A Multi-OS Cross-Layer Study of Bloating in User Programs, Kernel and Managed Execution Environments

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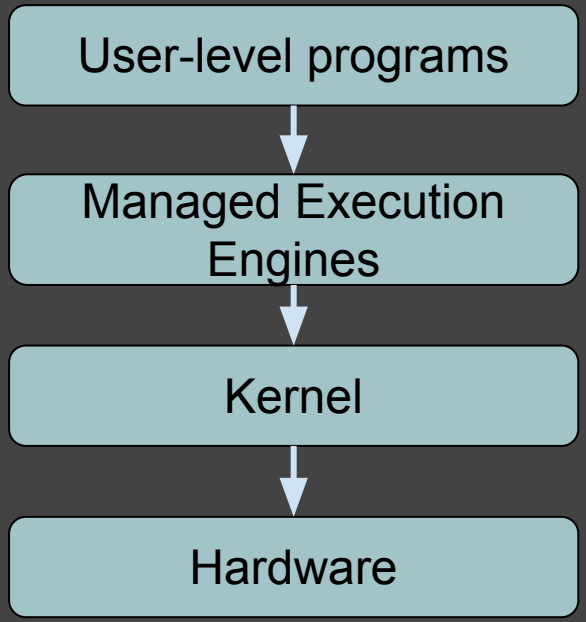
Code Bloating in Software Stack

- Bloating: unused resource in memory
  - Management cost
  - Vulnerabilities
  - Gadget source
- Modular and abstraction
- Occurs across layers



Bloat in User-level Programs

- Bad coding practice --- redundant copies of code, unnecessary inlining, etc.
- Feature-rich generic libraries (e.g., libc, BOOST, FFMpeg)
- Static Approach --- What is the minimum amount of bloat in the program?
  - Recursive dependency analysis
  - Include address-taken functions for indirect code references
- Dynamic Approach --- How much code executes for an average workload?
  - Dynamic analysis in a controlled execution monitor (Pin for user programs and QEMU for kernel)

Lower Bound Bloat Results (Using Static Analysis)

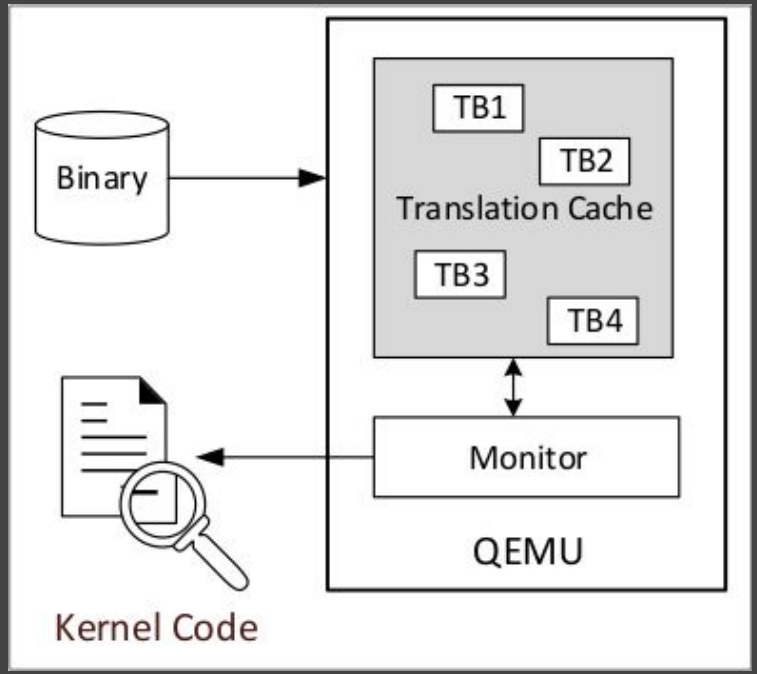
Program	% Library Instructions Required	% Overall Instructions Required	% Library Functions Required	% Overall Functions Required
firefox	67.20%	68.37%	36.42%	38.60%
chrome	69.72%	95.67%	33.57%	36.75%
webbrowser-app	58.86%	59.03%	29.34%	30.22%
vlc	78.22%	78.25%	42.44%	42.79%
rhythmbox	77.92%	77.92%	29.83%	29.83%
evince	70.84%	71.34%	33.61%	36.19%
sublime	68.88%	84.95%	39.13%	41.42%
gnome-calculator	68.59%	69.21%	34.02%	36.18%
git	62.70%	78.11%	22.75%	29.11%
clang	53.99%	73.91%	34.32%	56.83%
g++	52.36%	64.37%	23.90%	29.58%
make	52.13%	56.06%	23.11%	27.75%
Average	**65.12%**	**73.10%**	**31.87%**	**36.27%**

User-level Programs Average Bloat Results

Program	Workload	% Instructions Executed in Libraries	% Overall Instructions Executed	% Functions Executed in Libraries	# Unique Syscalls (out of 402)
firefox	Open top 10 websites in Alexa's list	28.66%	28.70%	17.04%	101
webbrowser-app	Open google.com and youtube.com. Play a video on youtube.com.	12.70%	12.76%	15.28%	93
vlc	Play 1 song	12.44%	12.44%	10.54%	80
libreoffice	Create, write and save a new word file.	23.41%	23.41%	16.03%	86
sublime	Create, write and save a new word file.	26.66%	38.12%	16.85%	67
gnome-calculator	Add and subtract numbers.	35.18%	36.25%	21.35%	59
git	Clone a respository	12.61%	11.78%	6.71%	47
clang++	Compile a C++ program	6.63%	10.32%	8.62%	23
g++	Compile a C++ program	4.52%	17.57%	2.53%	17
make	Run make on a C++ project.	11.97%	18.20%	6.22%	26
Average		**17.48%**	**20.96%**	**12.12%**	**59.9**

Measuring Bloat in Kernel

- Linux kernel: “bloated and huge”*, monolithic
- Measuring kernel bloat is hard! [DECAF, TSE’16]
- Light-weight Qemu-based kernel tracer
  - Intercept translation state
  - No need to acquire CPU state



* Torvalds, Linus. LinuxCon, 2009

Bloating in Kernel Results

System Call	Kernel Code Executed (B)		% Kernel Code Executed	
	kFreeBSD	Debian	kFreeBSD	Debian
exit	941961	778361	8.92%	7.89%
exit_group	Not Supported	462053	Not Supported	4.68%
open+close	1076732	964614	10.20%	9.78%
getuid	792612	575879	7.51%	5.84%
execve	1453331	1388650	13.77%	14.07%
getcwd	681763	903860	6.46%	9.16%
write	792519	713358	7.51%	7.23%
getpid	670177	533857	6.35%	5.41%
Average	**915585**	**836939.9**	**8.67%**	**8.48%**

Bloating in Managed Execution Engines

- Designed to support all features.
- Managed programs may use some features
- Dynamic approach: code executed for a typical workload

Bloating in JVM

Program	Workload	# Modules in JVM	% Instructions Executed	% Functions Executed
Eclipse	Created a java program, compiled and executed it.	6	10.50%	25.13%
		8	33.65%	35.45%
Jabref	Created a bibliography file	13	31.88%	30.42%
Jenkins	Installed plugins, created an admin user, and created a pipeline	12	34.51%	32.39%
Average		**10**	**27.63%**	**30.85%**

Bloating in Python Interpreter

Program	Workload	# Modules in python	% Instructions Executed	% Functions Executed
Calibre	Opened and read a book	34	6.75%	4.97%
		34	7.08%	7.66%
Mercurial	Cloned a repository	4	39.76%	69.23%
		6	40.84%	44.44%
Pip	Installed a program	11	14.52%	60.49%
		11	9.21%	60.49%
Ubuntu software center	Installed and removed a program	2	11.33%	53.85%
		16	32.75%	14.32%
		17	44.88%	30.07%
Gramps	Created a family tree	8	54.25%	36.67%
Average		**14.3**	**26.14%**	**38.22%**

Debloating Approaches and Challenges

- Partition problem space into Binary and Source code
  - Wide use of opensource libraries.
- Partition shared libraries into smaller libraries
- Challenges for code removal:
  - Semantic gap across layers, Code sharing, Context sensitive approach
- Quantifying the security benefits of debloating

Questions