Latest Improvements and Applications of Steel, a Concurrent Separation Logic for F*

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What is F*

- A **proof-oriented**, functional programming language
- With support for dependent types, user-defined effects, …
- Semi-automated verification by relying on SMT solving
- Also offers a metaprogramming and tactic framework (Meta-F*)

F* Successes

- Vale/HACL*/EverCrypt:
  - A verified, large, industrial-grade cryptographic provider
  - Over 100k lines of verified C and Assembly code

    (~200k-300k lines of manually-written F* code)
  - Deployed in Firefox, Linux, Wireguard, Tezos, …

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- But no concurrency, and memory reasoning is tedious

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- Predicates to reason about memory: r ↦ v

$$\frac{\{r \mapsto v\}\ r\ \coloneqq 0\ \{r \mapsto 0\}}{\{s \mapsto u \star r \mapsto v\}\ r\ \coloneqq 0\ \{s \mapsto u \star r \mapsto 0\}}$$

- Many extensions (Concurrency, Resource usage, …)

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- Automation through a cooperation between SMT solving and custom separation logic decision procedures [ICFP’ 21]
- Many verified, dependently-typed libraries (AVL trees, concurrent queues, lock-free concurrency, message-passing concurrency, …)

Steel by Example

Steel a p q: a computation that has return type a, under the precondition p, and with the postcondition q

```
let swap (p1 p2:ref int) : Steel unit
   (ptr p1 ★ ptr p2)
   (λ _→ ptr p1 ★ ptr p2)
   (requires λ _→ T)
   (ensures λ s0 _ s1 → s0.[p1] == s1.[p2] /\ s0.[p2] == s1.[p1])
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= let v1 = read p1 in
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   write p1 v2;
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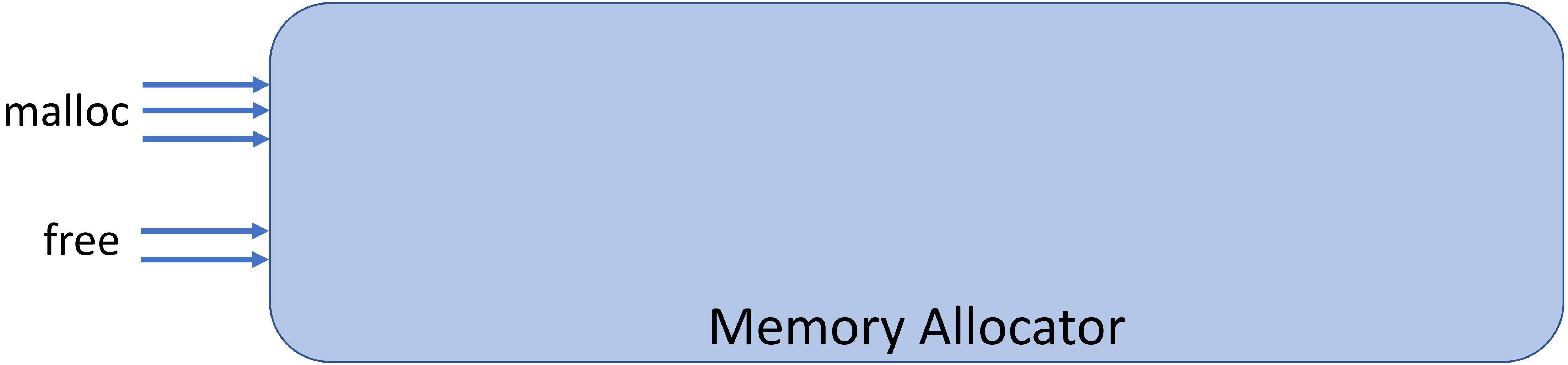
Ongoing Project: Verifying a Memory Allocator

- **<u>Goal:</u>** Develop a verified, performant, concurrent **memory allocator** with modern security defenses in Steel



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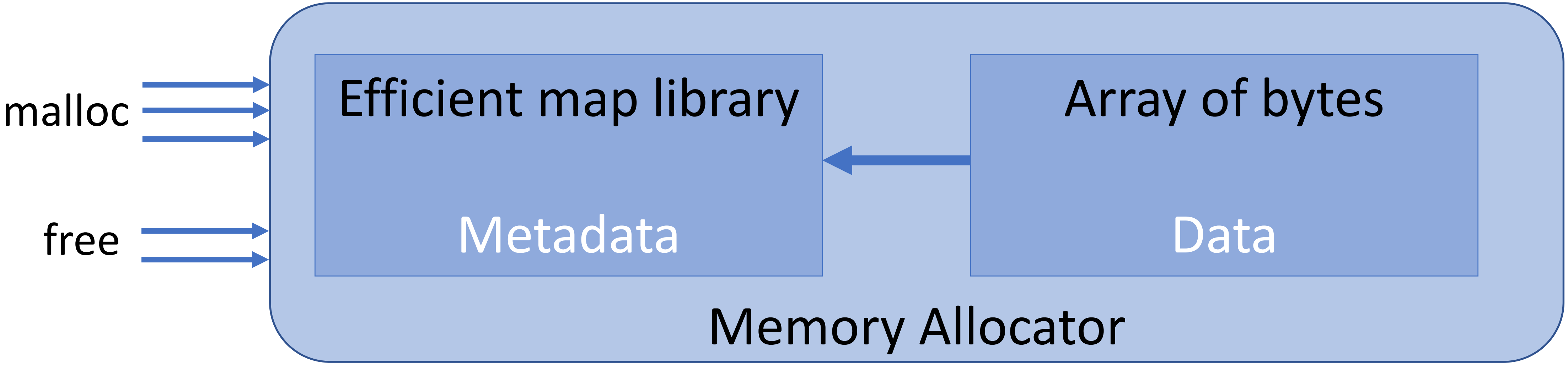

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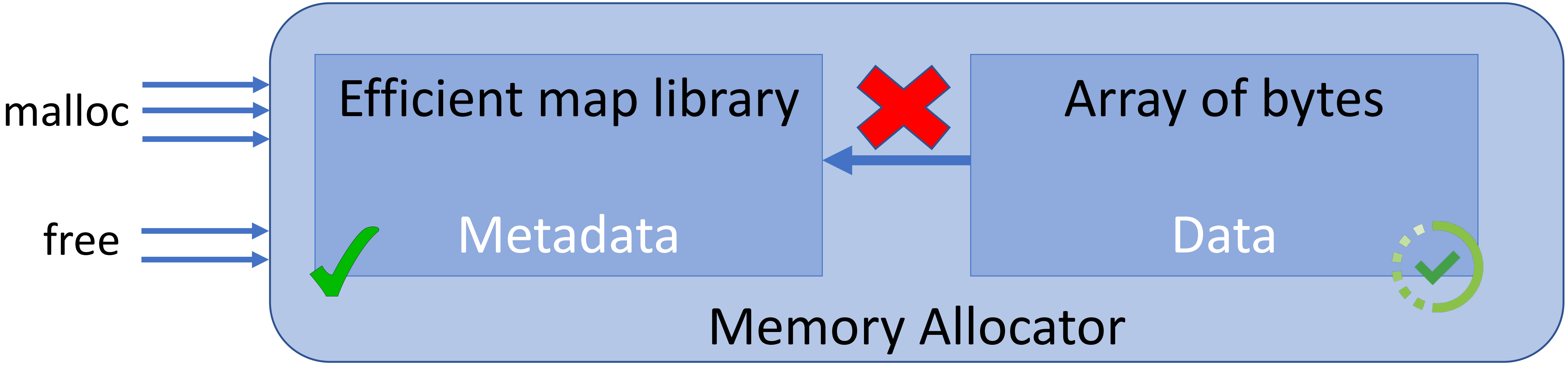

- **<u>Current status:</u>**
  - Partially verified C implementation
  - Working with the Zathura PDF viewer

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- Translation is entirely done using tactics, and is hence **provably sound**

A Vision for Steel

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- Ongoing and Future Directions:
  - Verification of a secure memory allocator
  - Improve the programmability, usability and tooling
  - End-to-end verification of secure communication protocols
  - Drop-in replacements for high-assurance Rust libraries

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