Journée du GT Méthodes Formelles et Sécurité

30 janvier 2020
Paris 6, campus de Jussieu

Organisation :
Karine Heydemann, Damien Couroussé

Reponsables du GT :
Sébastien Bardin, Stéphanie Delaune

EXCLUSIF !!

Cristian Cadar	Titre à venir.
Barbara Fila	Attack trees: meaning, analysis, and correctness
Itsaka Rakotonirina	Efficient verification of observational equivalences in finite-process calculi.
Cătălin Hriţcu	When Good Components Go Bad: Formally Secure Compilation Despite Dynamic Compromise.
Thomas Letan	Specifying and Verifying Hardware-based Security Enforcement mechanisms.
Patricia Mouy	Use of formal methods in the Common Criteria Context.
Johan Laurent	A Cross-Layer Security Approach: Combining Accurate Modelling of Hardware Faults with Static Software Analysis.

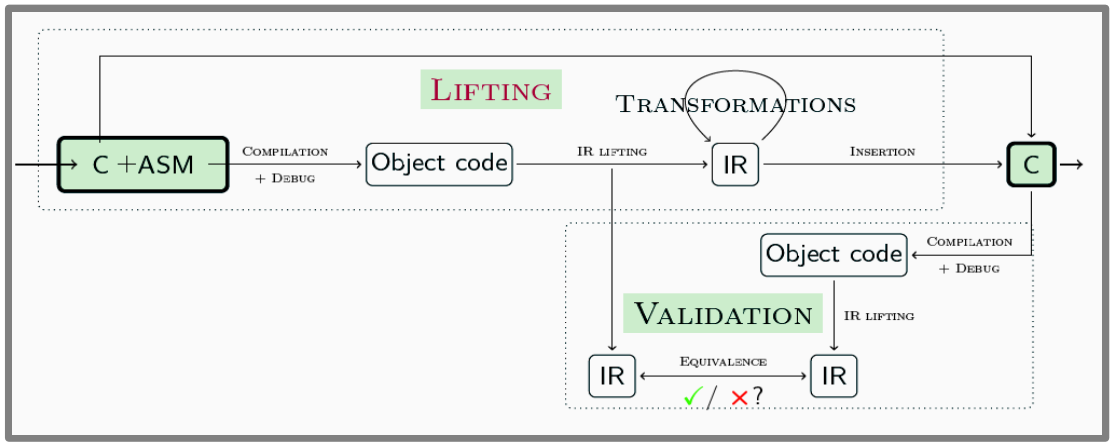
Pensez à vous inscrire !! https://gtmfs2020.github.io/

Breaking news 1
Inline assembly & verification (ASE 2019)

BINSEC

By Frédéric Recoules

- Problem = verifying mix code
- Standard verif tools do not work
- Solution : verification-oriented lifting
- Evaluation :
  . 2000+ asm chunks from Debian
  . Frama-C, Klee



Get rid of inline assembly through verification-oriented lifting

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***Abstract*—Formal methods for software development have made great strides in the last two decades, to the point that their application in safety-critical embedded software is an undeniable success. Their extension to non-critical software is one of the notable forthcoming challenges. For example, C programmers regularly use inline assembly for low-level optimizations and system primitives. This usually results in rendering state-of-the-art formal analyzers developed for C ineffective. We thus propose TINA, the first automated, generic, *verification-friendly* and trustworthy lifting technique turning inline assembly into semantically equivalent C code amenable to verification, in order to take advantage of existing C analyzers. Extensive experiments on real-world code (including GMP and ffmpeg) show the feasibility and benefits of TINA.**

***Index Terms*—Inline assembly, software verification, lifting, formal methods.**

I. INTRODUCTION

Context. Formal methods for the development of high-safety software have made tremendous progress over the last two decades [1], [2], [3], [4], [5], [6], with notable success in regulated safety-critical industrial areas such as avionics, railway or energy. Yet, the application of formal methods to more usual (non-regulated) software, for safety or security, currently remains a scientific challenge. In particular, extending the applicability from a world with strict coding guidelines and disciplined mandatory validation processes to more liberal and diverse development and coding practices is a difficult task.

Problem. We consider here the issue of analyzing "mixed code", focusing on the use of inline assembly in C/C++ code. This feature allows to embed assembly instructions in C/C++ programs. It is supported by major C/C++ compilers like GCC, clang or Visual Studio, and used quite regularly — usually for optimization or to access system-level features hidden by the host language. For example, we estimate that 11% of Debian packages written in C/C++ directly or indirectly depends on inline assembly, with chunks containing up to 500 instructions, while 28% of the top rated C projects on GitHub contains inline assembly according to Rigger et al. [7]. As a matter of fact, *inline assembly is a common engineering practice in key areas such as cryptography, multimedia or drivers.* However, *it is not supported by current state-of-the-art C/C++ program analyzers*, like KLEE [4] or Frama-C [1], possibly leading to incorrect or incomplete results. *This is a clear applicability issue for advanced code analysis techniques.*

Given that developing dedicated analyzers from scratch is too costly, the usual way of dealing with assembly chunks is to write either equivalent host code (e.g, C/C++) or equivalent logical specification when available. But *this task is handled manually* in both cases, precluding regular analysis of large code bases: manual translation is indeed time-consuming and error-prone. The bigger the assembly chunks are, the bigger these problems loom.

Goal and challenges. *We address the challenge of designing and developing an automated and generic lifting technique turning inline assembly into semantically equivalent C code amenable to verification.* The method should be:

Verification-friendly The produced code should allow *good enough* analyses in practice (informally dubbed *verifiability*), independently of the underlying analysis techniques (e.g., symbolic execution [8], [9], deductive verification [10], [11] or abstract interpretation [12]);

Widely applicable It should not be tied to a particular architecture, assembly dialect or compiler chain, and yet handle a significant subset of assembly chunks found in the wild;

Trustworthy The translation process should be insertable in a formal verification context without endangering soundness: as such it should maintain exactly all behaviors of the mixed code, and provide a way to show this property.

Verifiability alone is already challenging: indeed, straightforward lifting from assembly to C (keeping the untyped byte-level view) does not ensure it as standard C analyzers are not well equipped to deal with such low-level C code.

Scarce previous attempts do not fulfill all the objectives above. Vx86 [13] is tied to both the x86 architecture and deductive verification, while the recent work by Corteggiani et al. [14] focuses on symbolic execution. None of them addresses verifiability or trust. At first sight, decompilation techniques [15], [16], [17] may seem to fit the bill. Yet, as they mostly aim at helping reverse engineers, correctness is not their main concern. Actually, *"existing decompilers frequently produce decompilation that fails to achieve full functional equivalence with the original program"* [18]. Some recent works partially target this issue: Schwartz et al. [19] do not *demonstrate* correctness (they instead measure a certain degree of it via testing), while Schulte et al. [18] use a correct-by-design but intractable (possibly non-terminating) search-based method. Again, none of them study verifiability.

Breaking news 2
Code protection & obfuscation (ACSAC 2019)

BINSEC

By Mathilde Ollivier

- Problem = semantic attacks !
- Semantic attacks very effective
- Solution : path-oriented protections
- Strong, Cheap, Stealth
- « protection of VMx3, no cost »

Transformation (#TO/#Samples)	Dataset #1		Dataset #2		
	Goal 1 3h TO	*Goal 2 1h TO*	*Goal 1 24h TO*	*Goal 2 3h TO*	*Goal 2 8h TO*
Virt	0/46	0/15	0/7	0/7	0/7
Virt ×2	1/46	0/15	0/7	0/7	0/7
Virt ×3	5/46	2/15	1/7	0/7	0/7
SPLIT ($k = 10$)	1/46	0/15	0/7	0/7	0/7
SPLIT ($k = 13$)	4/46	0/15	1/7	1/7	0/7
SPLIT ($k = 17$)	18/46	2/15	3/7	2/7	1/7
FOR ($k = 1$)	2/46	0/15	0/7	0/7	0/7
FOR ($k = 3$)	30/46	8/15	3/7	2/7	1/7
FOR ($k = 5$)	46/46	15/15	7/7	7/7	7/7

How to Kill Symbolic Deobfuscation for Free
(or: Unleashing the Potential of Path-Oriented Protections)

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ABSTRACT

Code obfuscation is a major tool for protecting software intellectual property from attacks such as reverse engineering or code tampering. Yet, recently proposed (automated) attacks based on Dynamic Symbolic Execution (DSE) shows very promising results, hence threatening software integrity. Current defenses are not fully satisfactory, being either not efficient against symbolic reasoning, or affecting runtime performance too much, or being too easy to spot. We present and study a new class of anti-DSE protections coined as path-oriented protections targeting the weakest spot of DSE, namely path exploration. We propose a lightweight, efficient, resistant and analytically proved class of obfuscation algorithms designed to hinder DSE-based attacks. Extensive evaluation demonstrates that these approaches critically counter symbolic deobfuscation while yielding only a very slight overhead.

CCS CONCEPTS

• **Security and privacy** → **Software reverse engineering**; *Logic and verification*; Malware and its mitigation; • **Software and its engineering** → *Formal methods.*

KEYWORDS

Reverse Engineering; Code Protection; Obfuscation

ACM Reference Format:
Mathilde Ollivier, Sébastien Bardin, Richard Bonichon, and Jean-Yves Marion. 2019. How to Kill Symbolic Deobfuscation for Free (or: Unleashing the Potential of Path-Oriented Protections) . In *2019 Annual Computer Security Applications Conference (ACSAC '19), December 9–13, 2019, San Juan, PR, USA.* ACM, New York, NY, USA, 13 pages. https://doi.org/10.1145/3359789.3359812

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ACM ISBN 978-1-4503-7628-0/19/12…$15.00
https://doi.org/10.1145/3359789.3359812

1 INTRODUCTION

Context. Reverse engineering and code tampering are widely used to extract proprietary assets (e.g., algorithms or cryptographic keys) or bypass security checks from software. *Code protection* techniques precisely seek to prevent, or at least make difficult, such *man-at-the-end* attacks, where the attacker has total control of the environment running the software under attack. Obfuscation [21, 22] aims at hiding a program's behavior by transforming its executable code in such a way that the behavior is conserved but the program becomes much harder to understand.

Even though obfuscation techniques are quite resilient against basic automatic reverse engineering (including static attacks, e.g. disassembly, and dynamic attacks, e.g. monitoring), code analysis improves quickly [39]. Attacks based on *Dynamic Symbolic Execution* (DSE, a.k.a. *concolic execution*) [18, 30, 40] use logical formulas to represent input constraints along an execution path, and then automatically solve these constraints to discover new execution paths. DSE appears to be very efficient against existing obfuscations [5, 8, 13, 24, 37, 51], combining the best of dynamic and semantic analysis.

Problem. *The current state of symbolic deobfuscation is actually pretty unclear.* Dedicated protections have been proposed, mainly based on hard-to-solve predicates, like Mixed Boolean Arithmetic formulas (MBA) [52] or cryptographic hash functions [42]. Yet the effect of complexified constraints on automatic solvers is hard to predict [6], cryptographic hash functions may induce significant overhead and are amenable to key extraction attacks (possibly by DSE). On the other hand, DSE has been fruitfully applied on malware and legit codes protected by state-of-the-art tools and methods, including virtualization, self-modification, hashing or MBA [8, 37, 51]. A recent systematic experimental evaluation of symbolic deobfuscation [5] shows that most standard obfuscation techniques do not seriously impact DSE. Only nested virtualization seems to provide a good protection, assuming the defender is ready to pay a high cost in terms of runtime and code size [37].

Goals and Challenges. We want to propose a new class of dedicated anti-DSE obfuscation techniques to render automated attacks based on symbolic execution inefficient. These techniques should be *strong* – making DSE intractable in practice, and *lightweight* – with very low overhead in both code size and runtime performance. While most anti-DSE defenses try to break the symbolic reasoning

GT SSLR - Ramp-UP

Pub: OWASP Paris et Lizard Meetups - sécurité du code

OWASP

- Talk chapître OWASP France du 10/10/2019 Yvan P. OWASP pour 0 euros
- ASVS Application Security Verification Standard, même un word et un excel,

Le prochain Meetup, c'est demain sur l'IAC et la cybersécurité.

Référentiel 62443 (ISA)

Cf. présentation club 27001 et ici en pdf.

Certification 62443 - ISA Secure

1. Maintenir la capacité de contrôle - Capacité à maintenir la boucle de contrôle principale, quelles que soient les conditions de trafic réseau,
2. Maintenir la capacité de commande - Capacité à continuer à répondre à des signaux de commande de systèmes de plus haut niveau dans des temps contraints, quelles que soient les conditions de trafic réseau,
3. Maintenir les lectures sur l'équipement - Capacité de continuer à fournir la visibilité sur le process dans des temps contraints, quelles que soient les conditions de trafic réseau,
4. Maintenir les capacité d'alarmes et de traçage des alarmes - Capacité à maintenir le système d'alarme et de traçage des alarmes dans des temps contraints, quelles que soient les conditions de trafic réseau,
5. Maintenir les fonctions essentielles de reporting de l'his[illegible] Capacité à maintenir les fonctions d'historique des do[illegible] dans des temps contraints, quelles que soient les conditions de

Certification 62443 - ISA Secure

- Exemple de test de fuzzing HUD,
- CRT test tools

SPARK for Security

AdaCore ALTRAN

PARTNERSHIP

PROOF IN USE

SPARK-2014.ORG/PROOFINUSE

Yannick Moy – AdaCore

Journée thématique du GT SSLR

SPARK – Flow Analysis

```
procedure Stabilize (Mode    :  in Mode_T;
                     Success : out Boolean)
  with Global => (Input  => (Accel, Giro),
                  In_Out => Rotors);
```

SPARK – Proof

```
procedure Stabilize (Mode    :  in Mode_T;
                     Success : out Boolean)
  with Pre  => Mode /= Off,
       Post => (if Success then
                   Delta_Change (Rotors'Old, Rotors));
```

SPARK – a Subset of Ada

strong typing

low level programming

generics

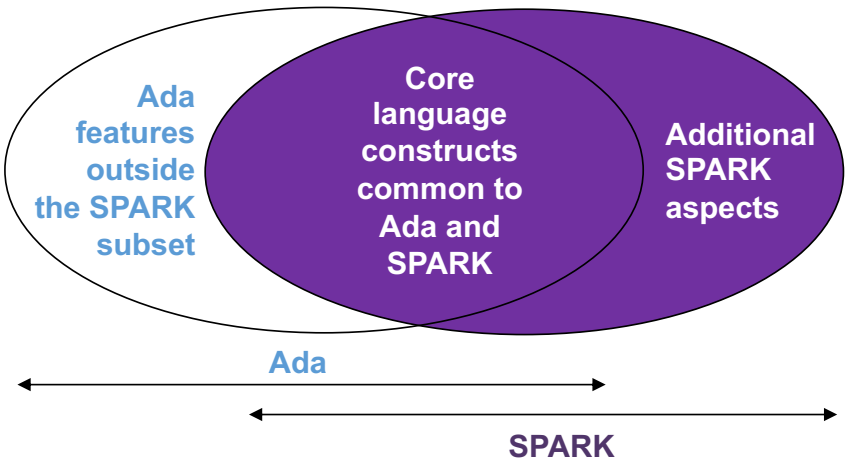
object orientation

concurrency

unrestricted pointers

exception handlers

function with effects



Abstract_State

Initializes

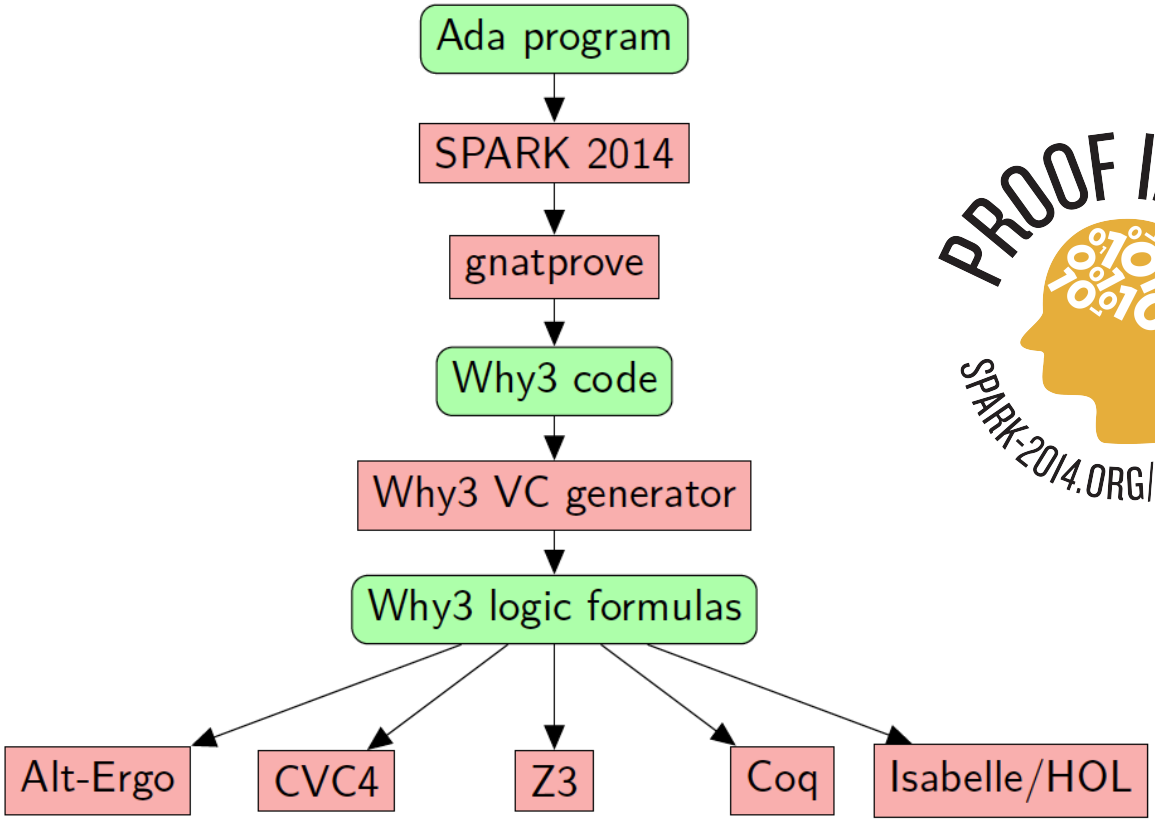
Initial_Condition

Contract_Cases

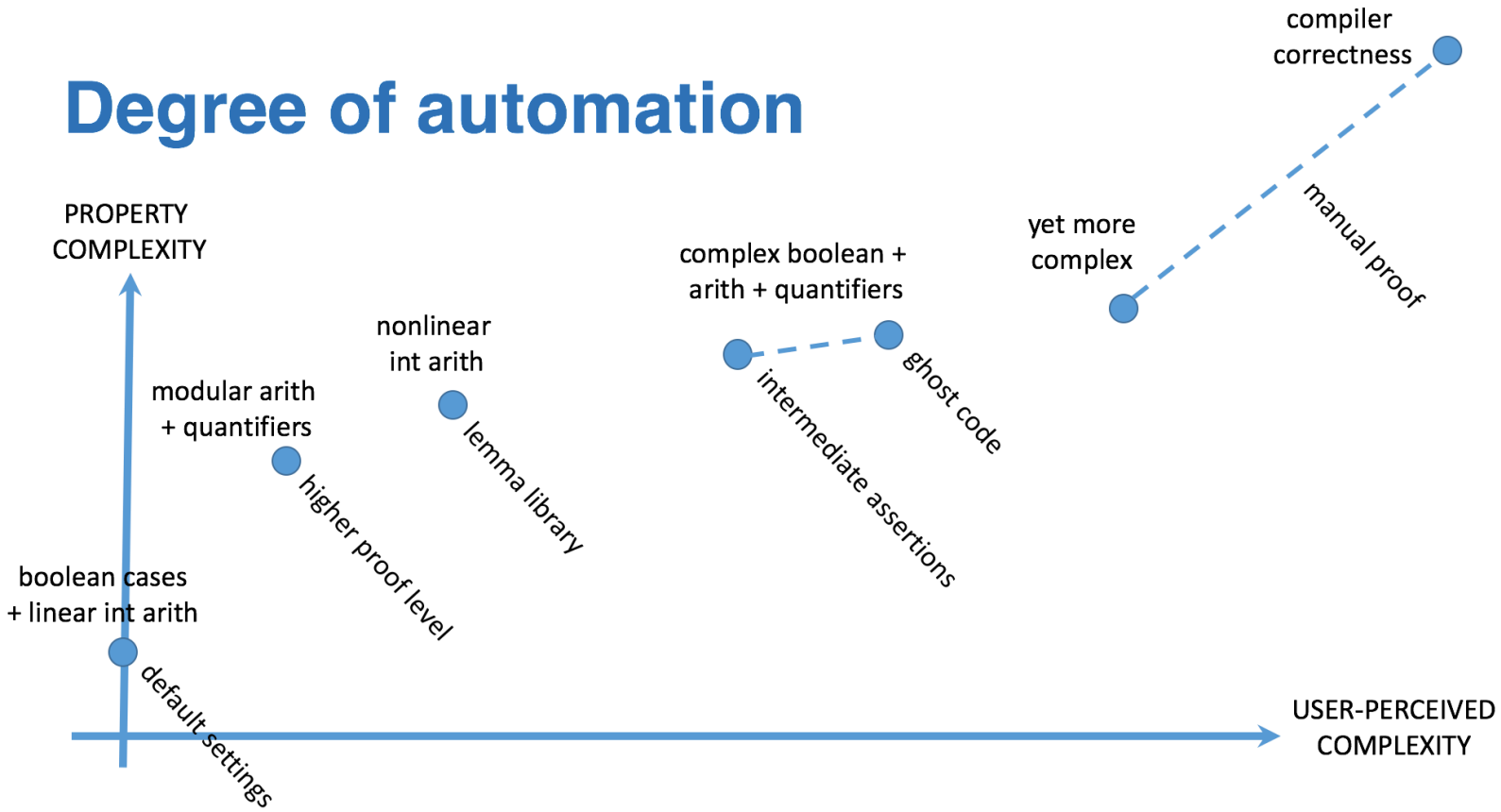
Global

Depends

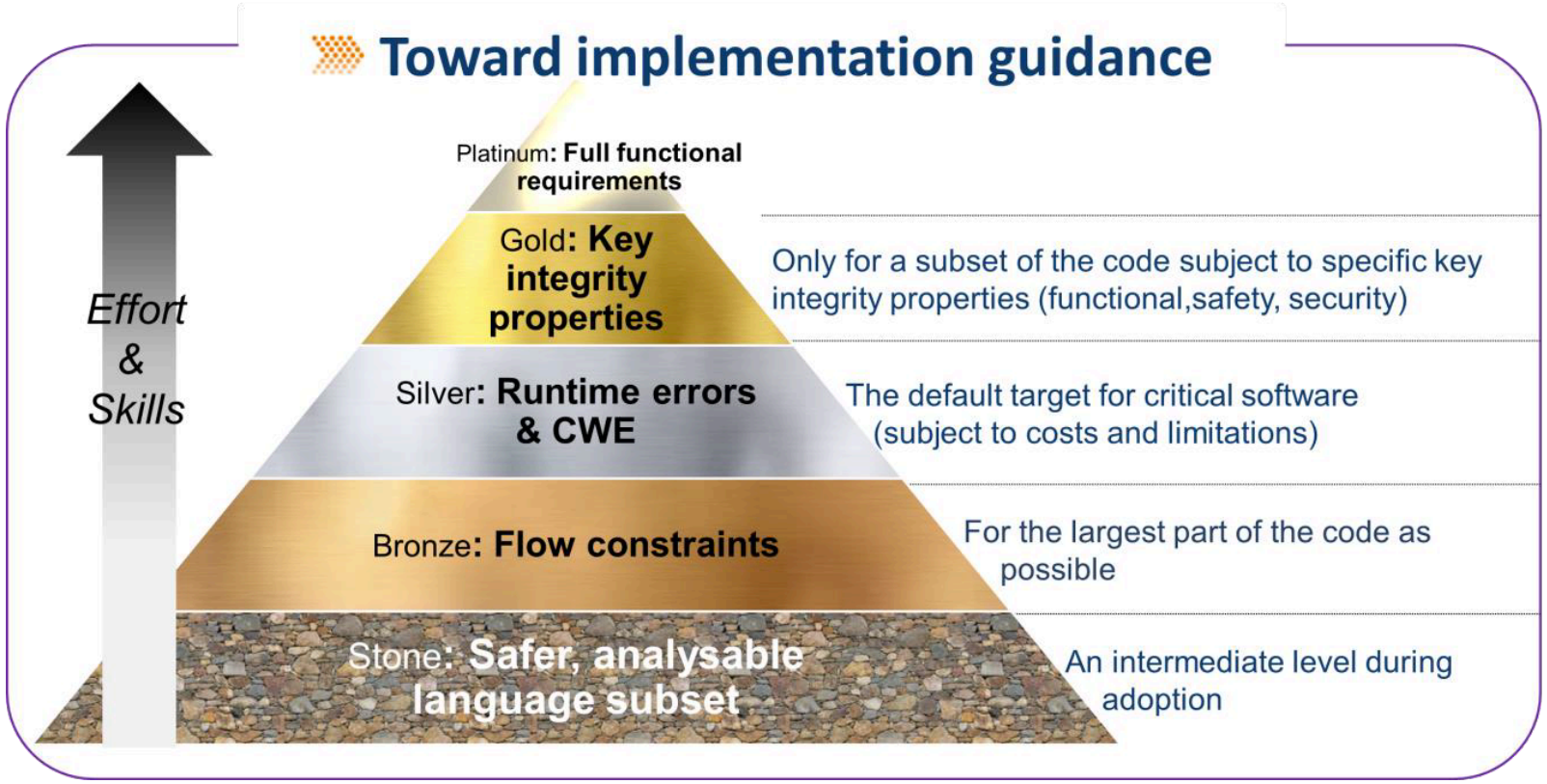
SPARK Open Source Ecosystem



Key Feature - Automation

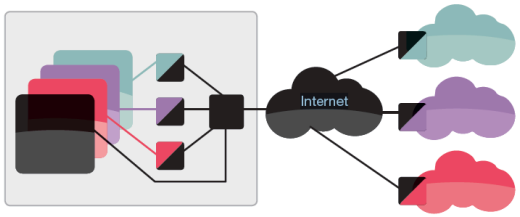


Software Assurance Levels

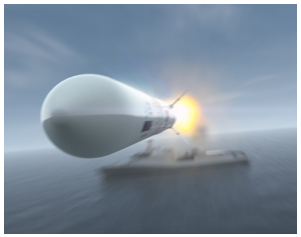


Some SPARK Projects in Security

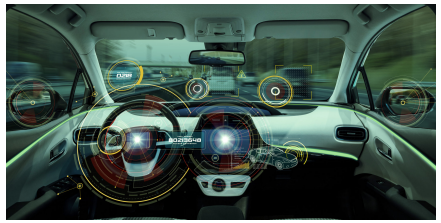
Rockwell Collins
Turnstile/SecureOne
cross-domain switch
Silver and **Gold**



Secunet **MLW**
multilevel workstation
Silver and **Gold** (for encryption-related properties)



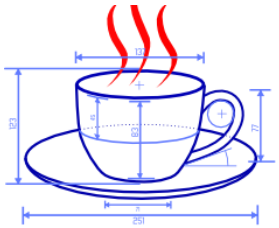
MBDA **EISR**
secure in-the-field updating with code-signing
Silver



NVIDIA **SP/FW**
Falcon/RISC-V security processors
Security-critical firmware
Silver and **Gold**

Program Proof Tools

SPARK2014



JML

VIPER

frama C

Software Analyzers

Academic

Industrial

SPARK for Security

SPARK supports 5 levels of increasing software assurance

From strong semantic coding standard to full functional correctness

Bronze level (correct information flow) is key for confidentiality

Silver level (AoRTE) is a must-have for secure software

SPARK can be combined with Ada at fine-grain (subprogram) level

SPARK can be combined with C at coarser-grain (file) level

Common Code Generator (CCG) generates C code from SPARK

SPARK Resources

SPARK toolset

http://www.adacore.com/sparkpro http://www.adacore.com/community

SPARK adoption guidance

www.adacore.com/knowledge/technical-papers/implementation-guidance-spark

AdaCore Technologies for Cyber Security booklet

https://www.adacore.com/books/adacore-tech-for-cyber-security

SPARK reference documents (User's Guide + Reference Manual)

https://www.adacore.com/documentation/#SPARK

SPARK online training

http://learn.adacore.com

Componolit
Secure Systems Engineering

RecordFlux: Formal Message Specification and Generation of Verifiable Binary Parsers

Journée thématique du GT SSLR 2019

Alexander Senier

Paris, November 27th, 2019

RecordFlux
Communication Protocols

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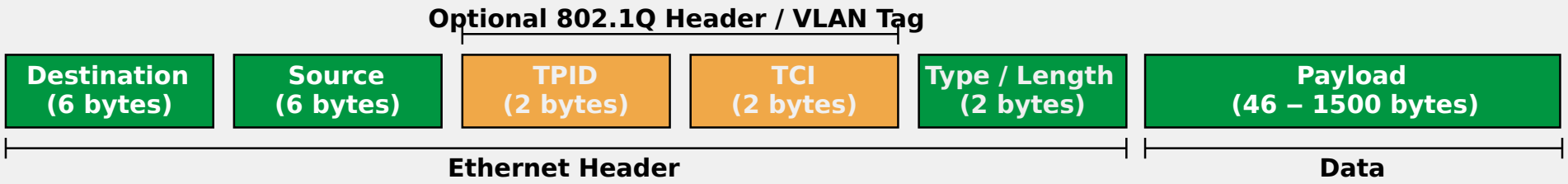
Secure Systems Engineering

- **Vulnerabilites**

- **Critical Applications**
  - Automotive
  - Aviation
  - Critical infrastructure
  - Medicine

- Complex message formats
- No formal specifications
- Error-prone manual implementation
- Use of unsafe programming languages

RecordFlux
Example: Ethernet Frame



- Meaning of Type/Length field depends on its value
  - ≤ 1500: Length of Payload (IEEE 802.3)
  - ≥ 1536: Type of Payload (Ethernet II)
- Payload length depends on value of Type/Length field or on length of message
- Optional VLAN tag (IEEE 802.1Q)
  - Existence depends on the first two bytes of its own field
- VLAN tag and Type/Length field overlap

RecordFlux
Representation: Directed Acyclic Graph

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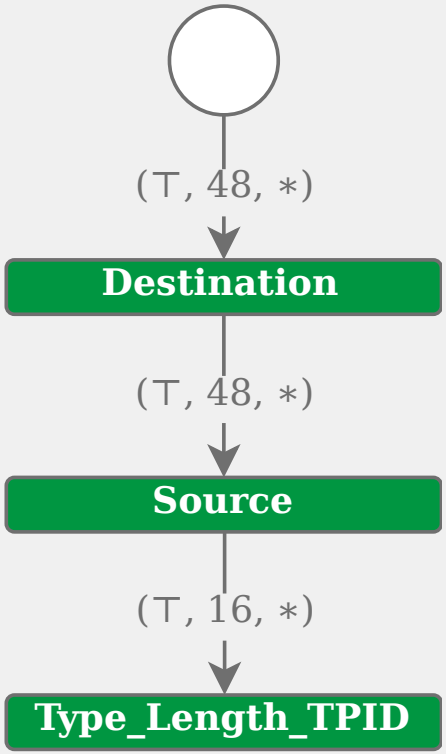

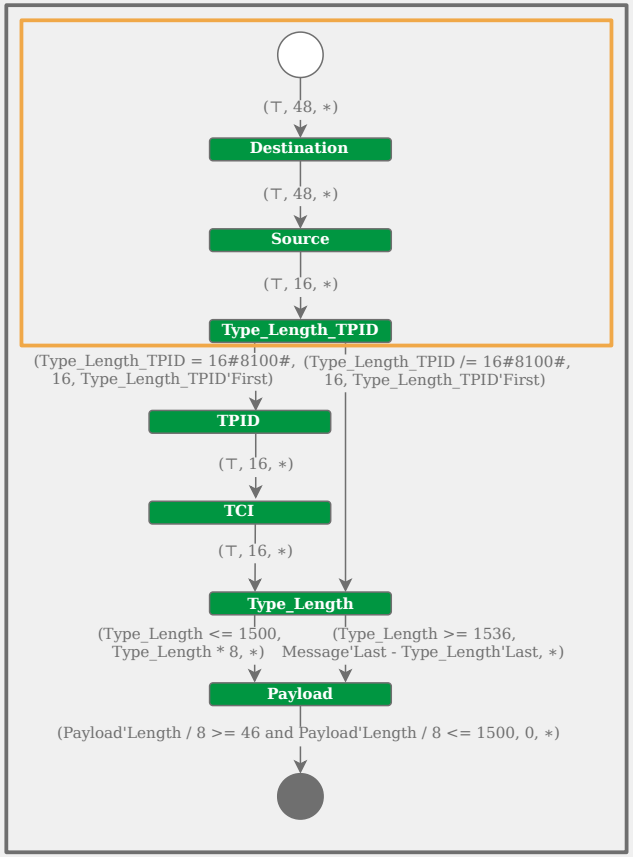

RecordFlux
Representation: Directed Acyclic Graph

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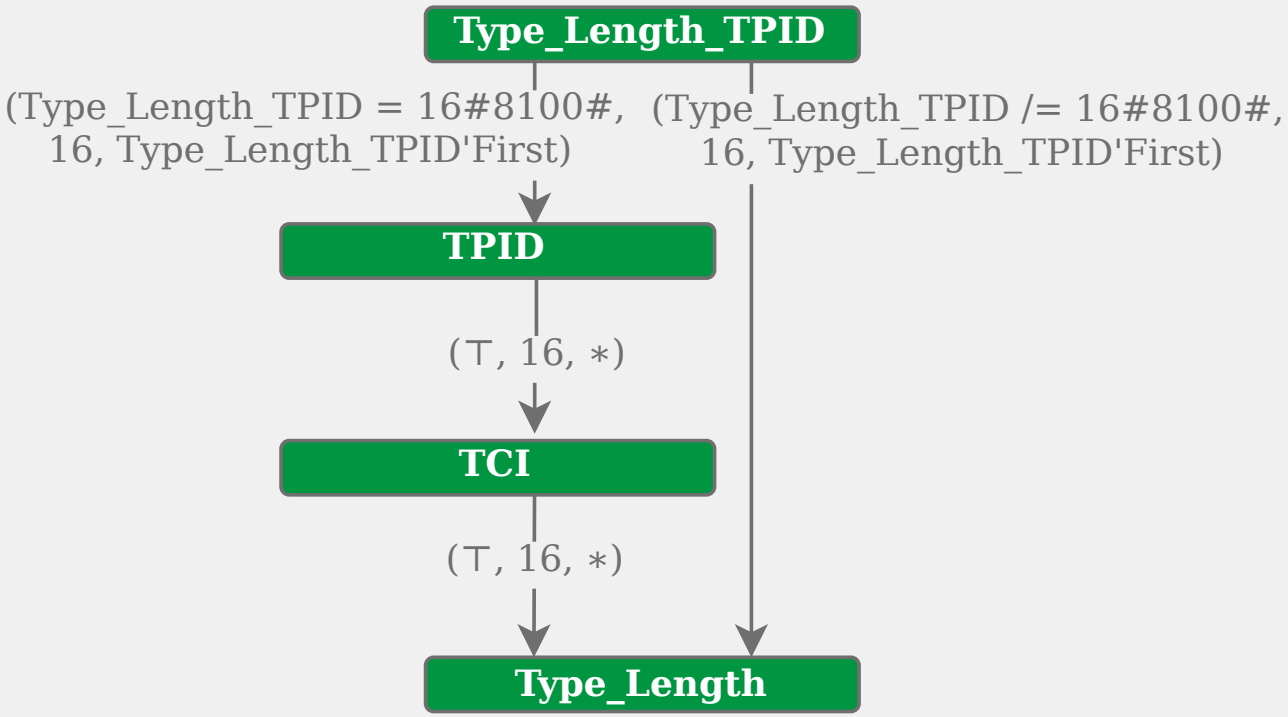
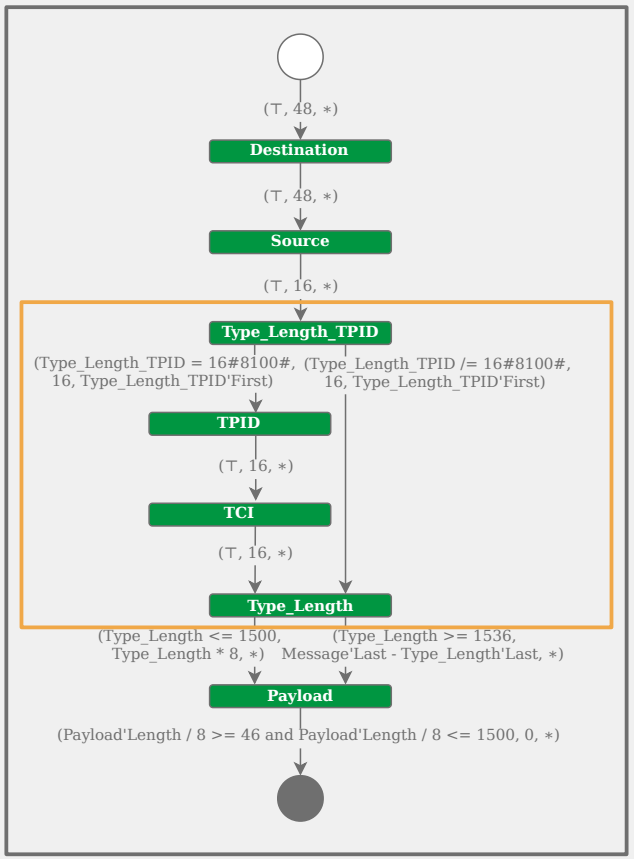
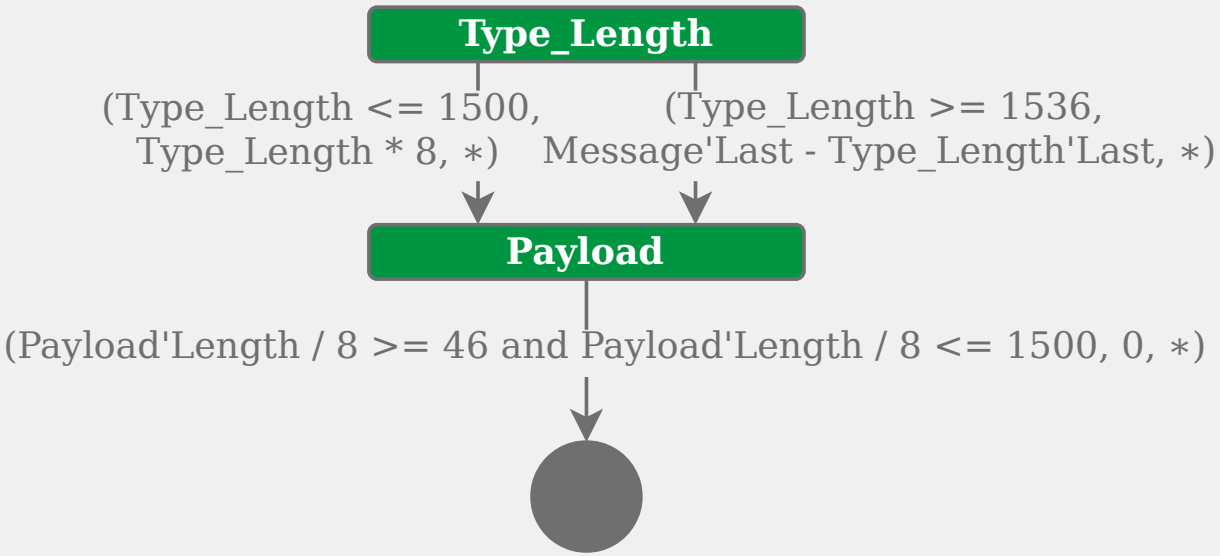
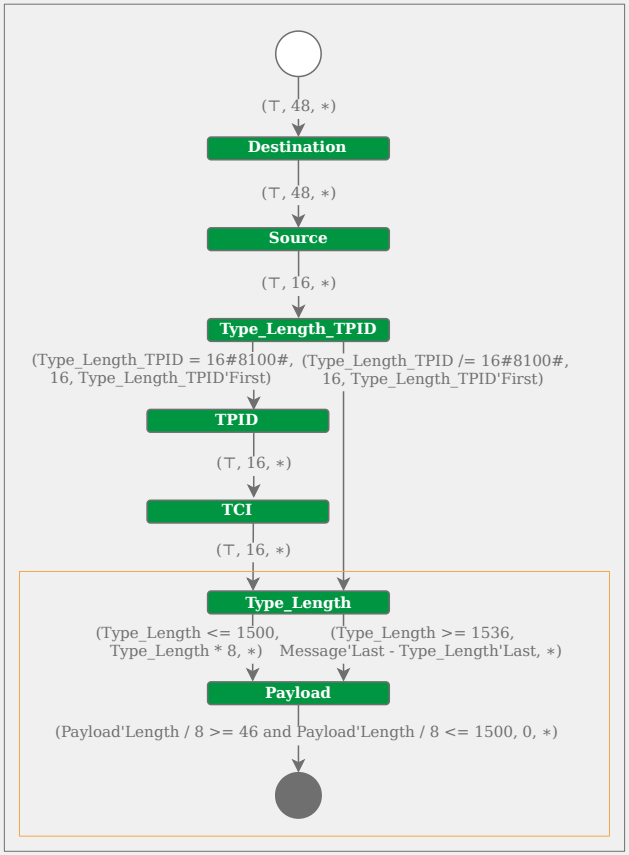




RecordFlux
Representation: Directed Acyclic Graph

Componolit
Secure Systems Engineering





RecordFlux
Specification Language

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Secure Systems Engineering

- **Order of Fields**
  - then
- **Length and Location**
  - with Length / with First
- **Field Condition**
  - if

```
package Ethernet is
   type Address is mod 2**48;
   type Type_Length is range 46 .. 2**16 - 1 with Size => 16;
   type Frame is message
         Destination : Address;
         Source      : Address;
         Type_Length : Type_Length
            then Payload
               with Length => Type_Length * 8
               if Type_Length <= 1500,
            then Payload
               with Length => Message'Last - Type_Length'Last
               if Type_Length >= 1536;
         Payload : Payload
            then null
               if Payload'Length / 8 >= 46
                  and Payload'Length / 8 <= 1500;
      end message;
end Ethernet;
```

RecordFlux
Model Verification

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Secure Systems Engineering

- **Invariants proven for the model**
  - Field conditions are mutually exclusive
  - Field conditions do not contradict each other
  - Each field is reachable on at least one path from the initial node
  - Message fields are always located after the first message bit
  - Field length is never negative
  - Message fields cover all bits of a message on all paths
  - Overlaid fields are congruent with exactly one other field

RecordFlux
Code Generation

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Secure Systems Engineering

- **Code Generation**
  - SPARK code
  - Suitable for low-resource/embedded targets
  - Binary parser and generator
- **Properties**
  - Absence of runtime errors
  - Functional correctness

RecordFlux
Case Study: Verified TLS Parser

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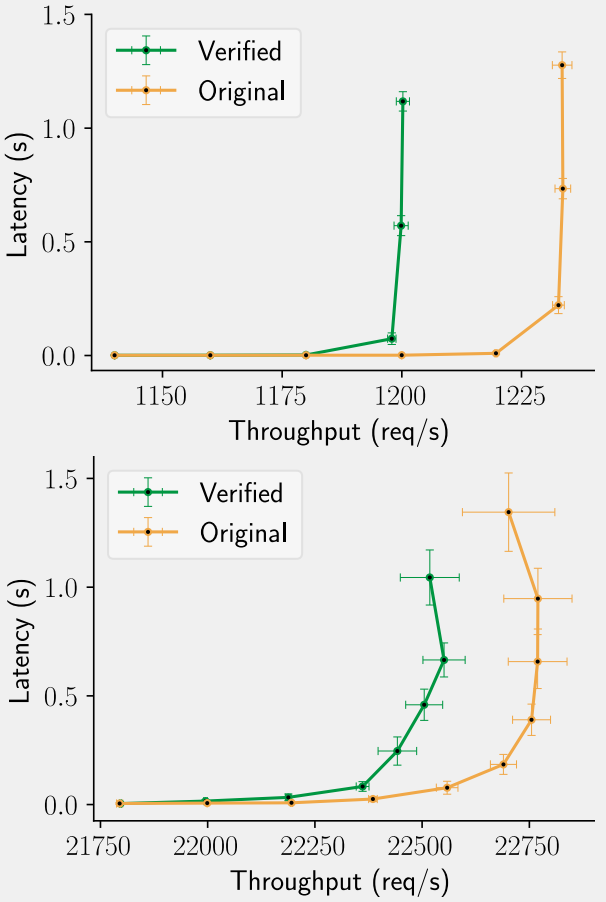
Secure Systems Engineering

- Fizz – C++ TLS 1.3 implementation by Facebook[1]
- Fizz' parser replaced by SPARK implementation[2]
  - RecordFlux TLS 1.3 specification (RFC 8446)
  - Integration with C++ using manual glue code: mainly conversion between C++ data structures (e.g. vectors) and SPARK counterparts
- Absence of runtime errors proven for the parser
- Performance impact mostly due to conversion
  - Handshake: 2.7 % throughput loss (upper chart)
  - Record: 1.1 % throughput loss (lower chart)



[1]) https://github.com/facebookincubator/fizz [2]) https://github.com/Componolit/fizz

RecordFlux
Summary

Componolit
Secure Systems Engineering

- **Source, Language Reference**
  - https://github.com/Componolit/RecordFlux
- **Work in progress**
  - Message sequences
  - Verified component-based TLS 1.3
- **Future work**
  - Protocol fuzzing
  - Cryptographic Proofs
  - Reverse Engineering
  - Traceability to informal specifications

Questions?

Componolit
Secure Systems Engineering

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RESSI 2020

Grégory Blanc Olivier Levillain

27 novembre 2019

RESSI en quelques mots

Les rendez-vous de la recherche et de l'enseignement en SSI

- un rendez-vous pour fédérer la communauté en SSI grâce à une « retraite » de 3 jours, héritier des conférences SAR et SSI

RESSI en quelques mots

Les rendez-vous de la recherche et de l'enseignement en SSI

- un rendez-vous pour fédérer la communauté en SSI grâce à une « retraite » de 3 jours, héritier des conférences SAR et SSI
- un événement du GDR Sécurité Informatique depuis cette année

RESSI en quelques mots

Les rendez-vous de la recherche et de l'enseignement en SSI

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- un événement du GDR Sécurité Informatique depuis cette année
- un ensemble varié d'activités

Des activités diverses

- Rejeux de papier et de soutenances de thèse
- Présentations invitées (keynotes ou tutoriels)
- Session thèses (avec posters)
- Présentations de projets collaboratifs
- Échanges sur l'enseignement
- Ateliers impromptus (Nouveauté 2020)
- Challenge défensif

Éditions passées

2015 – Troyes

2016 – Toulouse

2017 – Grenoble

2018 – Nancy

2019 - Rennes

?

2020 - Evry

RESSI 2020

Domaine de Chalès (Sologne)

18-20 mai 2020

Venez nombreux, et soumettez !

`https://ressi2020.sciencesconf.org`

SMIB

Sécurité Made in Breizh

SMIB, à Rennes, c'est …

- Une **ambition commune** aux acteurs locaux : CNRS, CentraleSupélec, ENS de Rennes, IMT Atlantique, Inria, INSA de Rennes, l'Université Rennes 1 et l'Université Rennes 2
- Un **lieu** : dès la fin de travaux (!), 3000 m^2 pour la **recherche**, la **formation**, l'**innovation** / développement économique
- Un **agenda scientifique** s'appuyant sur les expertises locales fortes
- Une **intégration souhaitée des succès rennais** avec accord de leurs partenaires : LHS, filière SSI du Labex CominLab, séminaire et semestres thématiques, EUR CyberSchool
- Gouvernance simple, modèle économique simple

Un outil pour rechercher, innover et enseigner

1. Besoins larges …

> Matériels : composants électroniques, communications numériques

> Logiciels : systèmes, protocoles, génie logiciel, sciences des données

> Modélisation : systèmes complexes, preuves formelles et vérifications

> Mathématiques : primitives cryptographiques

> SHS : usages, droit, organisation des entreprises, économie, histoire, philo

2. … et donc large implication

> **Centre Inria de Rennes**, CREAD, **IETR**, IODE, **IRISA**, **IRMAR**, LiRIS, LTSI, MSHB, LP3C, RPpsyc et Tempora

Zoom sur les équipes « informatique »

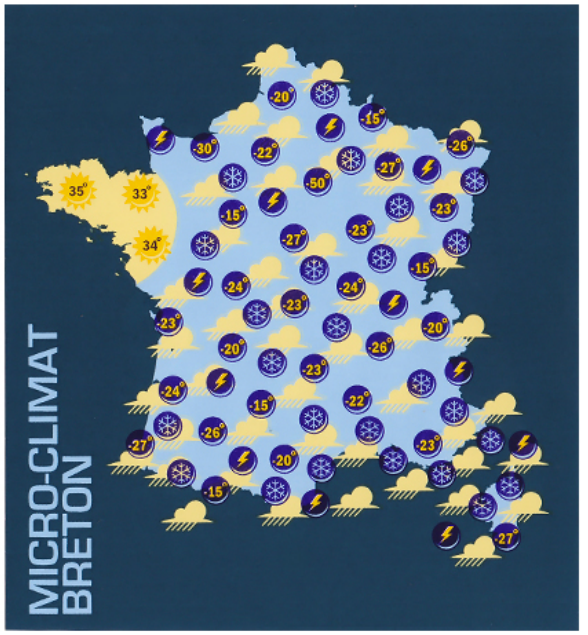
Eq.Inria/IRISA	Crypto	Matériel	Logiciel	Réactif	PVP	Sec. IA
Emsec	X	X				
Tamis	X	X	X			
Cidre		X	X	X	X	
Expression				X		
Logica				X		
Druid					X	
Diverse					X	
Wide					X	
Panama					X	
Stack					X	
Celtique			X			
Pacap			X			
Ocif			X			
Sumo			X			
Linkmédia						X

TOUTE L'ACTUALITÉ / SÉCURITÉ

Michel Van Den Berghe (Orange Cyberdéfense) planche sur le campus cybersécurité

SMIB

Sécurité Made in Breizh



GT SSLR, GDR SécuInfo, kezako?

Aurélien Francillon Olivier Levillain

27 novembre 2019

GT SSLR

Outils du groupe de travail « Sécurité des systèmes, des logiciels et des réseaux »

- une liste de diffusion
  - publication d'offres de stage / postes
  - annonces d'événements
  - appels à soumission
- un événement annuel : RESSI
- des journées thématiques
  - novembre 2018 (journée commune SRI/SSL)
  - novembre 2019 (sécurité du logiciel)
  - 2020 ?

GDR Sécurité Informatique

Un outil d'animation de la communauté

- trois événéments annuels
  - les journées nationales en juin
  - l'école d'été
  - les REDOCS (rencontres entreprises/doctorants)
- des moyens d'échanges
  - des listes de diffusion (annonces / forum)
  - un site web
  - la gazette
- autres événements
  - événements des GT
  - événements labellisés