ASLR: How Robust is the Randomness?

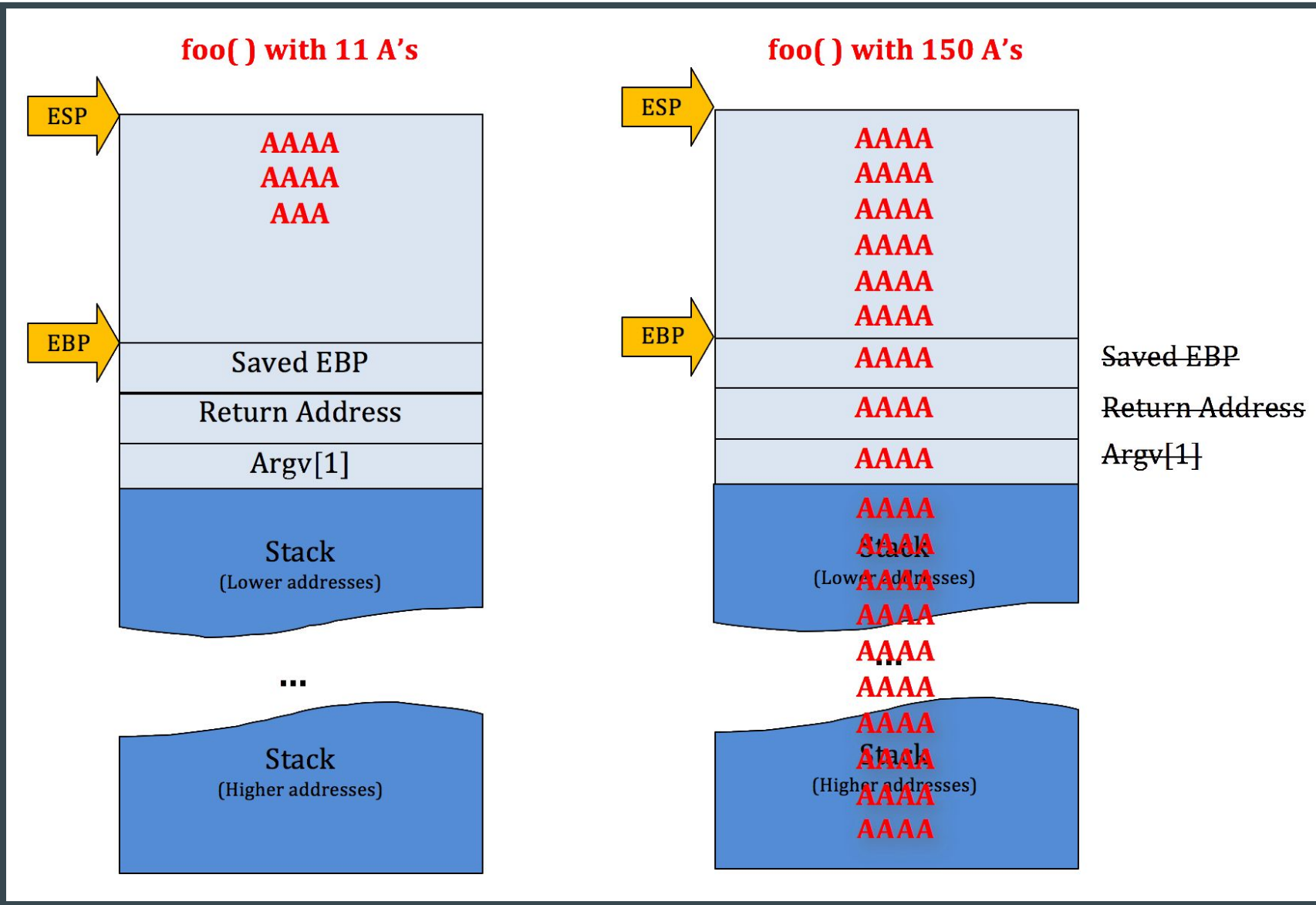
...

Jonathan Ganz

What is Address Space Layout Randomization?

- Provides System-Level Control-Flow Integrity
- Adds Random Memory Offsets to Binaries
- Makes Buffer Overflows Harder to Exploit
  - Does Not Completely Remove Vulnerability
- Strength of ASLR Depends on Entropy of Offsets

What are Buffer Overflows?



https://www.securitysift.com/windows-exploit-development-part-2-intro-stack-overflow/

Why Attackers Perform Buffer Overflows

Why We Use ASLR

- Organizations Often Rely on Third-Party Software
- This Software May Be Vulnerable & Closed-Source
- Extra Hardening Features May Not Be Available
  - CPU Power
  - Thermal Design Power
  - Licensing / Cost
  - Architecture Compatibility

Motivation

- We Rely on Certain Security Features
- How Reliable are these Features?
- How Much Defense Does ASLR Provide?
- Remote Security Evaluation

ASLR Experiment

- Measure Entropy of ASLR Implementations
- Develop Buffer-Overflow-Vulnerable Program
- Develop Attack Program (Inspired by Blind-ROP)
- Evaluate Multiple Operating Systems
  - Debian, OpenBSD, HardenedBSD
  - 32-bit and 64-bit Architectures
- Perform Hundreds of Measurements

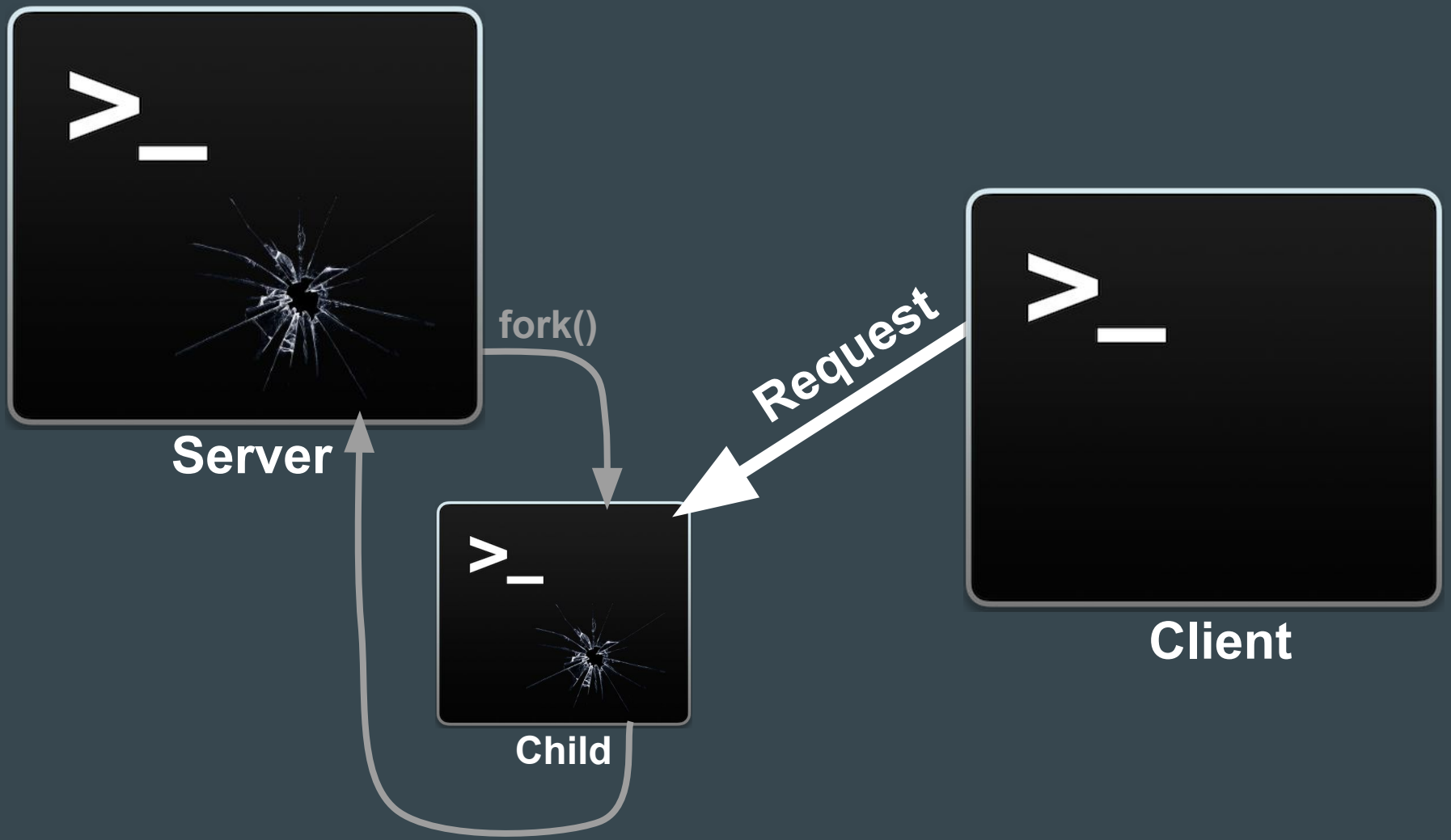
ASLR Assumption

- 64-bit Operating Systems Represent Memory with More Bits than their 32-bit Variants
- The 64-bit Versions Have More Bits Available to Manipulate Through ASLR
- 64-bit Implementations of ASLR Should Provide More Entropy than 32-bit Implementations

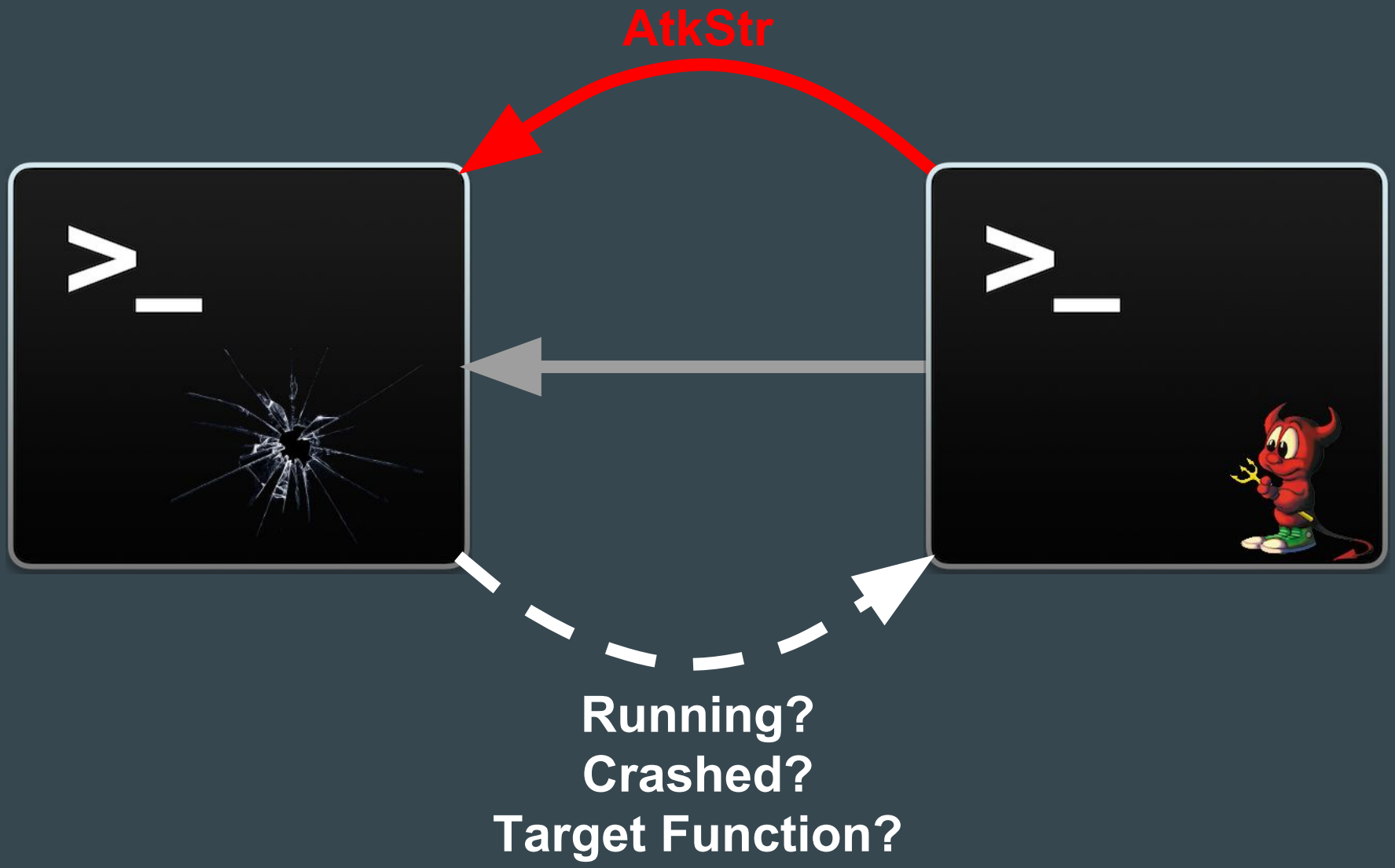
Claims of Entropy Provided by ASLR

	Entropy Claimed
64-bit HardenedBSD	30 bits
64-bit Debian	28 bits
64-bit OpenBSD	25 bits
32-bit Debian	24 bits
32-bit OpenBSD	16 bits
32-bit HardenedBSD	14 bits

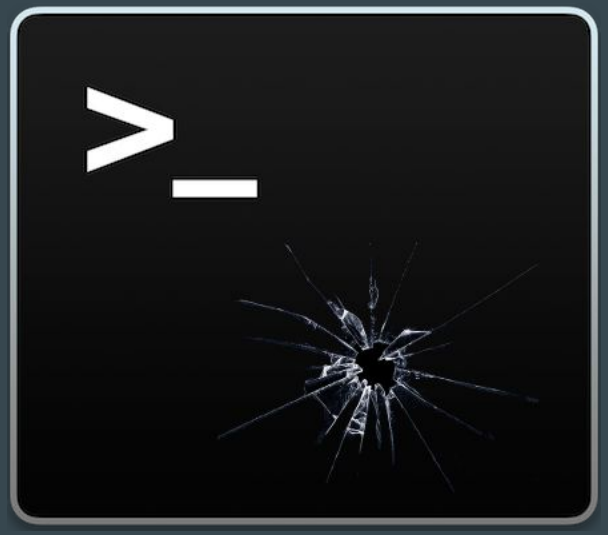
Vulnerable Network Service



Attacking the Vulnerable Service



Attack Strategy



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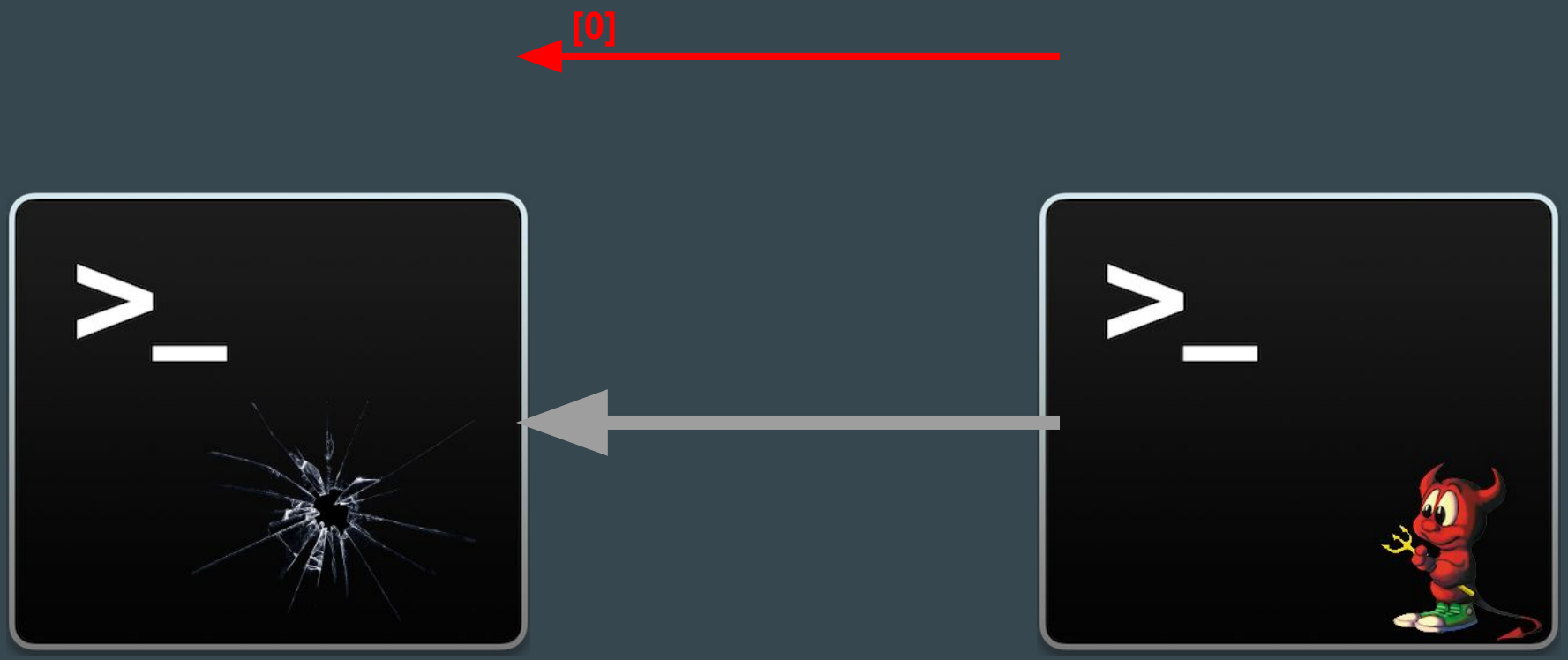

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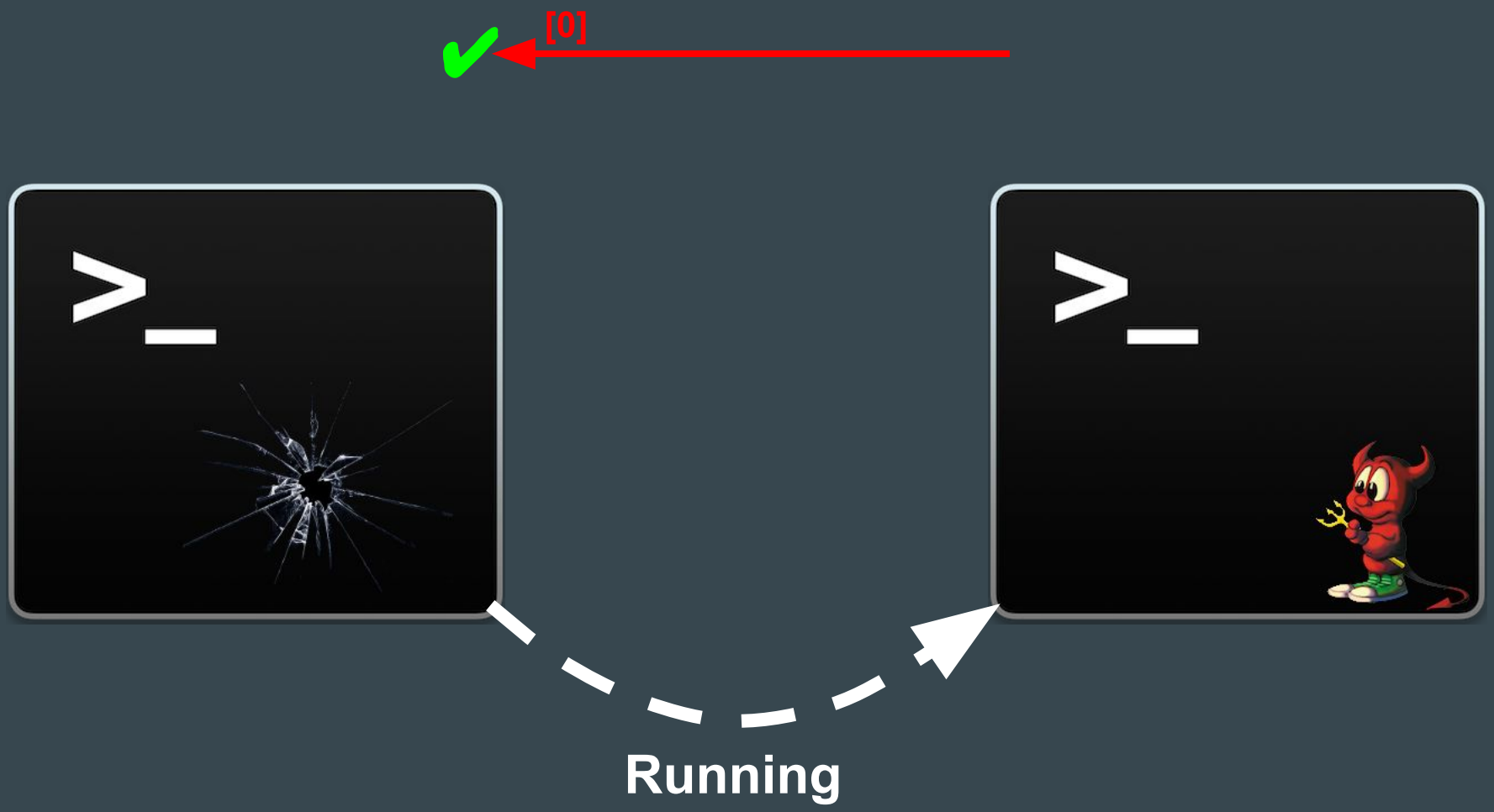

Attack Strategy

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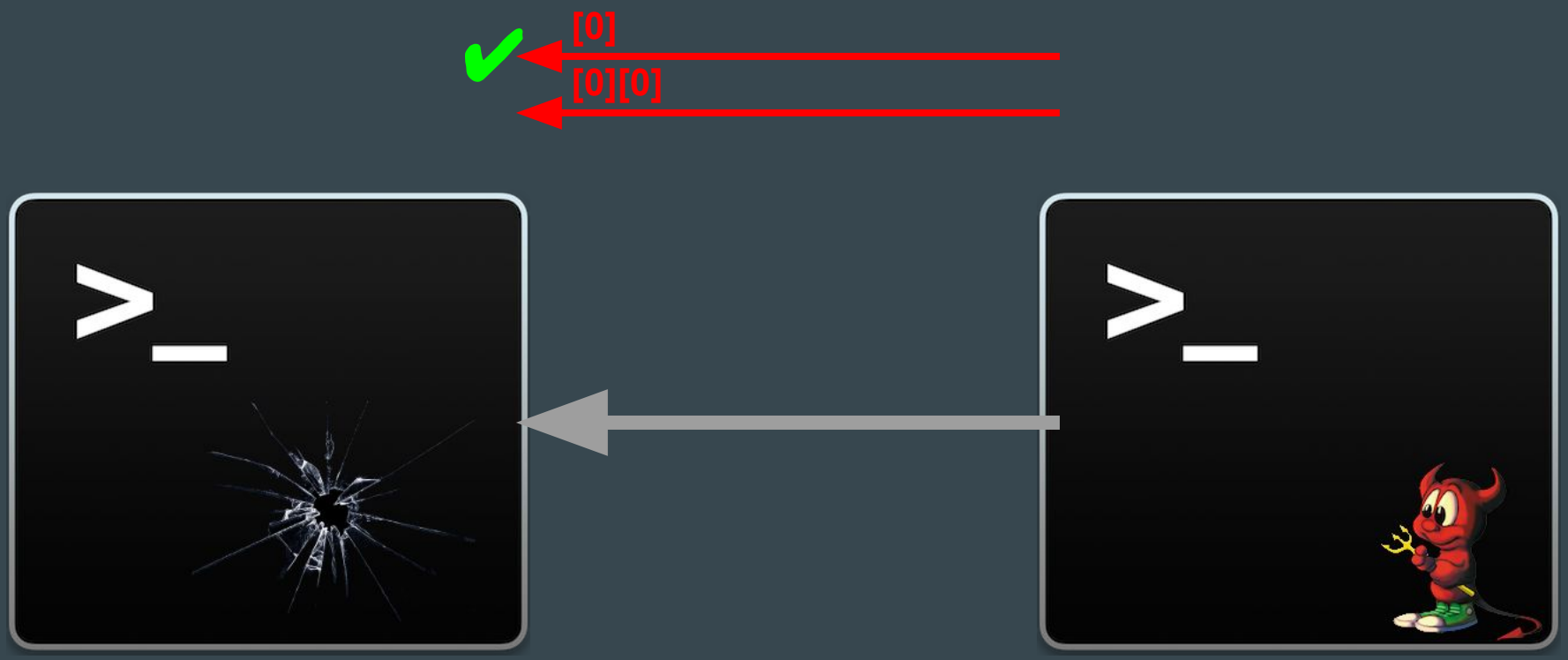

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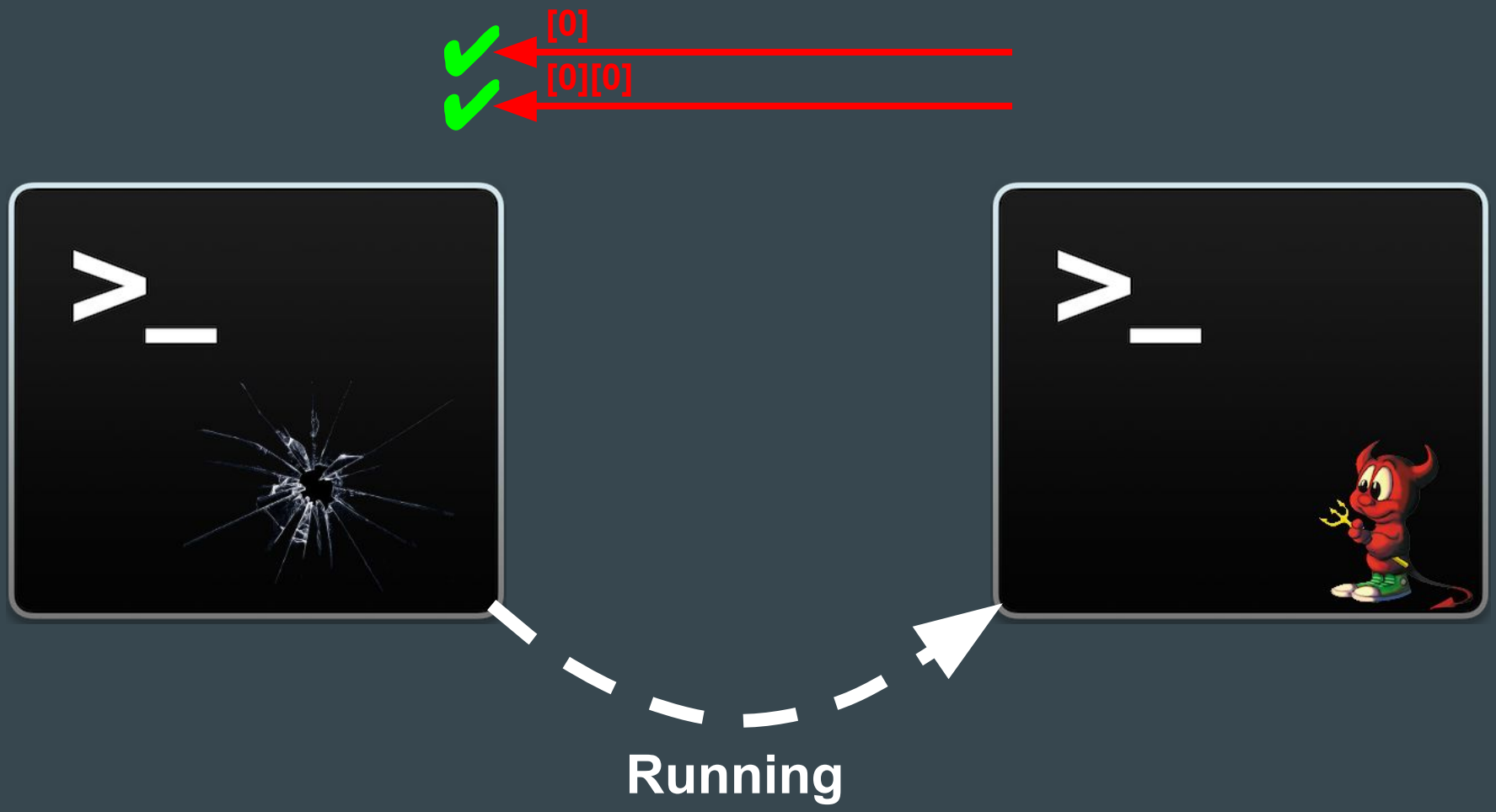

Attack Strategy

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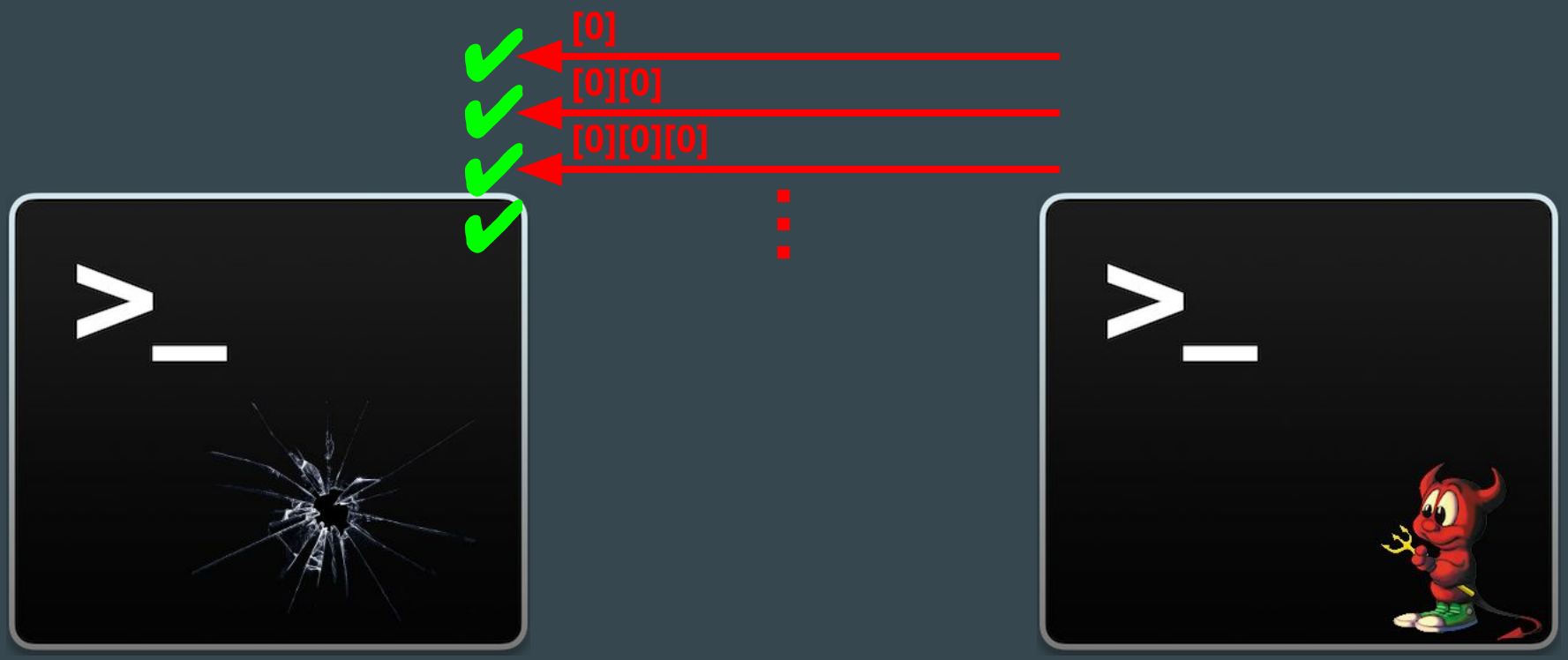

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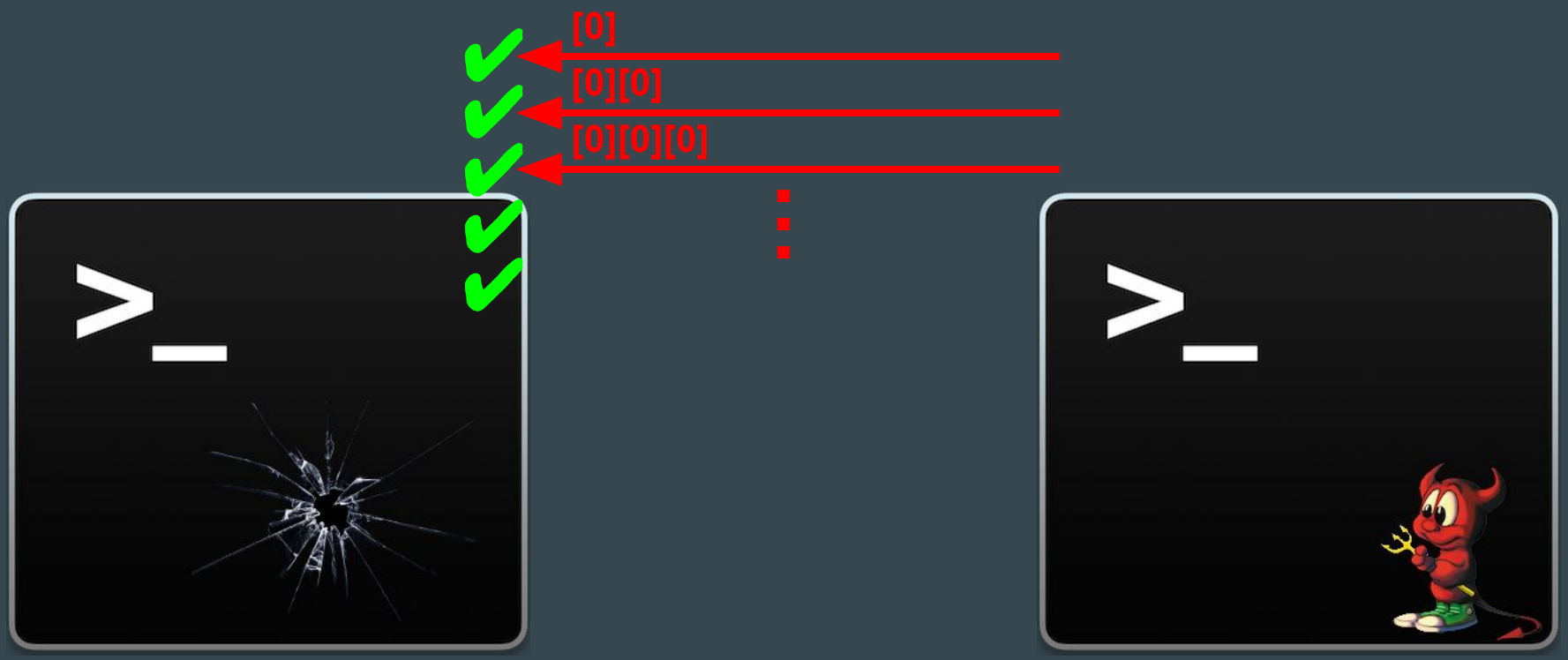

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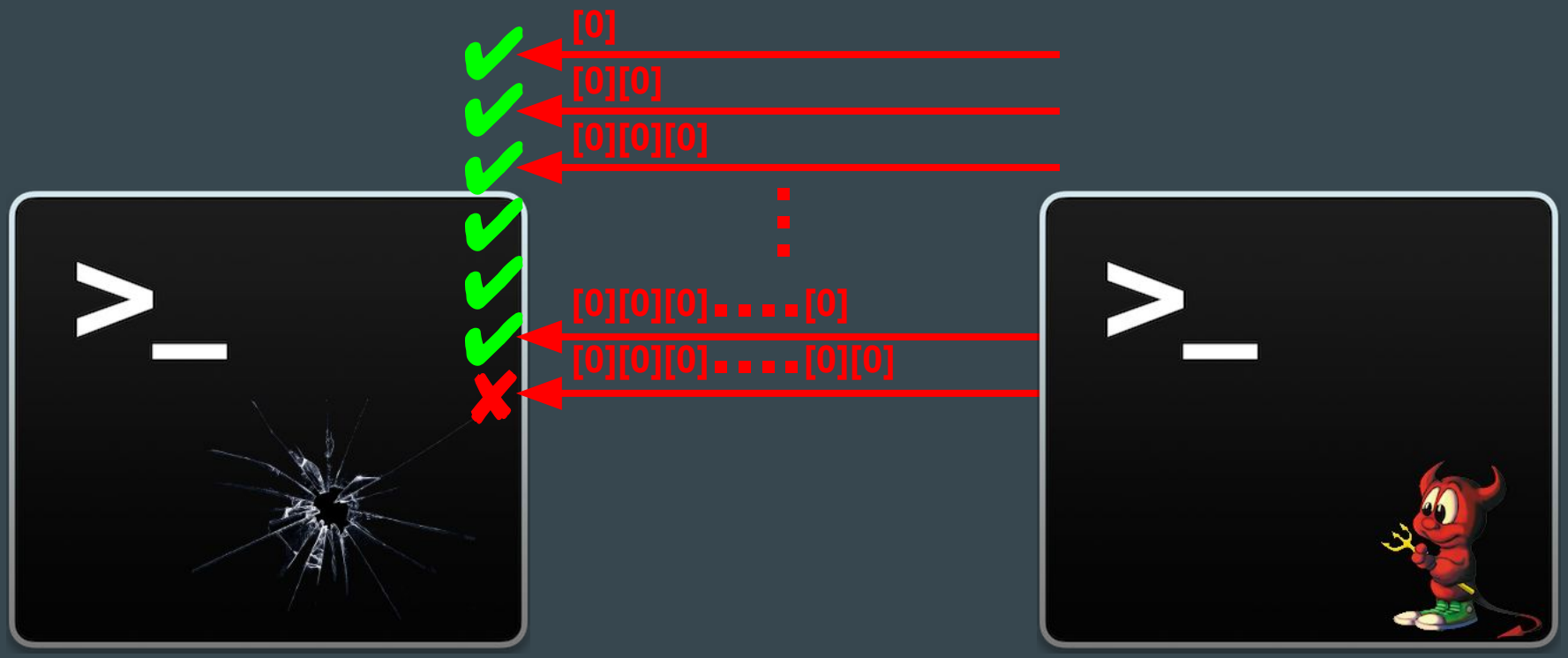

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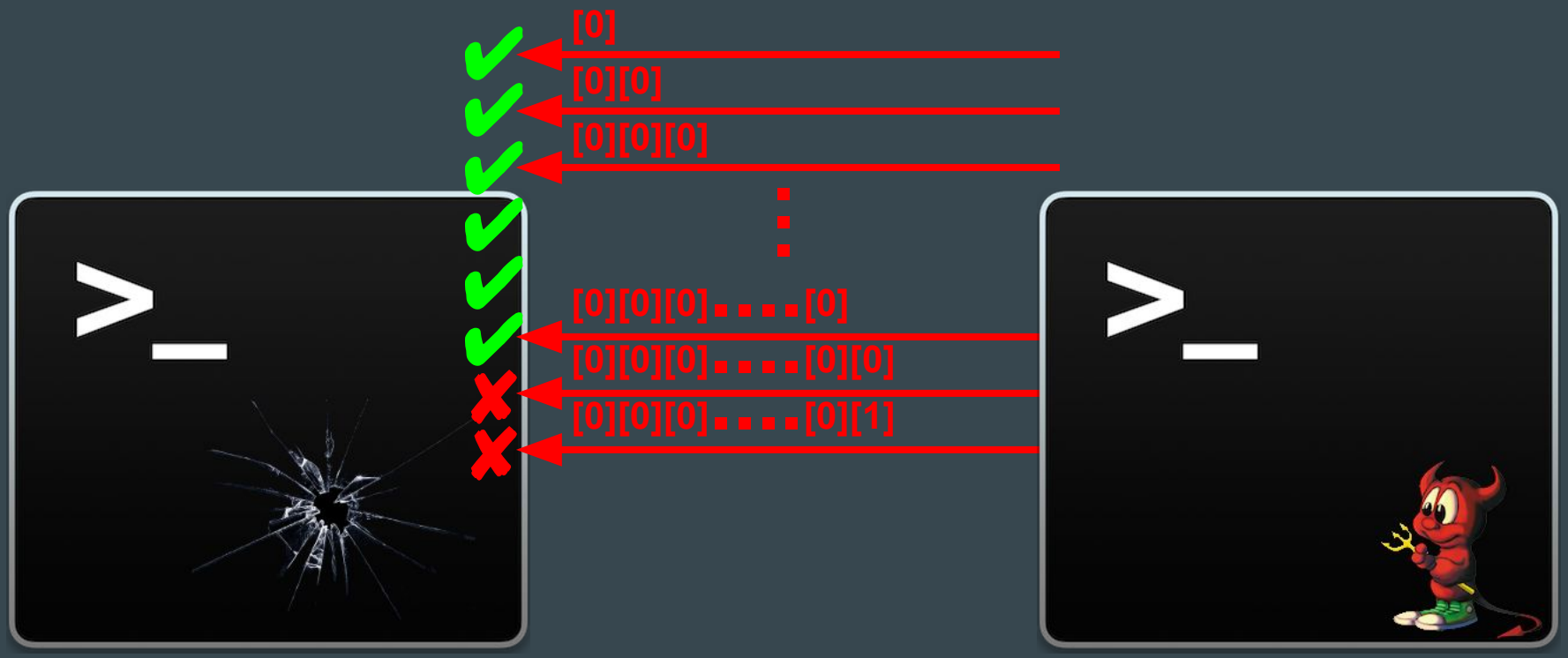

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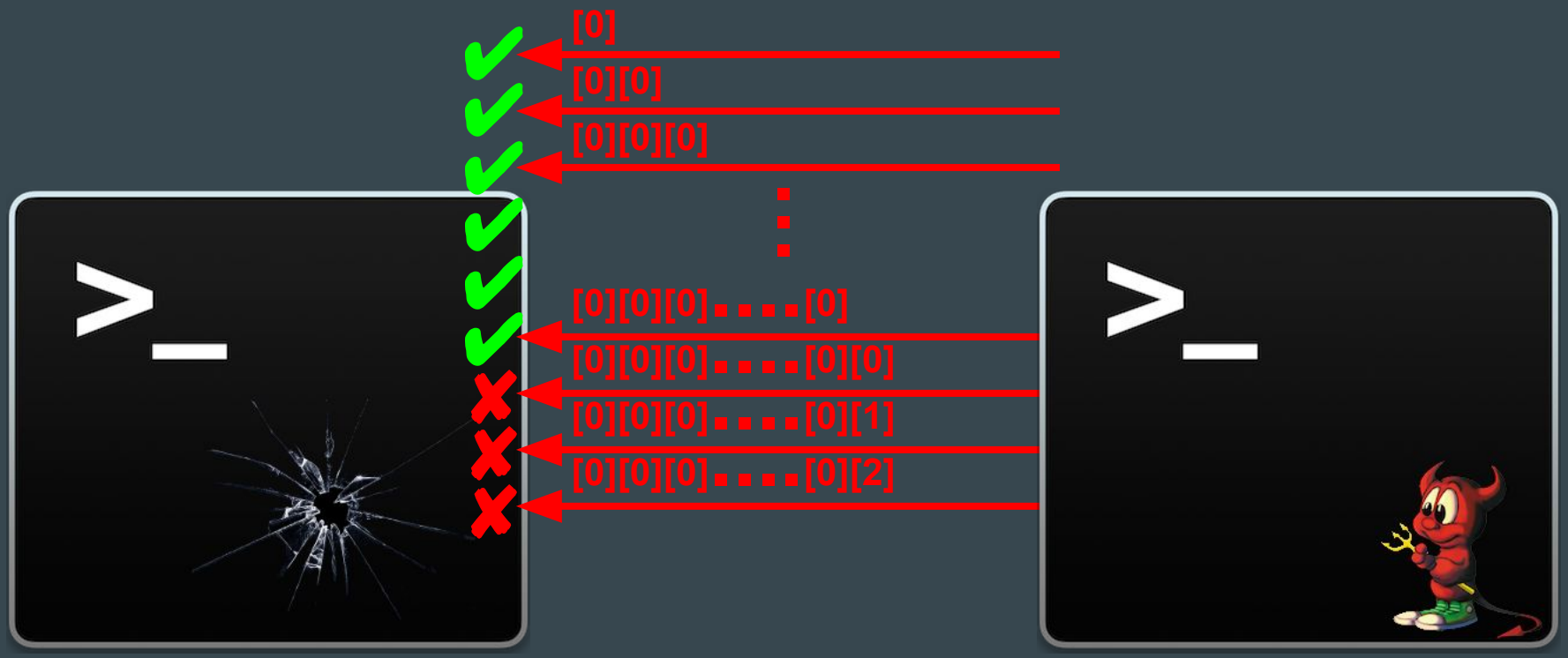

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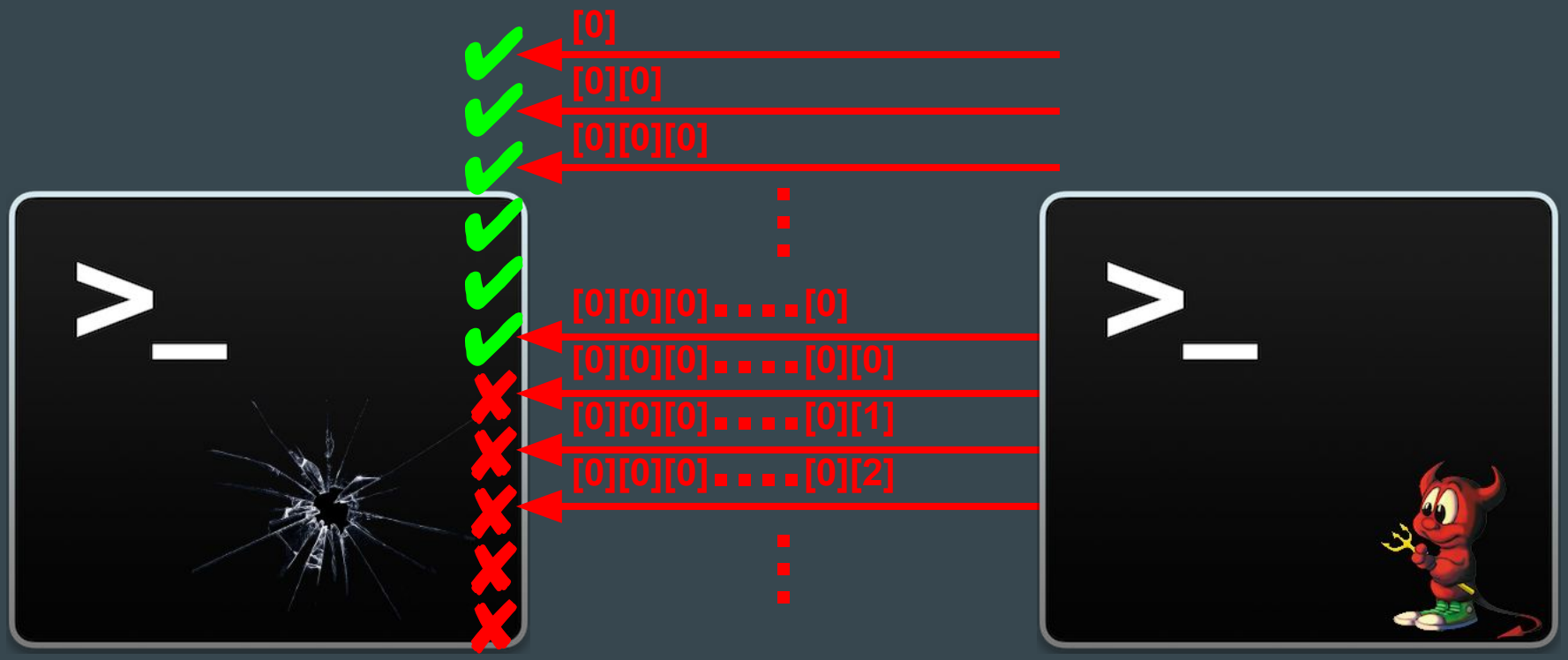

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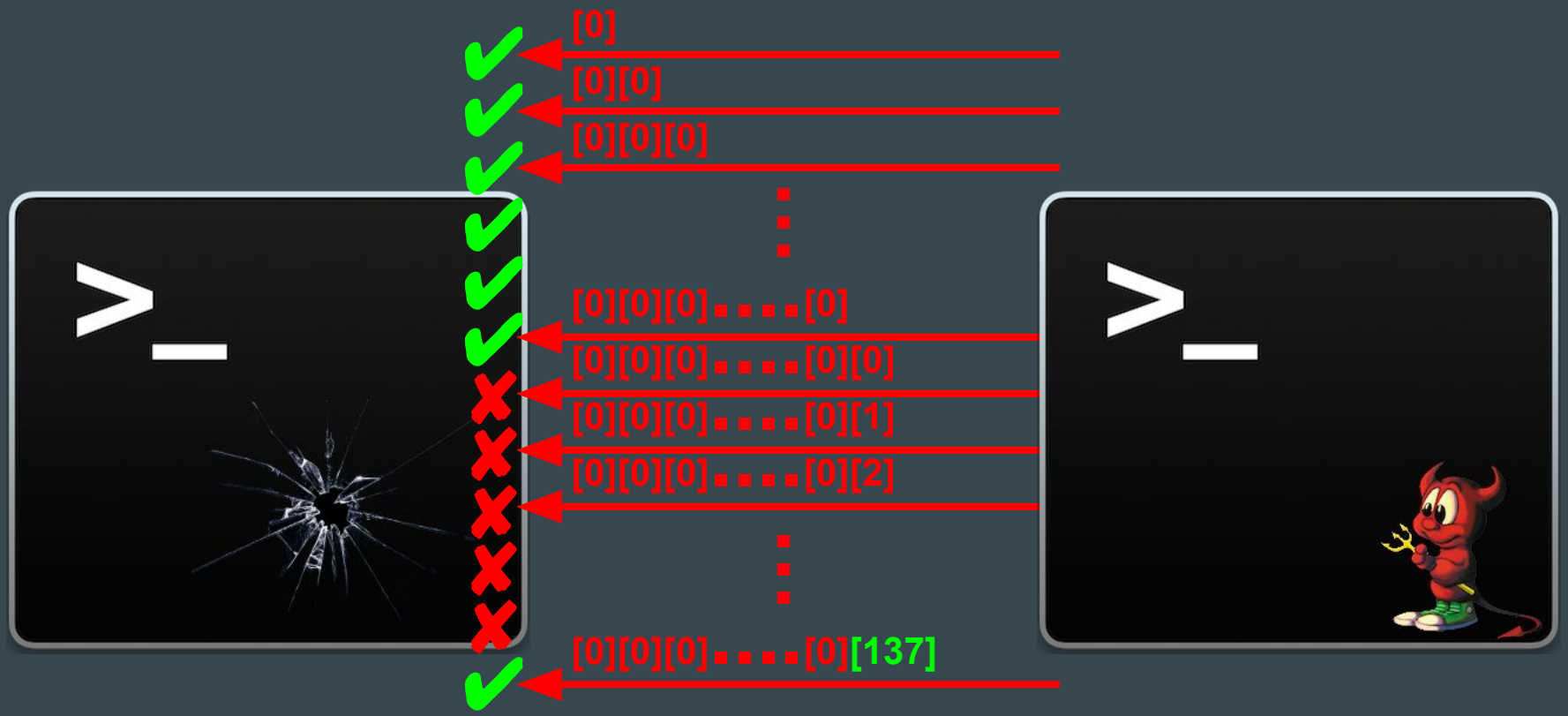

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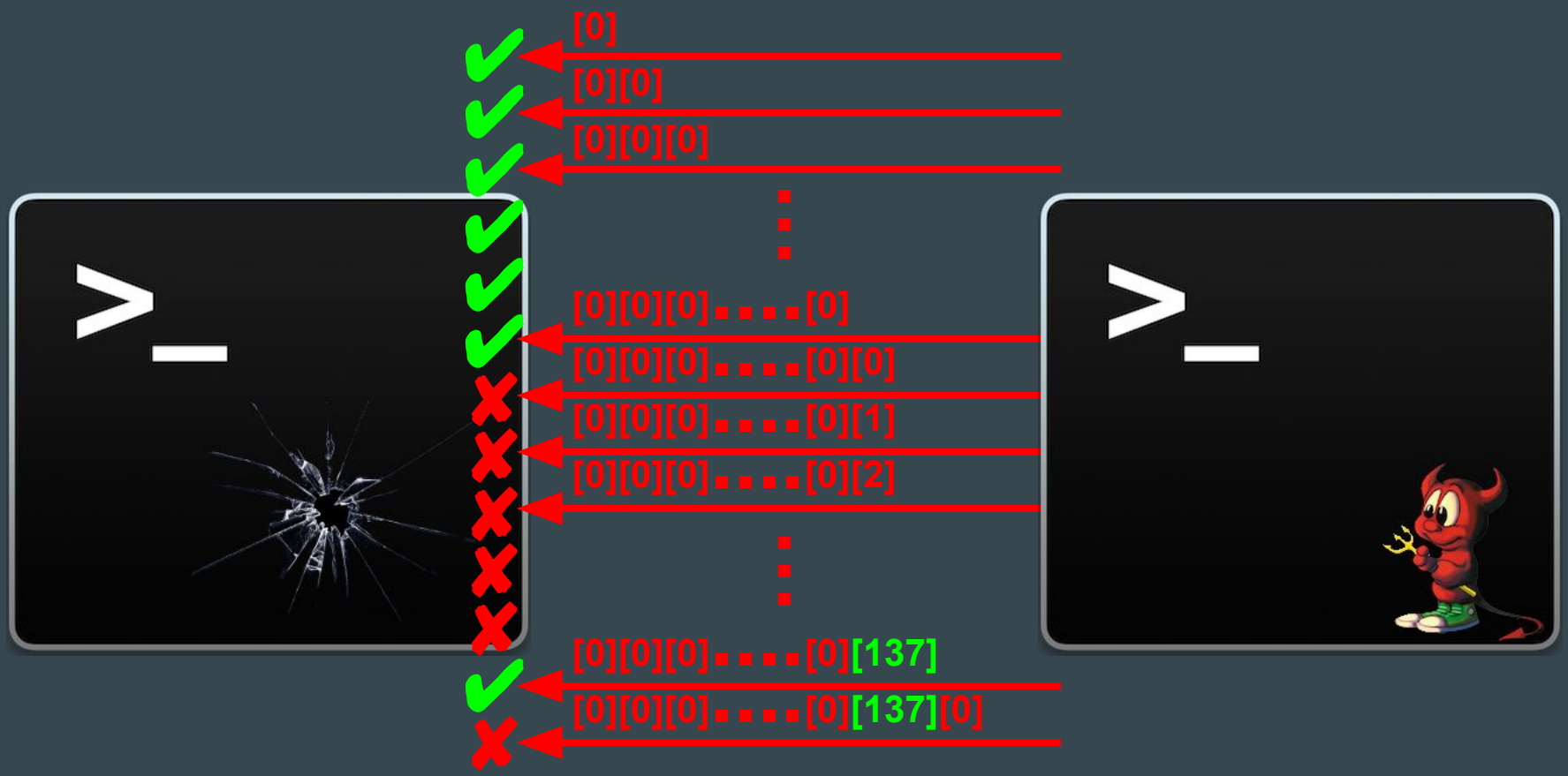

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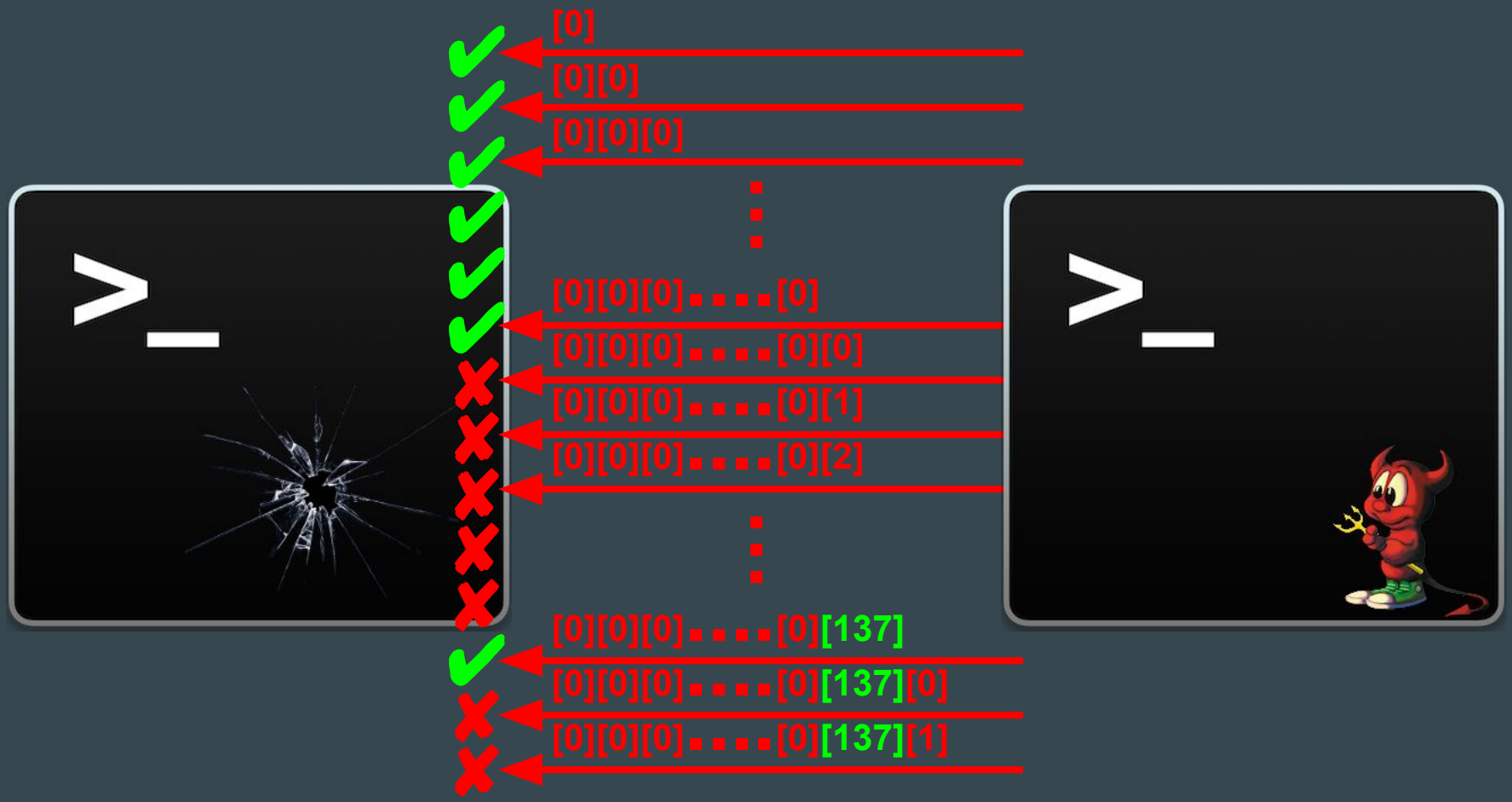

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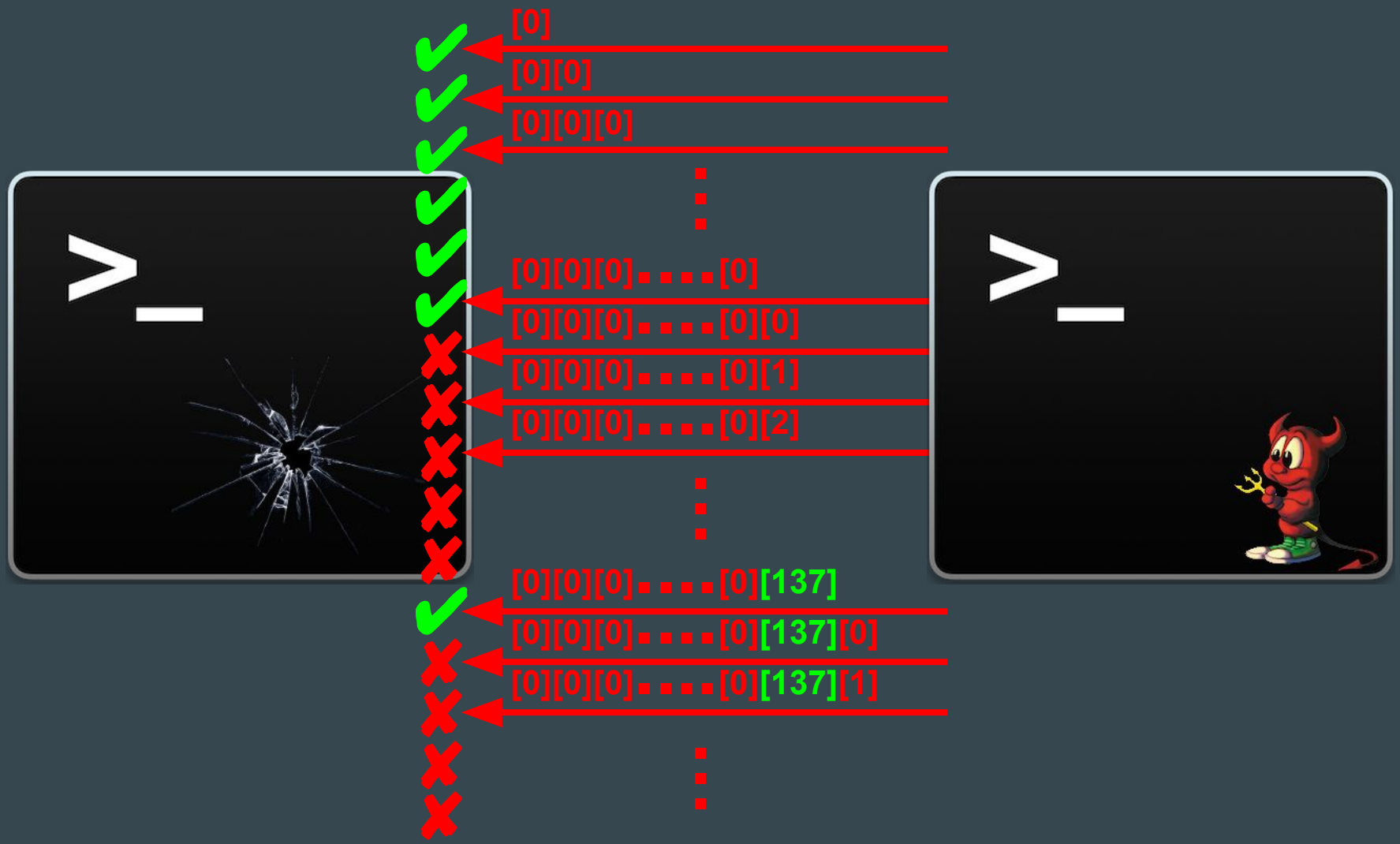

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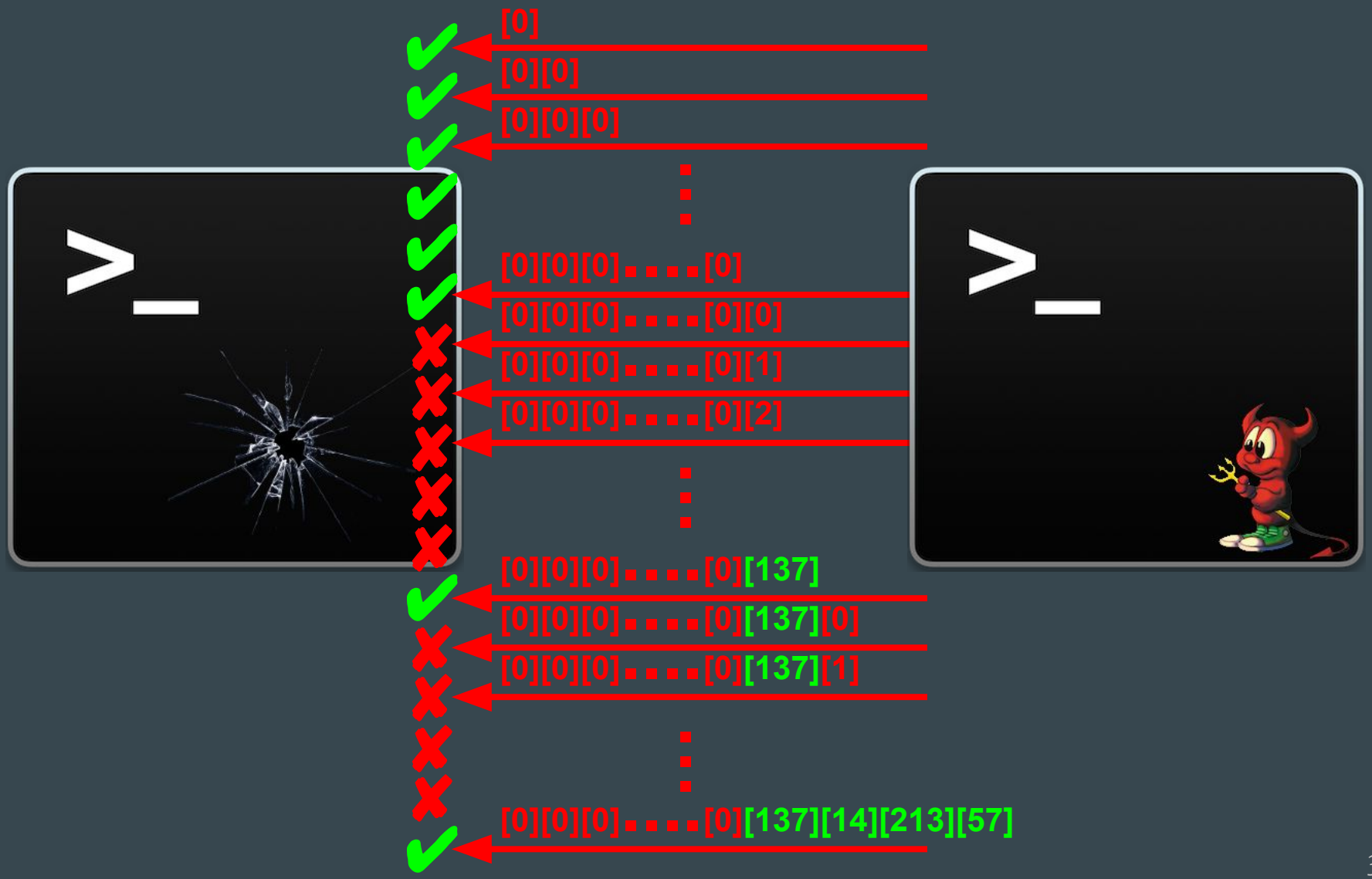

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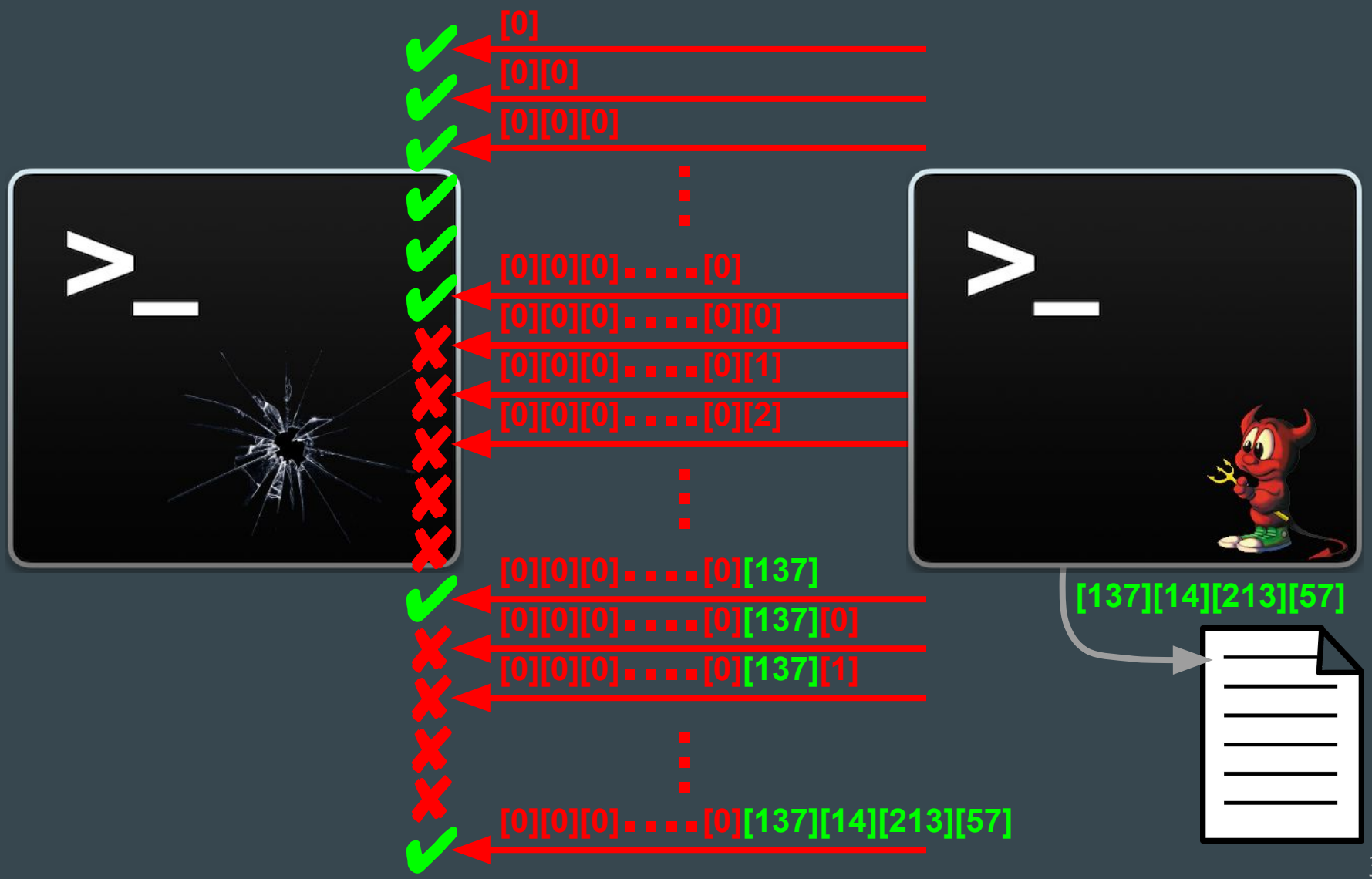
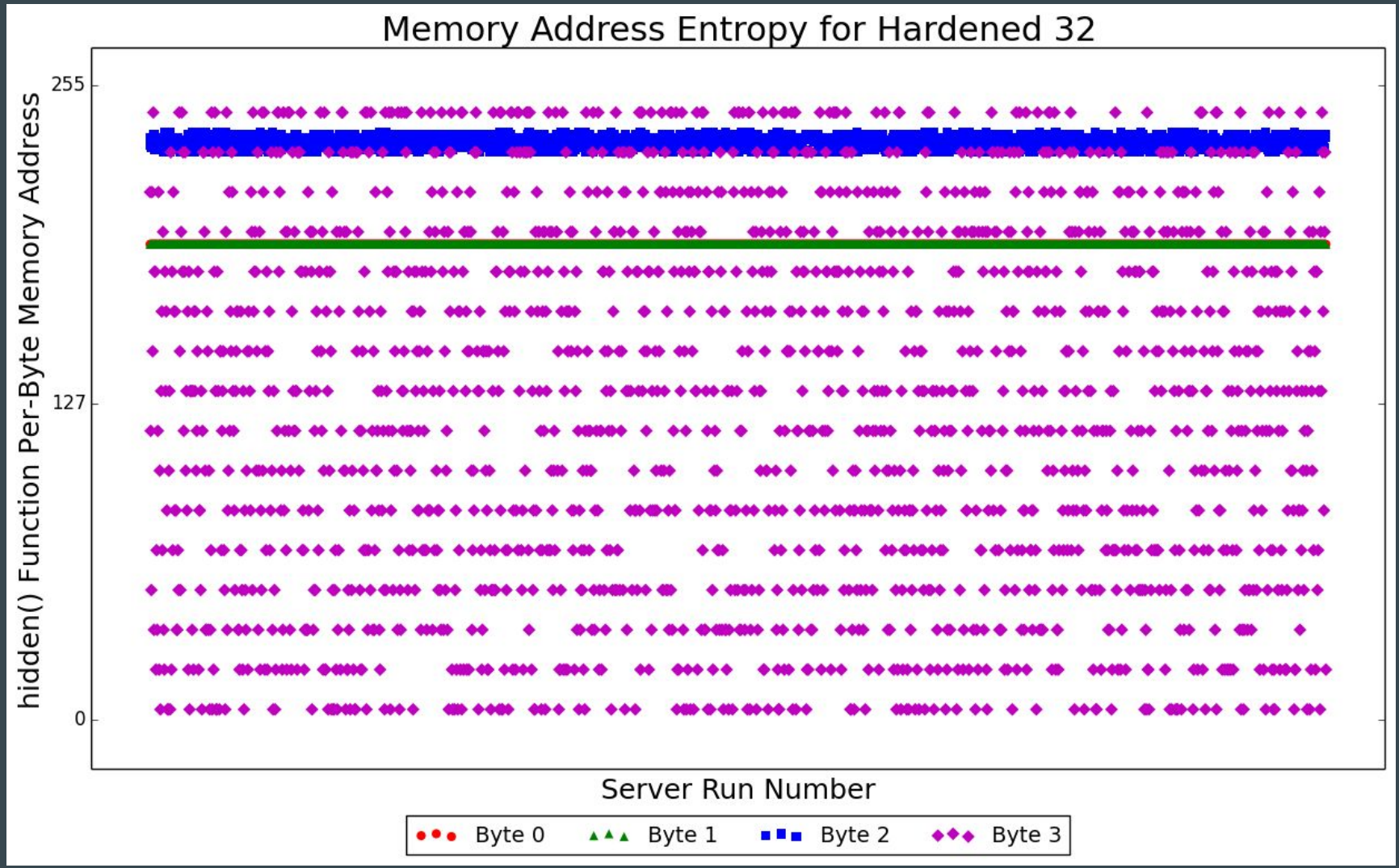
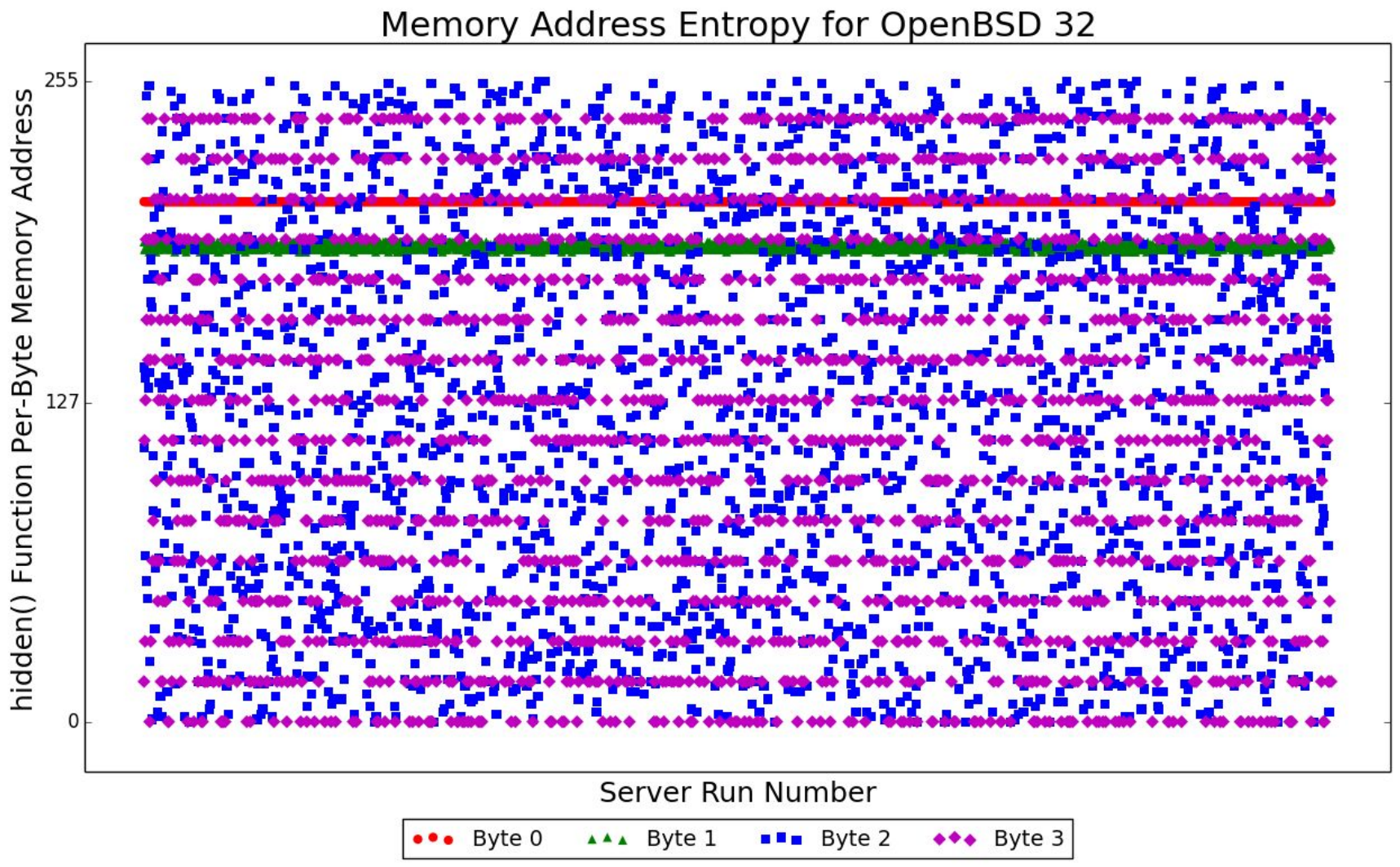


ASLR Results - 32-bit HardenedBSD



ASLR Results - 32-bit OpenBSD



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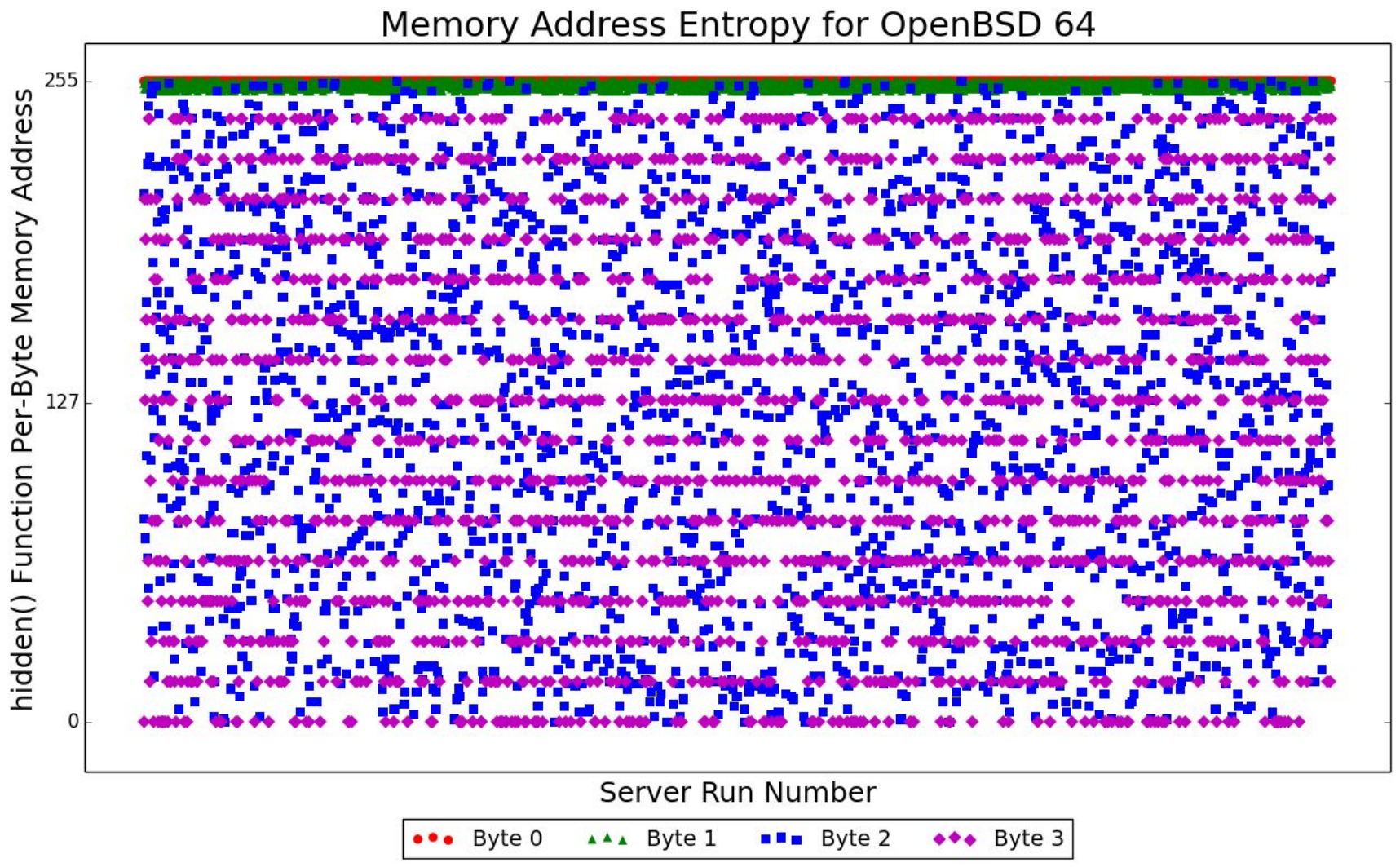
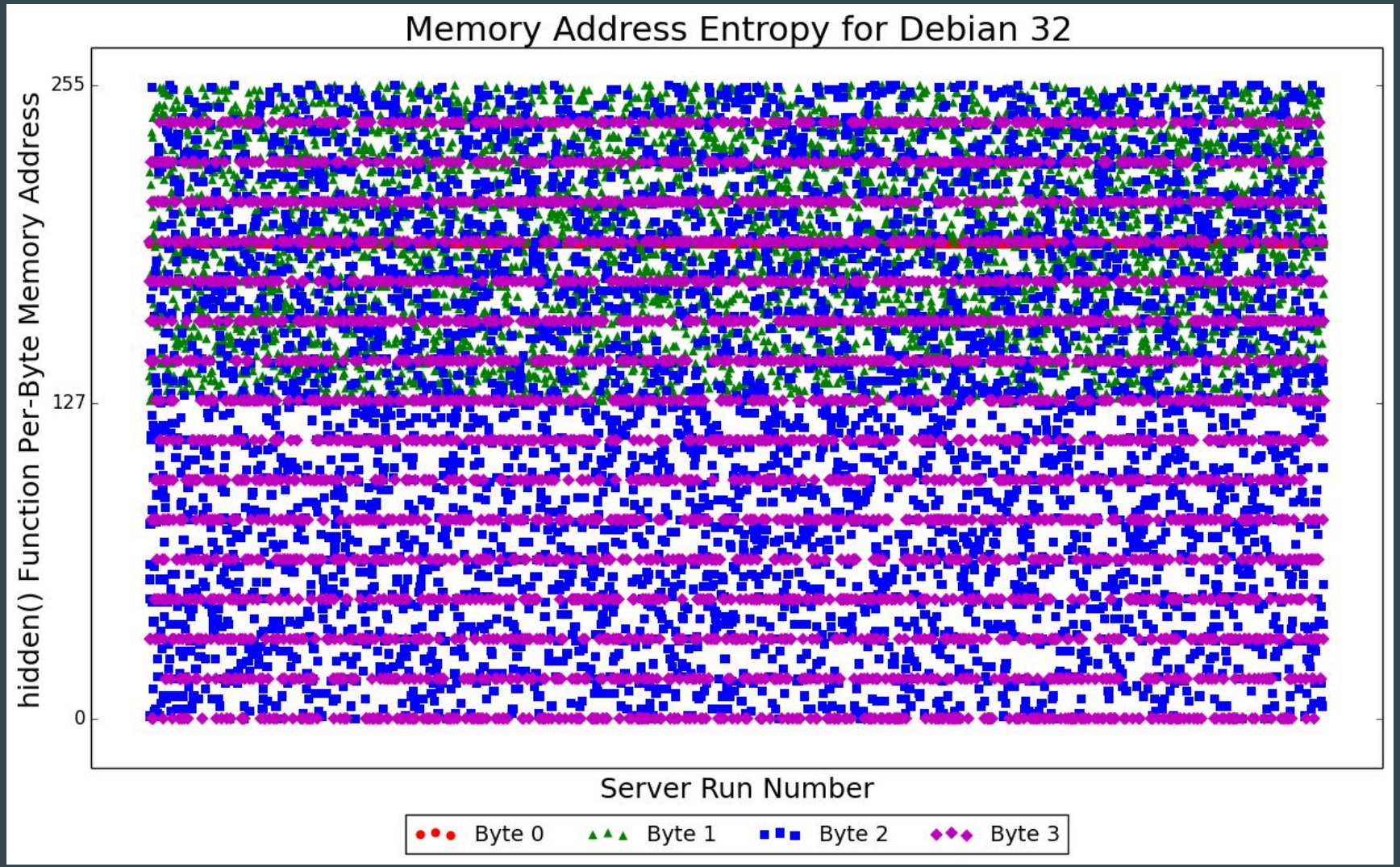
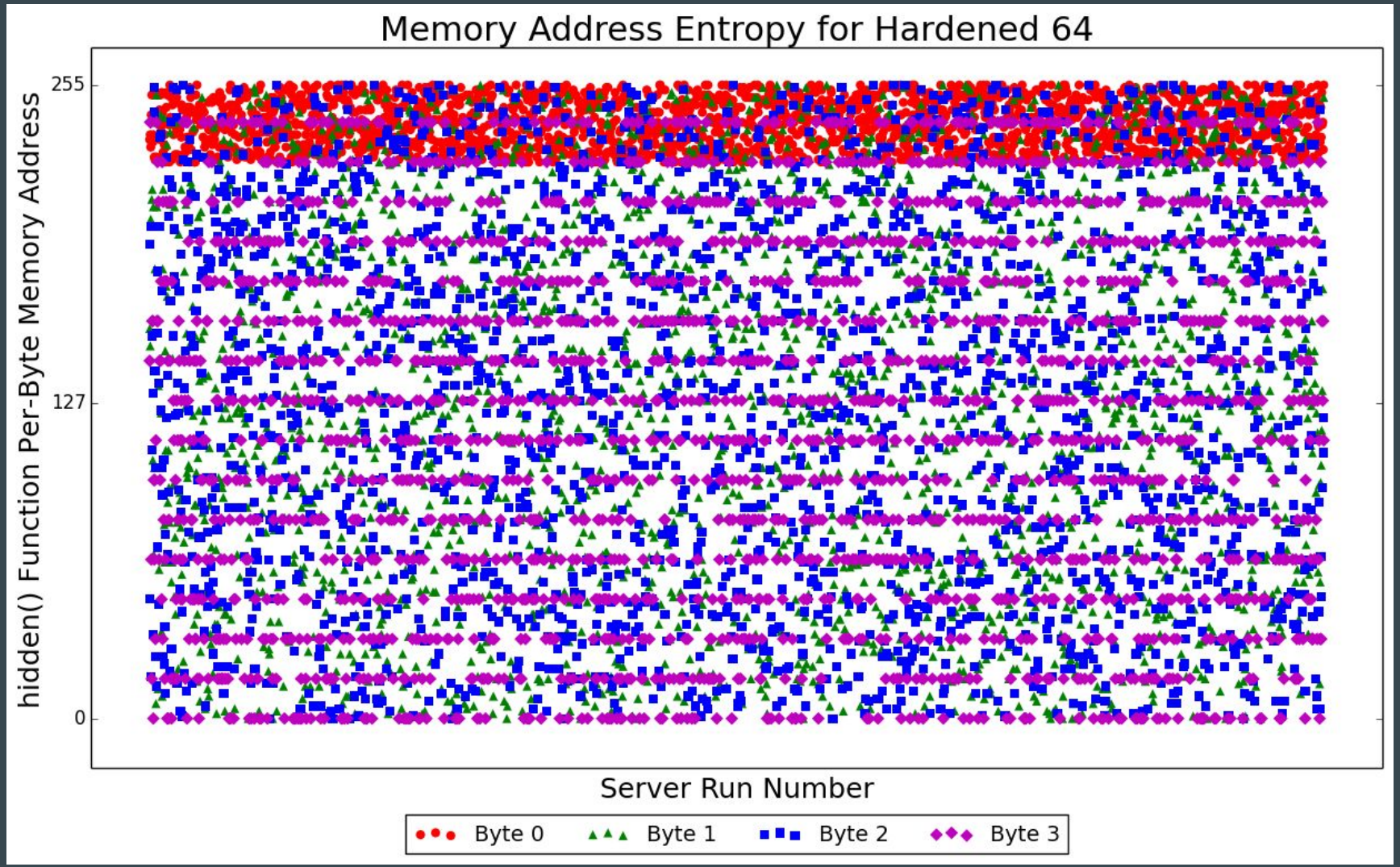


ASLR Results - 32-bit Debian Linux



ASLR Results - 64-bit HardenedBSD



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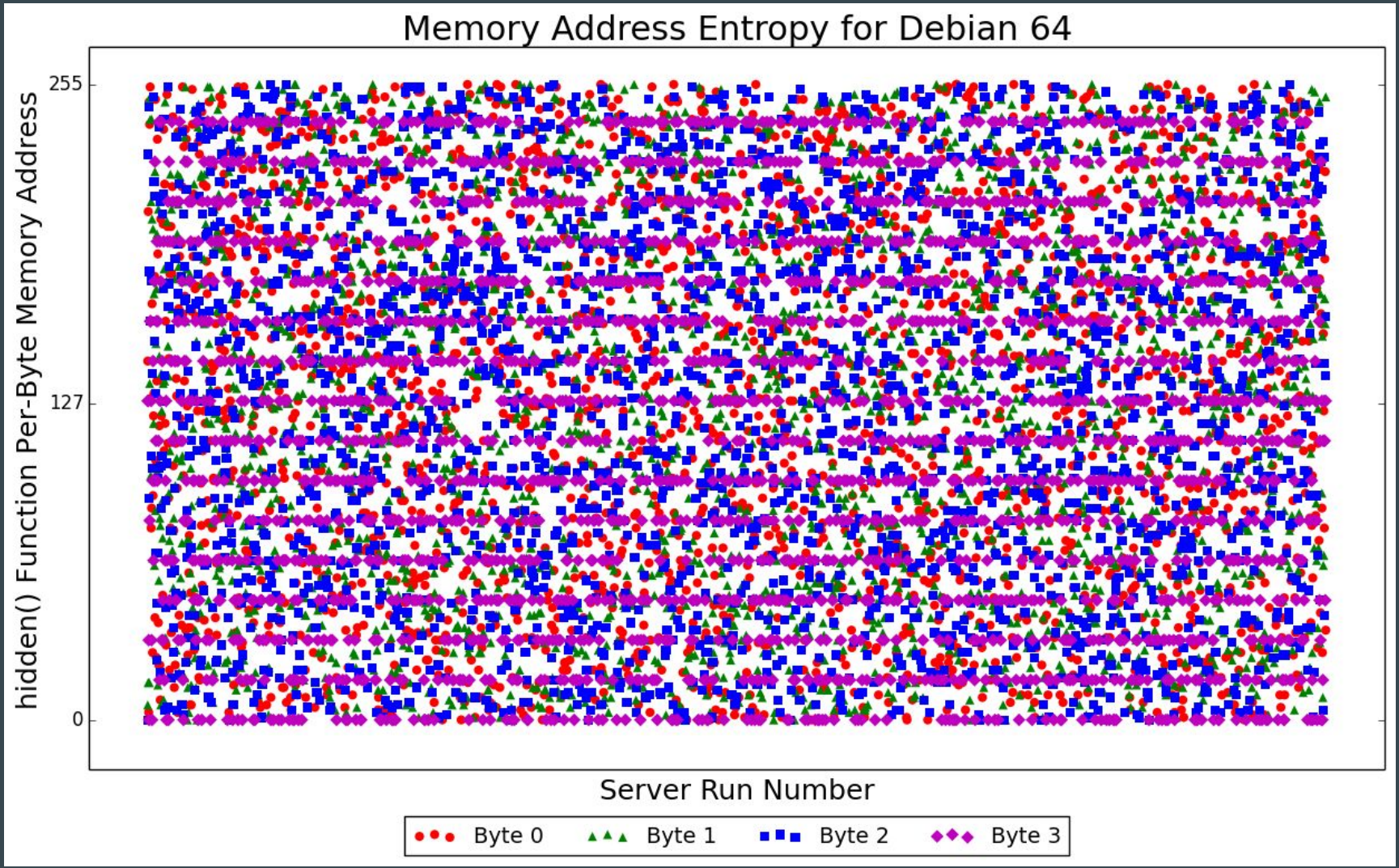

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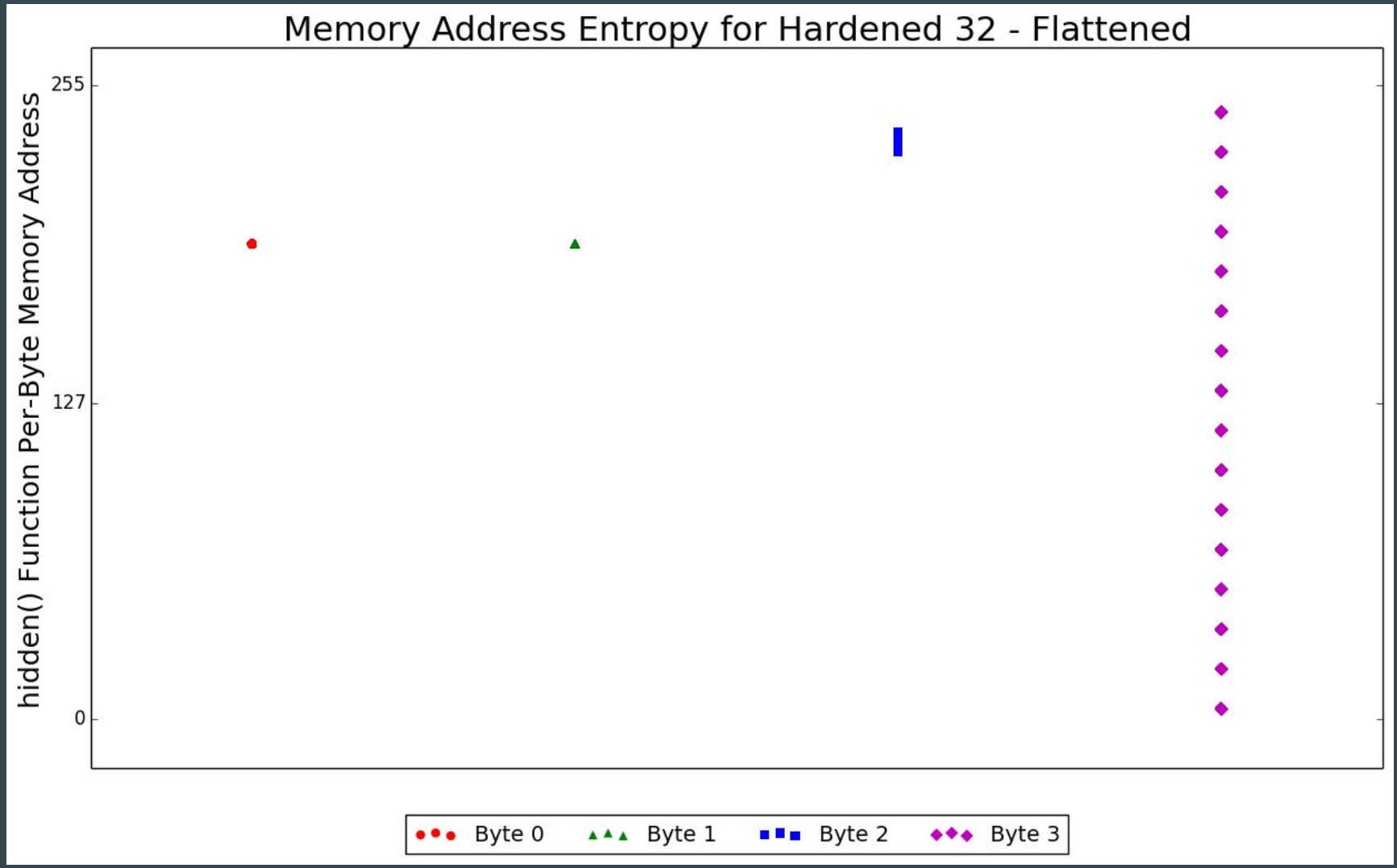

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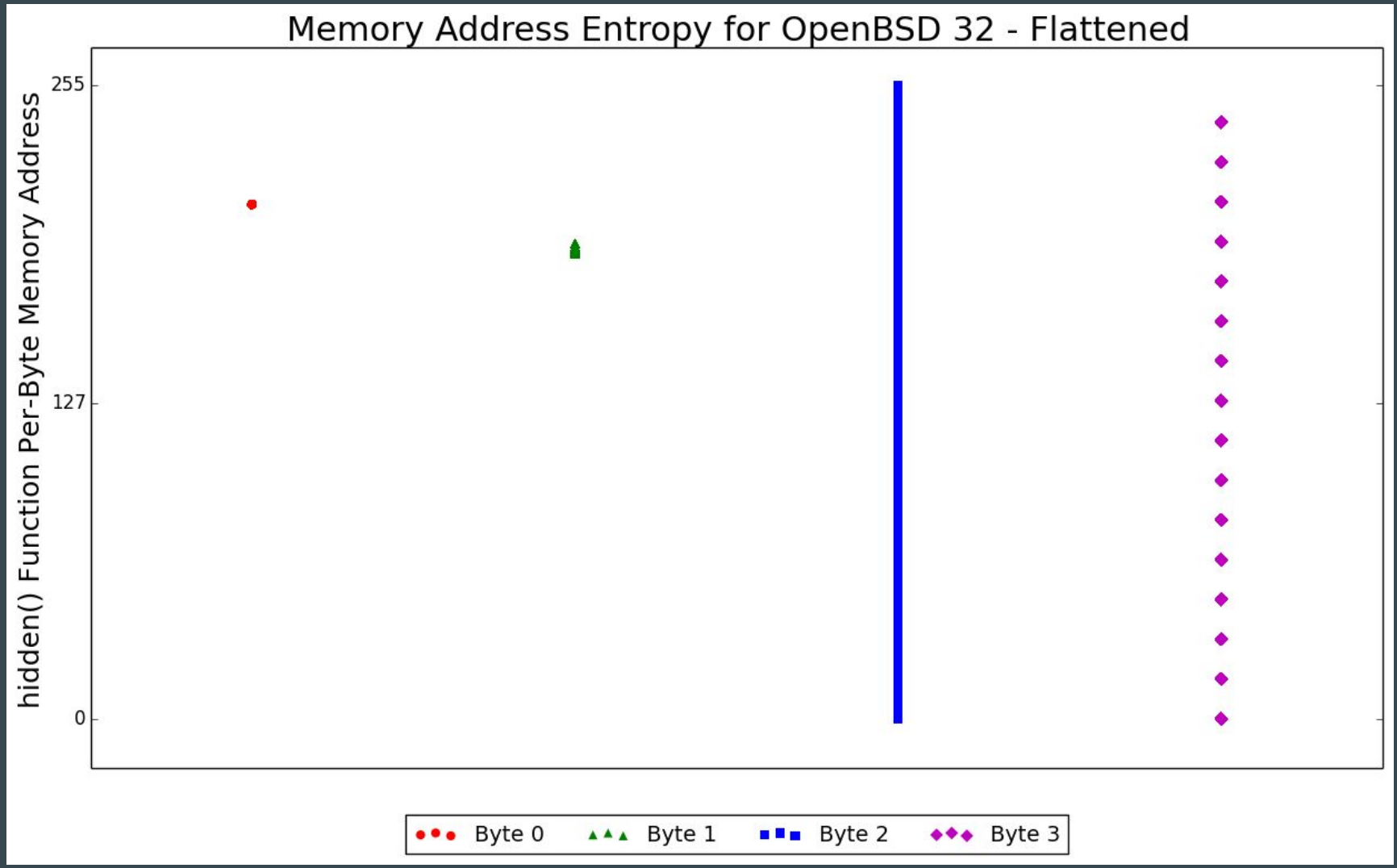

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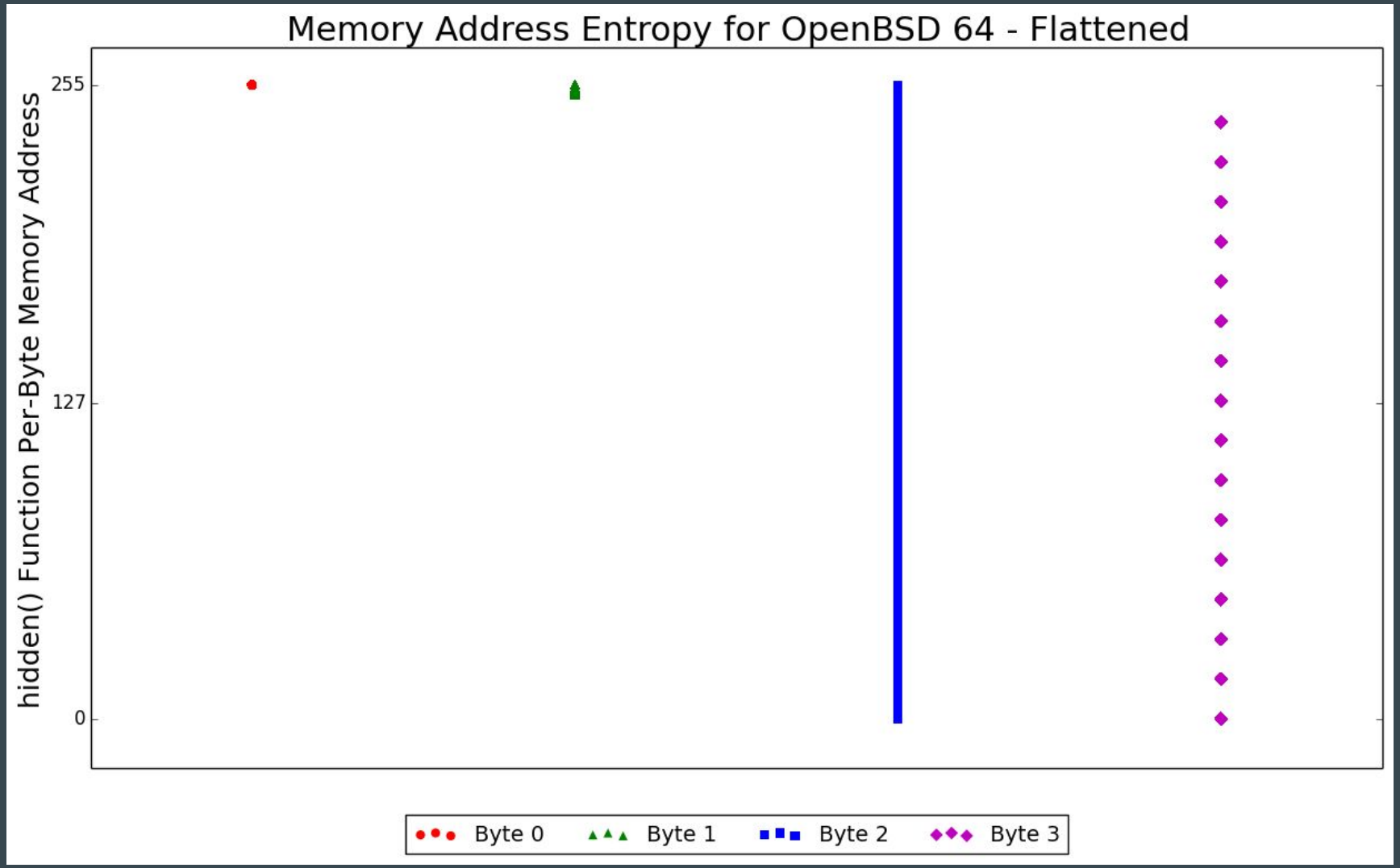

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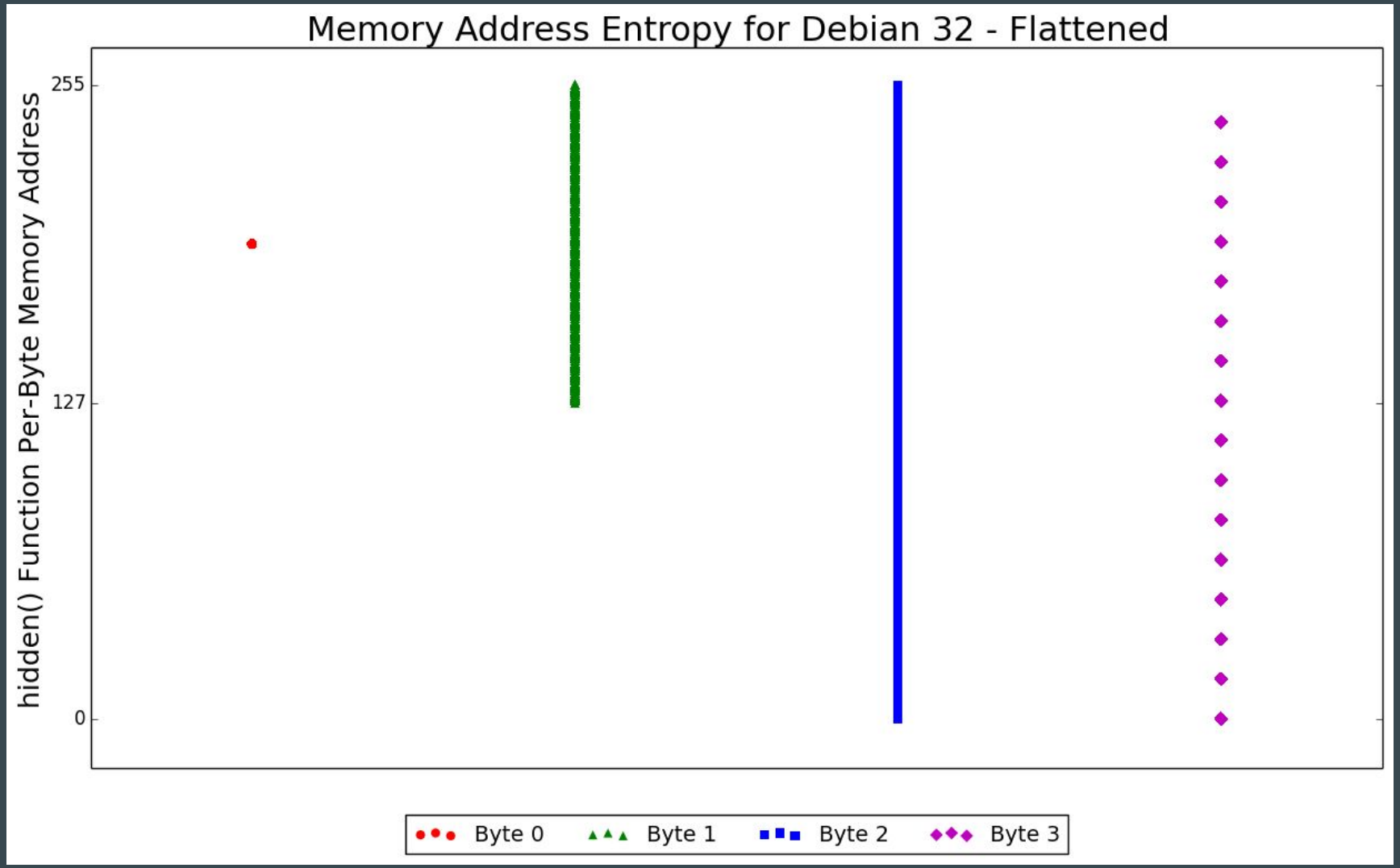

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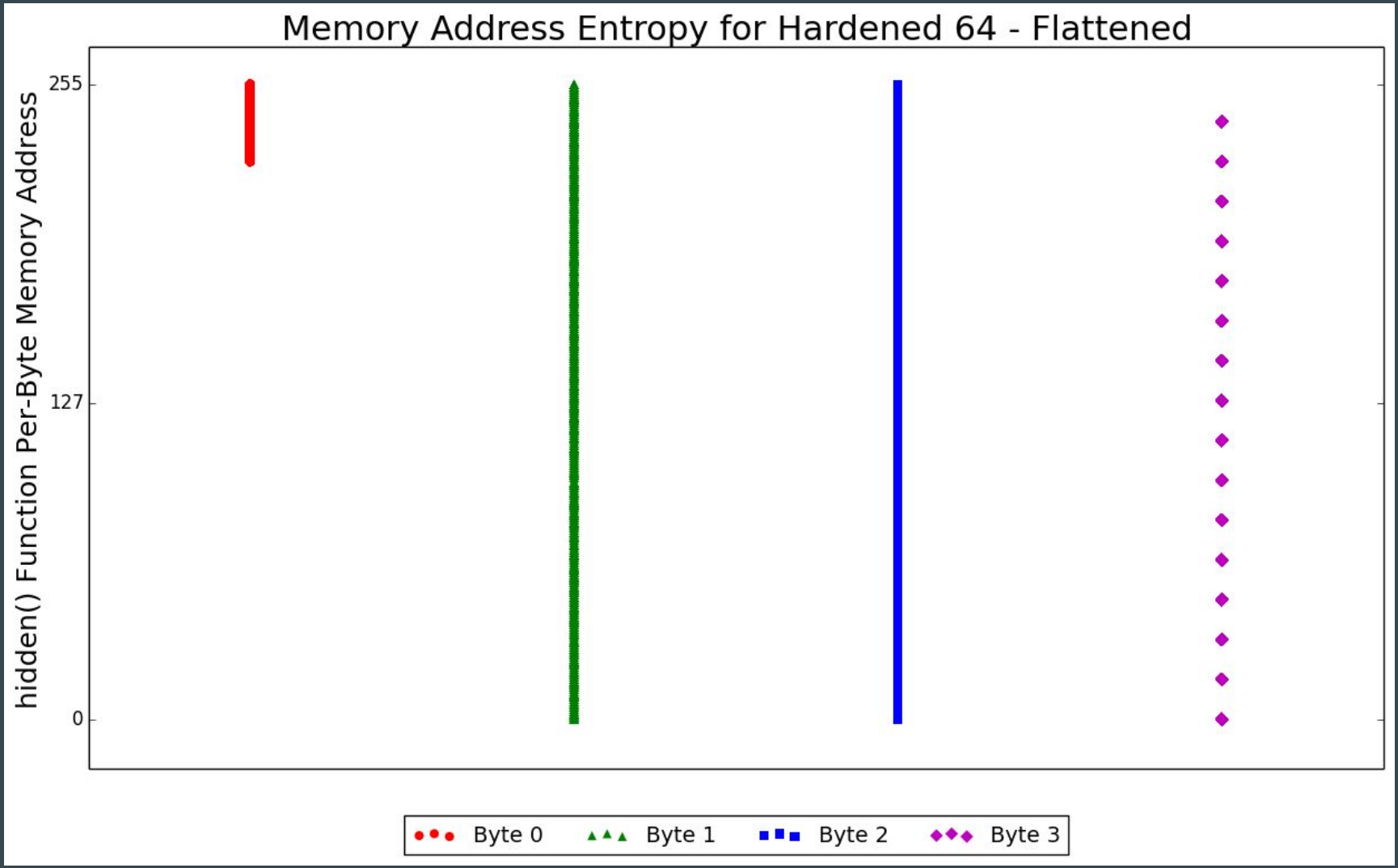

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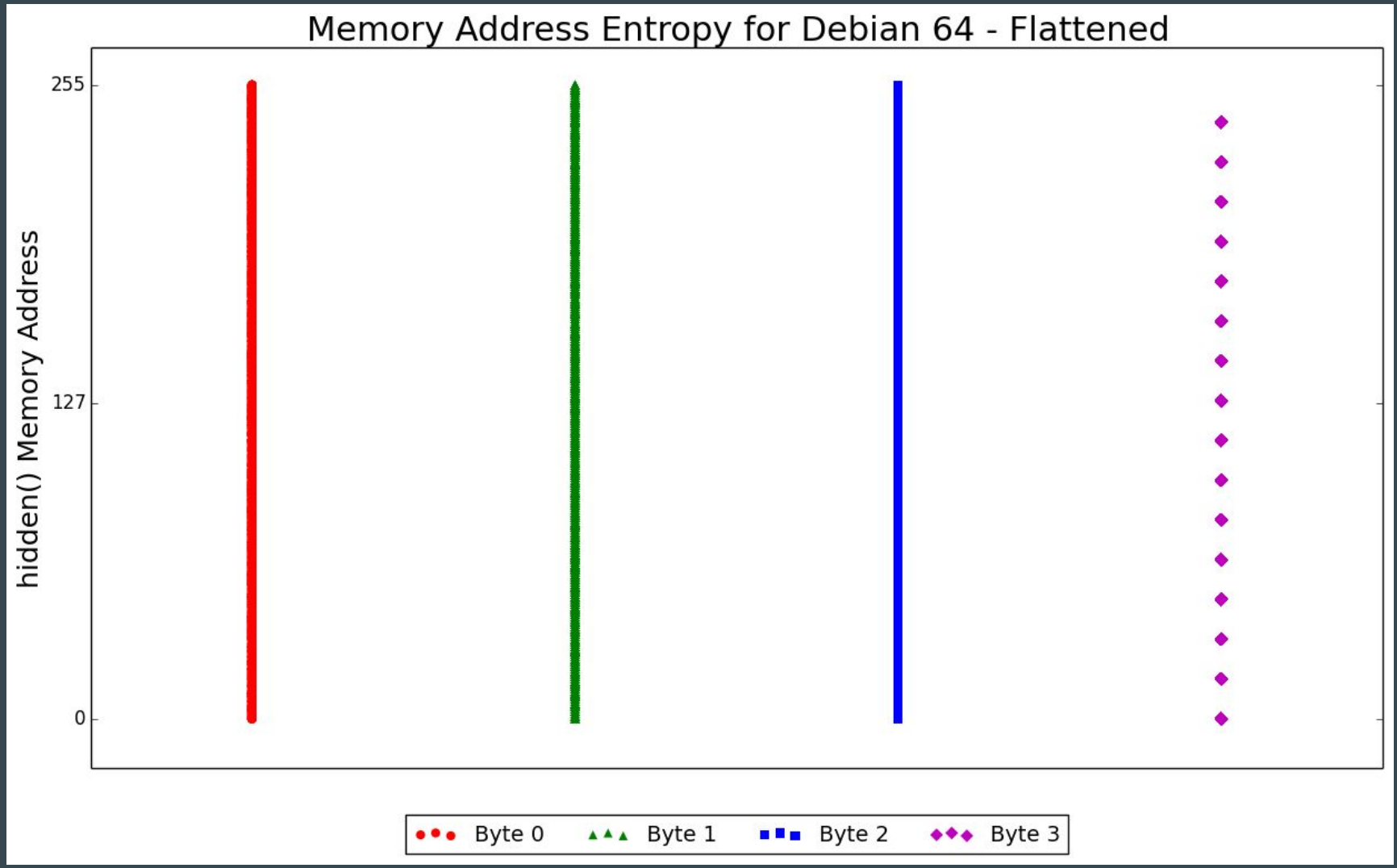

ASLR Results - Effective Entropy

	Claimed	Measured
64-bit Debian	28 bits	28 bits
64-bit HardenedBSD	30 bits	25 bits
32-bit Debian	24 bits	20 bits
64-bit OpenBSD	25 bits	15 bits
32-bit OpenBSD	16 bits	15 bits
32-bit HardenedBSD	14 bits	8 bits

Evaluation

- Debian (32-bit & 64-bit) ASLR Has Most Entropy
- 32-bit HardenedBSD ASLR Has Least Entropy
- *Operating Systems Often Provide Less Entropy than Claimed*
- We Must Perform Independent Tests of Security
- Evaluation Can Be Performed on More OSes

Limitations

- Small Set of Operating Systems Tested
  - Windows
  - macOS
  - Android
  - iOS
- Source Code Was Not Examined

Related Work

- “A Study of MAC Address Randomization in Mobile Devices and When it Fails” - Martin et al.
- “Techniques for the Dynamic Randomization of Network Attributes” - Chavez et al.

Conclusion

- Strength of Security Features Should Be Verified
- More Analysis Reveals Existing Limitations
- This Work Looks at Only One Defense Mechanism
- We Need More Quantitative Security Metrics

Questions?

www.jonganz.com

Security Research

- Malicious Media Sanitization
- Performance Analysis of Network Monitors
- Electronic Voting System Security Evaluation
- Multipath Routing Recovery Delay