What role for static analysis in malware detection?

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Overview

1. What is malware and how do we traditionally detect it?
2. What is static analysis?
3. How does static analysis promise to help detect malware?
4. How far can we go with it?
What is malware?

- Malign software: infiltrates and subverts.
- Uses from spam e-mail botnets to IP theft.
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- Malign software: infiltrates and subverts.
- Uses from spam e-mail botnets to IP theft.
- Executive summary: **malware is bad.**
How do we detect malware?

- Traditionally: signature (‘fingerprint’) detection.
- If a binary matches a malware signature, it’s a bad ’un.
- [Note: the signature may be for part(s) of a malware.]
How to defeat traditional signature matching.

- **Original malware:**
  
  ```
  MOV R0, #3  \hspace{1cm} x := 3
  BL DO_SOMETHING_WITH_R0 \hspace{1cm} f(x)
  ```

  Give it hash $H$. 
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  Give it hash \( H \).

- **Malware author (remember: bad, not mad) obfuscates it to:**
  
  MOV R0, #3 \( \quad \) \( x := 3 \)
  
  MOV R1, #4 \( \quad \) \( y := 4 \)
  
  BL DO_SOMETHING_WITH_R0 \( \quad \) \( f(x) \)

  Will have hash \( H' \) where \( H \neq H' \).
How to defeat traditional signature matching (2).

- Idea: can signatures be like regular expressions, ‘skipping’ over irrelevant stuff?

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```
MOV R0, #3 x := 3
BL DO_SOMETHING_WITH_R0 f(x)
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Malware author obfuscates it to:

```
MOV R0, #1 x := 1
ADD R0, R0, #2 x += 2
BL DO_SOMETHING_WITH_R0 f(x)
```

No regular expression matching will match that!

Metamorphic / polymorphic malware on the rise.

Traditional signature detection ever less effective.
Idea: can signatures be like regular expressions, ‘skipping’ over irrelevant stuff?

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A proposed approach.

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- What about the programs semantics?
- Intuition: a malware’s core semantics must be the same before and after obfuscation.
- So: we need to statically analyse its semantics!
Static analysis.

- Looking at a static program (source code or binary) and uncovering information about it.
- Take LLVM’s static analyser (*scan-build*). Spot the bug?

```c
char *expand_path(const char *path)
{
    char *exp_path;
    // If path begins with "~/", we expand that to the users home directory.
    if (strncmp(path, HOME_PFX, strlen(HOME_PFX)) == 0) {
        struct passwd *pw_ent = getpwuid(geteuid());
        if (pw_ent == NULL) {
            free(exp_path);
            return NULL;
        }
        if (asprintf(&exp_path, "%s%s%s", pw_ent->pw_dir, DIR_SEP, path + strlen(HOME_PFX)) == -1)
            errx(1, "expand_path: asprintf: unable to allocate memory");
        return NULL;
    }
    if (asprintf(&exp_path, "%s", path) == -1)
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        errx(1, "expand_path: asprintf: unable to allocate memory");
    return exp_path;
}
```
cur_ext->working = false;
if (conf->mode == DAEMON_MODE) {
    // If we're in daemon mode then, if this external has been found
    // not to be working, check the timeout (if it exists). If the
    // timeout hasn't been exceeded, then we have to give up on
    // trying to send this messages via this, or other, externals -
    // we need to wait for the timeout to be exceeded.
    if (cur_ext->timeout != 0 &&
        cur_ext->last_success + cur_ext->timeout > time(NULL)) {
        goto fail;
    }
}

cur_ext = cur_ext->next;
}

fail:
for (int j = 0; j < nargv; j += 1)
    free(argv[j]);
free(argv);
free(stderr_buf);
free(dhd_buf);

return false;

argv[i] = arg;
}
argv[nargv] = NULL;

// Setup a buffer into which we will read stderr from any child processes.

size_t stderr_buf_alloc = STDERR_BUF_ALLOC;
char *stderr_buf = malloc(stderr_buf_alloc);
if (stderr_buf == NULL) {
    syslog(LOG_CRIT, "try_groups: malloc: \n");
    exit(1);
}

// We now need to record where the actual message starts.

off_t mf_body_off = lseek(fd, 0, SEEK_CUR);
if (mf_body_off == -1) {
    syslog(LOG_ERR, "Error when ftell'ing from '\n', msg_path);
    goto fail;

    Control jumps to line 803
}

// Read in the messages header, doctoring it along the way to make it
// suitable for being searched with regular expressions. The doctoring is
// very simple. Individual headers are often split over multiple lines: we
// merge such lines together.

size_t dumph_buf_alloc = HEADER_BUF:
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Static analysis (3).

- Intuition: do a ‘fuzzy match’ against a malware’s *semantic signature* and that of a new binary.
- If they match: it’s a malware; otherwise it’s OK.
- (We might need to play around with the ‘fuzziness’ a bit, but it should work.)
- My argument: *if you deploy this tomorrow, by the following day it will have been irrevocably circumvented.*
- Why?
Static analysis assumptions.

- Underlying assumption of static analysis:
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Bunnies and photo: Anna Hull. (CC BY-NC-ND 3.0)

The *pink fluffy bunny* assumption.
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Static analysis assumptions (2).

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The *hostile* assumption.
Can we defeat the static analysis of malware?

- Consider a self encrypting malware.
- Consists of an initial decoder and an encrypted body.
- The following ARM(ish) code decrypts the data (w/length \( lp \)) and stores it back for execution.

```assembly
MOV R0, #0
MOV R1, BODY
L: LDR R2, R1[R0]
   XOR R2, R2, #constant
   STR R2, R2[R0]
   ADD R0, R0, #4
   CMP R0, lp
   BLT L

BODY:
   encrypted malware body
```

int *body = ...;
for (int i = 0; i < lp; i += 1) {
    int t = body[i];
    t = t ^ constant;
    body[i] = t;
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- What’s its semantic signature?
Can we defeat the static analysis of malware (2)?

- First thought: the decrypter is basically an XOR in a loop...

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  ...and `body` points to a constant chunk of data.

  Should be quite easy to statically analyse and obtain a signature.
The decryption key is central.
It must be a constant.
Pink fluffy bunny assumption: the key must be transparently contained in the binary.
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Hostile assumption: the key can be opaquely calculated by the binary.
Hiding the key.

- Can we hide the key so that it can’t easily be uncovered?
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- Let’s make it a lot harder:

```c
int k;
for (int i = 0; i < MAXINT; i += 1) {
    if (md5(i) == constant1 && sha256(i) == constant2) {
        k = i;
        break;
    }
}
```

- `constant1` and `constant2` are in the binary, but aren’t directly related to `k`.
- To statically analyse that, we need to analyse the MD5 and SHA256 functions.
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- Hash functions are meant to be hard to analyse; but not without their weaknesses.
- Take the hostile assumption: make it harder!
Hiding the key (2).

- Try statically analyzing random data:

```c
int k;
f = open("/dev/random", "r");
while (true) {
    int t = readc(f) | (readc(f)«8) | (readc(f)«16) | (readc(f)«24);
    if (md5(t) == constant1 && sha256(t) == constant2) {
        k = t;
        break;
    }
}
```

- Rough speed: in C, will find a key corresponding to the hash of a 5 character string on my laptop in under a minute.
Hiding the key (2).

- Try statically analyzing random data:

```c
int k;
char* f = open("/dev/random", "r");
while (true) {
    int t = readc(f) | (readc(f)«8) | (readc(f)«16) | (readc(f)«24);
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- Moser, Kreugel, and Kirda show examples of opaque constants whose static solution would be equivalent to solving an NP-hard problem.
Can limited dynamic analysis help?

- Opaque constants defeat static analysis on its own.
- Can we dynamically run the malware decrypter, stop it, and then semantically analyse the decrypted malware?
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- Opaque constants defeat static analysis on its own.
- Can we dynamically run the malware decrypter, stop it, and then semantically analyse the decrypted malware?
- Take the hostile assumption: will embed more than one layer of hard to analyse encryption.
What are the limits of static analysis?

- Assertion: static analysis of malware on its own would quickly be circumvented (by the hostile assumption).
- Could static analysis have any use in malware detection?
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- Could static analysis have any use in malware detection? Yes!
  1. In security labs analyzing malware (every tool helps).
  2. In an interleaved dynamic / static analysis.
Further reading

- *Static Analysis for Malware Detection* Andreas Moser, Christopher Kruegel, Engin Kirda.
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*But* there are uses for it, but not the ones that there first appeared to be.
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A general rule: anything that relies on static analysis for security must bear in mind the hostile assumption at all times.
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Thanks for listening