Understanding the Value of Ensemble of Moving Target Defenses in Morpheus

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Morpheus Defenses

Two Churnable Moving Target Defenses:
- Address Space Disposition
- Domain Encryption

One Attack Detection Unit:
Ramps up churn rate under attacks
A 60-bit entropy displacement

Data and Code are displaced under different keys

A translation from DAS to VAS is performed at fetches, loads and stores
Domain Encryption

Code, Code Pointer and Data Pointer are encrypted under different keys

Data are getting decrypted when fetched into L1 cache and are encrypted when stored to memory.
How effective is each layer? Is the ensemble necessary? How do we evaluate them?
Idea: Evaluating by Attacking it

How effective is each layer?

We can show the effectiveness of each defense layer by showing how much it deters attacks.

Is the ensemble necessary?

We can show the value of ensemble by showing a combination of two defenses is significantly stronger than any single defense layer.
Threat Model

“"I would like to exploit a stack buffer overflow vulnerability in a victim program and open up a shell. (By calling system())”

Fellow Attacker

Nefarious Process

IPC call

Victim Process

Hardware
Threat Model and Assumptions

- Function layout get randomized during compilation
- No Churn
- Single encryption key in a process (Forge a code pointer by crafting Data pointer)
- Same displacement in all processes (Nefarious program can attack itself to derandomize the address space)
- Crash Resistant
Attack Ideas

Displacement Off, Encryption Off ($EP$):

Overall Time Required: $1 \times$ IPC call + Search for system()
Attack Details

Encryption On, Displacement Off: blind-call into 4-byte aligned positions until a shell pop up.

Overall Time Required:
(IPC call + segfault handling + Mimicry) * (Code Size/4)
Attack Details

Encryption Off, Displacement On:

Overall Time Required: $\text{AnC} + (\text{IPC call} + \text{Segfault}) \times 2^{16} + \text{Search in a program of GO size}$
Attack Details

Encryption On, Displacement On:
A combination of previous two attacks

Overall Time Required: \( A_nC + (\text{IPC call} + \text{Segfault}) \times 2^{16} + (\text{IPC call} + \text{segfault handling} + \text{Mimicry}) \times (\text{Code Size}/4) \)
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<td>mimicry</td>
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Experimental Setups

We use gem5 to simulate the attacks and estimate the time needed for the attacks.

Hardware Configurations:
CPU frequency : 2.5GHz
BTB entries: 4096
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Results

![Chart showing attack probe time]
Discussion and Conclusion

• Each of two defenses layer makes it significantly harder for the attacker to penetrate than no defense.

• The ensemble of two defenses is more concrete than any individual defense and makes the time needed to penetrate the system 5000x greater than the target churn rate - 50ms.
Acknowledgement

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Thanks for listening!