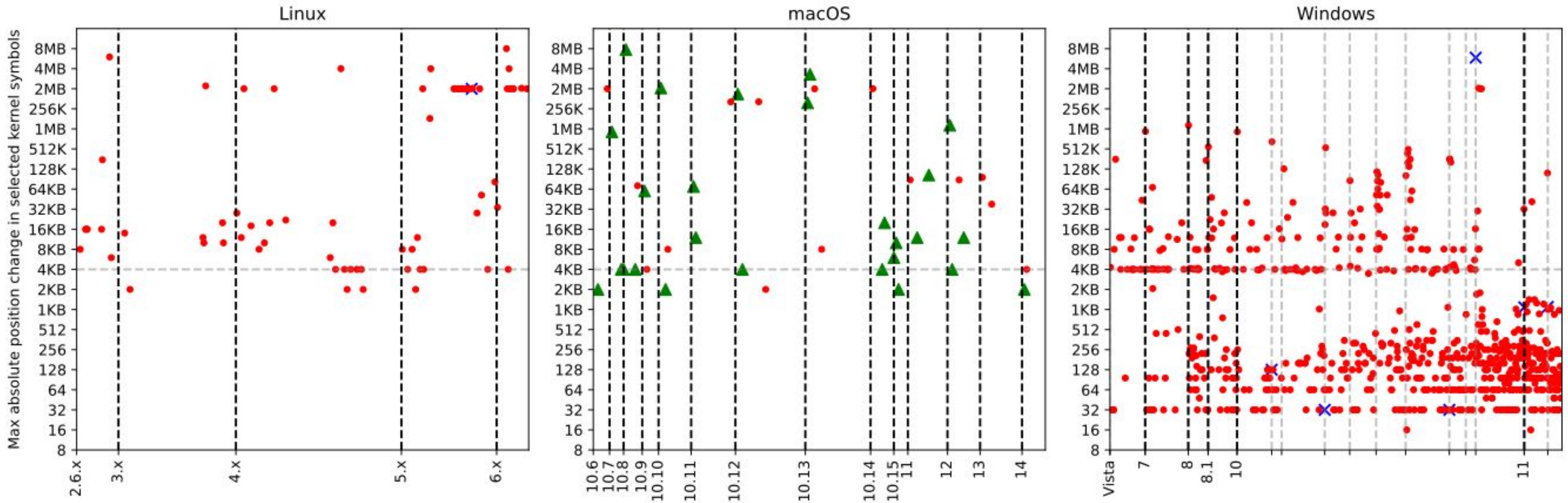

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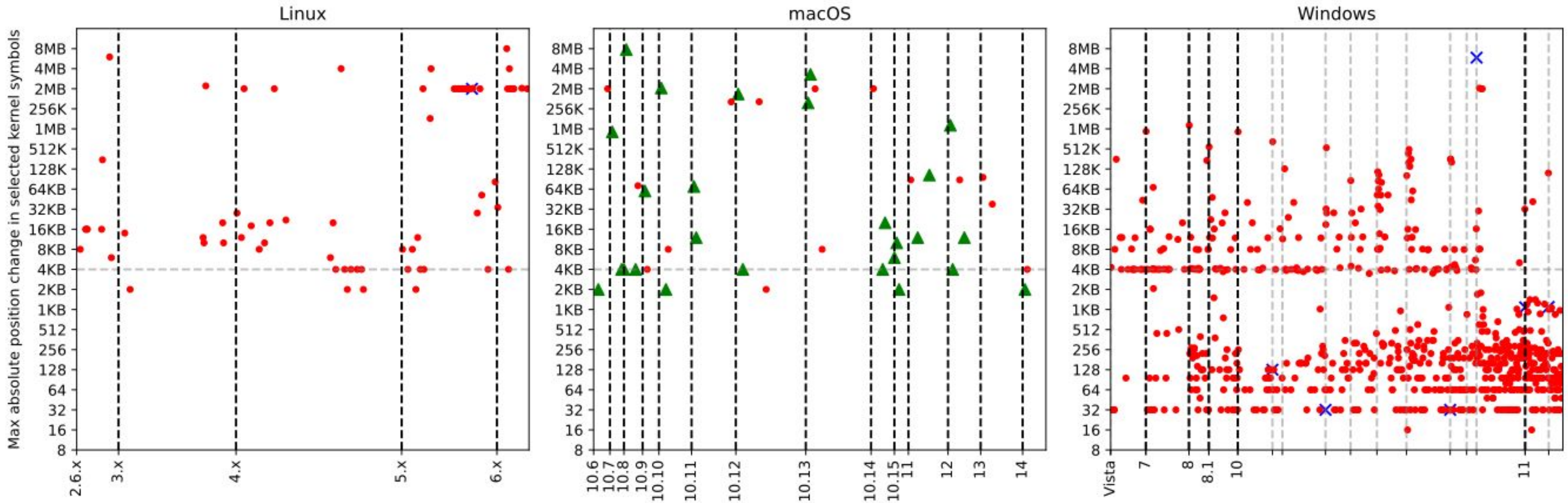

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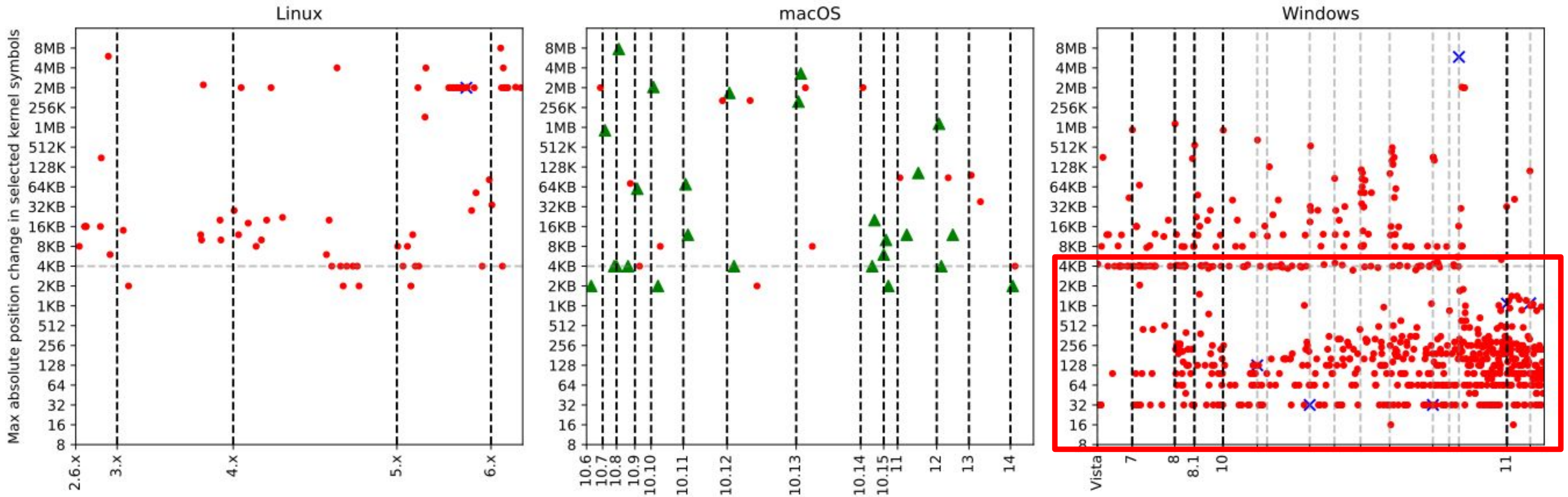

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- **76%** of the **offset** shift is **less than the page size** (4KB)

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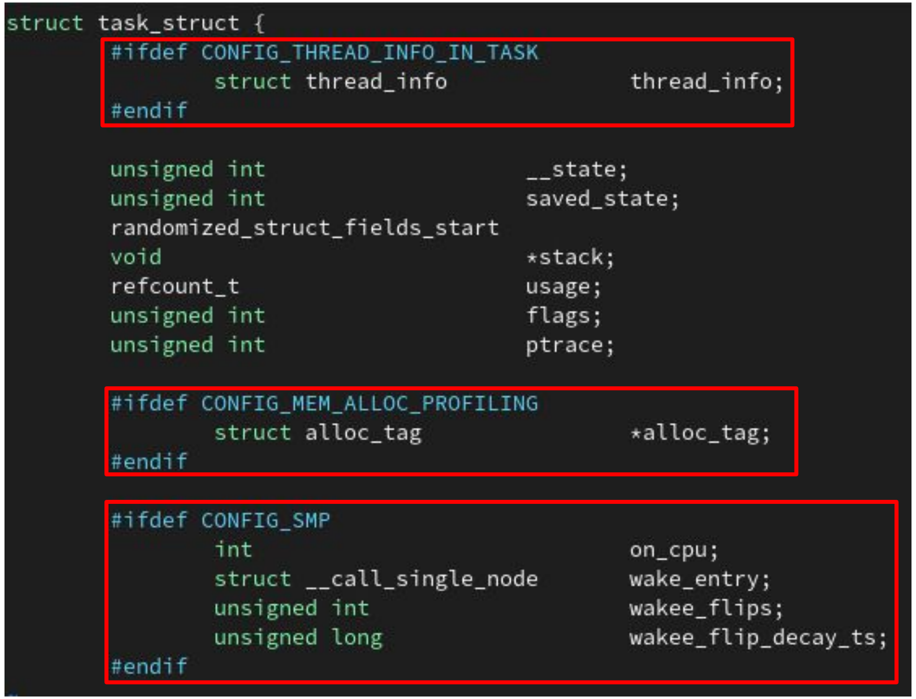
Global variables can require to be **brute forced**…

⇒ **Is it possible to automate** the creation of a profile from a near one?

<u>RESEARCH IN PROGRESS</u>

Linux Kernel Compilation Option Dependency

- The **KConfig** options **influence**:
  - the kernel behaviour
  - **the layout of data structures**



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	#endif

	unsigned int			__state;
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	randomized_struct_fields_start
	void				*stack;
	refcount_t			usage;
	unsigned int			flags;
	unsigned int			ptrace;

	#ifdef CONFIG_MEM_ALLOC_PROFILING
		struct alloc_tag		*alloc_tag;
	#endif

	#ifdef CONFIG_SMP
		int				on_cpu;
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		unsigned int			wakee_flips;
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Linux Kernel Compilation Option Dependency

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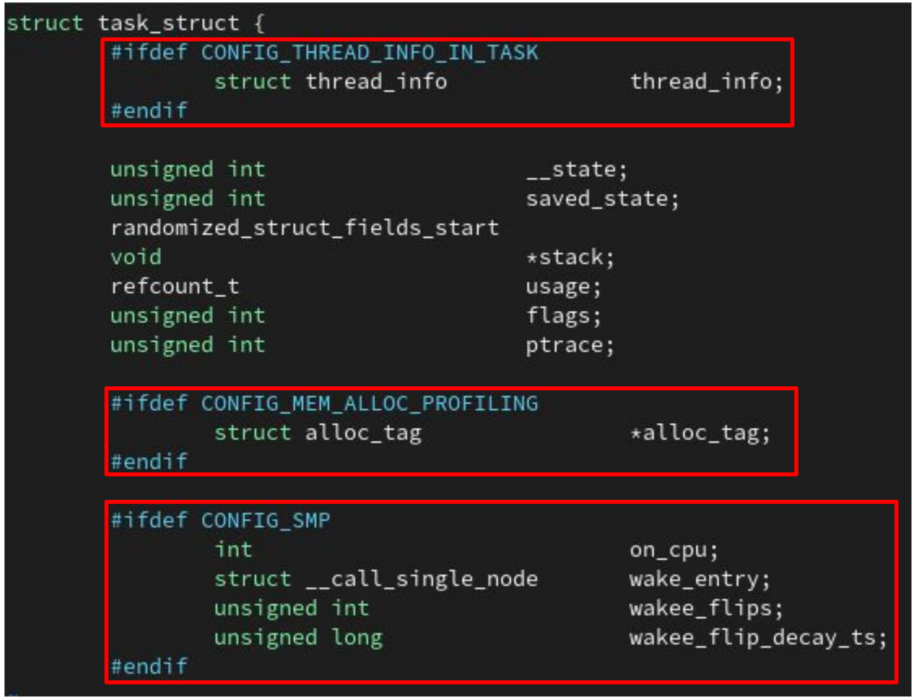
How the **KConfig** options **influence** the forensics data **structures layout?**

Which KConfig options have the **major impact?**



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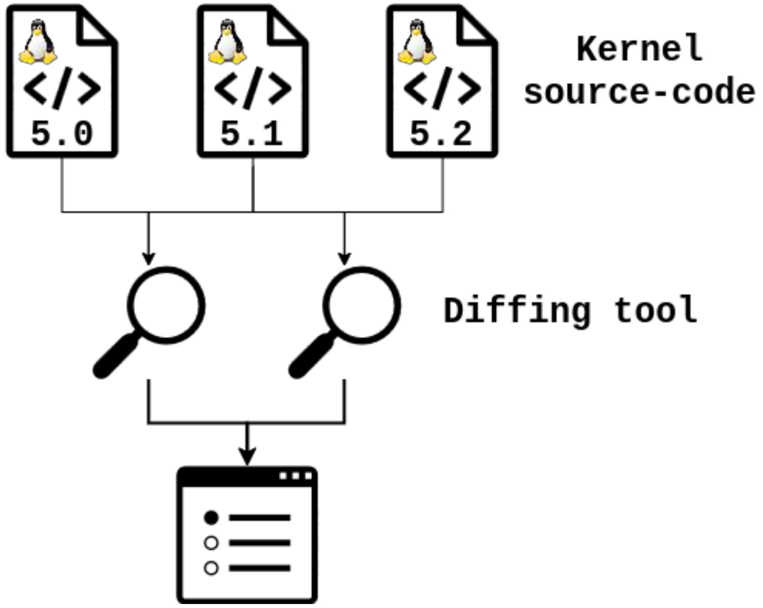

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- We **parse and compare source code of adjacent kernel** versions
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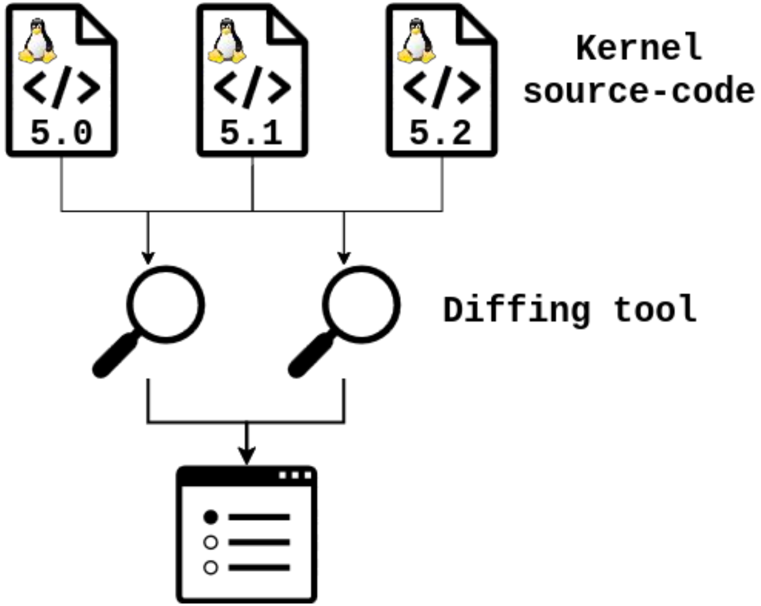
  - Focus on x64 and ARM64

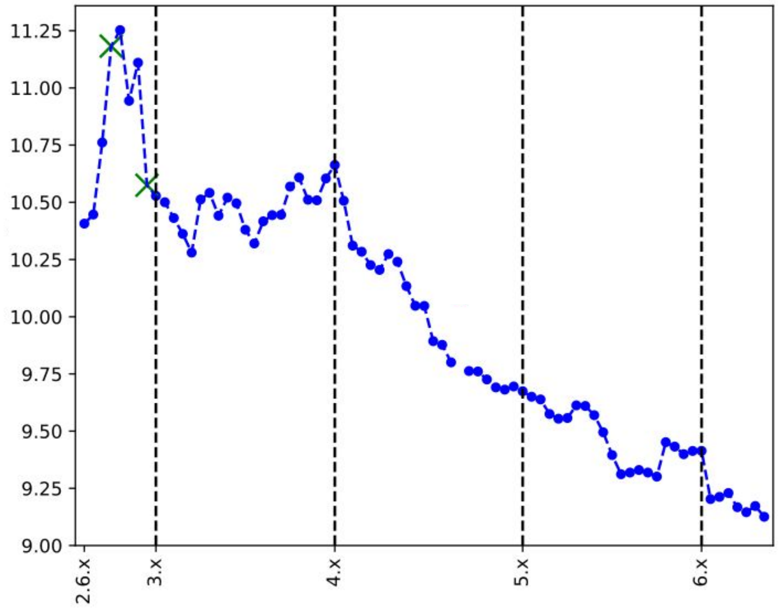
- 77 different minor **versions**
  - from **2.6.32** up to **6.7**
  - covering **96.6% of C structs**



Structs KConfig Dependency: General Stats

Percentage of **structs affected** by KCONFIGs

⇒ **~10%** in continue decrease



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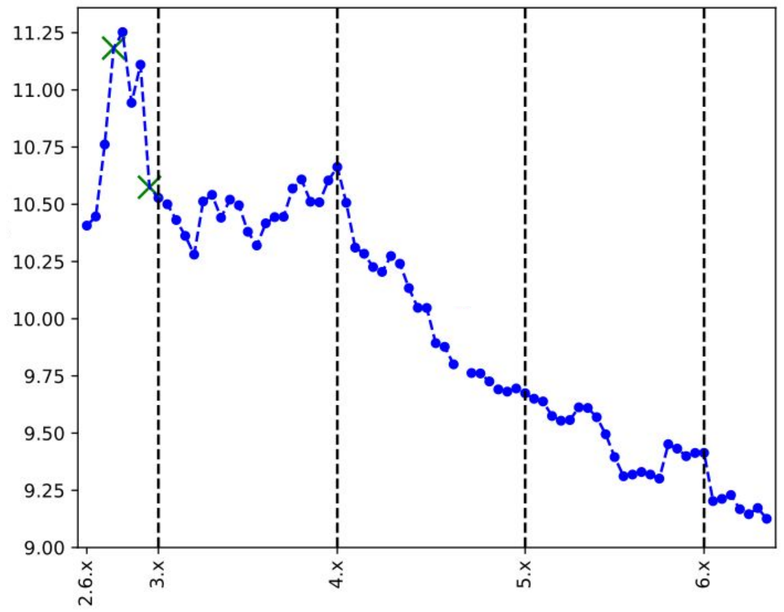

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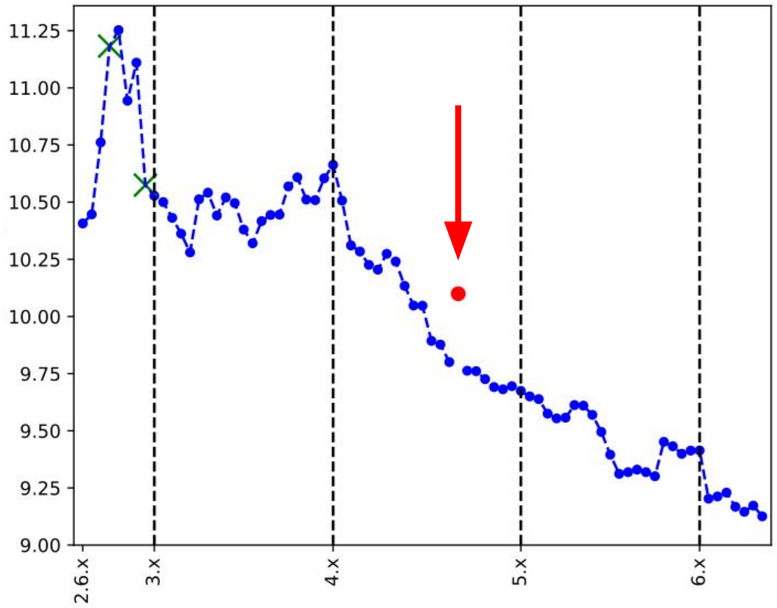

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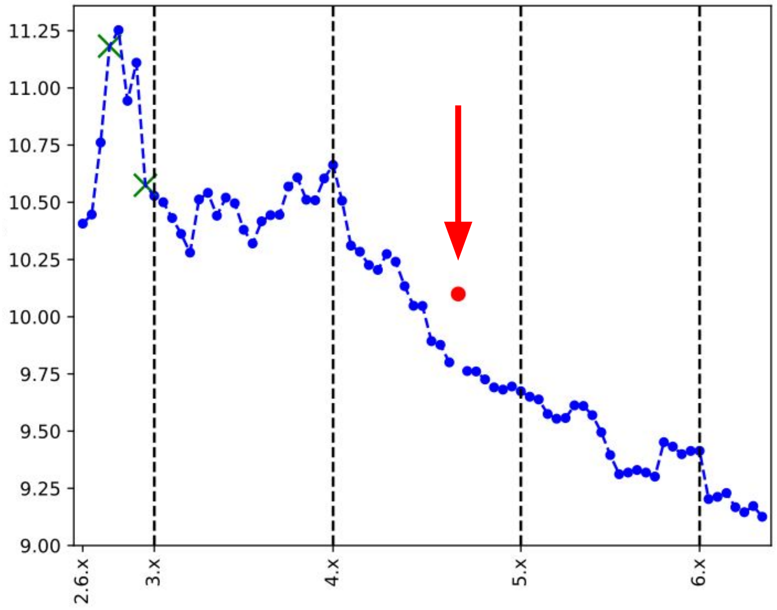

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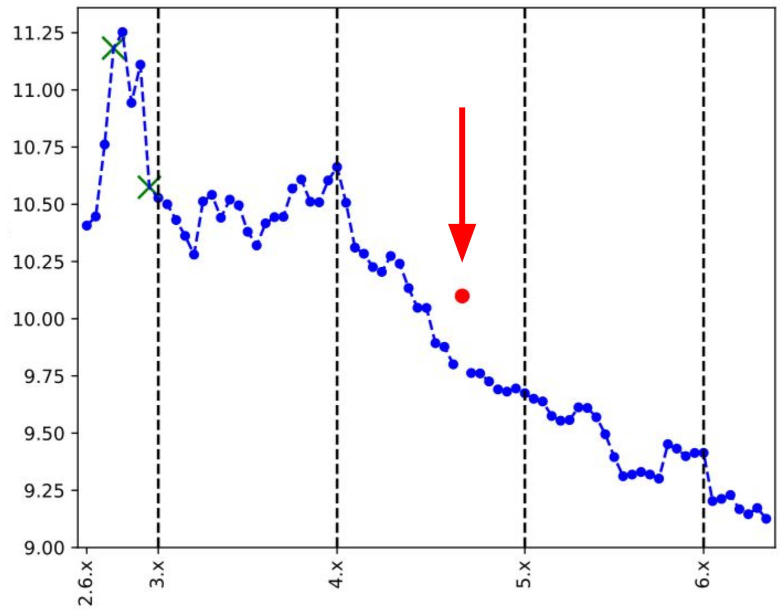

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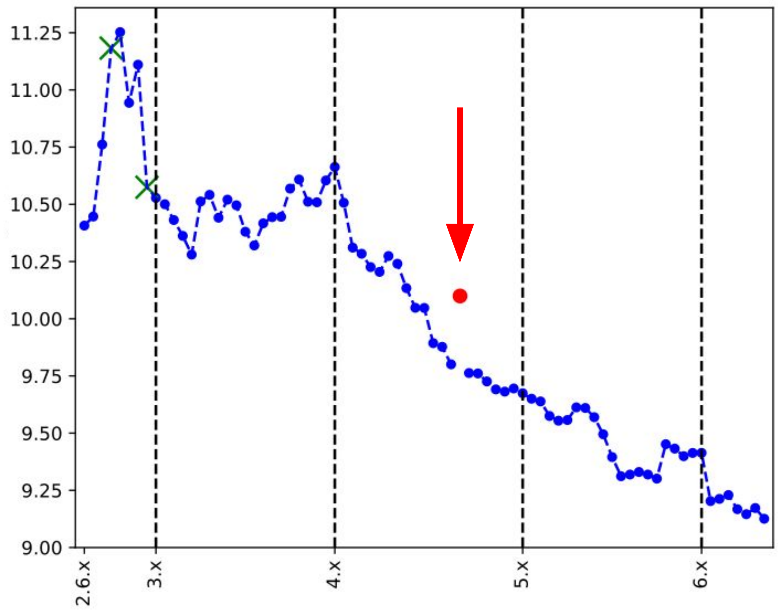

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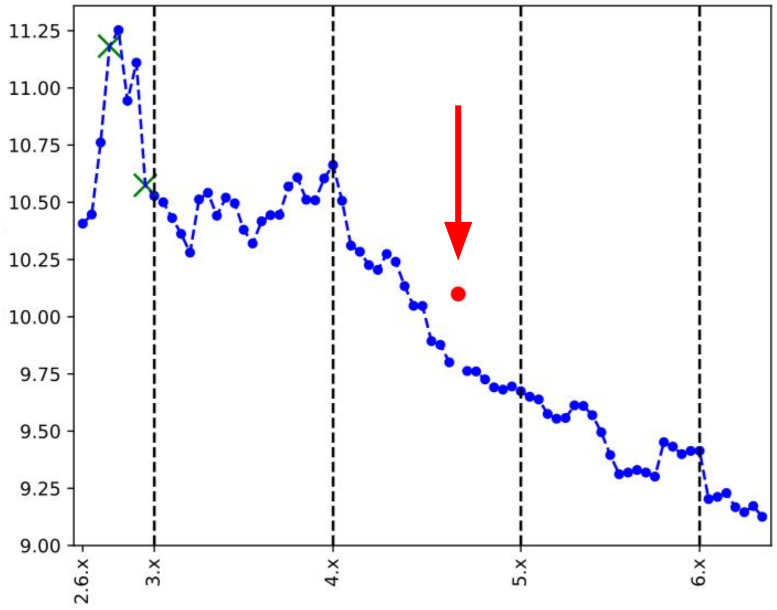
- CONFIG_LOCKDEP_CROSSRELEASE **removed in 4.15** due to huge performance penalty



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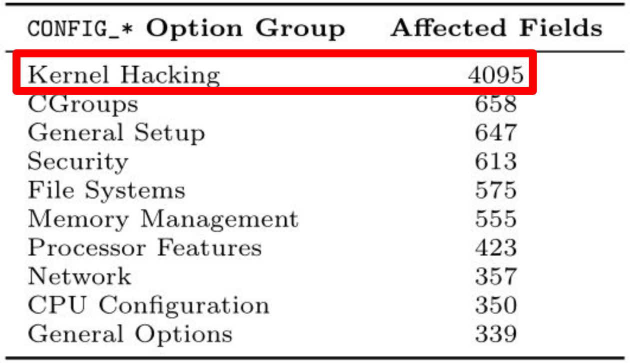

CONFIG_* **Option Group**	**Affected Fields**
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General Setup	647
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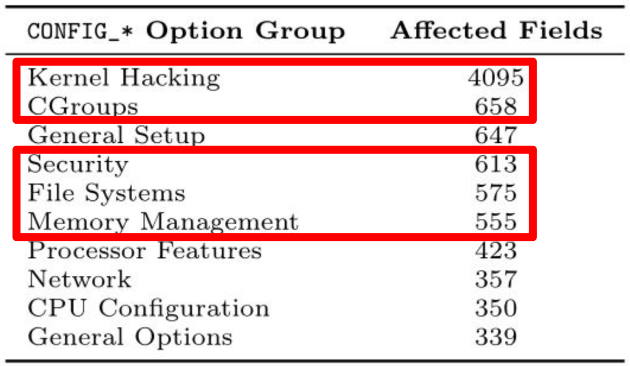

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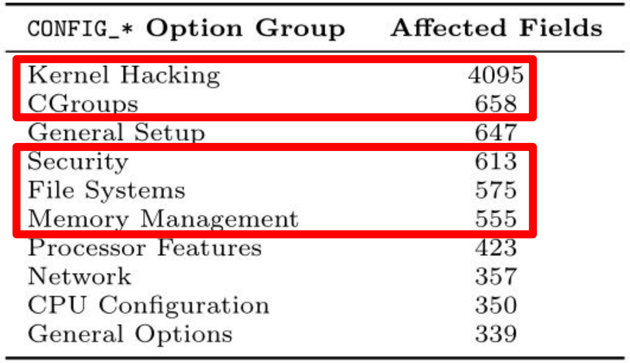

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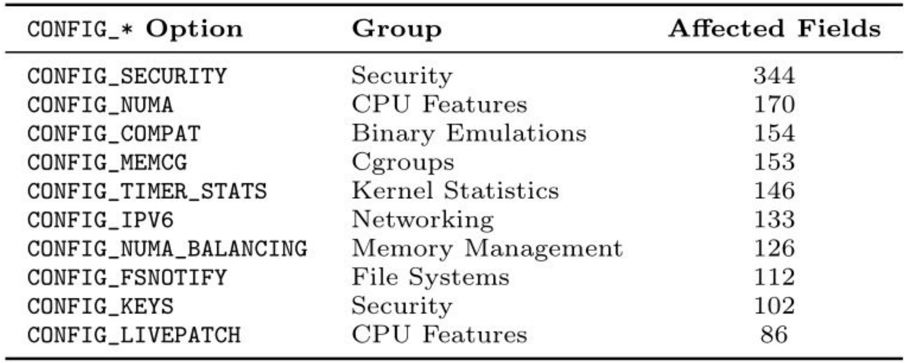

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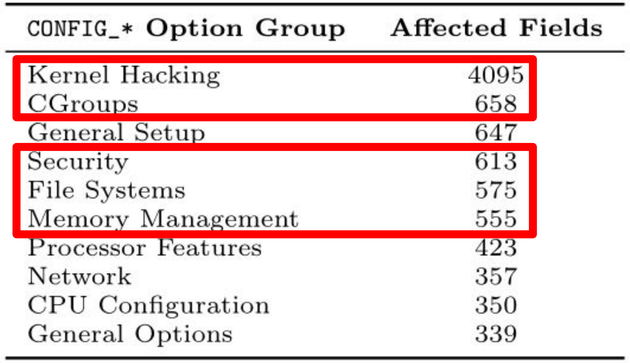
- **CONFIG_SECURITY** ⇒ most influencing one
  - Support for AppArmor and SELinux
- **CONFIG_MEMCG**
  - Support for Memory CGroup
- **CONFIG_IPV6**
  - Support for IPv6



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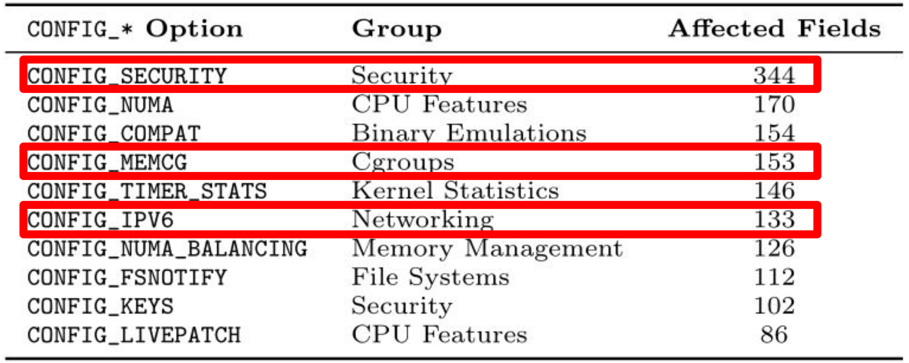

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- Identified **most influence KConfigs on forensics structs**.

… and **we release Volatility 3 profile dataset and code to the community!**
https://s3.eurecom.fr/datasets/

Questions?

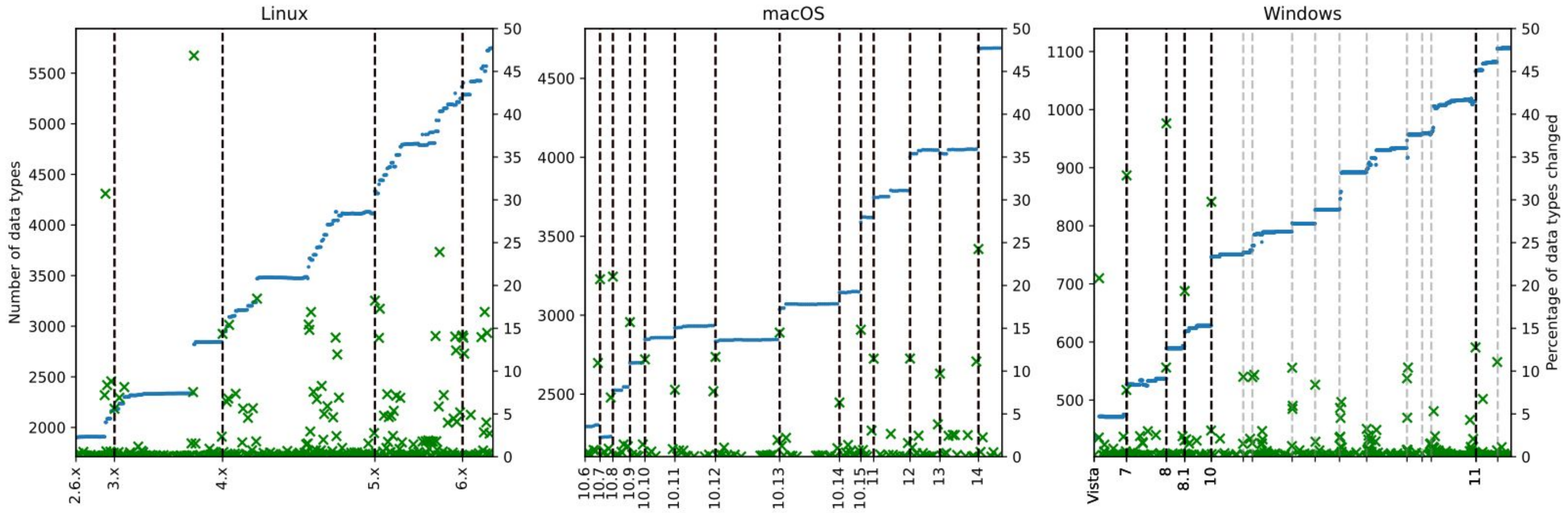
Appendix: Forensics Structures

Linux: address_space, anon_vma, cred, dentry, file, file_system_type, inet_sock, inode, kmem_cache, mm_struct, module, module_kobject, neighbour, neigh_table, nf_hook_ops, path, proto, resource, rtable, seq_operations, sk_buff, sock, sock_common, super_block, task_struct, timespec, tty_struct, vm_area_struct, vfsmount

macOS: cpu_data, dyld_all_image_infos, fileglob, fileproc, fs_event_watcher, inpcb, ifnet, kauth_scope, kmod_info, kmod_info_t, mac_policy_list, mac_policy_list_element, memory_object_control, mount, pmap, proc, protosw, queue_entry, session, sockaddr, socket, socket_filter, sysctl_oid, task, thread, ubc_info, _vm_map, vm_map_header, vm_map_links, vm_map_entry, vm_map_object, vm_object, vm_page, vnode, vnodeopv_desc, zone

Windows: _CM_KEY_NODE, _CMHIVE, _CONTROL_AREA, _DEVICE_OBJECT, _DISPATCHER_HEADER, _DRIVER_OBJECT, _EPROCESS, _ETHREAD, _FILE_OBJECT, _HHIVE, _HANDLE_TABLE, _HANDLE_TABLE_ENTRY, _HEAP_ENTRY, _KMUTANT, _KPCR, _KPRCB, _KPROCESS, _LDR_DATA_TABLE_ENTRY, _LUID_AND_ATTRIBUTES, _MM_AVL_TABLE, _MMADDRESS_NODE, _MMPFN, _MM_SESSION_SPACE, _MMVAD, _MMVAD_FLAGS, _OBJECT_HEADER, _OBJECT_SYMBOLIC_LINK, _OBJECT_TYPE, _PEB, _PEB_LDR_DATA, _POOL_HEADER, _POOL_TRACKER_BIG_PAGES, _POOL_TRACKER_TABLE, _RTL_USER_PROCESS_PARAMETERS, _SUBSECTION, _SECTION_OBJECT_POINTERS, _SEP_TOKEN_PRIVILEGES, _SHARED_CACHE_MAP, _SID_AND_ATTRIBUTES, _SID, _SID_IDENTIFIER_AUTHORITY, _TEB, _TOKEN, _VACB

The Development Cycle Influence the Struct Definitions



Blue dots: total number of C structs/unions

Green crosses: percentage of structs changed between two consecutive kernel versions

Linux: **after 4.x** random and changes, **rolling release model**

macOS: new types at **major releases**

Windows: “commercial code names” are major releases

Structs KConfig Dependency: Forensics Structs

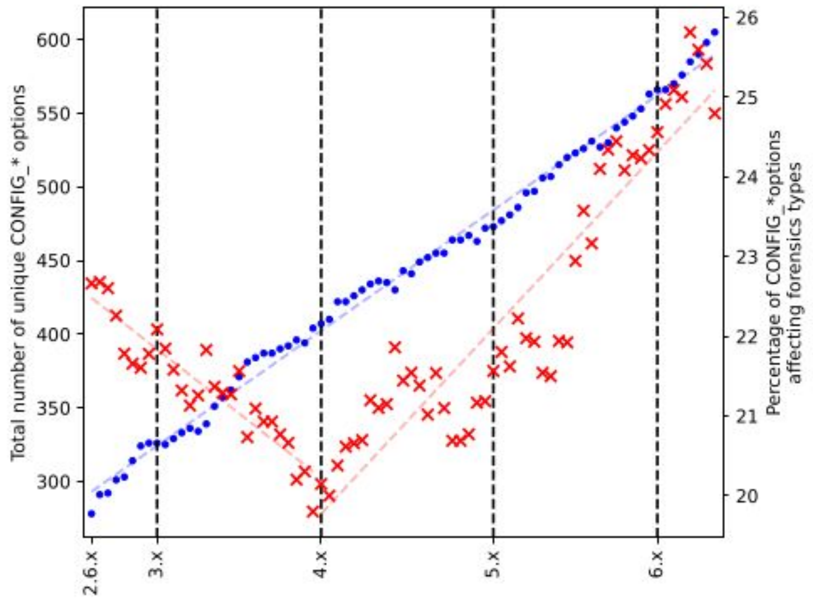
How the KConfig options affect forensics structures?

In blue: Total number of KConfig options

- ⇒ **Linearly increase** across the entire kernel history

In red: KConfig percentage affecting forensics structs

- ⇒ **Decreasing before 4.x and increase after it.**
- **85 (4.0) –> 150 (6.7)** different options


Total number of unique CONFIG_* options
Percentage of CONFIG_*options affecting forensics types
2.6.x
3.x
4.x
5.x
6.x