CyberExcellence-2022

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ÉCOLE POLYTECHNIQUE DE LOUVAIN

SEMA

Symbolic Execution toolchain for Malware Analysis - **Packing**

By ***Christophe Crochet*** & ***Charles-Henry Bertrand Van Ouytsel*** & ***Khanh Huu The Dam*** & ***Serena Lucca***
Under the supervision of ***Axel Legay***

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Malware analysis to defeat them all

Symbolic Execution you said ?

SEMA

Packing is kinda a problem

What's next ?

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Malware analysis to defeat them all

Malware

= "*Malware is a piece of code which changes the behavior of either the operating system kernel or some security sensitive applications, without a user consent and in such a way that it is then impossible to detect those changes using a documented features of the operating system or the application (e.g. API).*" - Introducing Stealth Malware Taxonomy

Malware Analysis

= Process to understand behavior of suspicious program

Malware analysis techniques

Static analysis

= Malware analysis based on syntaxic properties defining a signature

Example of tool: Yara

Dynamic analysis

= Malware analysis based on program execution

Example of tool: volatility

Malware analysis techniques problems

Static analysis

- Easily tricked with variants
- With encryption/packing
- Example: detecting string "I'm evil"

```
ULONGLONG uptime = GetTickCount();
Sleep(500000);
ULONGLONG uptimeBis = GetTickCount();
if ((uptimeBis - uptime)<500000 || IsDebuggerPresent()){
   MessageBox(NULL,"Hello world!", "", MB_OK);
} else{
    char message[20] = "";
    HINSTANCE hlib = LoadLibrary("msvcrt.dll");
    MYPROC func = (MYPROC) GetProcAddress(hlib,
                                          "strcat");
    (func) (message, "I'm ");
    (func) (message, "evil!!");
    MessageBox(NULL, message, "", MB_OK);
 }
```

Malware analysis techniques problems

Dynamic analysis

- Anti-debugger
- Time constraints
- ...

- Example: detecting string "I'm evil"

```
ULONGLONG uptime = GetTickCount();
Sleep(500000);
ULONGLONG uptimeBis = GetTickCount();
if ((uptimeBis - uptime)<500000 || IsDebuggerPresent()) {
   MessageBox(NULL,"Hello world!","", MB_OK);
} else {
    char* fl[2] = {"cat","str"};
    char buf[10],message[20];
    strcpy(buf, fl[1]);strcat(buf, fl[0]);
    HINSTANCE hlib = LoadLibrary("msvcrt.dll");
    MYPROC func = (MYPROC) GetProcAddress(hlib, buf);
    (func) (message, "I'm "); (func) (message, "evil!!");
     MessageBox(NULL, message, "", MB_OK);
}
```

Malware analysis techniques problems

Dynamic analysis

- Anti-debugger
-
-
-

Solution

Symbolic Execution

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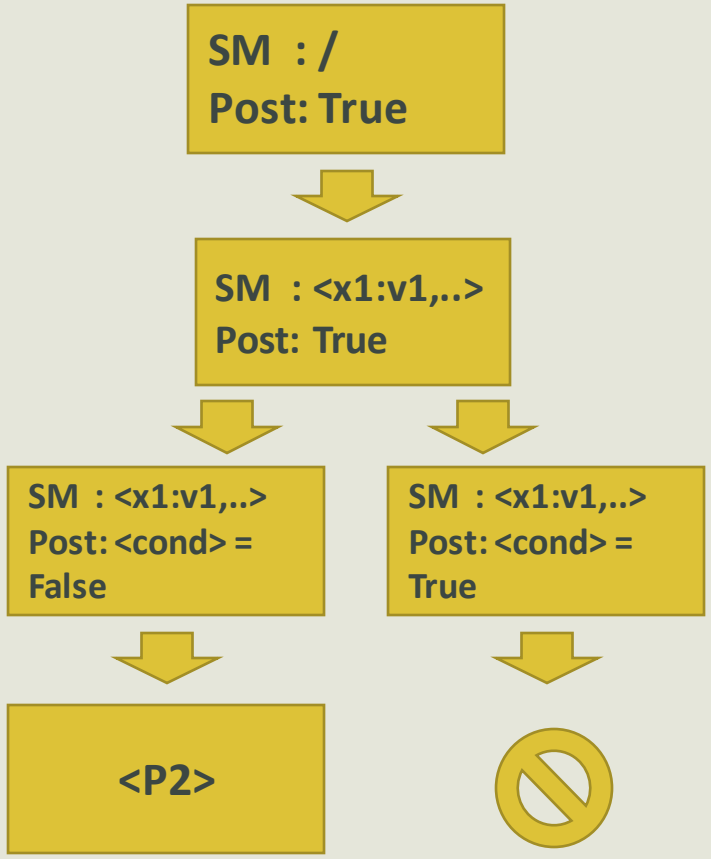
Symbolic Execution you said ?

- Program execution of all possible paths (in theory)
  - Symbolic execution engine
- Symbolic memory store (*SM*)
  - For symbolic value &
  - Symbolic expression
- SMT solver use for satisfiability during path exection (post/pre)

```
<INIT>
if (<CONDITION>) {
    <exit>
 } else{
    <P2>
 }
```



Symbolic Execution you said ?

- Program execution of all possible path
  - Symbolic execution en
- Symbol
- S
  (p

Solve previous problems

BUT

Path explosion problem

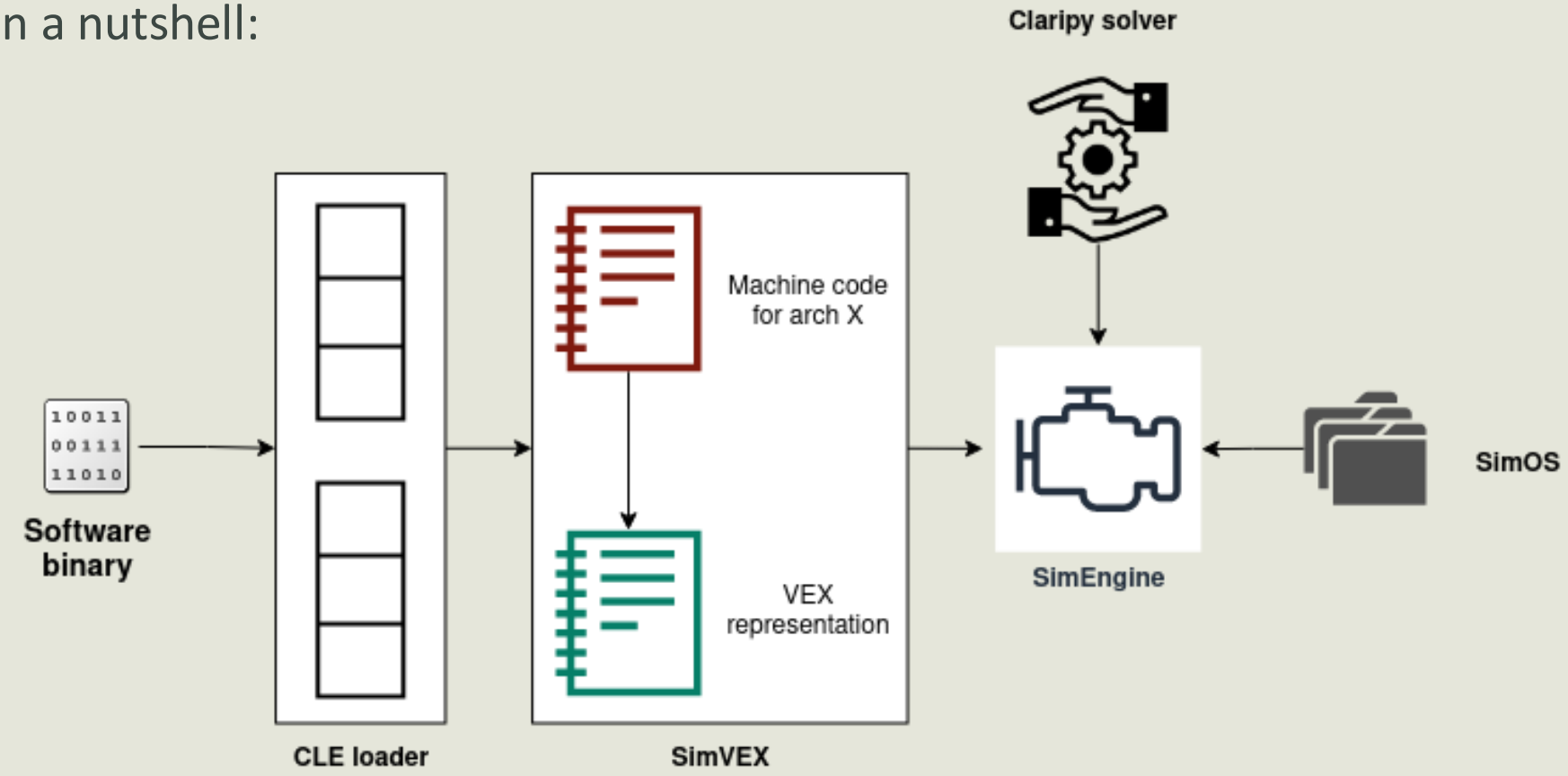
Angr(rr)

- "Open-source binary analysis platform for Python"
- Designs goals:
  1. Cross-architecture support
  2. Cross-platform support
  3. Multiple analysis paradigms support
  4. Usability

(State of) The Art of War: Offensive Techniques in Binary Analysis
Yan Shoshitaishvili, Ruoyu Wang, Christopher Salls, Nick Stephens, Mario Polino, Audrey Dutcher, John Grosen, Siji Feng, Christophe Hauser, Christopher Kruegel, Giovanni Vigna

Angr(rr)

Angr in a nutshell:



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Malware analysis to defeat them all

Symbolic Execution you said ?

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Packing is kinda a problem

What's next ?

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SEMA

- Open-source project too !

- Build on top of Angr

- Goals:
  1. Malware detection
  2. Malware classification
  3. Collaborative works
  4. System calls graph (SCDGs) based analysis

SEMA

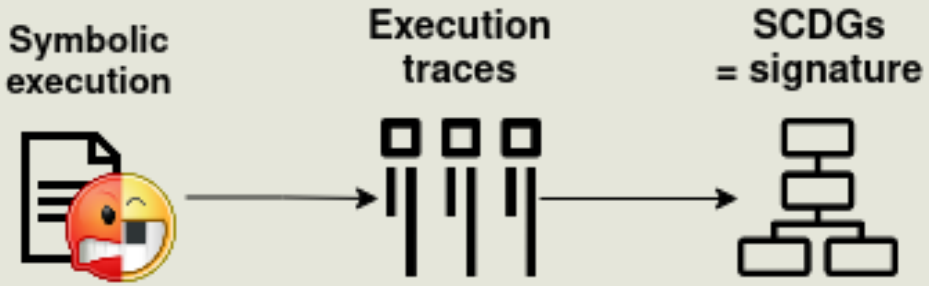
SEMA in a nutshell:

1. SEMA-SCDGs
2. SEMA-Classifier
3. SEMA-FL

SEMA

SEMA in a nutshell:

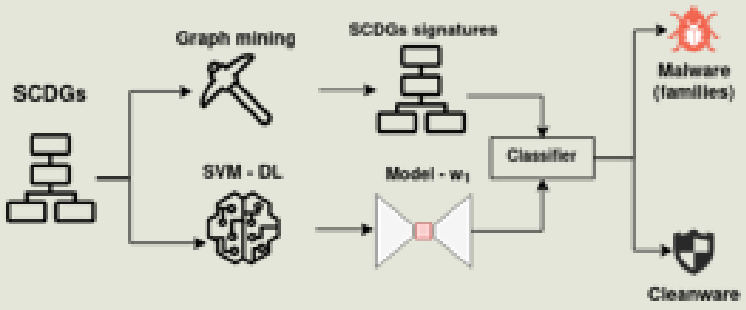
- SEMA-SCDGs
  - ELF & PE programs
  - Custom explorations techniques (CDFS & CBFS)
  - Track of executions paths with SCDGs



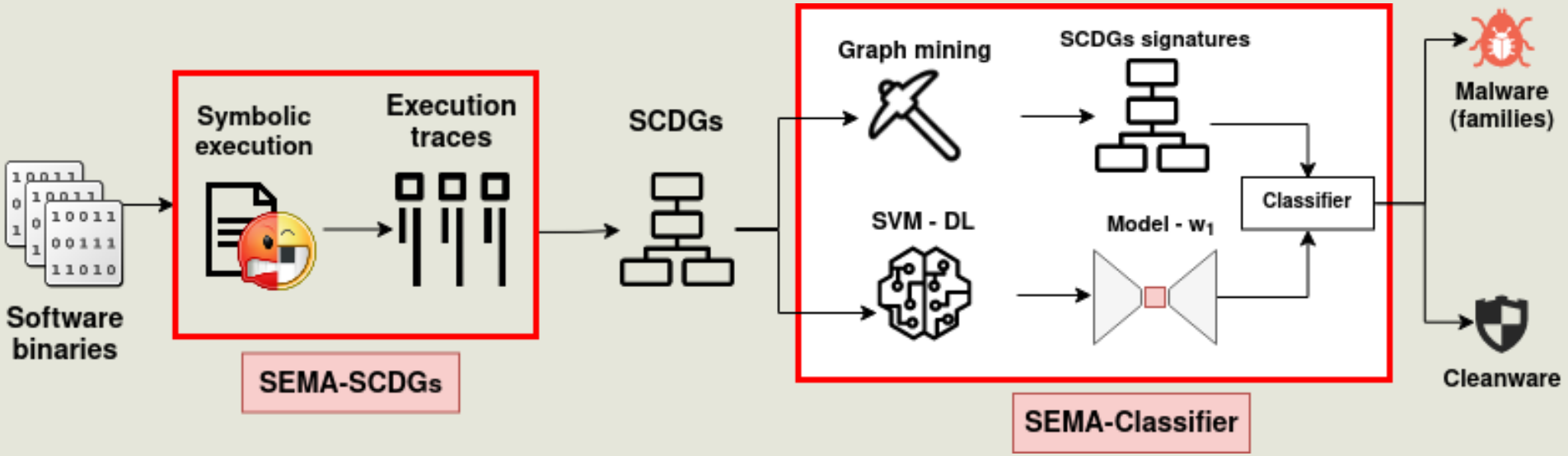
SEMA

SEMA in a nutshell:

- SEMA-Classifier
  - Use SCDGs produced as signature
  - Graph mining model (gSPAN)
  - SVM with graph kernel model
  - Deep learning model



Standalone

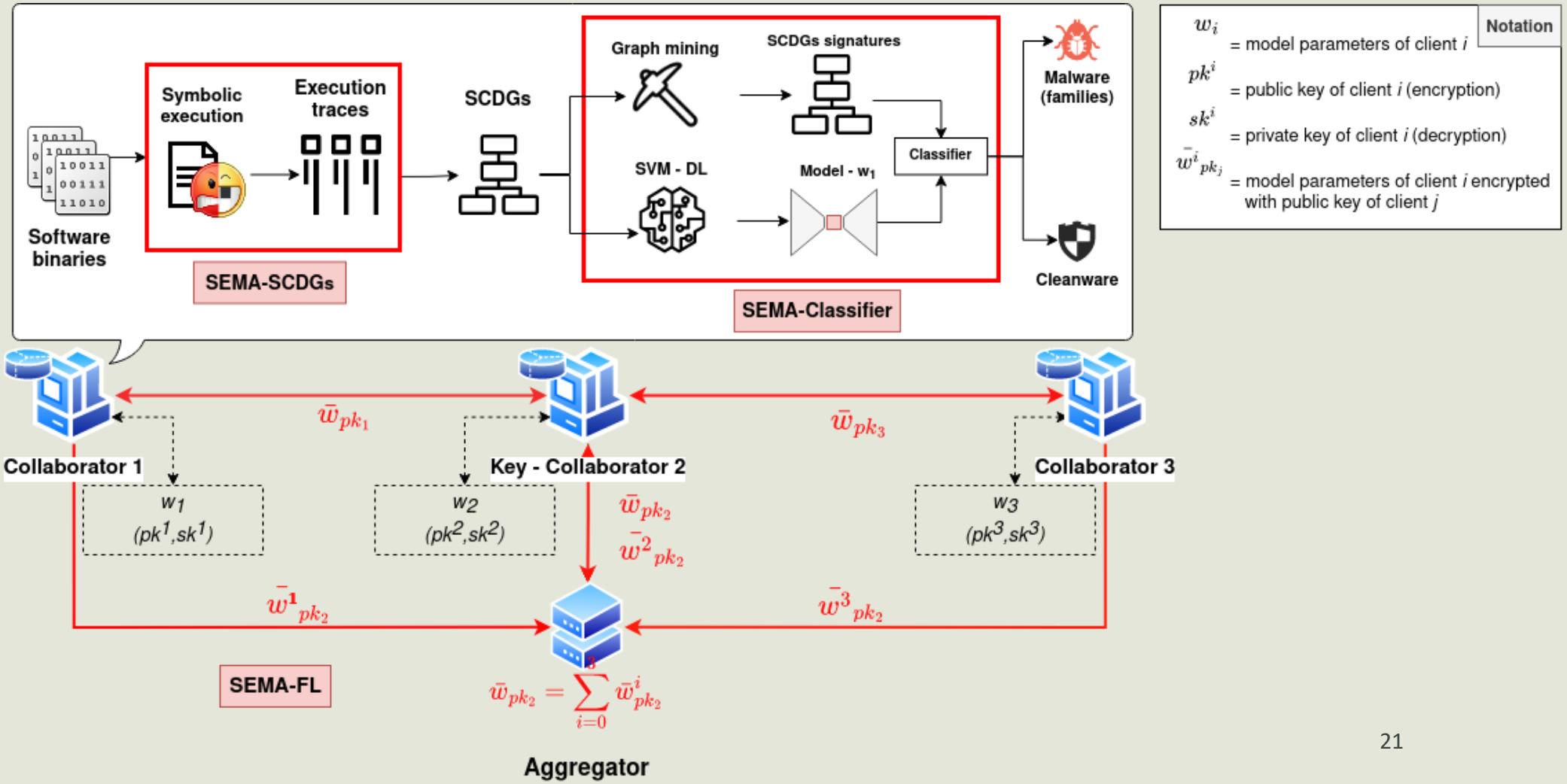

Software binaries
Symbolic execution
Execution traces
SEMA-SCDGs
SCDGs
Graph mining
SCDGs signatures
SVM - DL
Model - w_1
Classifier
SEMA-Classifier
Malware (families)
Cleanware

SEMA

SEMA in a nutshell:

- SEMA-FL
  - Trust server model
  - N clients with their own database
  - Only deep learning model
  - Homomorphic encryption for shared parameters

Adding Federating Learning



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Packing is kinda a problem

What's next ?

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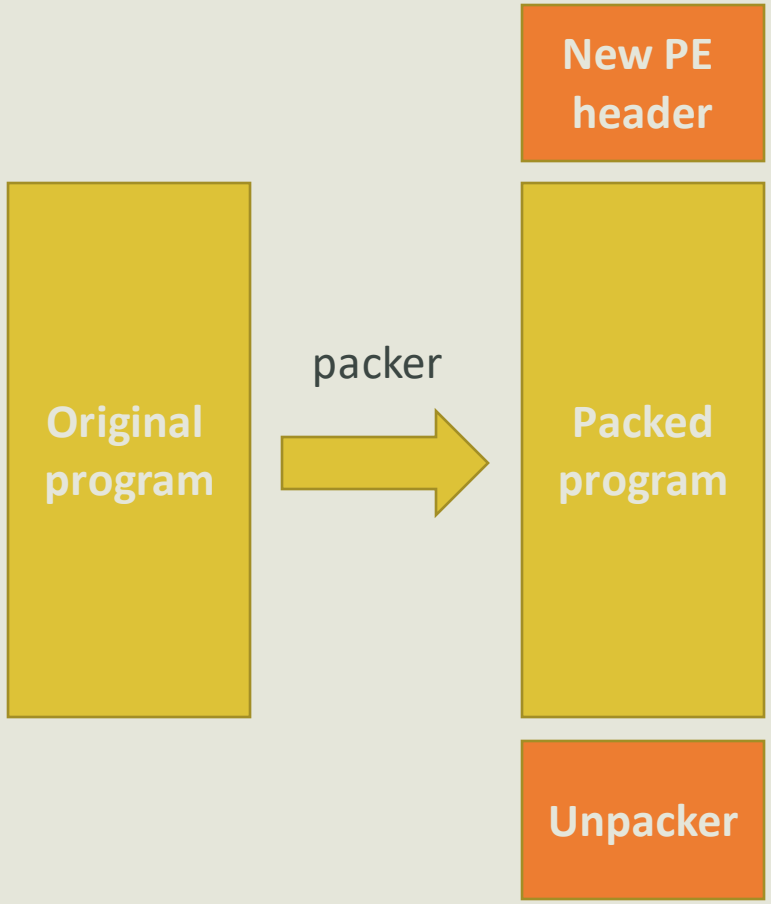
Packing is kinda a problem

What is packing ?

- Obfuscation technique use to hide original program
  - Formatting, compression, etc
- Stub routine to unpack the original code
- E.g: UPX, PE-packer, etc.



Packing is kinda a problem

What is packing ?

- Obf

- S

- E.g

Solution

Concolic Execution

Concolic Execution

Idea = Concolic Execution with Symbion

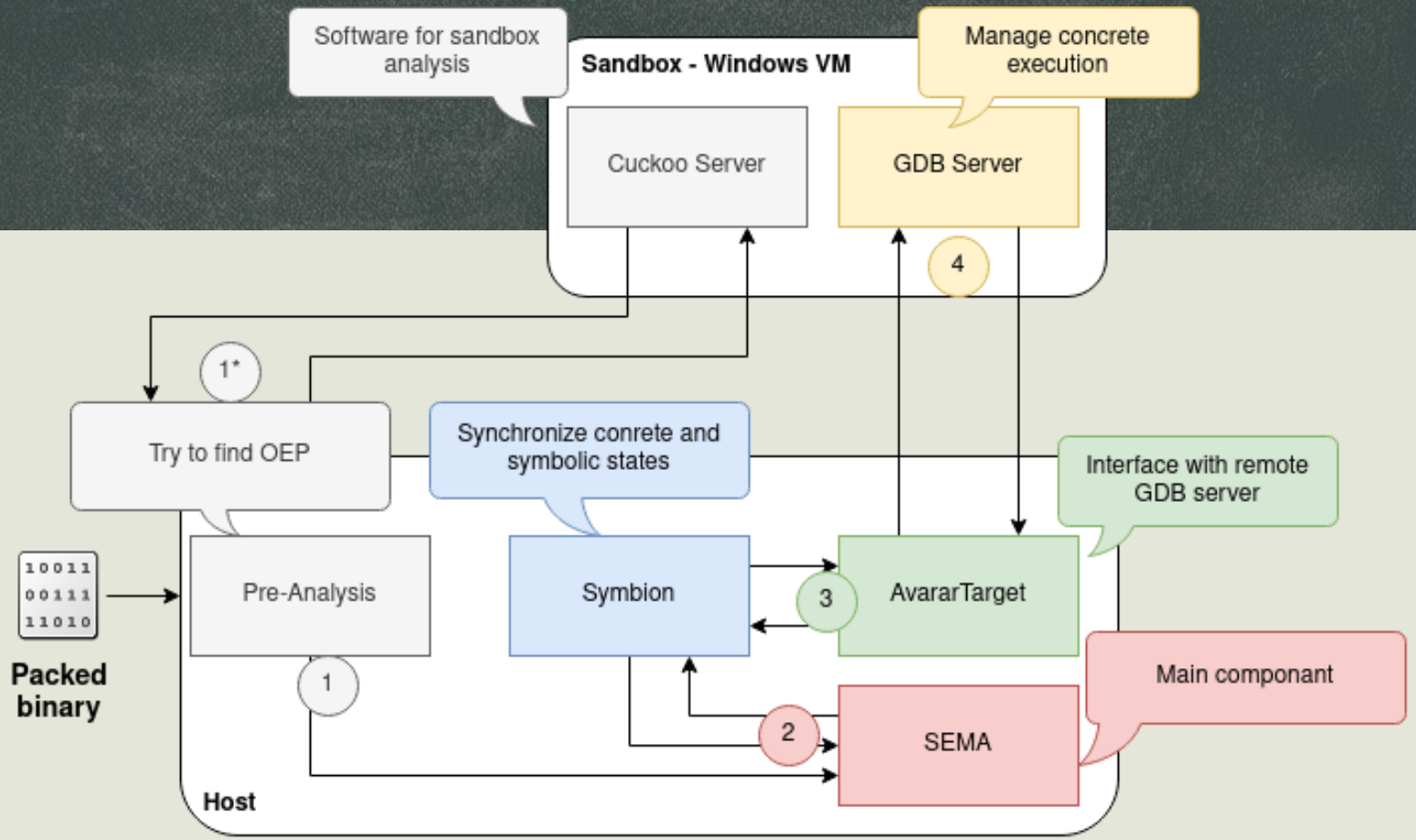
- Execute concretly the unpacking routine
- Execute symbolically the original malware

Challenges:

- Find original entry point of the malware
- Synchronize the state after concrete execution
- Dealing with modified headers

More concretly...

- Memory dumping for multi-layer packer
- Header reconstruction



1 **Send:** OEP if found + other informations to SEMA

2 **Send:** Address to stop concrete execution to Symbion
Receive: Synchronized state of desired address from Symbion

3 **Send:** Concrete output from steps to Symbion
Receive: Symbolic steps from Symbion

4 **Send:** Concrete output from command to Target
Receive: GDB command from Target

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Packing is kinda a problem

What's next ?

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What's next ?

- Extend federated learning to all models
- Support new types of programs (.NET, Java, Macros Excel, …)
- Extend exploration techniques
- Manage packed programs
- Manage obfuscation techniques

Concolic execution

- Many more

What's next ?

- Extend federated learning to all mod
- Support new typ
-
-
-
- M

All in progression !!

What's next ?

- Extend federated learning to all mod
- Support new typ
-
-
-
- M

Checkout our git

https://github.com/csvl/SEMA-ToolChain

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Toward Formal Specification of QUIC attackers with IVy

By ***Christophe Crochet*** & ***Tom Rousseaux***
Under the supervision of ***Axel Legay***

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QUIC is the future

Methodology for the formal verification of QUIC

Previous work

Attacker model

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QUIC is the future

Methodology for the formal verification of QUIC

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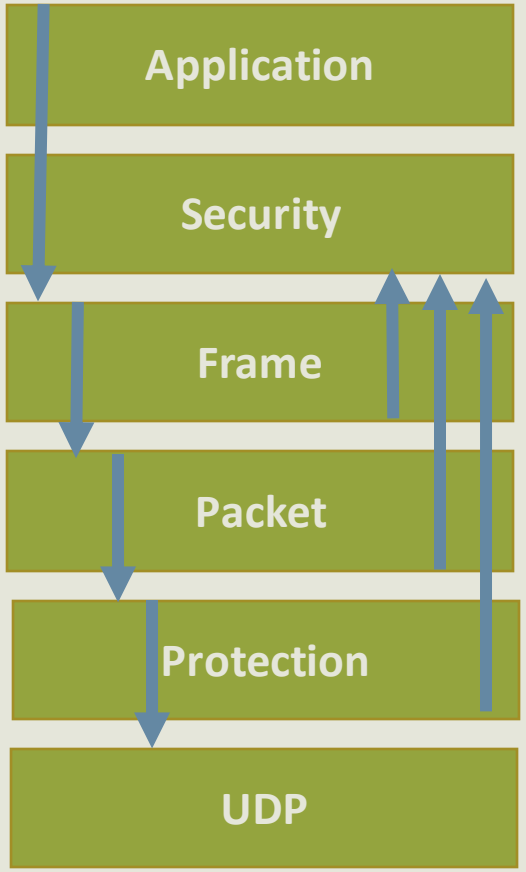
QUIC is the future

- QUIC: a new **secure** transport protocol
  - Intended to replace TCP
  - RFC9000 = textual document

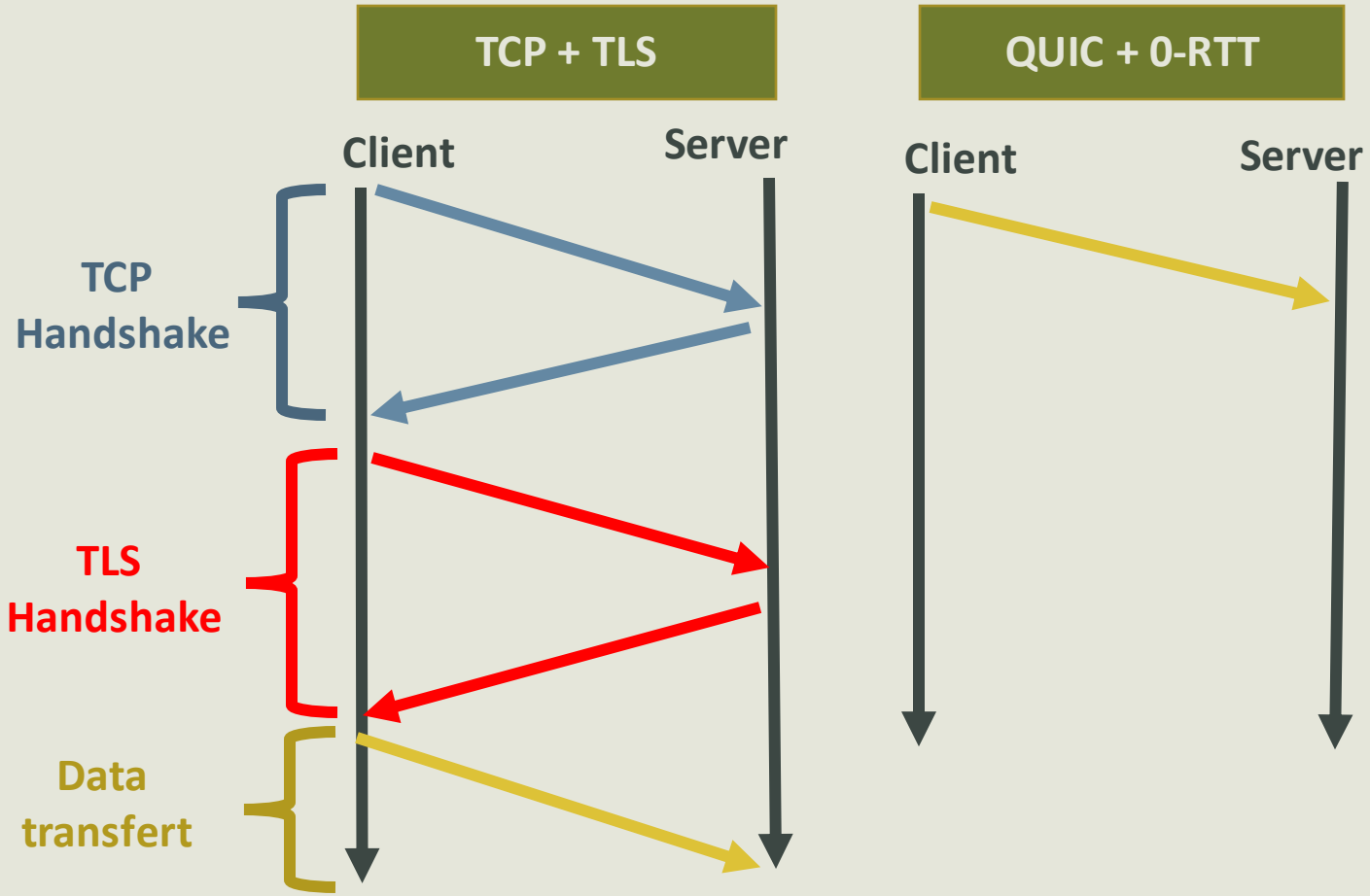
- Importance to test compliance of QUIC to its specification

- Formal verification versus interoperability tests



QUIC, a protocol with innovative features

- QUIC connection
- QUIC multiplexing
- QUIC migration
- Extensibility



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QUIC, a protocol with innovative features

Methodology for the formal verification of QUIC

Previous work

Attacker model

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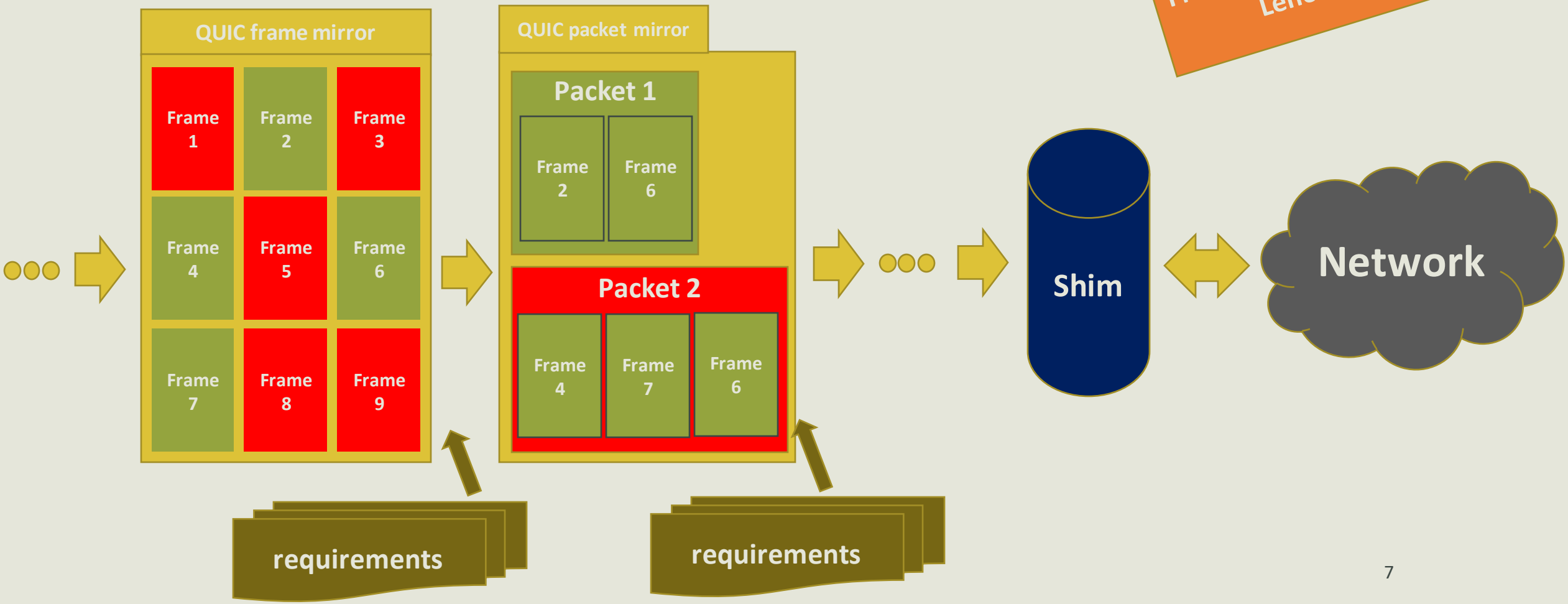
Randomized and Network-centric Compositional testing

From Kenneth McMillan and Lenore D. Zuck



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QUIC, a protocol with innovative features

Methodology for the formal verification of QUIC

Previous work

Attacker model

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What we done

- Update the model to RFC9000 (from draft 18)
- Errors found in every implementation
  - Tested on 8 implementations
- Problems in the draft detected
  - Ambuiguities
- One implementation improved

Main problems founds

1. Violation of the specification
2. Feature not implemented
3. Internal errors and crashes
4. Problem in the draft

35 main errors developed

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QUIC, a protocol with innovative features

Methodology for the formal verification of QUIC

Previous work

Attacker model

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Attack model

- Instead of formally specify QUIC protocol from RFC9000

- We formally specify "Man in the Middle" attacker of QUIC

Difficulties:

- No clear specification
- Localhost
- Usually attacks are very specific

Attack model

- Instead

- U very specific

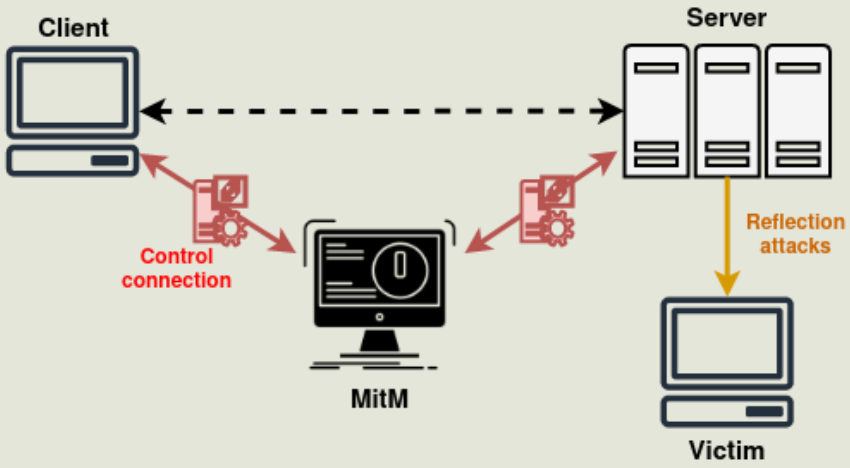
Template model

+

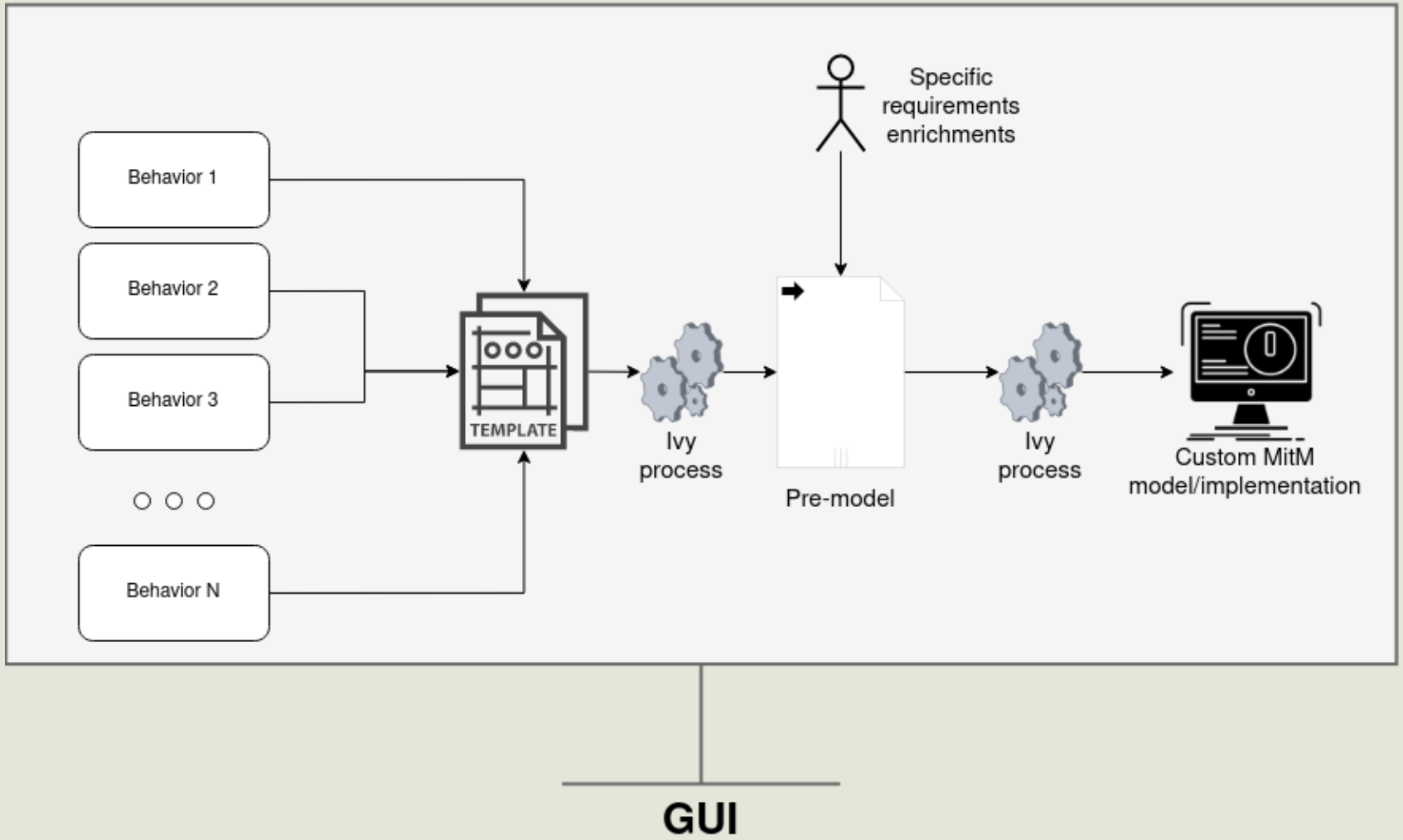
Simulator

Man in the Middle

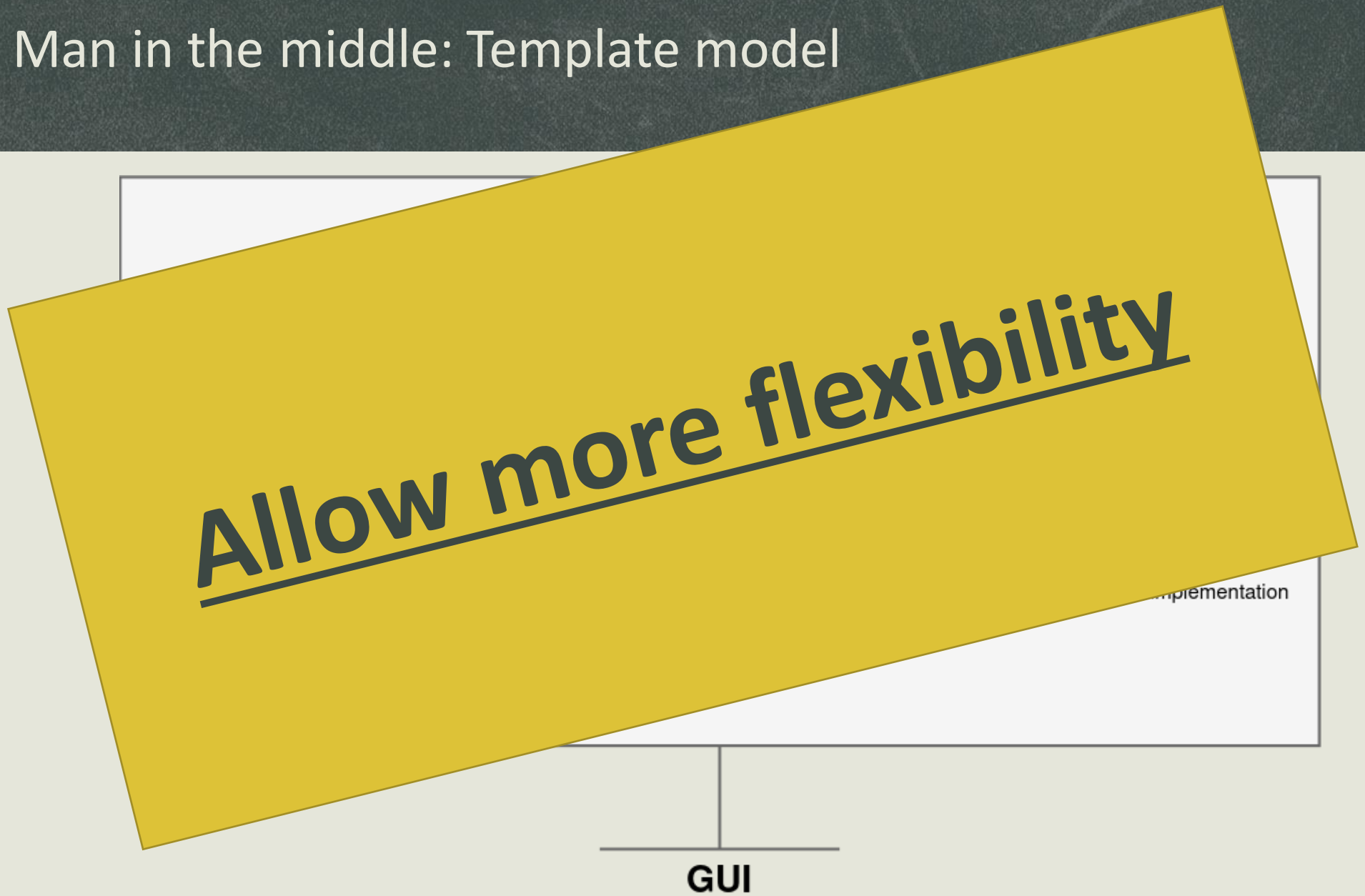
- MitM =
  - attacker placed between communication(s)
  - Able to listen/alter the communication(s)
  - Endpoints are not conscious of the attacker



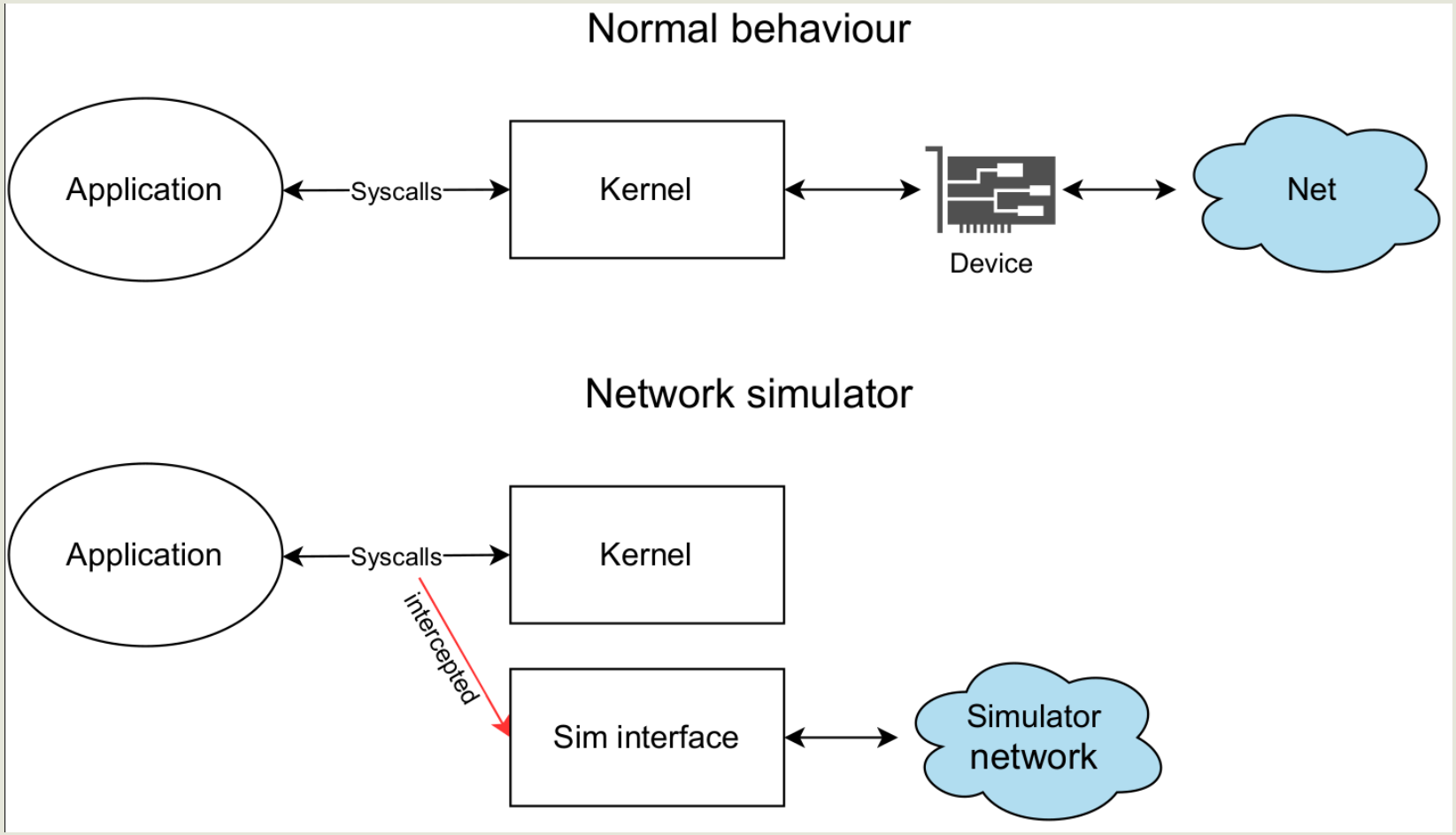
Man in the middle: Template model



Man in the middle: Template model



Simulator


Normal behaviour
Application
Syscalls
Kernel
Device
Net
Network simulator
Application
Syscalls
Kernel
intercepted
Sim interface
Simulator network

Simulator

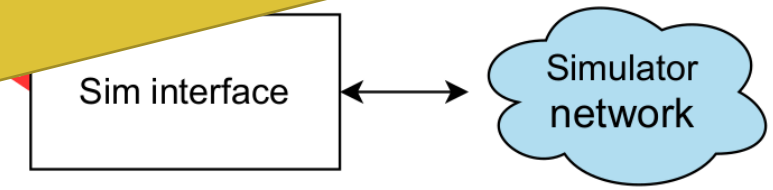
Reproductible experiments

+

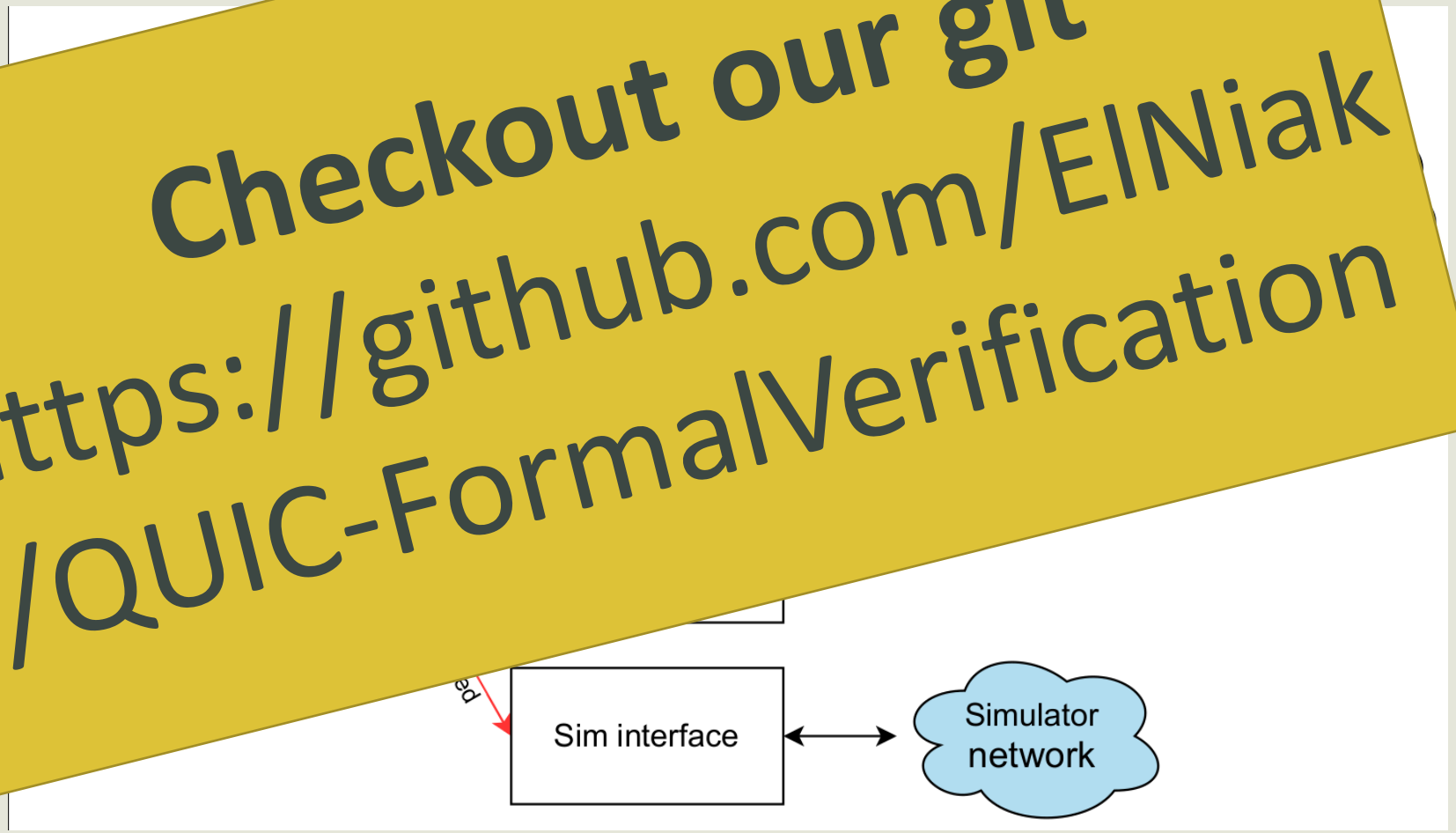
More realist experiments

+

Liveness property assumptions



Simulator



Checkout our git

https://github.com/ElNiak/QUIC-FormalVerification

What's next ?

- Develops more complex templates
- Extend the methodology to other protocol (i.e DNS)
- Improve the GUI for easier configuration

- Many more

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Any question ?

Thanks for your attention

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