Applying Runtime Verification to Group Key Establishment

Secure Communication in the Quantum Era (SPS G5448)

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NATO OTAN

Authenticated group key establishment

Secure communication depends on establishing **common secret key**

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Proving the protocol correct is first step...

a) A sends B the message $(A, E_B(MA), B)$,
b) B answers A by sending $(B, E_A(MB), A)$.

What can go wrong at runtime?

…but in practice is far from enough

(High level) Wrong protocol implementation	The protocol implementation might deviate from the verified (theoretical) design
Low level threats	Arithmetic overflows, undefined downcasts, and invalid pointer references
Hardware	Can hardware be trusted?

Passive / Active attacks

Something bad accidentally happens

Vs

Something bad actively sought

Unintended consequences

- ❏ Timing attacks
- ❏ Cache timing attacks
- ❏ Microarchitecture side-channel attack
- ❏ Power/EM/acoustic attacks
- ❏ Fault attacks
- ❏ Reaction attacks
- ❏ Data remanence attacks
- ❏ Attacks on random number generators

Timing attack

If (secret)

Do something lengthy

Else

Do something simple

An external observer can learn the secret by observing the duration of the execution. (or the power used or any other side effect)

What has been done?

High level logic

- Before any data is sent by the client,

  the server hash is verified to match the client's version

- If the operation is of type “Send”,

  then the message receiver ID must be in the set of approved receiver IDs

Low level considerations

General considerations for any code

- Arithmetic overflows
- Undefined downcasts
- Invalid pointer references

Mid-level

Applicable to any crypto protocol

Data flow monitoring

E.g. Ensuring not control is decided on secret data

(which affects the timing of the program)

Frama-C

Is a framework supporting all of these levels

Low-level is inbuilt

Mid-level is provided through library support

High-level is provided through specification languages

Other tools/frameworks?

Copilot and other tools focus more on high level properties

Work on hyperproperties

    I.e. properties on several runs of a program

What are the challenges?

Challenges for RV

Over and above the usual correctness and overheads concerns

The monitor can present an additional security vulnerability

>> As a piece of code

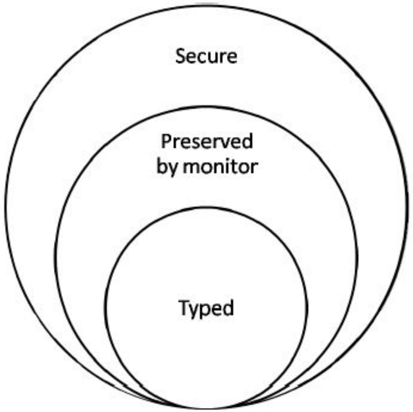
>> As a reaction triggering device

Soundness/Completeness of dynamic analysis

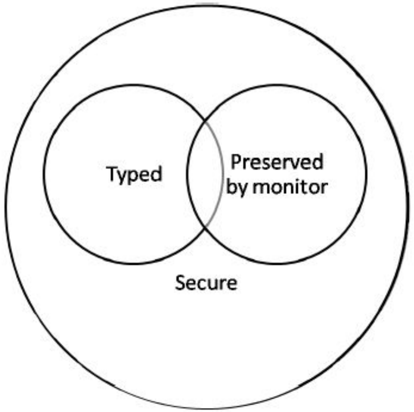
$$\texttt{if } h = 1 \texttt{ then } b := 1 \texttt{ else skip;}$$
$$\texttt{if } b \neq 1 \texttt{ then } l := 1 \texttt{ else skip;}$$
$$\texttt{output}_L(l)$$

Assume h is a high security variable
When h != 1,
Monitor can’t mark b as high
(without analysing the “if” statically)

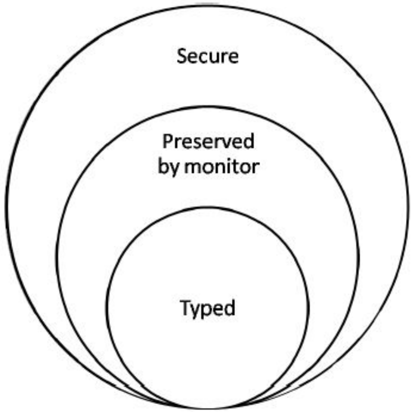
Soundness/Completeness of dynamic analysis



(a) Flow-insensitive analysis



(b) Flow-sensitive analysis



(c) Flow-sensitive analysis, *hybrid* monitors

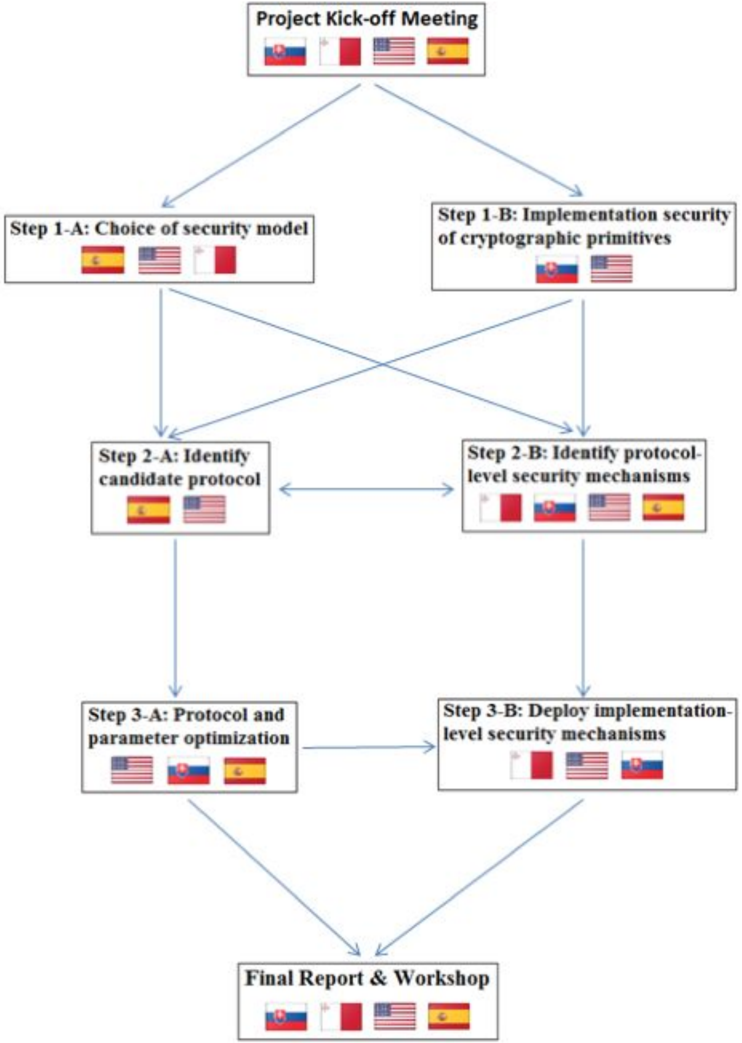
Other techniques?

For example Multi-execution approach:

Generate low security outputs with only low security inputs in the system

→ **Result:** No high security output may depend on low security input

Our plan


Project Kick-off Meeting
Step 1-A: Choice of security model
Step 1-B: Implementation security of cryptographic primitives
Step 2-A: Identify candidate protocol
Step 2-B: Identify protocol-level security mechanisms
Step 3-A: Protocol and parameter optimization
Step 3-B: Deploy implementation-level security mechanisms
Final Report & Workshop

Questions to be answered

To what extent existing tools/frameworks are immune to attacks themselves

Is there any effect of the quantum prospect on RV?

What mix of new/existing techniques + technologies to adopt