GUARNARY: Mitigating Buffer Overflow Using Hardware Assisted Virtualization Features

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1. CONTEXT AND MOTIVATION

- Buffer overflow is the top one vulnerability in 2021 according to the CWE (Common Weakness Enumeration) [?]
- Secure Allocators (Slimguard [?], Guarder [?], etc.) use *guardians* to prevent and detect overflows
- Existing types of guardians:
  - **Canary**: Low memory overhead + Asynchronous detection
  - **Guard Page**: High memory overhead + Synchronous detection

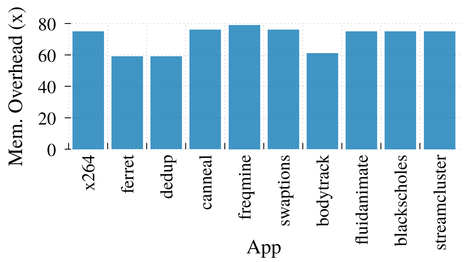


Figure 1: Memory waste of PARSEC when all application's buffers are allocated at the boundary of a guard page using Slimguard as the memory allocator.

3. INTEL SPP: SUB-PAGE WRITE PERMISSION

SPP [?] is a recent Intel hardware virtualization feature that allows the hypervisor to write-protect guest's memory at a sub-page (128B) granularity instead of 4KB.

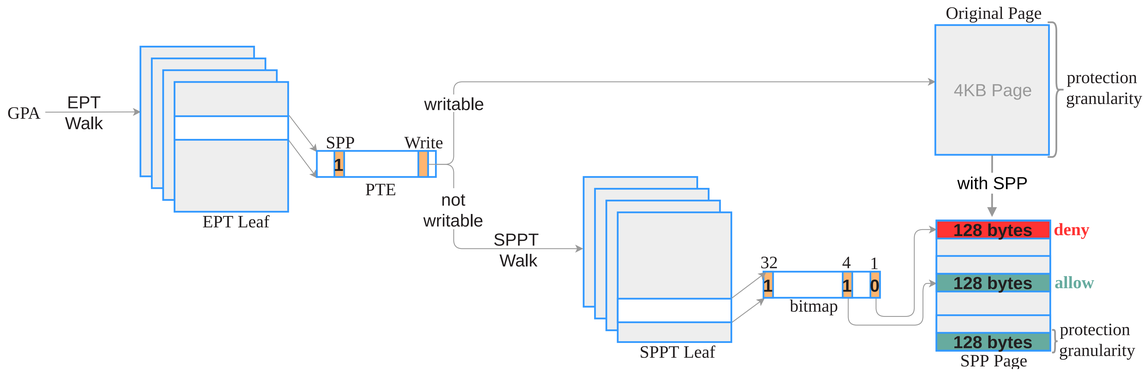


Figure 5: Overview of SPP functioning.

2. DILEMMA: SYNCHRONUOUS DECTECTION VS. MEMORY OVERHEAD

- Security distance: for a vulnerable buffer `b`, it is the number of bytes that separate it from a guardian
- Protection frequency: `F` is called the protection frequency if a guard page is placed for every `F` allocated buffers
- User configures `F` and the allocator combines guard pages with canaries to minimize the security distance while optimizing the memory consumption

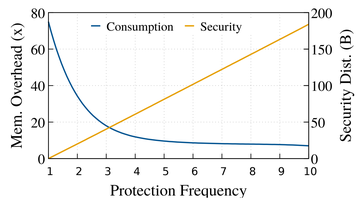


Figure 2: Memory waste and average security distances of PARSEC-`blackscholes` when varying the protection frequency.

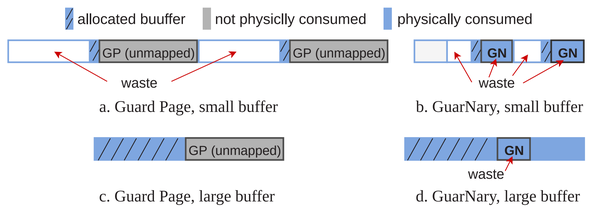
Frequency	1	2	3	4	5	6	7	8	9	10
Buffers protected(%)	100	50	33.33	25	20	16.67	14.28	12.5	11.11	10

Table 1: Proportion of PARSEC-`blackscholes`'s buffers placed at the boundary of a guard page for different values of the protection frequency. The allocator is Slimgard.

4. GUARNARY CHALLENGES

Guarnary is midway between canaries and guard pages, which gives it the advantages of both guardians: low memory consumption and synchronous detection.

(C_1) One size does not fit all:



Guarnary must satify the following equation:

$$\sum GN + \sum RGN < \sum RGP$$

Figure 3: Challenge C_1 illustration. GN stands for Guarnary, $\sum GN$ memory consumed by guarnary, $\sum RGN$ and $\sum RGP$ internal fragmentation waste resp. of guarnary and guard page.

(C_2) Costly hypercalls: SPP is configurable solely by the hypervisor.

(C_3) Physical page heterogeneity: see Figure 4.

(C_4) Protection pattern heterogeneity: the protection pattern is the bitmap of sub-pages that are write-protected within an SPP page.

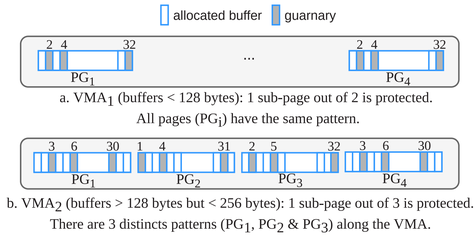


Figure 4: Protection pattern and frequency illustration.

REFERENCES

[1] Cwe/sans top 25 most dangerous software errors. https://www.sans.org/top25-software-errors, 2022.

[2] Beichen Liu et al. Slimguard: A secure and memory-efficient heap allocator. *Middleware*, 2019.

[3] Sam Silvestro, Hongyu Liu, Tianyi Liu, Zhiqiang Lin, and Tongping Liu. Guarder: A tunable secure allocator. In *27th USENIX Security Symposium (USENIX Security 18)*, pages 117–133, Baltimore, MD, August 2018. USENIX Association.

[4] Intel ept-based sub-page write protection support. https://lwn.net/Articles/736322/, October 2017.

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