DeepFuzz: Triggering Vulnerabilities Deeply Hidden in Binaries (Extended Abstract)

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Donostia-San Sebastián

Agenda

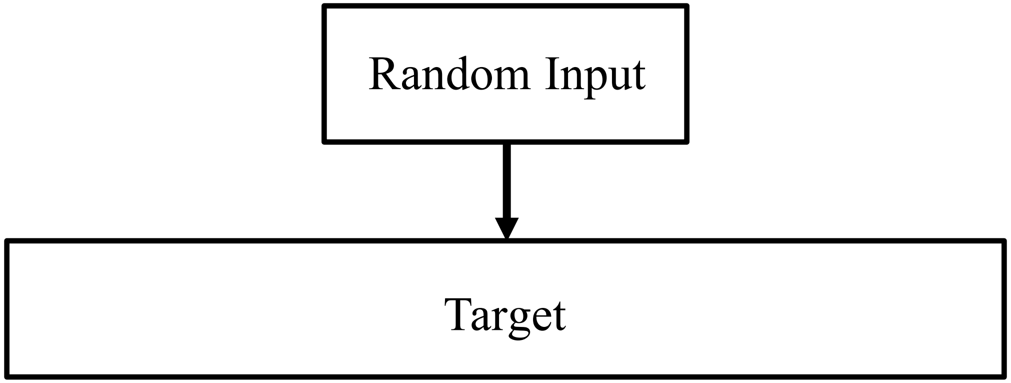
- Motivation
- Background
- Fuzzing Algorithm
- Implementation and Observations

Motivation

main goal:

improve fuzzing

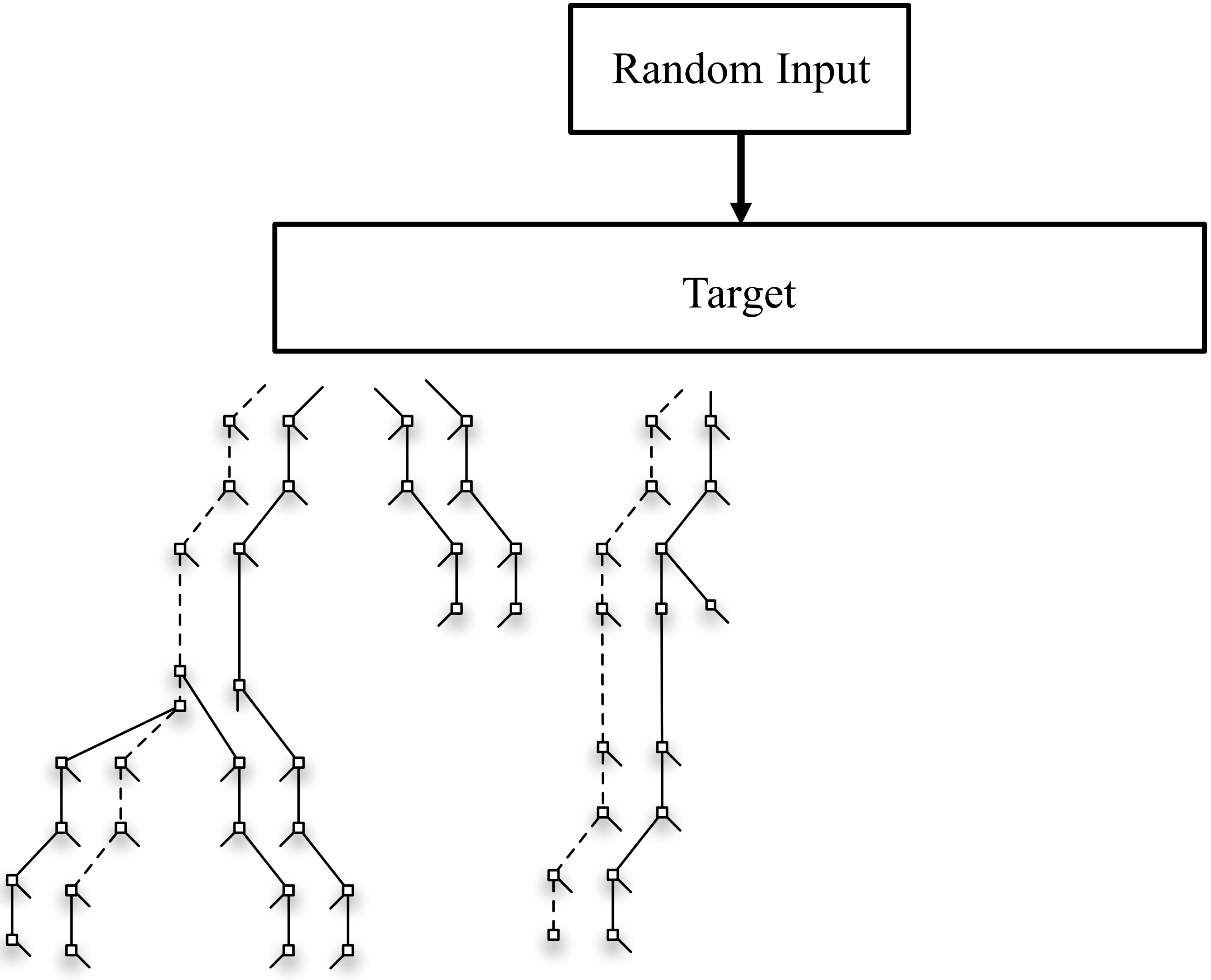
Motivation



Random Input

Target

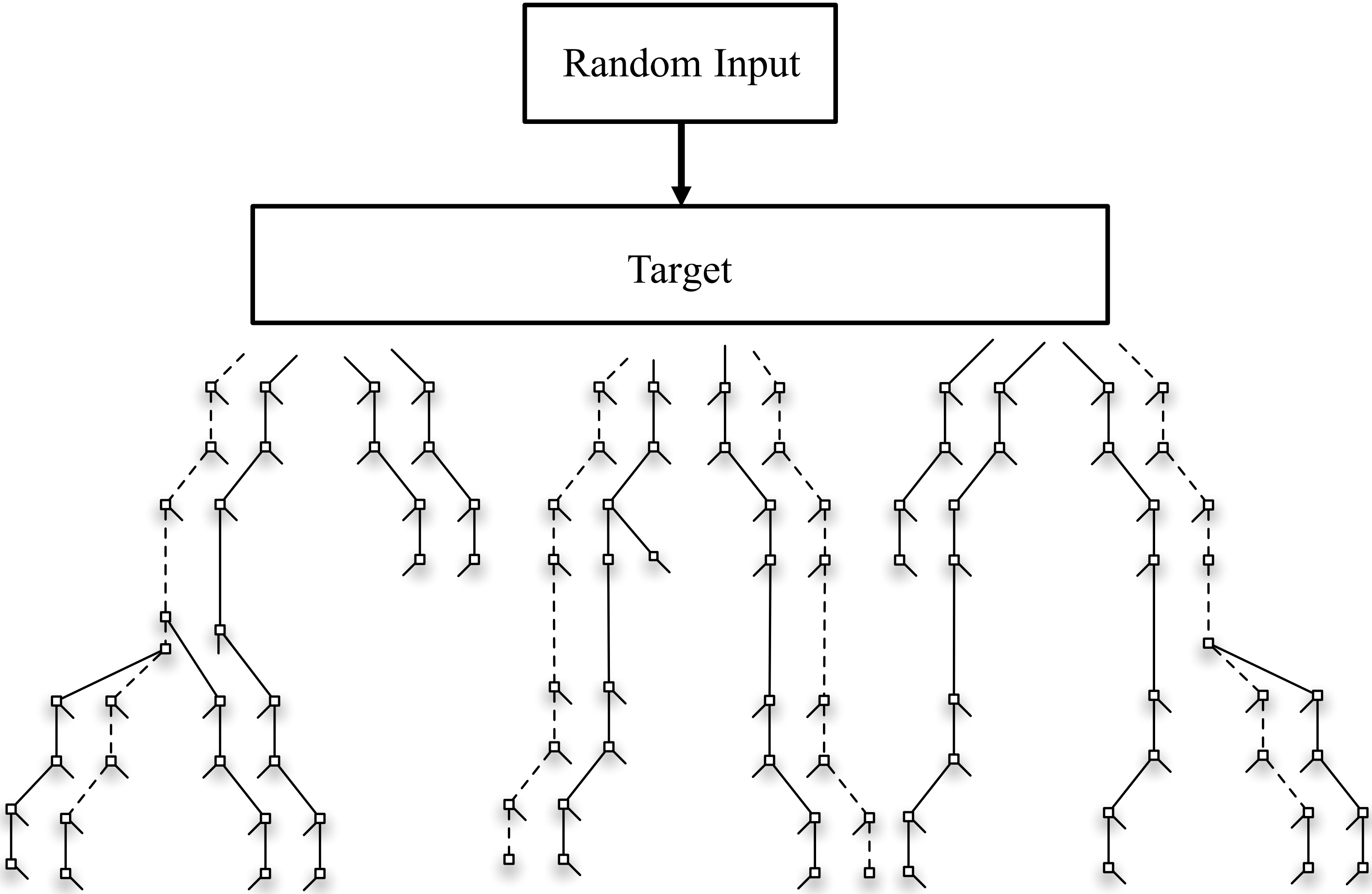
Motivation



Random Input

Target

Motivation


Random Input

Target

Motivation

```
#include <stdint.h>
...
int check( uint64_t num ){
        if( num == UINT64_C(0) )
                assert( false );
}
```

- probability of 2^{-64} to pass the `if` statement
  - → *fuzzing wall*

Motivation

How can we fuzz through fuzzing walls

to reach deep layers of the program?

Background

- Concrete symbolic (concolic) execution
  - assign symbolic representations to input variables of a program and generate formulas over the symbols according to the transformations in the program execution
  - program is initially executed with arbitrary concrete input values and symbolic constraints over the symbols are generated along the program execution path
  - one of the collected branch conditions is negated and together with the remaining constraints given to an SMT solver
  - The solution (*model*) generated by the SMT solver is injected as new input into the program, which now takes the branch alternative when executed
  - effective for complex arithmetic operations, pointer manipulations, calls to external library functions, or system calls

Background

however

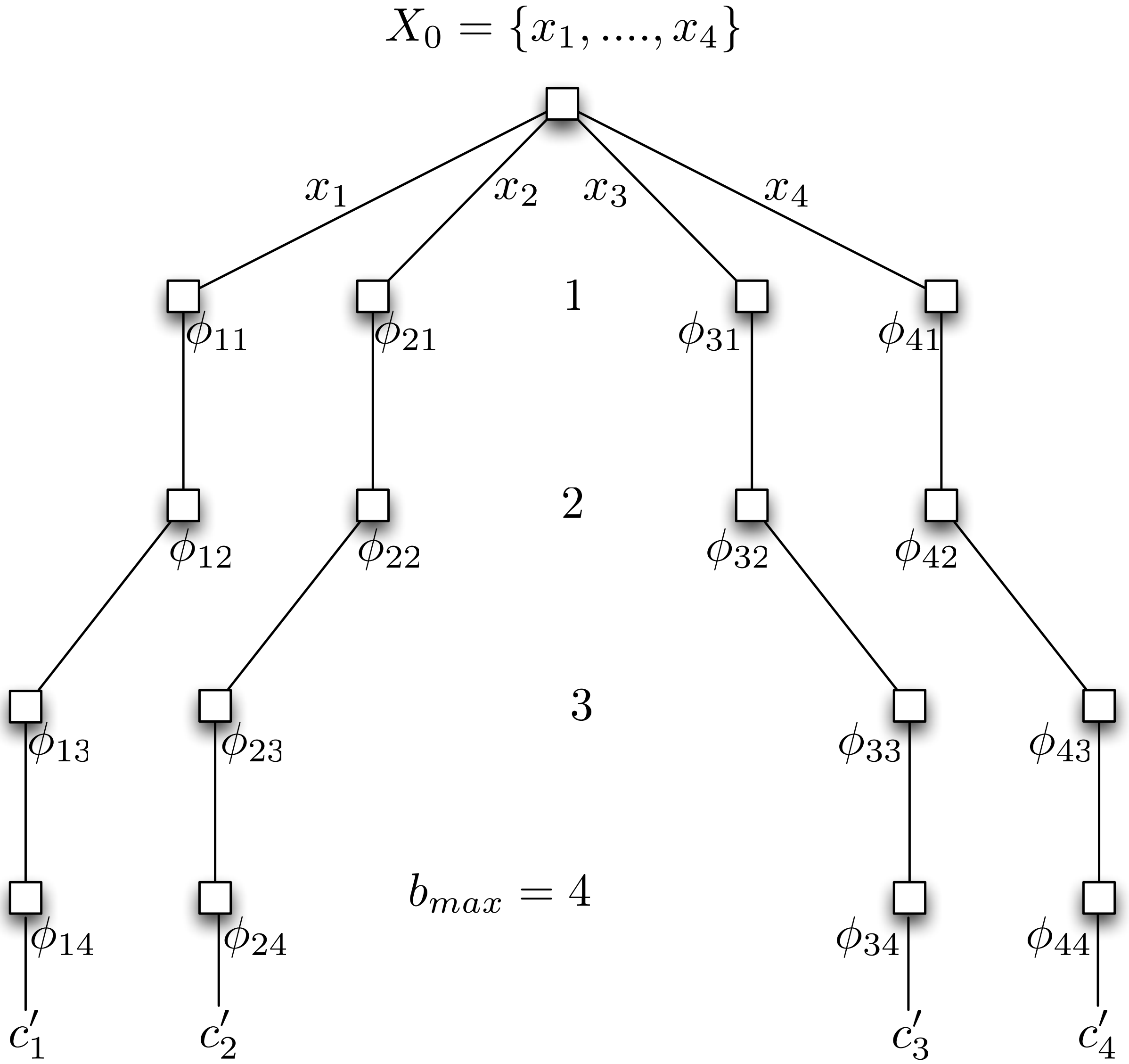
path explosion

Background

- want to fuzz deep areas of a program
  - find a way to construct execution paths into such areas
  - delay path explosion until we have found such a tunnel

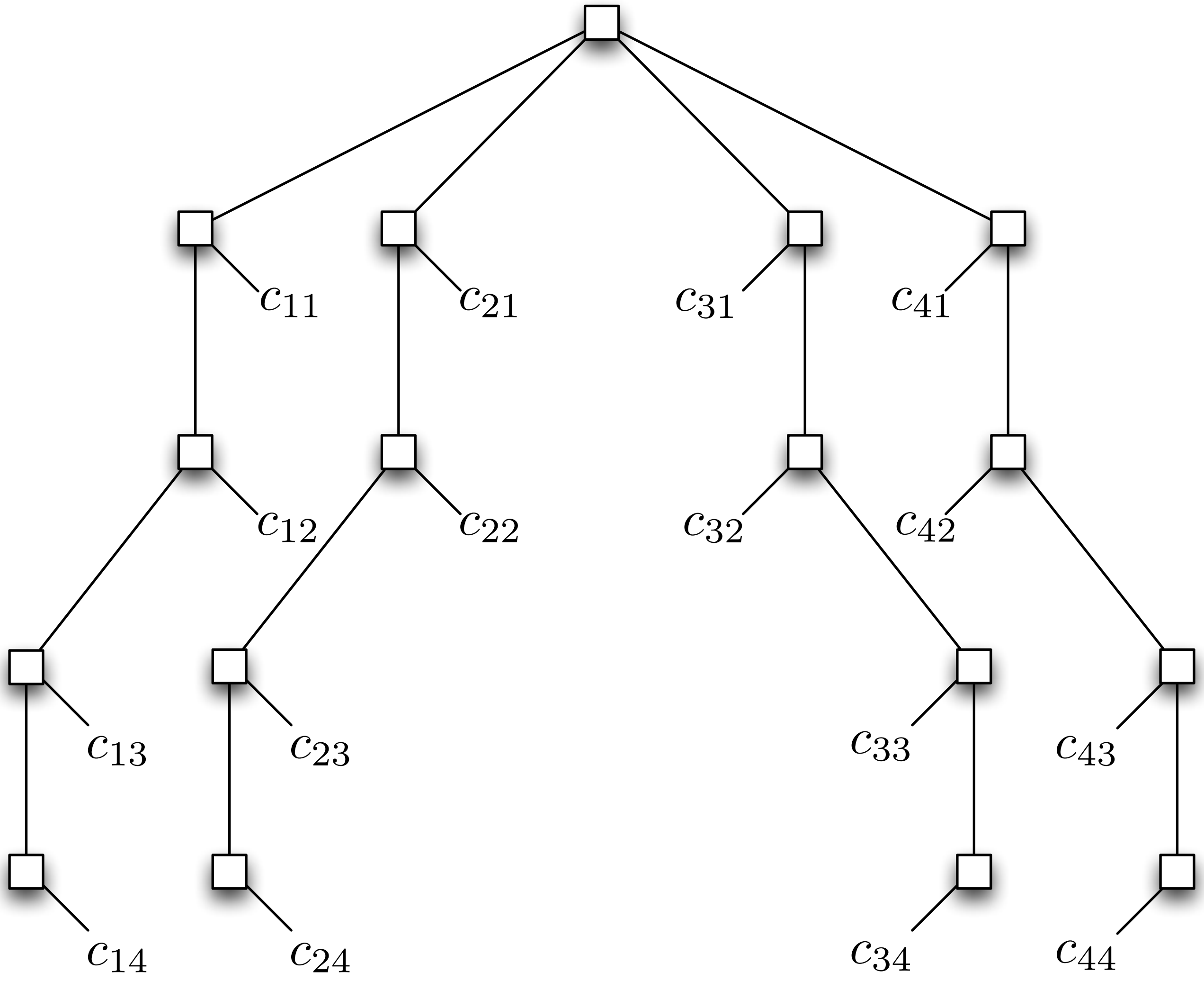
- idea:
  - interleave concolic execution with constrained fuzzing
  - assign weights (corresponding to fuzzing performance) to the explored paths after each concolic execution step in order to select the ones with highest probability

Algorithm


$X_0 = \{x_1, ..., x_4\}$
x_1
x_2
x_3
x_4
1
ϕ_{11}
ϕ_{21}
ϕ_{31}
ϕ_{41}
2
ϕ_{12}
ϕ_{22}
ϕ_{32}
ϕ_{42}
3
ϕ_{13}
ϕ_{23}
ϕ_{33}
ϕ_{43}
$b_{max} = 4$
ϕ_{14}
ϕ_{24}
ϕ_{34}
ϕ_{44}
c_1'
c_2'
c_3'
c_4'

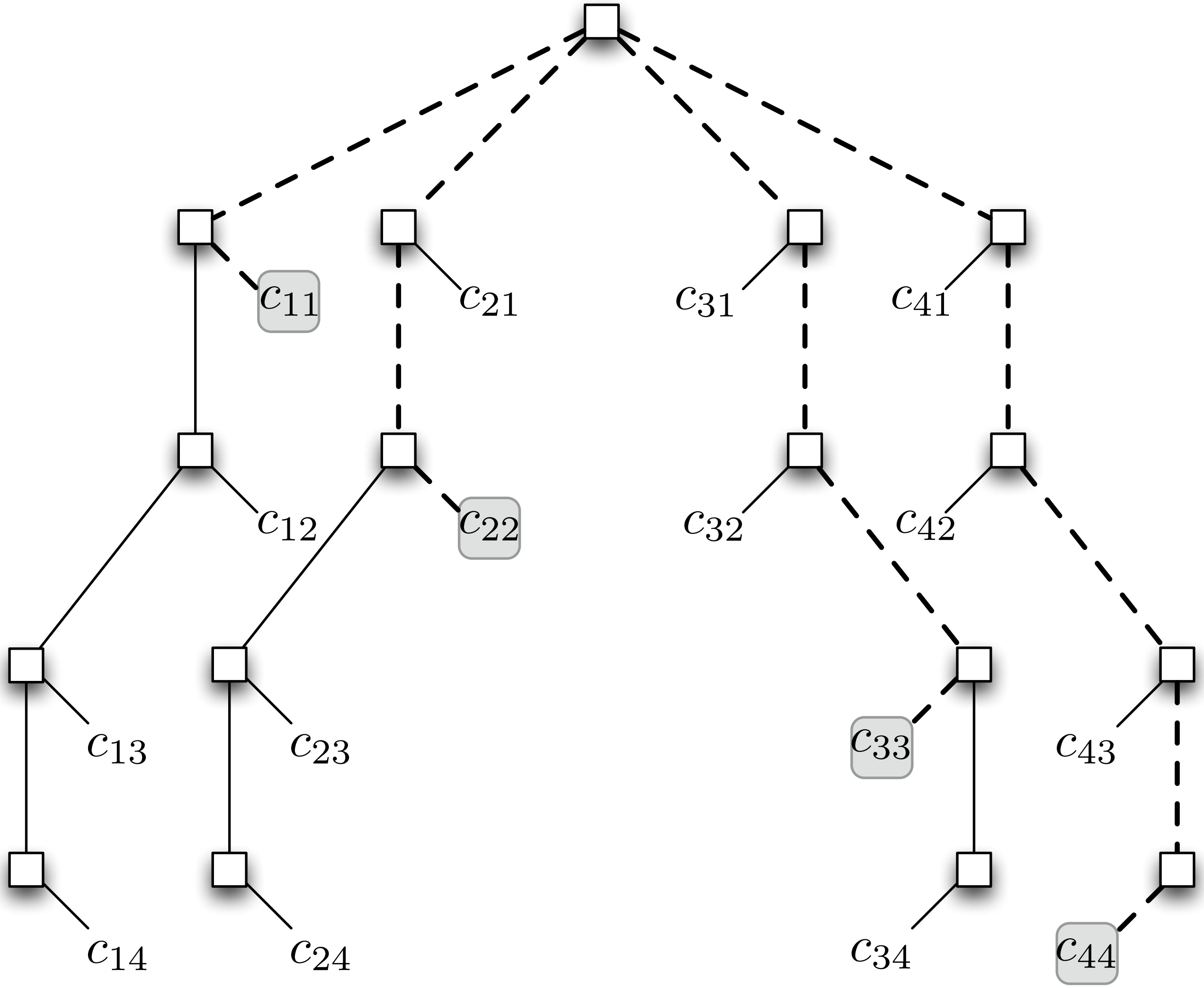
Algorithm

$$\{x_{11}, x_{12}, x_{13}, x_{14}, x_{21}, x_{22}, x_{23}, x_{24}, x_{31}, x_{32}, x_{33}, x_{34}, x_{41}, x_{42}, x_{43}, x_{44}\}$$



Algorithm

$$\{\boxed{x_{11}}, x_{12}, x_{13}, x_{14}, x_{21}, \boxed{x_{22}}, x_{23}, x_{24}, x_{31}, x_{32}, \boxed{x_{33}}, x_{34}, x_{41}, x_{42}, x_{43}, \boxed{x_{44}}\}$$



Algorithm

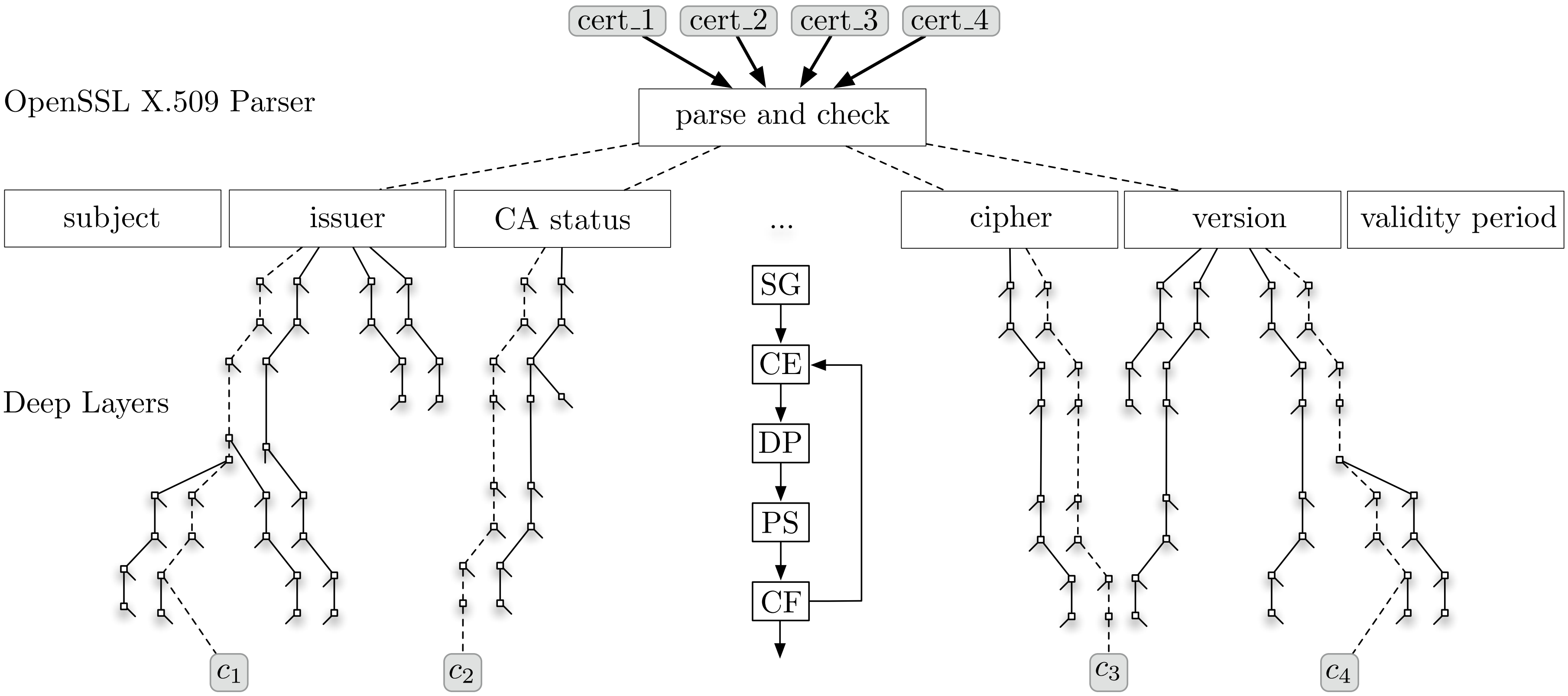
```
**Input:** Program $P$, Parameters $m,\ k_{min},\ T_0,\ T_1,\ T_2,\ b_{max}$

$X_{seed} \leftarrow \mathrm{SG}\ (P)$
do:
    $\Phi = \emptyset$
    $C = \emptyset$
    for each $x$ in $X_{seed}$ do:
        $c,\ \phi\ \leftarrow \mathrm{CE}\ (x, b_{max})$
        append $\phi$ to $\Phi$
        append $c$ to $C$
    $Prob\ \leftarrow\ \mathrm{DP}\ (\Phi, C, T_0)$
    $C_{high}\ \leftarrow\ \mathrm{PS}\ (Prob, C)$
    $X_{seed}\ \leftarrow\ \mathrm{CF}\ (C_{high}, \Phi, T_1)$

while $\neg$ condition (11)    ; i.e. $\left(\sum_{i=1}^{m} k_i(\phi_i, T_0) \geq k_{min}\right)$

$\mathrm{CF}(C_{high}, \Phi, T_2)$
```

Implementation and Observations



OpenSSL X.509 Parser

cert_1 cert_2 cert_3 cert_4

parse and check

subject

issuer

CA status

...

cipher

version

validity period

Deep Layers

SG

CE

DP

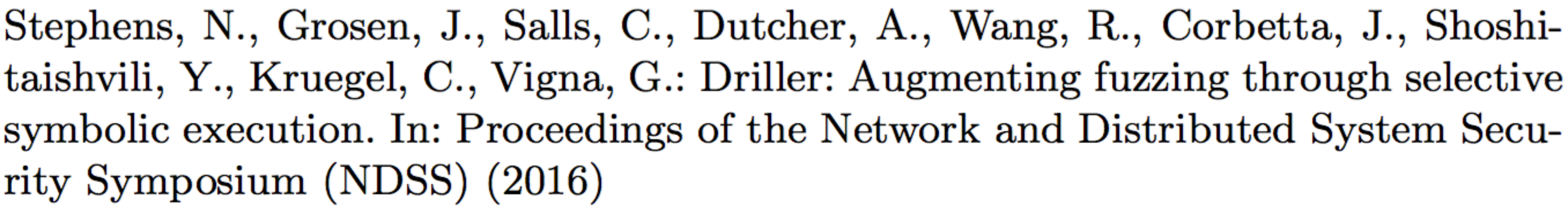
PS

CF

c_1 c_2 c_3 c_4

Related Work

Driller



Stephens, N., Grosen, J., Salls, C., Dutcher, A., Wang, R., Corbetta, J., Shoshitaishvili, Y., Kruegel, C., Vigna, G.: Driller: Augmenting fuzzing through selective symbolic execution. In: Proceedings of the Network and Distributed System Security Symposium (NDSS) (2016)

Summary and Conclusion

- Proposal of a new search heuristic that delays path explosion effectively into deeper layers of the tested binary
- Novel technique to assign probabilities to execution paths
- Algorithm combining initial seed generation, concolic execution, distribution of path probabilities, path selection, and constrained fuzzing

Thank you for your attention!

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