PROSECCO

Cătălin Hrițcu, Inria Paris

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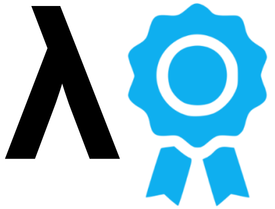
Our research



Solving security problems

- **programming securely with cryptography**
- stopping web attacks
- building secure systems

Devising formal methods

- clear attacker models
- program verification tools
- bug finding techniques

Developing practical tools and systems

- F*, miTLS, HACL*, ProVerif, CryptoVerif, ProScript, CryptoCat, QuickChick, ...

Finding attacks in TLS

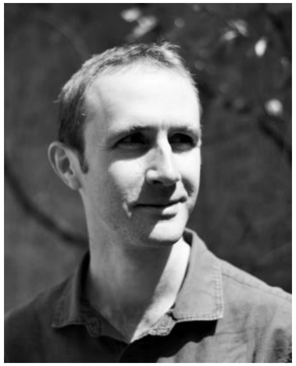
Researchers

Karthik Bhargavan

Bruno Blanchet

Harry Halpin

Cătălin Hrițcu



Graham Steel
Cryptosense

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Current team

Researchers (6)
Karthik Bhargavan
Bruno Blanchet
Harry Halpin
Cătălin Hriţcu
Graham Steel
Christine Rizkallah

PhD Students (4)
Benjamin Beurdeuche
Nadim Kobeissi
Kenji Maillard
Jean Karim Zinzindohoue

PostDocs (2)
Danel Ahman
Marco Stronati

Engineers (2)
Tomer Libal
Marc Sylvestre

Interns (4)
Victor Dumitrescu
Guglielmo Fachini
Natalia Kulatova
Théo Laurent

Visitors (3)
David Baelde (ENS Cachan)
Ana Nora Evans (Univ of Virginia)
David Evans (Univ of Virginia)

Diverse and international **11 nationalities** **Our working language is English**

Collaborators at Microsoft Research, UPenn, MIT, Northeastern, Portland State, IMDEA, Imperial, UCL, ...

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Use formal methods to achieve security of critical software

- **HTTPS stack** (miTLS, Everest)
- **Modern cryptographic library** (HACL*)
- **Secure messaging app** (CryptoCat, NEXTLEAP)
- **Web browser core** (CIRCUS)
- **Compilers & monitors** (Micro-Policies, SECOMP)
- **TCP/IP network stack ...**

Tools for analyzing abstract models of crypto protocols

- **ProVerif**
  - symbolic model (Dolev-Yao)
  - fully automatic, efficient, precise, produces attack traces
  - wide range of crypto primitives and properties
- **CryptoVerif**
  - computational model
  - semi-automatic: sequence of crypto games
  - exact security: bound on attack probability
- **Recent case studies**: TLS 1.2 & 1.3, Signal, ARINC823
  - upcoming TLS 1.3: big redesign, new hope for verification

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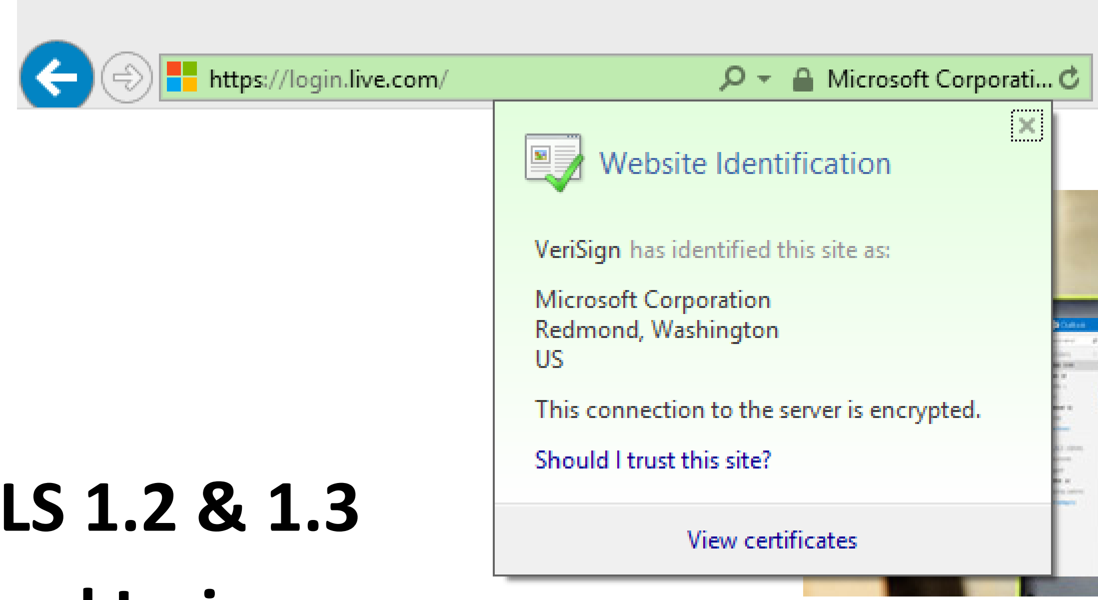
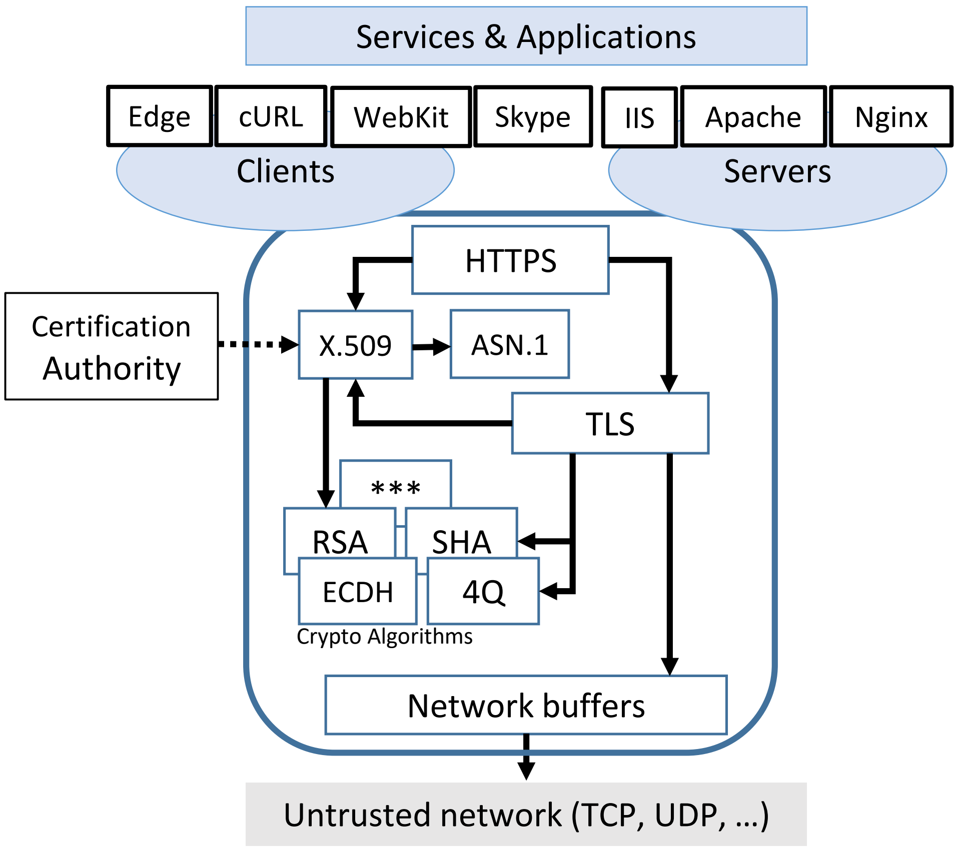
From verifying protocol models to actual implementations

- **Protocol models**
  - capture core behavior: succinct, abstract, high-level
  - great for finding logical flaws [3Shake] and incorrect use of crypto [Lucky13] early in the protocol design phase
  - *e.g.* TLS 1.2 & 1.3 in ~1000 lines of ProVerif **(best paper at Oakland'17)**
- **Protocol implementations**
  - large software projects: interoperable, efficient
  - concrete packet formats, multiple protocol modes
  - support legacy ciphersuites, complex APIs, composable subprotocols
  - *more attacks:* message parsing [HeartBleed], state machine [FREAK]



- **Verified reference implementation of TLS 1.2 & 1.3**
- **Microsoft Research and Inria**
- **Built on top of our HACL* crypto library**
  - verified and faster than OpenSSL libcrypto and Sodium
- **Towards a verified HTTPS stack** (Project Everest)

HTTPS ecosystem critical, complex



HTTPS ecosystem critical, complex and broken

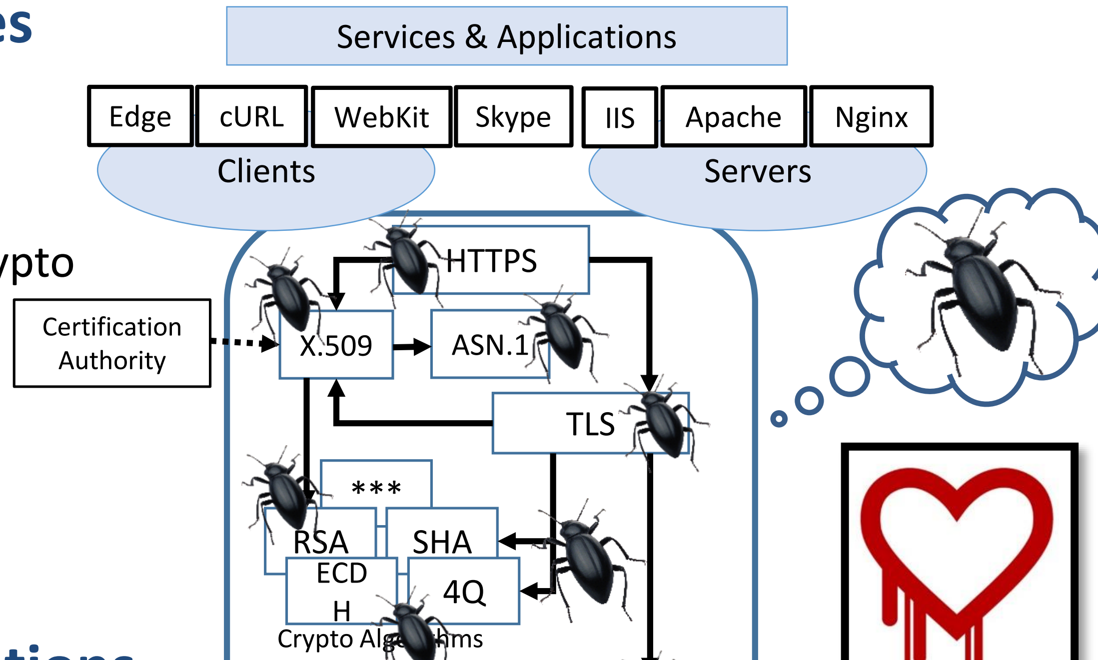
- **20 years of attacks & fixes**

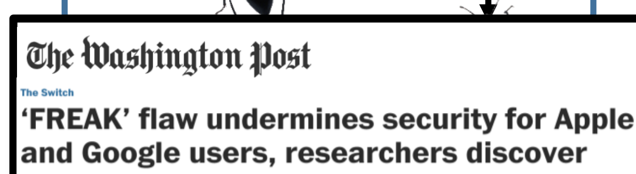
  Buffer overflows
  Incorrect state machines
  Lax certificate parsing
  Weak or poorly implemented crypto
  Side channels

  Informal security goals
  Dangerous APIs
  Flawed standards

- **Mainstream implementations**

  OpenSSL, SChannel, NSS, …
  Still patched every month!





The Washington Post

The Switch

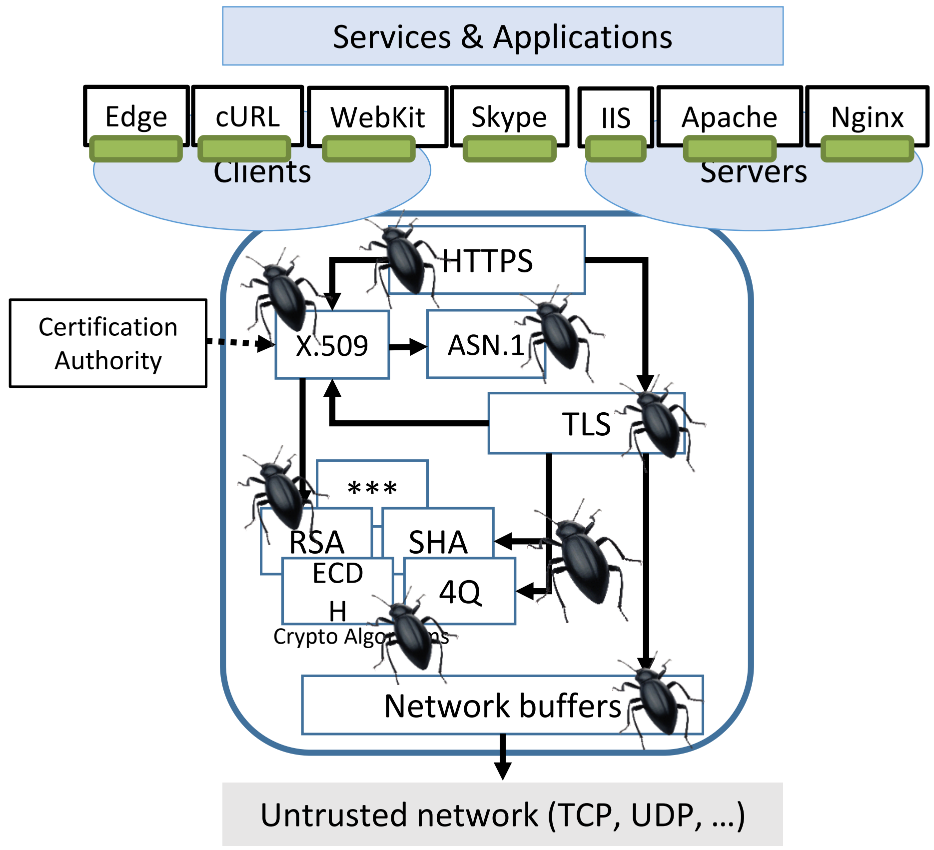
'FREAK' flaw undermines security for Apple and Google users, researchers discover

Project Everest Goals

Strong verified security

Widespread deployment

- efficiency
- interoperability
- drop-in replacement for OpenSSL, NSS, ...



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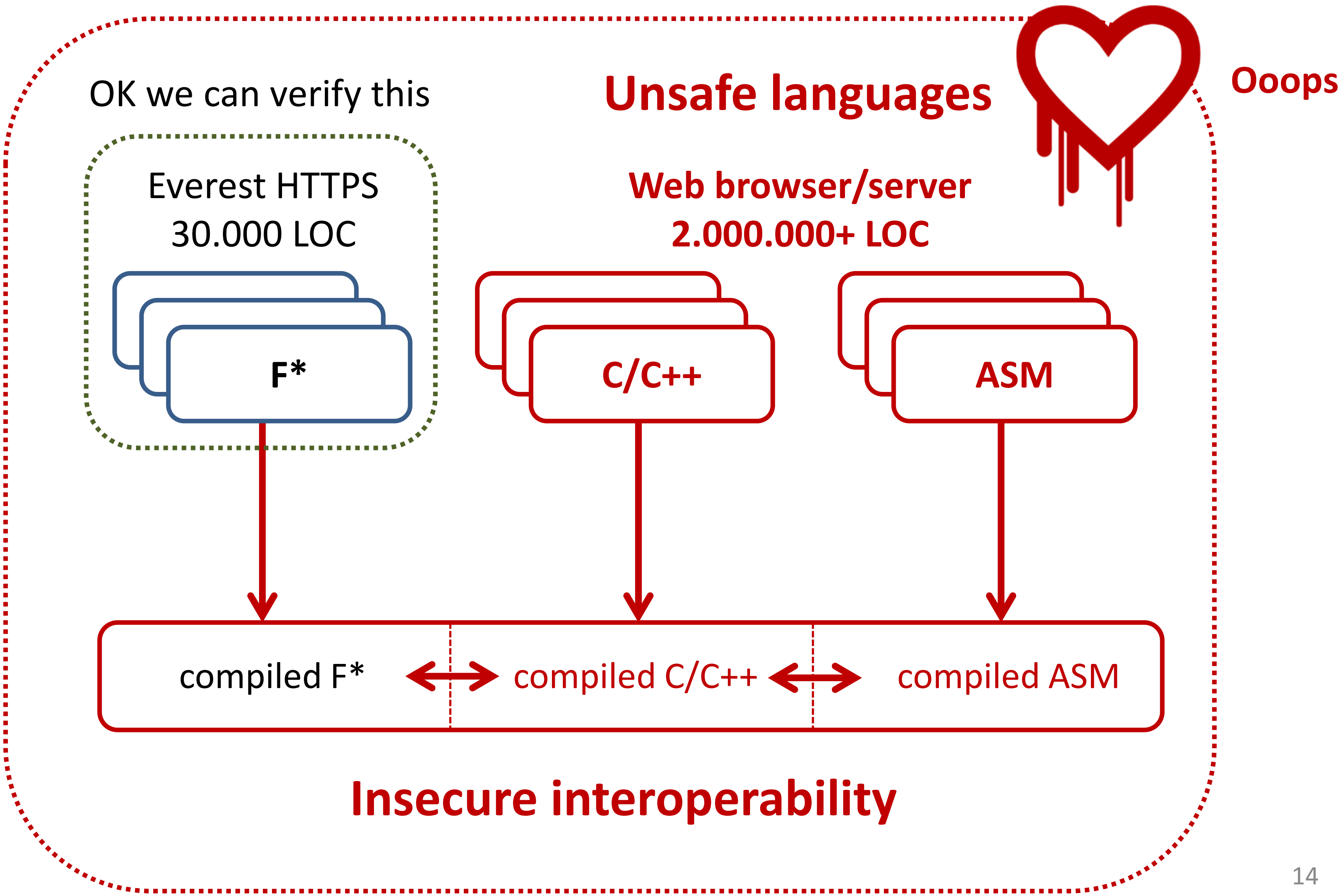
Everest stack verified with F*

- **Functional programming language**
  - like OCaml, F#, Haskell, …
  - extracted to OCaml or F# by default
  - subset of F* compiled to efficient C code
- **Semi-automated verification using SMT**
  - like Dafny, FramaC, Why3, …
- **Interactive verification using dependent types**
  - like Coq, Lean, Agda, …

Is verified code secure in practice?



Secure compilation

- **Secure interoperability with lower-level code**
  - component separation, call and return discipline, types, ...
- **Dynamic enforcement, but at what cost?**
  - **in software, 10x? 100x? 1000x?**
- **Micro-policies**

  - **new tagged hardware architecture**
  - associates **large metadata tag to each word**
  - efficiently propagates and checks tags; **hw caching**
  - dynamic monitoring: **software defined, very flexible, fine-grained** (words, instructions), **fast ...**
  - **... average 10% runtime overhead** for complex policies!

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