syzkaller

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FreeBSD Bay Area Vendor Summit
October 12, 2019

System Call Fuzzing: What?

- Common syscall usage patterns cover a small space
    - Why would you ever call `send(2)` after `listen(2)`?
- Increase coverage by generating and executing programs
- Look for crashes, hangs, sanitizer reports, etc.
- Cannot easily validate positive results

```
for (;;) {
        p = generate_prog();
        execute(p);
}
```

System Call Fuzzing: Why?

- Kernel is part of the TCB
- System calls present a huge attack surface
- Jails and Capsicum help but are not sufficient
- FreeBSD has 500 system calls
  - Plus `COMPAT_FREEBSD32`, `COMPAT_LINUX`...
  - Plus de-muxing via `ioctl(2)`, `fcntl(2)`, `setsockopt(2)`...
- Fine-grained parallelism makes things much worse

System Call Fuzzing: How?

- Naive fuzzing mostly catches input validation bugs
- Can do better with semantic knowledge of syscall params
- Idea: use code coverage as input to test case generation

```
for (cov = NULL;;) {
        p = generate_prog(corpus);
        cov1 = execute(p);
        if (!cov.contains(cov1)) {
            cov.add(cov1);
            corpus.add(p);
        }
}
```

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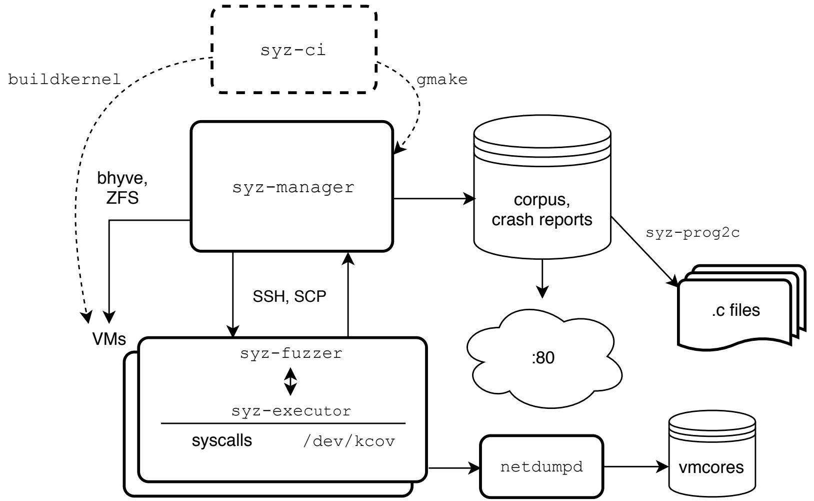
Introduction to syzkaller

- “Unsupervised, coverage-guided kernel fuzzer”
- By Dmitry Vyukov at Google, initially for Linux
- `https://github.com/google/syzkaller/docs`
- Kitchen sink approach:
  - Manages VMs running target kernels
  - Generates minimal reproducibles
  - Can inject network, USB, etc. packets
  - Collects, summarizes and deduplicates crash reports
  - Collects kernel code coverage info
  - Presents crash reports and test cases in a web dashboard
  - `syz-ci` periodically rebuilds kernel and syzkaller itself
  - Checks for regressions
  - Bisects new crashes
  - ...

syzkaller on FreeBSD



KCOV

- Thin user interface around LLVM SanitizerCoverage for kernel
- Initial implementation by mhorne@, finished by andrew@
- Open `/dev/kcov` and `mmap` to create shared buffer
- `KIOENABLE` ioctl enables tracing for the calling thread
- Buffer entries generated for every edge and comparison

```
include "./GENERIC"

ident           SYZKALLER
options         COVERAGE
options         KCOV
```

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System Call Descriptions

- syzkaller defines a syscall description grammar
- Supports “enhanced” types: flags, file descriptors, ...
- Implements compound types
- Each system call needs to be described - lots of work
- Some system calls have multiple flavours, e.g. `connect(2)`

```
#include <fcntl.h>

open(file ptr[in, filename], flags flags[open_flags], mode flags[open_mode]) fd
open_flags = O_RDONLY, O_WRONLY, O_RDWR, O_APPEND, ...
open_mode = S_IRUSR, S_IWUSR, ...

stat {
        dev     int64
        ino     int64
        nlink   int64
        mode    int16
        __pad0  const[0, int16]
        uid     uid
        gid     gid
        ...
}
```

Sample Reproducer

```
#{"threaded":true,"collide":true,"repeat":true,"procs":4,"sandbox":"none","fault_call":-1,
  "tmpdir":true,"segv":true}
r0 = socket(0x2, 0x10000001, 0x84)
connect$unix(r0, &(0x7f0000000000)=@file={0xbd5699bc1ec0282, './file0\x00'}, 0x10)
getsockopt$inet6_sctp_SCTP_ENABLE_STREAM_RESET(r0, 0x84, 0x900,
                                               &(0x7f0000000080)={<r1=>0x0, 0x4},
                                               &(0x7f00000000c0)=0x8)
getsockopt$inet6_sctp_SCTP_DELAYED_SACK(r0, 0x84, 0xf, &(0x7f0000000180)={r1, 0x9, 0x6},
                                        &(0x7f00000001c0)=0xc)
listen(r0, 0x9)
setsockopt$inet6_sctp_SCTP_EVENTS(r0, 0x84, 0xc, &(0x7f0000000040)={0x0, 0x0, 0x0, 0x6}, 0xb)
setsockopt$inet6_sctp_SCTP_RTOINFO(r0, 0x84, 0x1, &(0x7f0000000100)={0x0, 0x0, 0x80000001}, 0x10)
shutdown(r0, 0x1)
```

Run with `sudo syz-execprog ./repro.syz`

syzbot

- Hosted CI for syzkaller, on GCE
- `https://syzkaller.appspot.com`
- Fuzzes many different operating systems
- Thousands of bugs found
- Mails `syzkaller-freebsd-bugs@googlegroups.com` when a new crash is found
- Resolve reports automatically using a Reported-by tag:

```
commit fb4ce630e036f6b73bef06c3c4b9c7bf363a9b23
Author: markj <markj@FreeBSD.org>
Date:   Mon Mar 25 21:38:58 2019 +0000

    Reject F_SETLK_REMOTE commands when sysid == 0.

    A sysid of 0 denotes the local system, and some handlers for remote
    locking commands do not attempt to deal with local locks.  Note that
    F_SETLK_REMOTE is only available to privileged users as it is intended
    to be used as a testing interface.

    Reviewed by:    kib
    Reported by:    syzbot+9c457a6ae014a3281eb8@syzkaller.appspotmail.com
    MFC after:      2 weeks
    Sponsored by:   The FreeBSD Foundation
    Differential Revision:  https://reviews.freebsd.org/D19702
```

Netdump

- syzkaller does not do a perfect job generating reproducers:
  - Some panics happen asynchronously (e.g., in a callout)
  - Some reproducers do not work (race conditions)
  - Reproducer minimization is not perfect or reliable
- VM disk image is discarded during reboot
- netdump(4) to the rescue

FreeBSD and syzkaller

Why is it worth investing time into syzkaller?
What do we need?

- Bug triage and analysis
- More system call descriptions
- Fuzzing ZFS, NFS-based images
- Fuzzing non-amd64 kernels
- syzkaller jail image
- Sanitizer support