Using and extending Wasm for security

Deian Stefan

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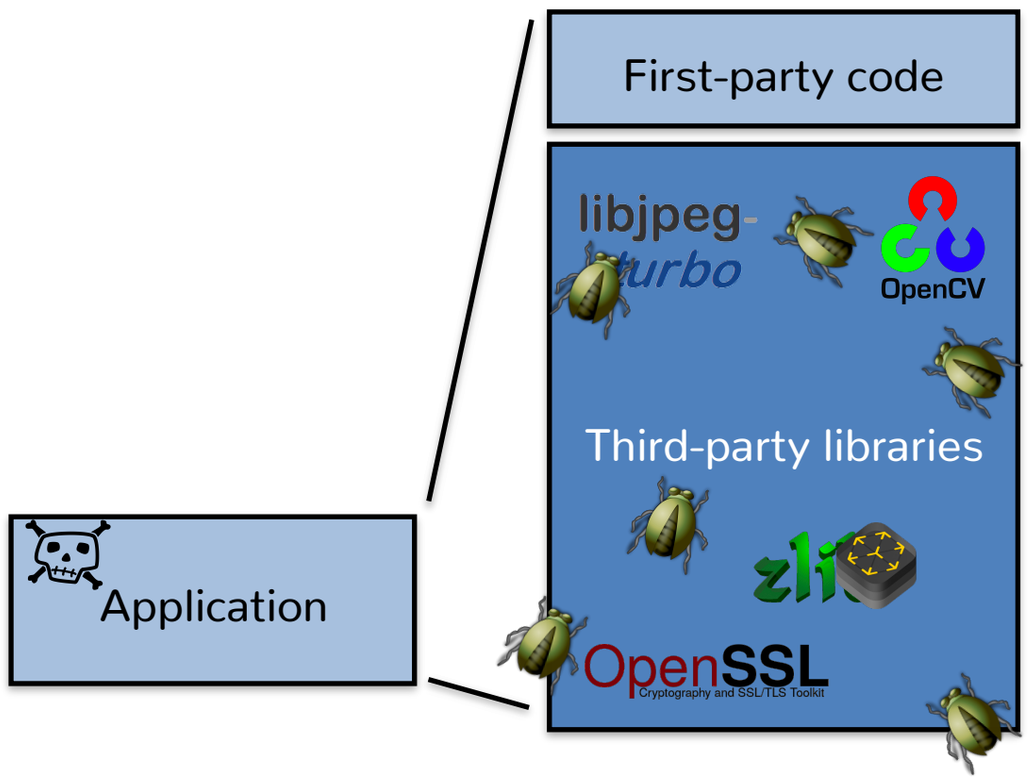
1. Sandboxing 3rd party libs

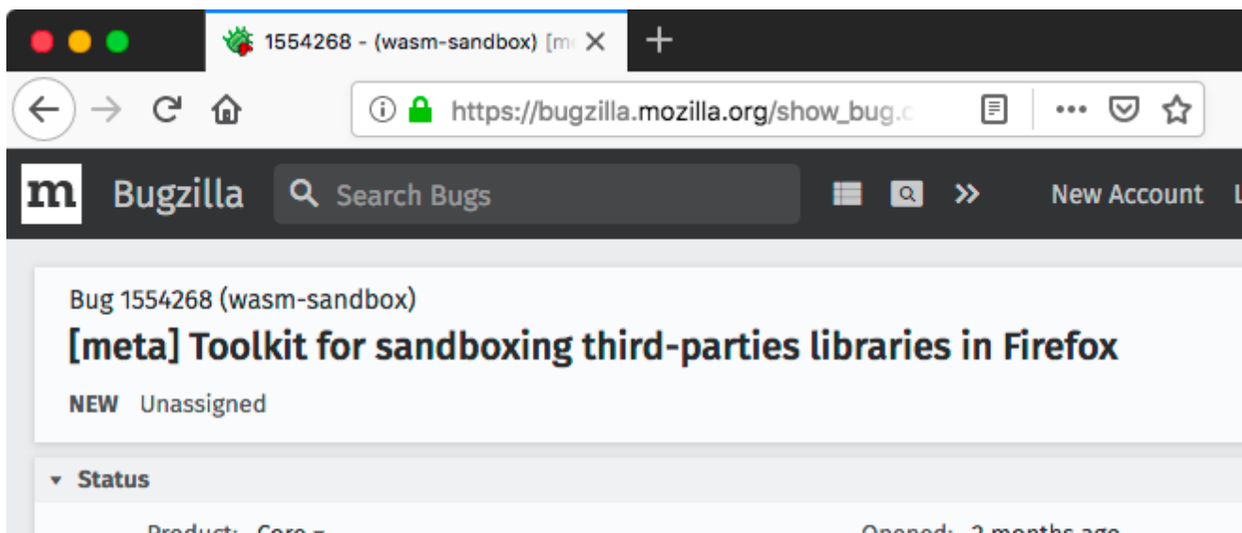
Shravan Narayan, Tal Garfinkel, Craig Disselkoen, Sorin Lerner, Hovav Shacham, Eric Rahm, Nathan Froyd



- Wasm is designed to be embedded in an app
  - I.e., designed to be sandboxed

Our approach

- Compile libraries to Wasm modules
  - Mediate Wasm→ runtime according to policy
- RLBox: toolkit for sandboxing libraries
  - Simplifies sandboxing and ensures application code cannot be abused by sandbox code
  - Available: rlbox.dev
  - Almost in production:



RLBox toolkit handles a lot...

wasm-sandbox.rlbox.dev

```
#include "rlbox_lucet_sandbox.hpp"
#include "rlbox.hpp"

int main()
{
    rlbox_sandbox<rlbox_lucet_sandbox> sandbox;
    sandbox.create_sandbox("libWasmFoo.so");
    // Invoke function bar with parameter 1
    sandbox.invoke_sandbox_function(bar, 1);
    sandbox.destroy_sandbox();
    return 0;
}
```

RLBox toolkit handles a lot...

Machines model differences, pointer swizzling, ABI issues for function calls and callbacks, how to port existing application, etc.

But sandboxing is not free

- Challenges we had/have to address:
  - AOT compilation (W)
  - x64 application, cross-platform (L,W)
  - Register and unregister callbacks (L)
  - 4gb heap alignment (L)
  - Library use case (L)
  - Re-entrant (L)
  - Threads

Going forward

- Wasm is THE way forward
  - Previous SFI toolkit (NaCl) is dead
- Library sandboxing as a use-case for Wasm
  - Compiler + sandbox: wasm-sandbox.rlbox.dev
- Need love: compiler, runtime, WASI

2. Verified Wasm compiler

- Jay Bosamiya, Bryan Parno, Benjamin Lin
- Implemented in F*: Wasm → x86/ARM
- Security property:
  - Compiled code cannot read/write outside region
- Going forward: how does this tie into runtimes? Can we implement a verified JIT vs AOT compiler?

Using and extending Wasm for security

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Extending Wasm for security

- CT-Wasm makes it possible for developers to write verifiably secure crypto algorithms
  - Conrad Watt, John Renner, Natalie Popescu, Sunjay Cauligi
- MS-Wasm is a progressive approach to preventing memory safety violations in C/C++
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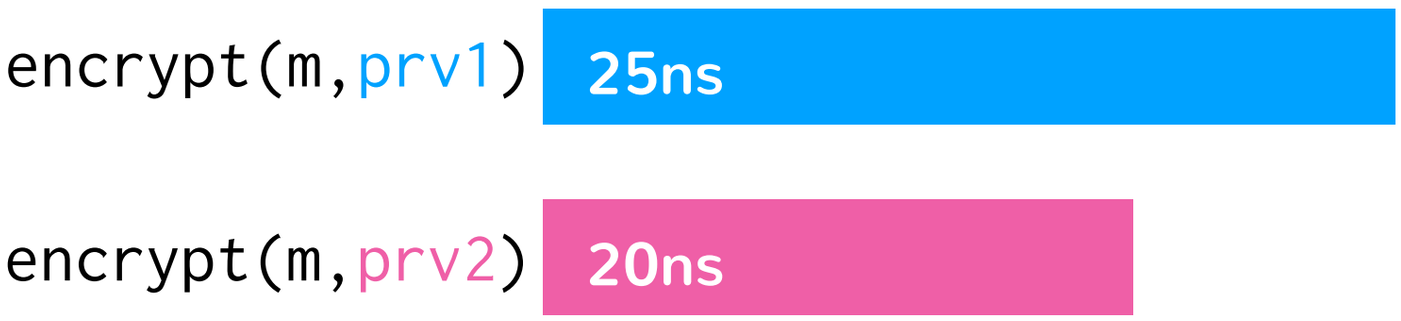
Writing crypto code is hard

- Need to ensure that code is not leaking secrets
  - Directly (e.g., by writing secrets to public memory)
  - Or indirectly, via timing channels



Wasm is close, but not enough

Doesn’t know what’s secret: can’t stop you from leaking it

CT-Wasm makes secrecy explicit

- Extend Wasm language with two new types
  - s32 and s64: secret 32- and 64-bit ints
  - All other types are public: i32, i64, f32, f64
- Extend compiler to turn leaks into type errors
  - Prevent direct leaks
  - Prevent implicit leaks (via control flow)
  - Prevent leaks via timing channels

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Prevent explicit leaks

(via local variables)

```
(local $pub i32)
(local $sec s32)
```

```
(set_local $pub (get_local $sec))
```

Prevent explicit leaks

(via local variables)

```
(local $pub i32)
(local $sec s32)

(set_local $pub (get_local $sec))
```

```
Error: type mismatch in set_local,
       expected i32 but got s32
```

Prevent implicit leaks

(via control flow)

```
(if (get_local $sec)
  (then (set_local $pub ...))
  (else (set_local $pub ...)))
```

Prevent implicit leaks

(via control flow)

```
(if (get_local $sec)
  (then (set_local $pub ...))
  (else (set_local $pub ...)))
```

```
TypeError
‘if’ requires i32
     found    s32
```

Prevent leaks via timing

- Disallow variable-time instructions on secrets
  - E.g., we don't define `s32.div` or `s32.mod`
- Disallow secret-dependent memory accesses
  - E.g., `(s32.load (get_local $sec))`

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Simple extension ➠ secure crypto

Extending Wasm for security

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➔ MS-Wasm is a progressive approach to preventing memory safety violations in C/C++

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Wasm code isn't necessarily memory safe...

Manual memory management

- Makes it easy to compile C/C++ that runs fast!

- C/C++ code is plagued with memory safety bugs
  - Buffer overflows
  - Use after frees

70% of security bugs at Microsoft

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May be worse than native code...

- Native code can use hardware mechanisms that check certain kinds of memory safety violations

Kostya Serebryany
@kayseesee

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Adopting the Arm Memory Tagging Extension in Android

Adopting the Arm Memory Tagging Extension in Android

Posted by Kostya Serebryany, Google Core Systems, and Sudhi Herle, Android Security & Privacy Team As part of our continuous commitment t...

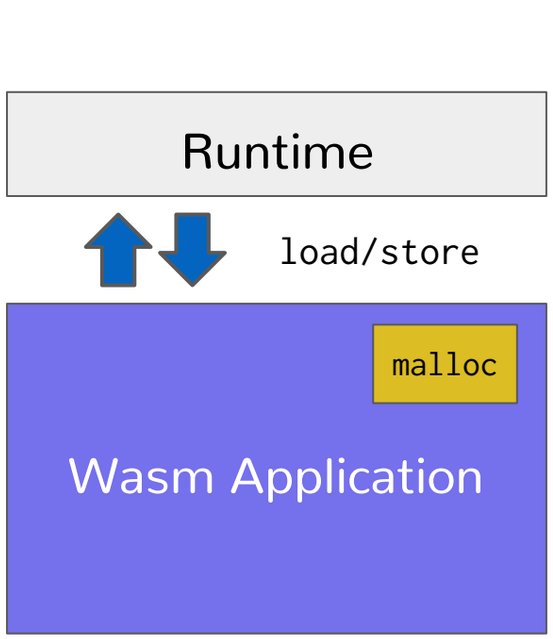
security.googleblog.com

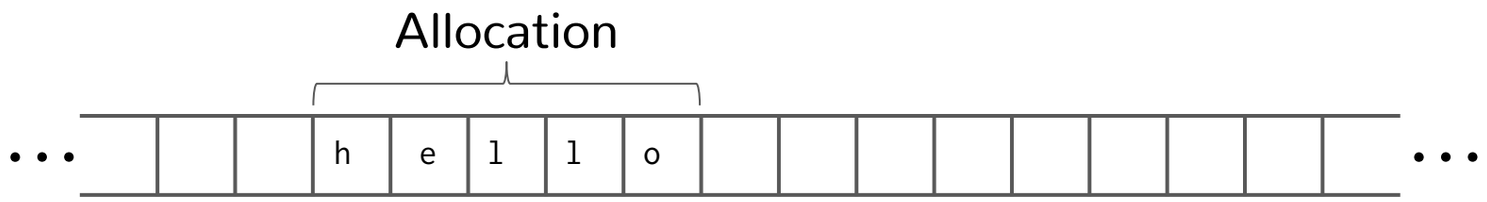
MS-Wasm: progressive safety

- Extend Wasm to capture the essence mem safety
  - Memory allocation is explicit
  - Typed handles associate pointers to allocations
- Leave enforcement up to the runtime
  - Depends on available HW and application demands

Challenge with Wasm today

- Wasm runtime isn't aware of allocations
  - Can't enforce bounds checks!





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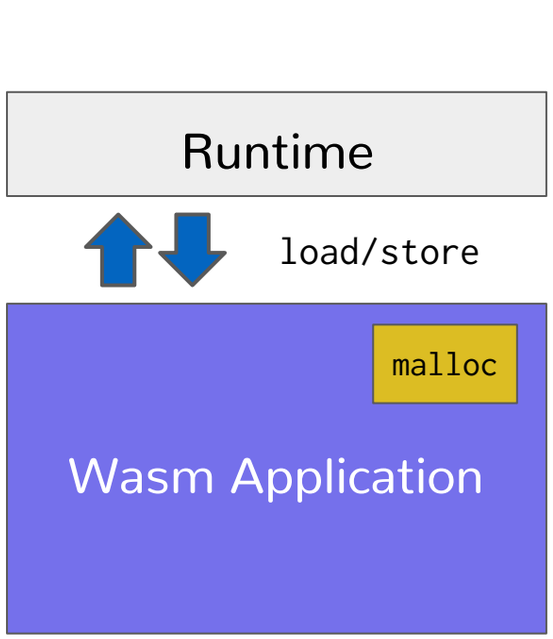

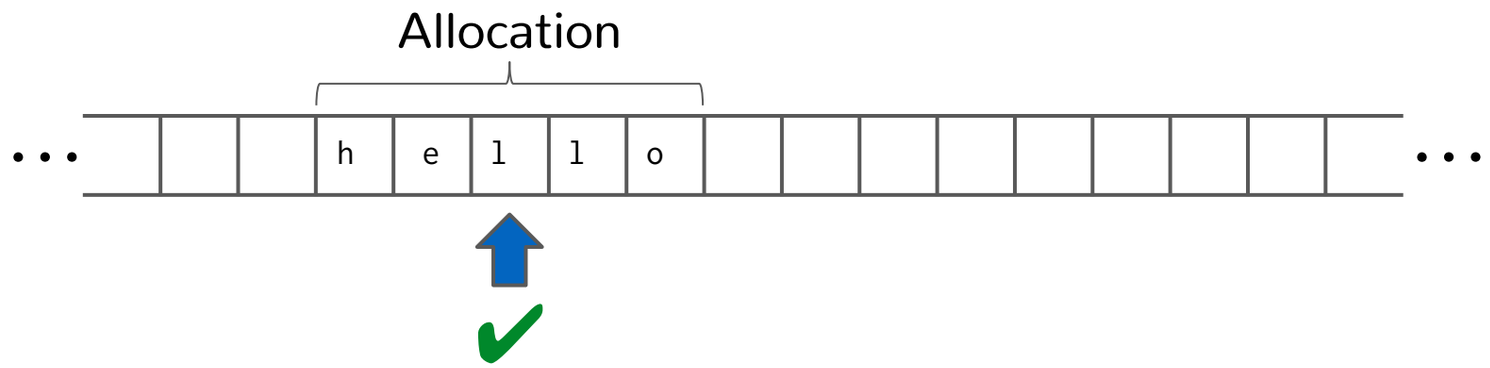

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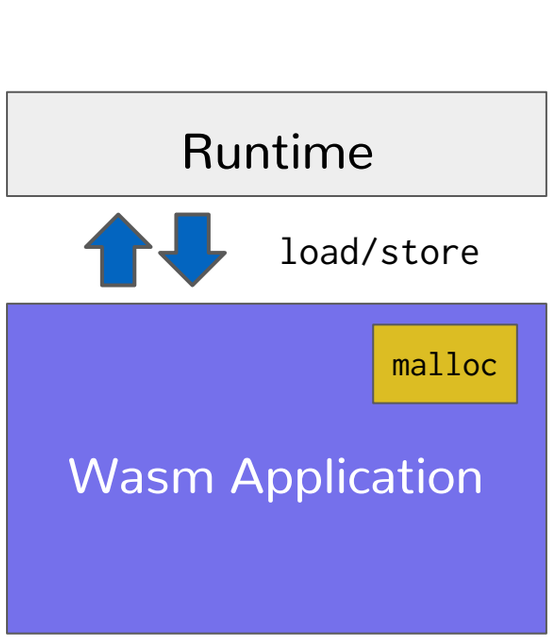
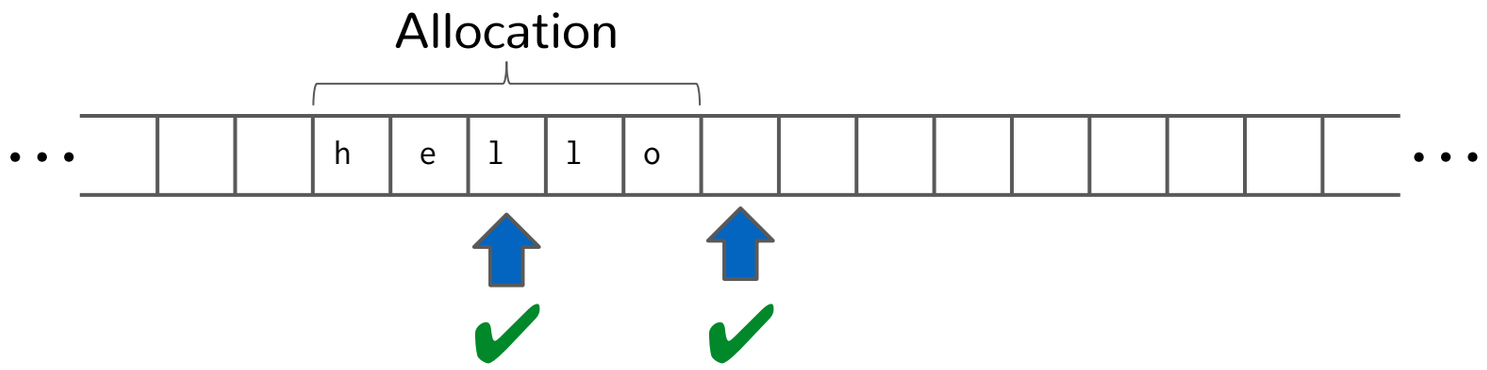
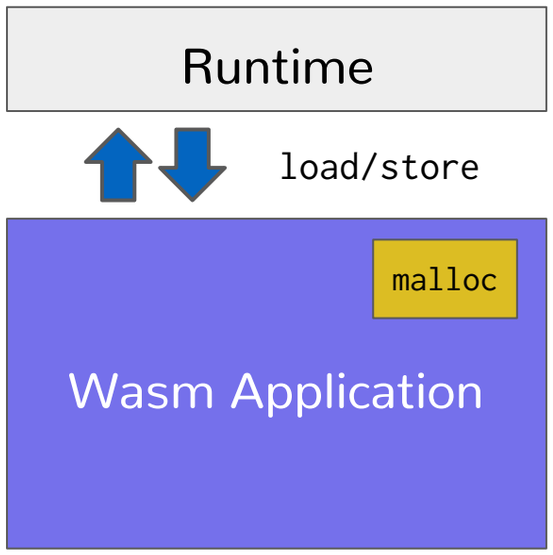
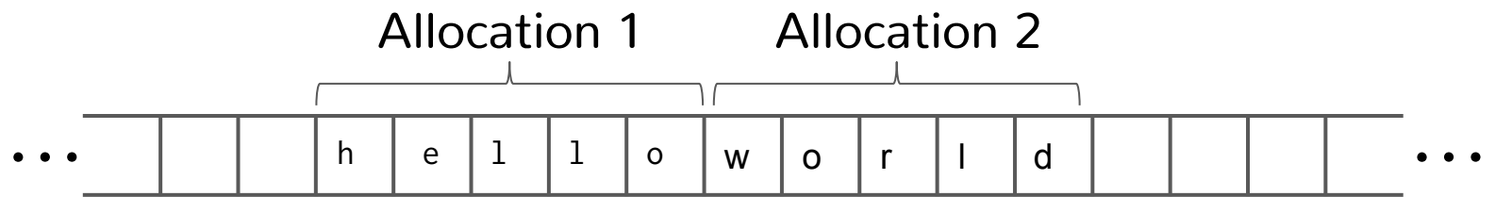




MS-Wasm: make safety explicit

- MS-Wasm runtime is aware of allocations
  - Allocations are explicit
  - Typed handles associate wtih allocations





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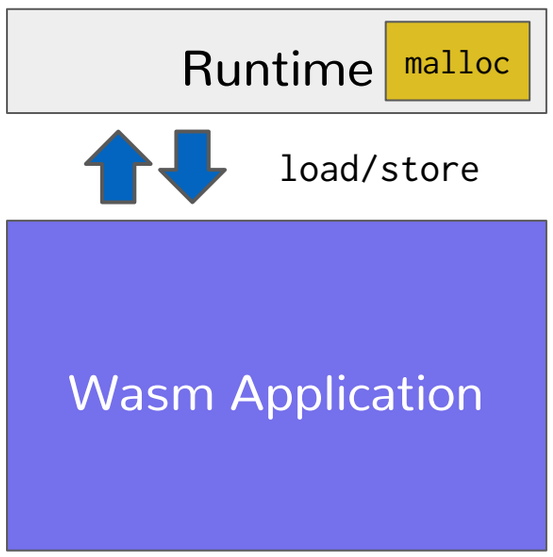

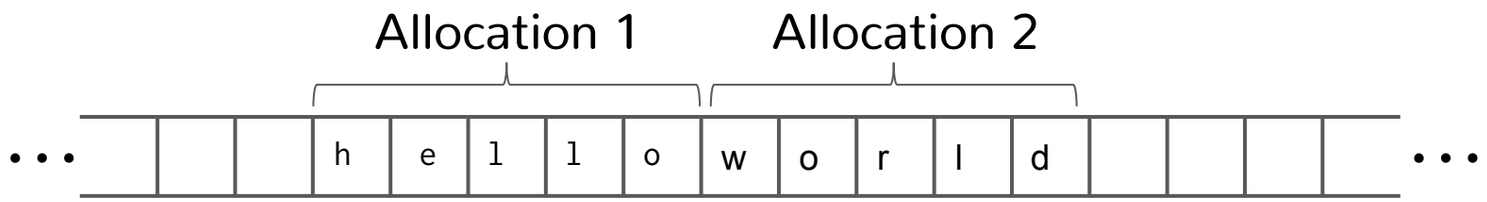

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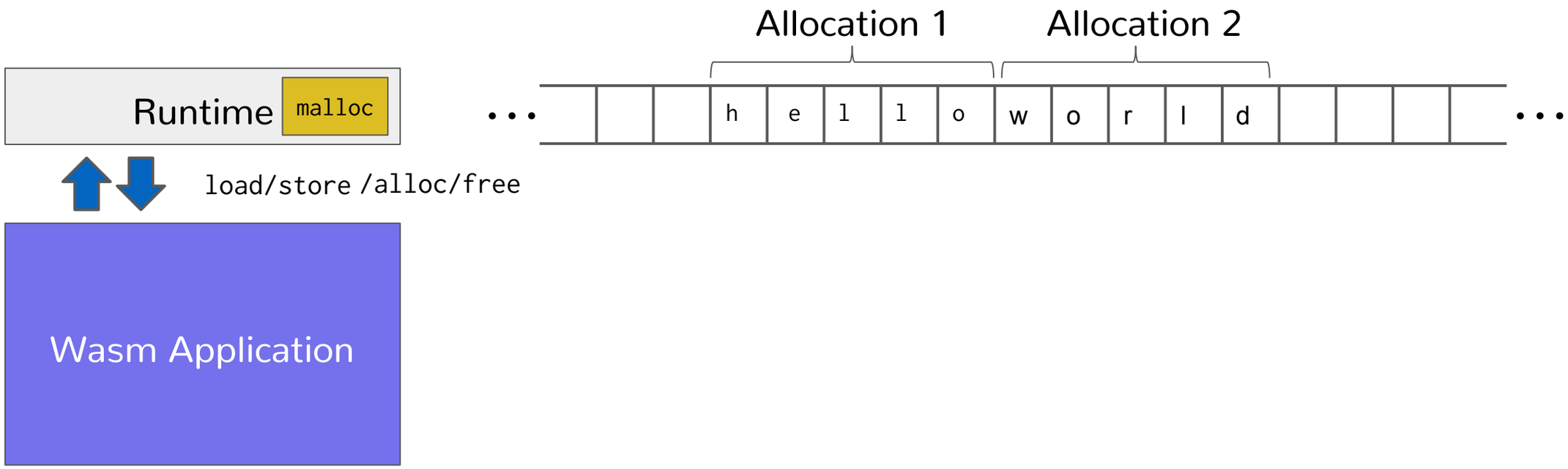

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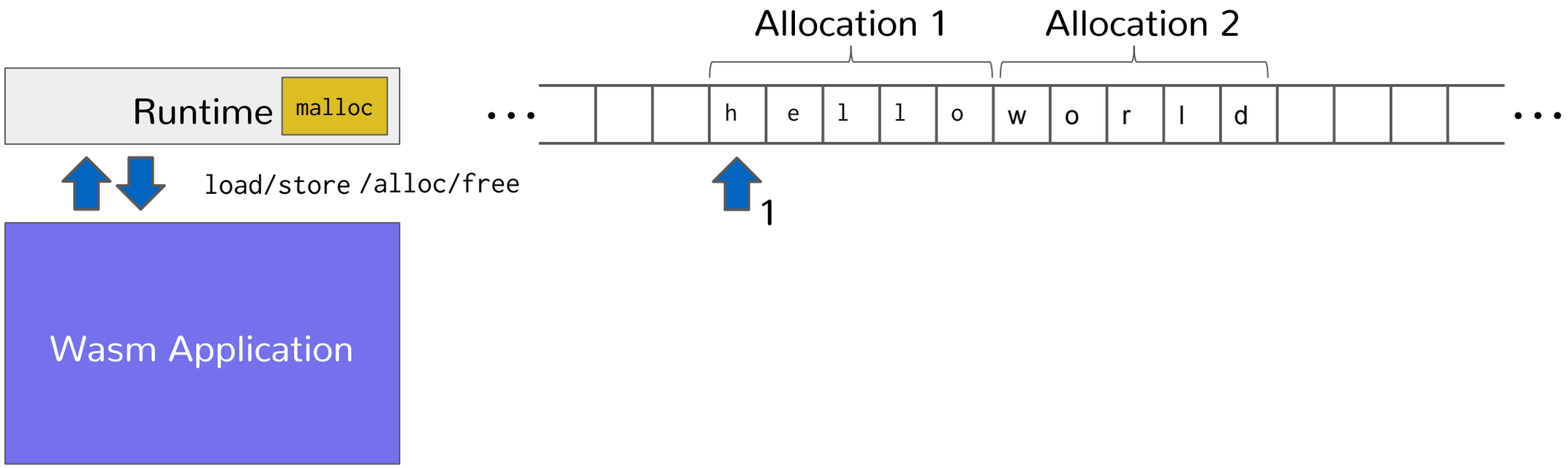

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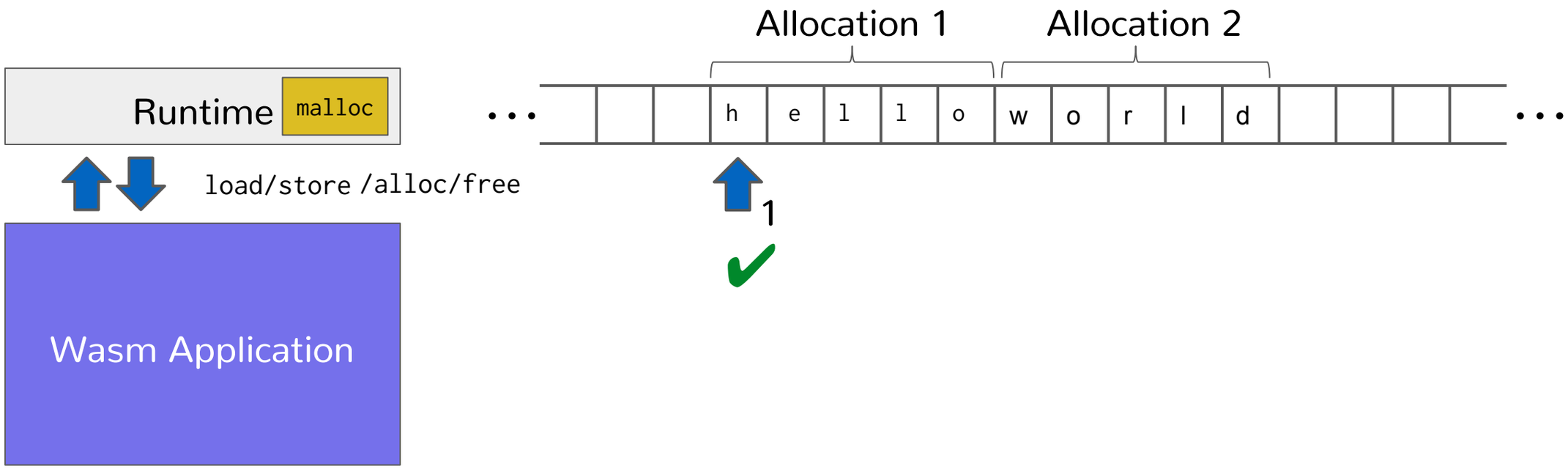

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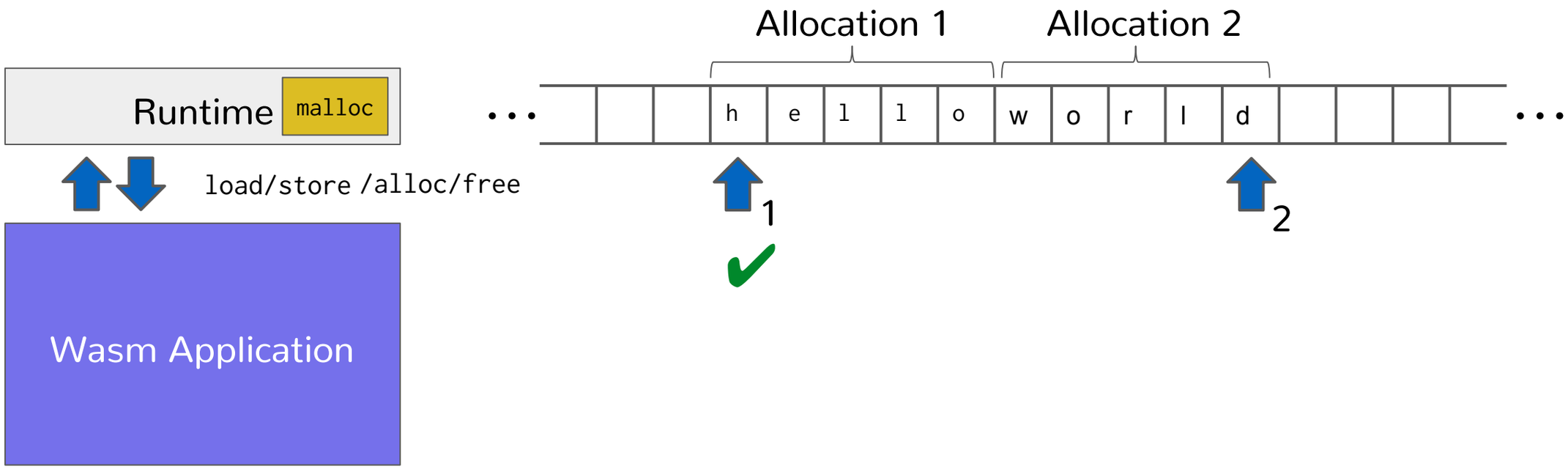

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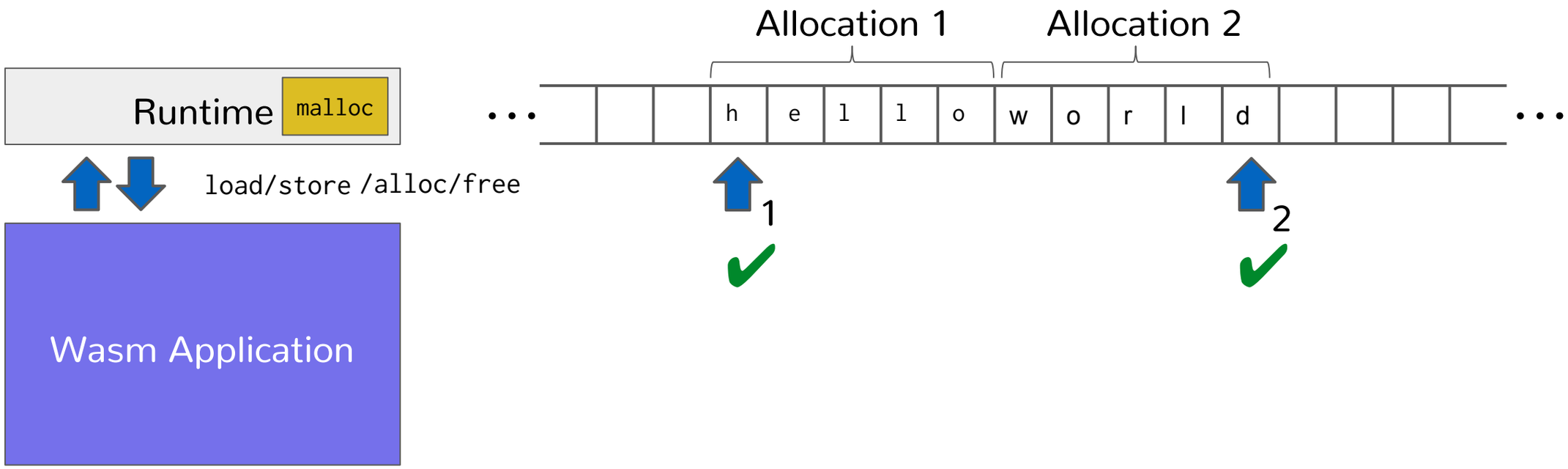

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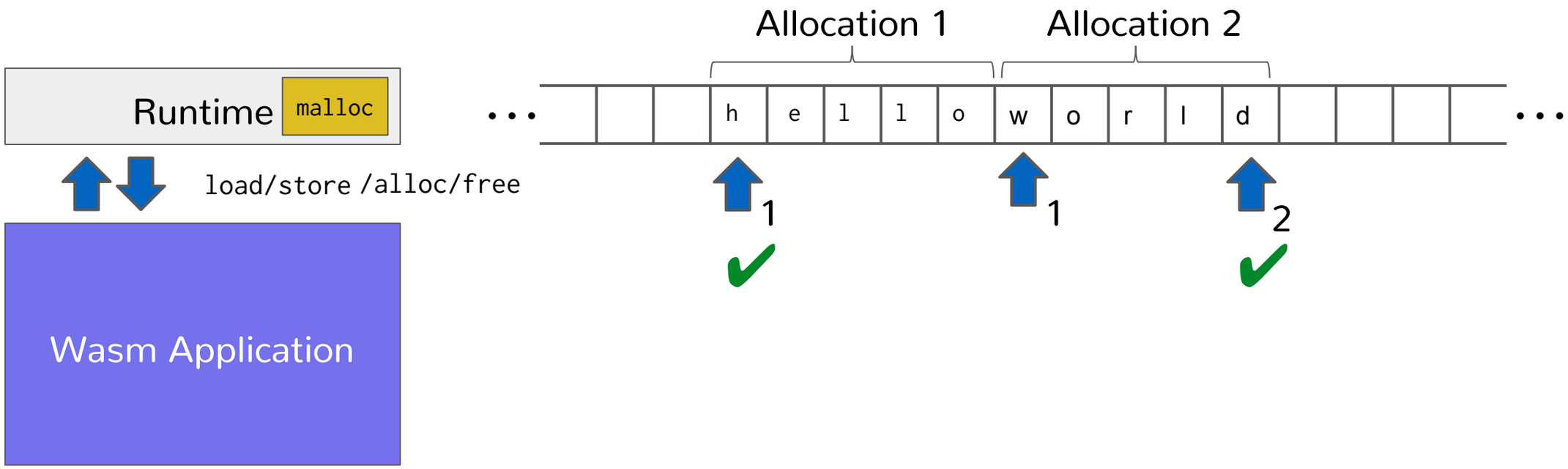

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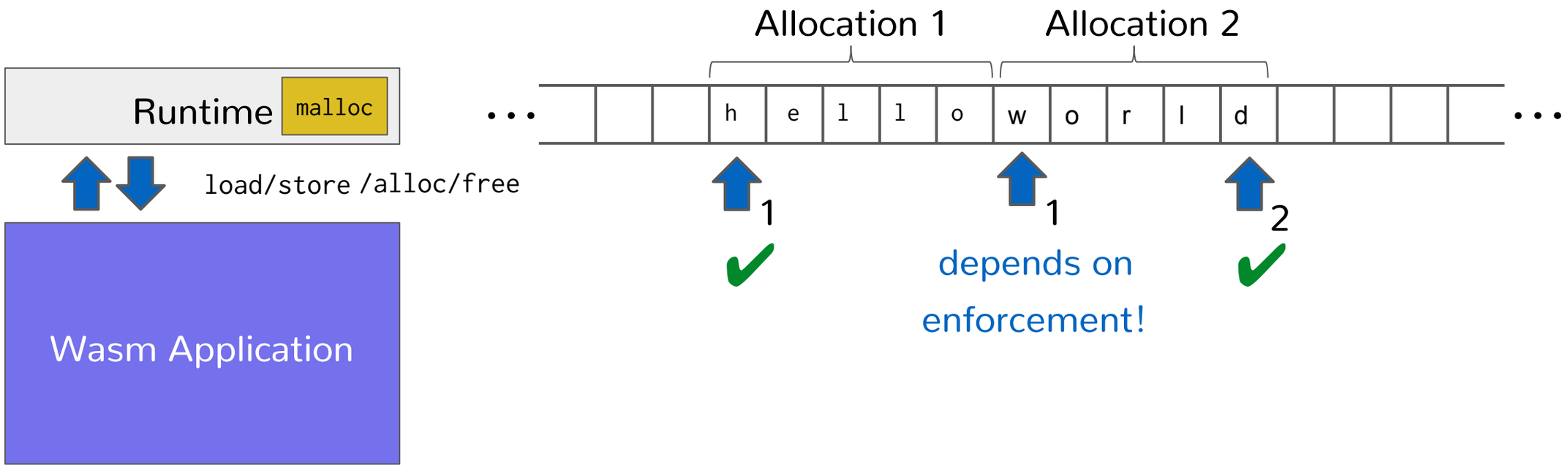
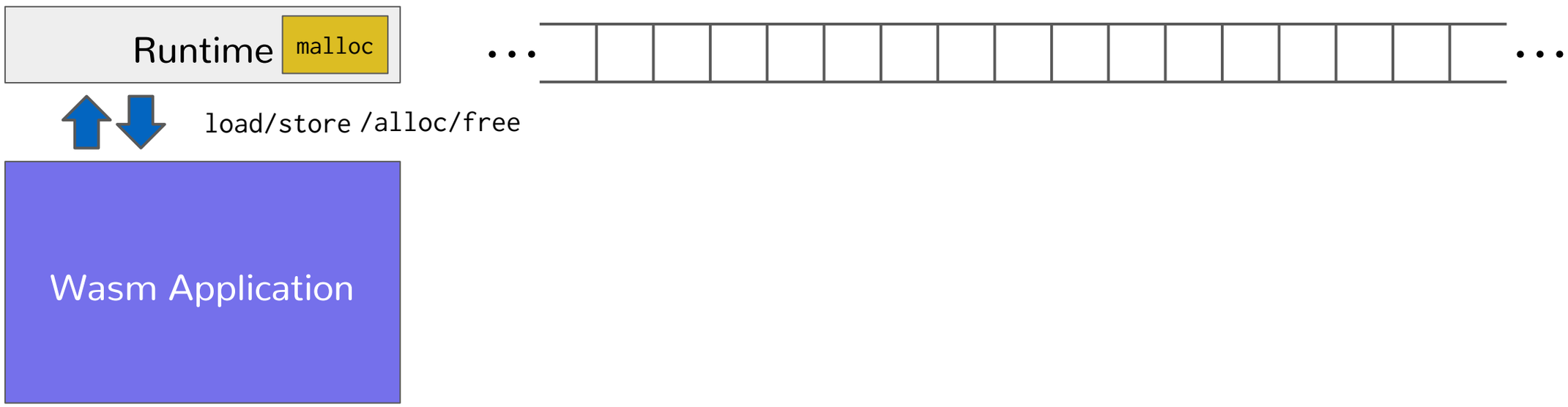


Leveraging available hardware

- Example: ARM's memory tagging extensions
  - Color allocations and handles
  - Enforcement: compare handle and allocation colors



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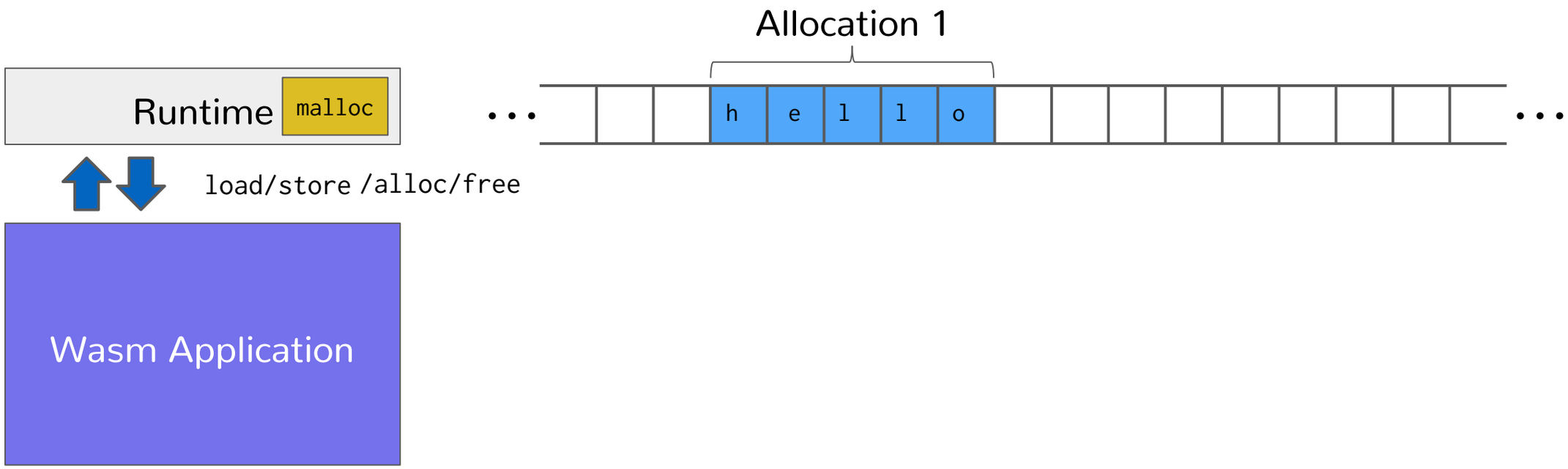

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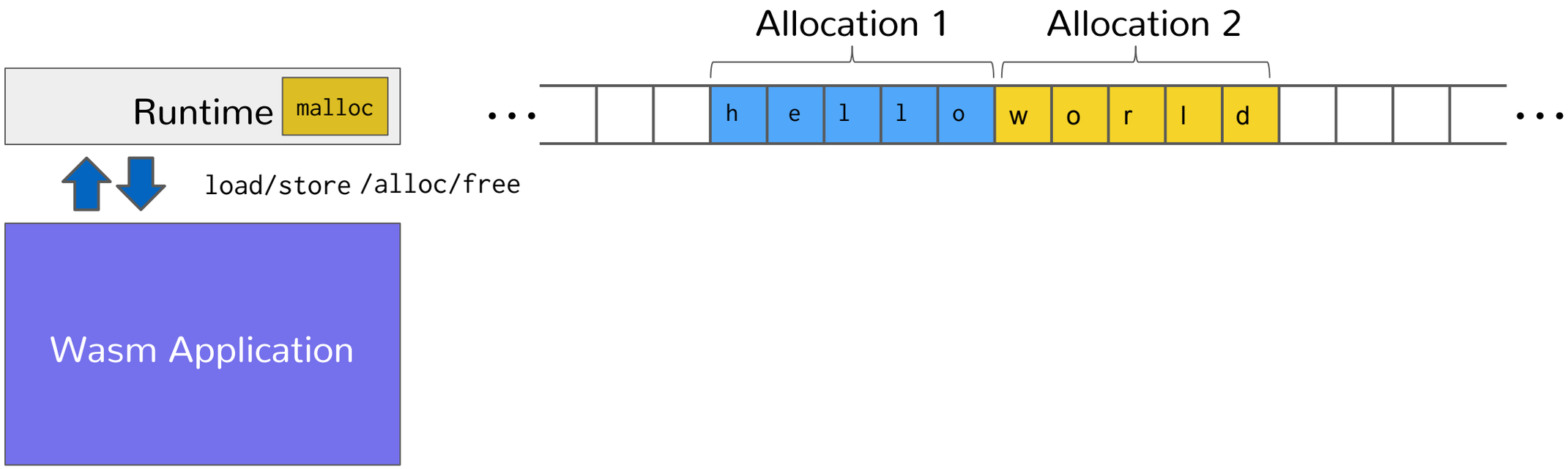

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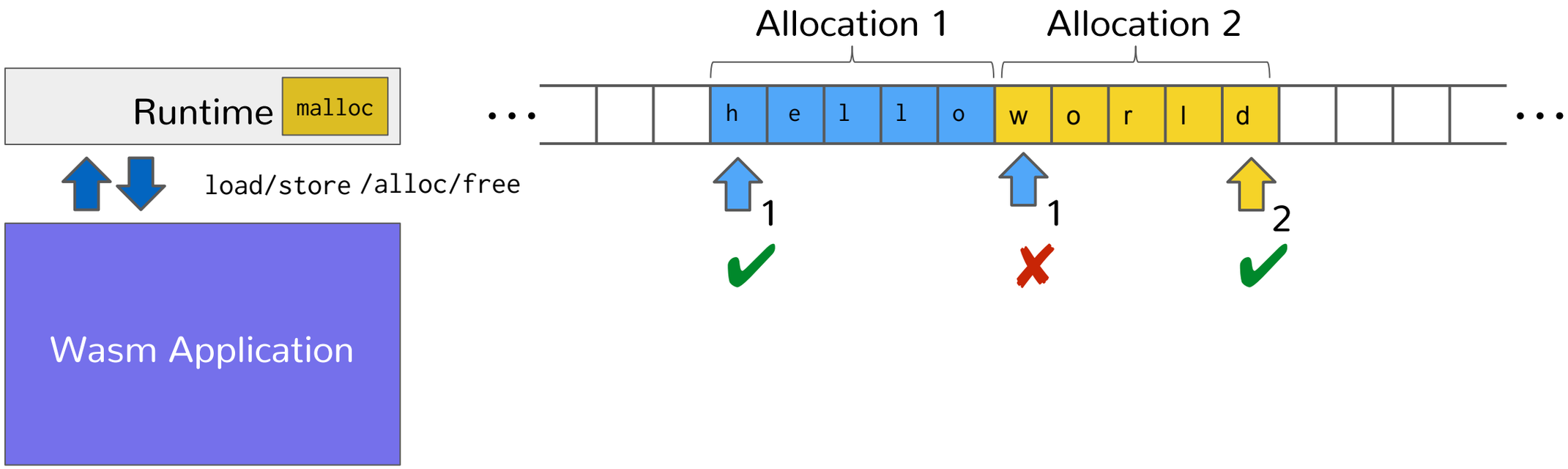

Gateway to memory safety

- Compile program to MS-Wasm once
- Security can improve over time
  - No enforcement today
  - MTE tomorrow
  - CHERI next year
  - MTE+CHERI or ??? the year after

- Prevent the repeat of the last 30 years of attacks

Going forward

- What are other extensions that can improve security?
- Can we do this without complete buy in?
  - Can we make Wasm extensible? (Microcode for the Web?)