RUHR UNIVERSITÄT BOCHUM RUB

VUSec

CISPA

Nyx-Net

Network Fuzzing with Incremental Snapshots

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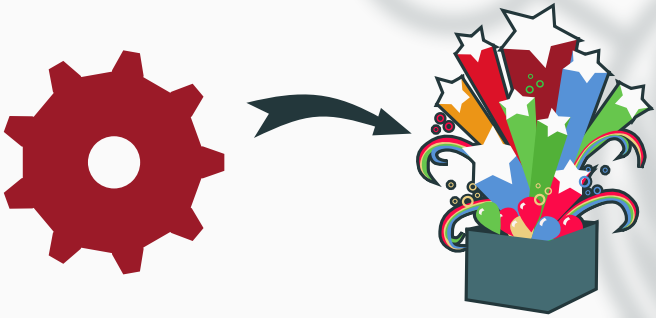
Fuzzing in a Nutshell

Fuzzing

Fuzzing



Fuzzing

Modern Fuzzers

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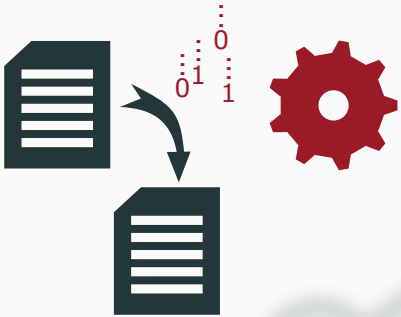

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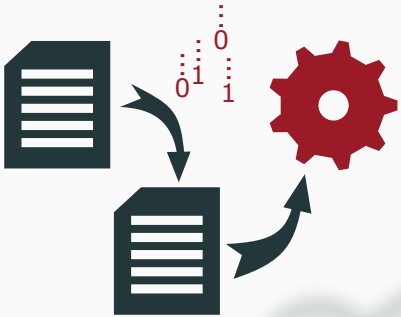

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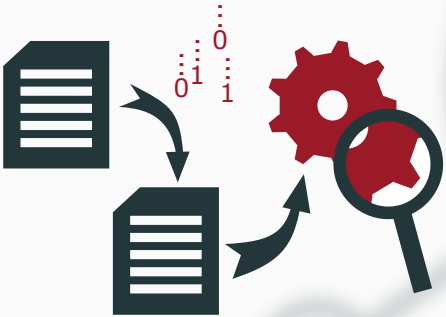

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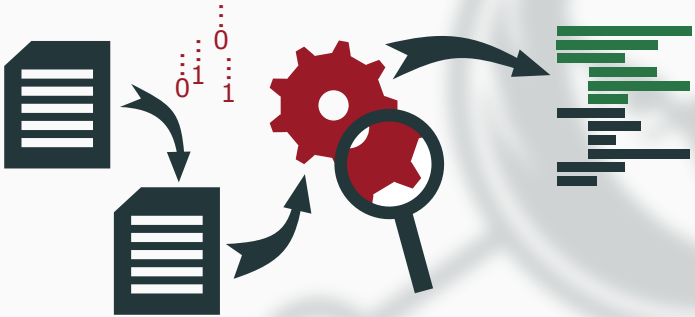

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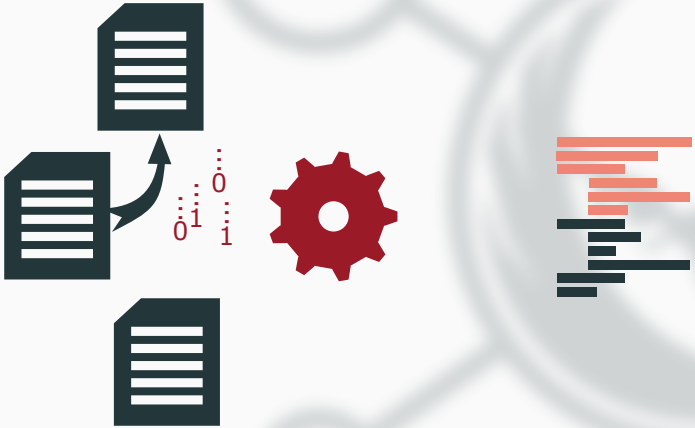

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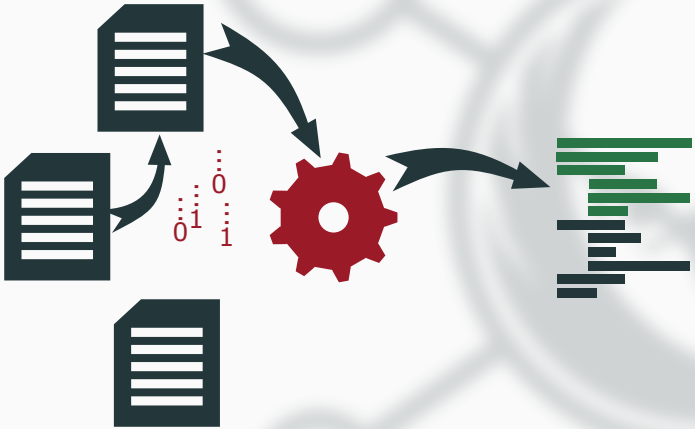

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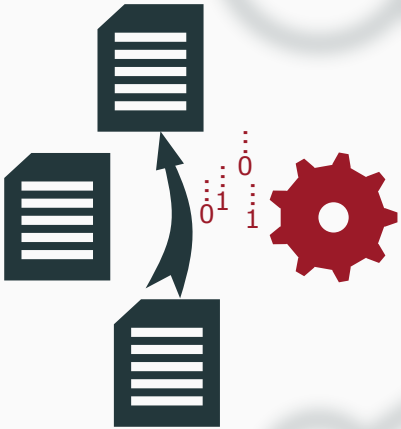

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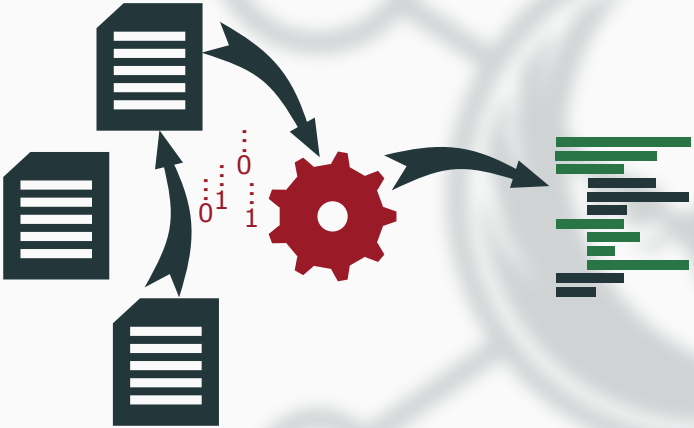
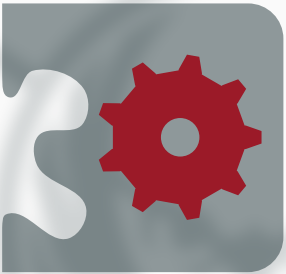


Modern Fuzzers

Motivation

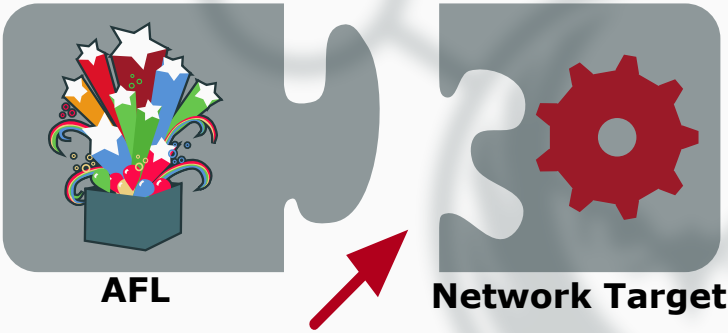
Motivation

AFL



Network Target

Motivation



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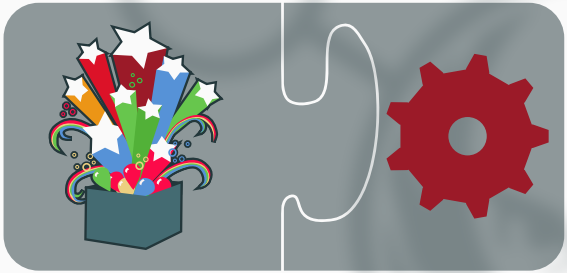

Pham et al. **"AFLNET: A Greybox Fuzzer for Network Protocols"** (ICST 2020)

Motivation

AFLNet's limitations:

- **requires target modifications**

  (to enable "state machine inference")

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- **requires target modifications**

  (to enable "state machine inference")

- **slow execution** (≈10 execs/sec)

  (due to costly init and de-init procedures)

- **poor scalability**

  (same network port, same FS, ...)

Can we do better?

Our Approach

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Nyx-Net is an extension of Nyx

https://nyx-fuzz.com

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- **Target runs in a VM**

  (scalability)

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Our Approach

Nyx-Net is an extension of Nyx

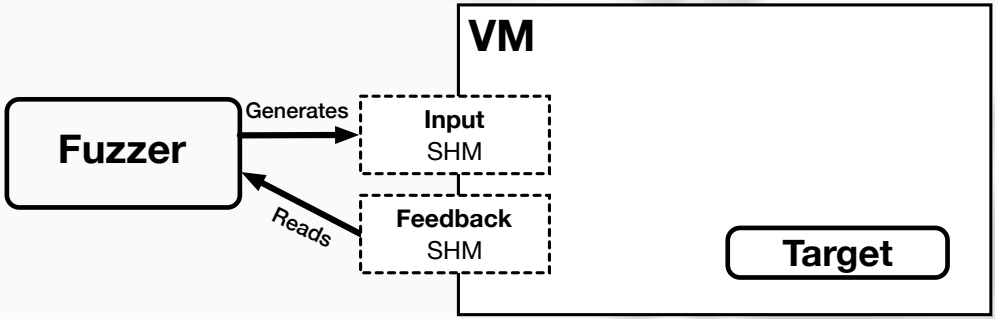
- **Target runs in a VM**
  (scalability)
- **Fast snapshots**
  (determinism)
- **Snapshots & emulation layer**
  (performance)

https://nyx-fuzz.com

Our Approach: Architecture

Host

Our Approach: Architecture



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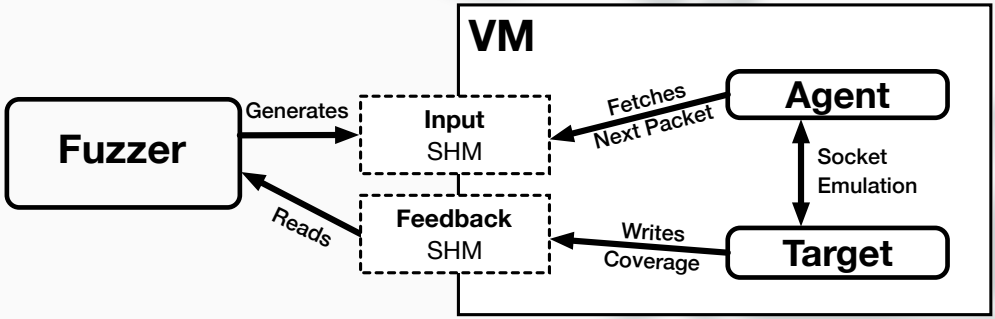

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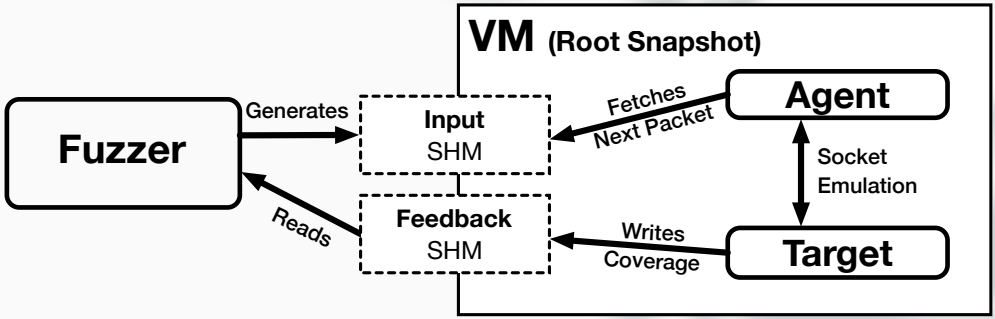

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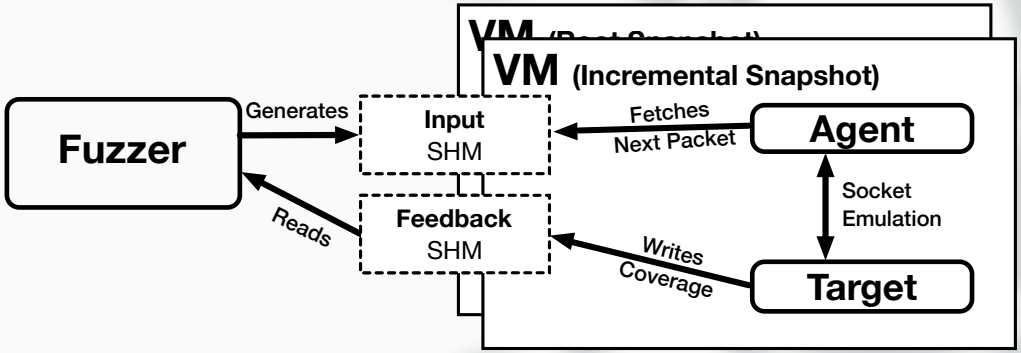

Our Approach: Emulation

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glibc emulation layer:

- **avoid kernel as much as possible**

  (improves overall performance)

- **fuzzing inputs passed via "syscalls"**

  (root snapshot created on first "request")

- **covers most I/O functions**

  (read, recv, recvmsg, select, poll, ...)

Approach: Incremental Snapshots

Input (sequence of messages):

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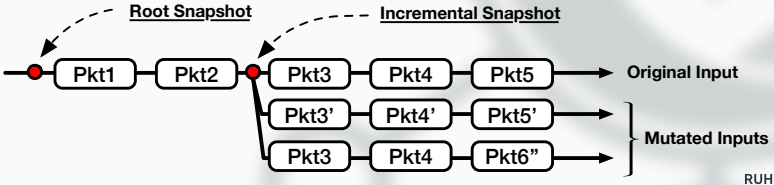
Approach: Incremental Snapshots

Input (sequence of messages):

Skip message sequence prefix:

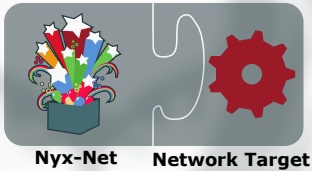


Use Cases

Use Case: Network Fuzzing

Fuzzing-harness for network targets

TCP/UDP as wells server/client support



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Supports complex targets

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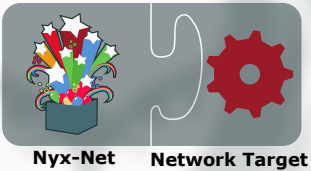


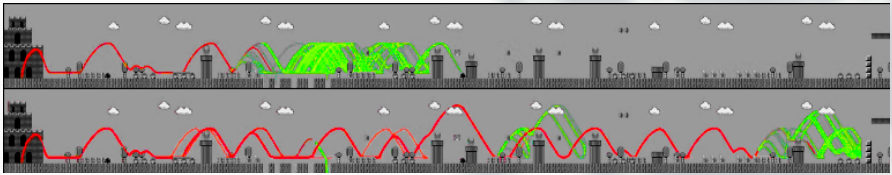
High test throughput (exec/sec)

no need to establish and close connections

Use Case: Super Mario

Solve levels by a fuzzer

Ijon: Exploring Deep State Spaces via Fuzzing (Aschermann et al., IEEE S&P 2022)



Use Case: Super Mario

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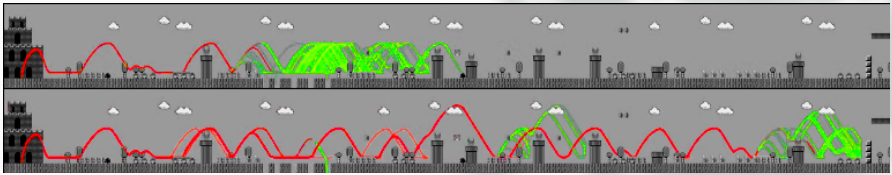
Accelerate Ijon by incremental snapshots

Keystrokes are represented by single "messages"



Use Case: Firefox

Long standing problem at Mozilla:

https://blog.mozilla.org/attack-and-defense/2021/01/27/effectively-fuzzing-the-ipc-layer-in-firefox/

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- **Emulation-Layer subset** enables fuzzing of the IPC-Subsystem

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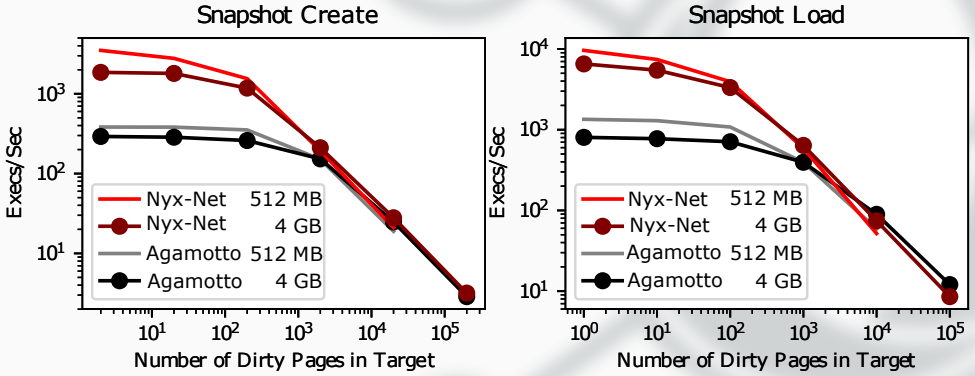
- **Emulation-Layer subset** enables fuzzing of the IPC-Subsystem
- Fuzzing of a **fully intilized Browser**

Evaluation

Evaluation: Snapshots

Nyx-Net vs Aggamotto (Song et al., USENIX Security 2020)



Evaluation: ProFuzzBench

Test suite for network fuzzers

ProFuzzBench: A Benchmark for Stateful Protocol Fuzzing - Natella et al., ISSTA 2021

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Set of differnt network targets:

FTP (pure-ftpd, proftpd, ...)

DNS (dnsmsq)

SMTP Server (exim)

DICOM (dcmtk)

...

Evaluation: ProFuzzBench

Crashes found by each fuzzer in PFB (24h experiments)

		Nyx-Net		
Target	**AFLNet**	none	balanced	aggressive
dcmtk	✓	(✓)	(✓)	✓
dnsmasq	✓	✓	✓	✓
exim	-	✓	✓	✓
live555	✓	✓	✓	✓
proftpd	-	✓	✓	✓
pure-ftpd	*	-	-	-
tinydtls	✓	✓	✓	✓

Evaluation: ProFuzzBench

Results compared to AFLNet:

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Results compared to AFLNet:

- Up to **100x faster** due to snapshots and emulation layer

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- **2x higher test throughput** due to incremental snapshots

Evaluation: ProFuzzBench

Results compared to AFLNet:

- Up to **100x faster** due to snapshots and emulation layer
- **2x higher test throughput** due to incremental snapshots
- **More coverage** in 24h compared to AFLNet and other fuzzers

Evaluation: Super Mario

Results compared to Ijon:

Evaluation: Super Mario

Results compared to Ijon:

- **Solves levels up to 4x faster**
  (due to snapshots and no process initalization)

Evaluation: Super Mario

Results compared to Ijon:

- **Solves levels up to 4x faster**
  (due to snapshots and no process initalization)

- **Up to 10x - 30x faster** with incremental snapshots

Evaluation: Firefox

- **3 bugs** found during development

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Evaluation: Firefox

- **3 bugs** found during development
- awarded a **special bug bounty** ($20.000)
- **used at Mozilla** by its security team
- plans to integrate Nyx-Net into their **CI-Pipeline**

Conclusion

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New approach: emulation & VM snapshots

Outperforms state-of-the-art (AFLNet)

Auto-harnessing for network targets

Solved a long-standing problem at Mozilla

Thank You!

Q & A

sergej.schumilo@rub.de

https://github.com/RUB-SysSec/nyx-net