Introduction

WebAssembly

What makes WebAssembly different from Assembly?

- Foundational concept is the Module, not the MMU
- I/O goes through imports and exports, not syscalls
  - Declared
  - Typed

Virtualization 😲

Shared-nothing linking

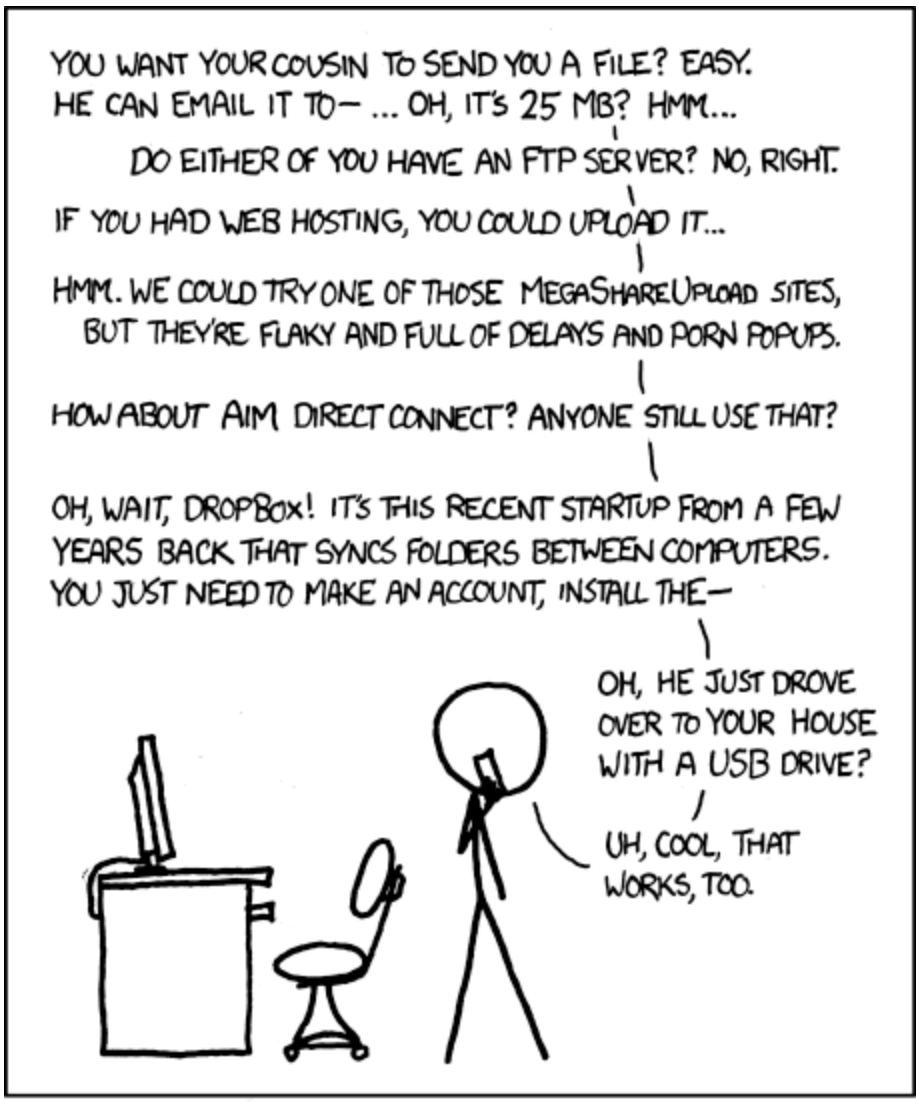
Isolation without virtual address space boundaries

Calls as "IPC"

Virtualization 😲

The hardest problem in computers 😉

How do I copy data from one computer to another? 🤣

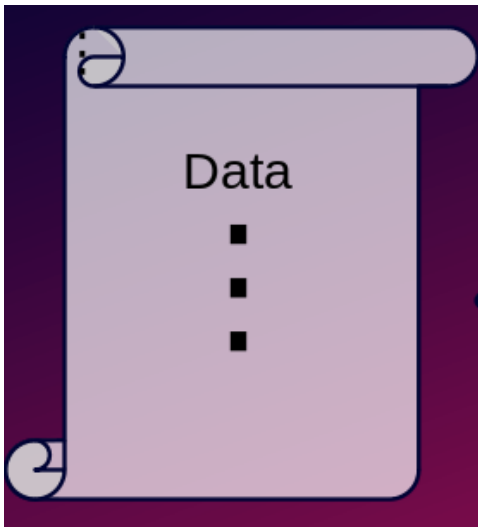


Source: https://xkcd.com/949/

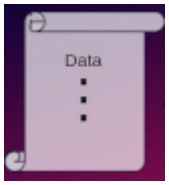
In a similar way, filesystems and socket APIs involve a lot of knowledge of the host.

What's in a File?

Data	Metadata

Data	Metadata
	

Compute and Metacompute

Compute	Metacompute
	
operate on data	configure resources
algorithms and data structures	organize and navigate storage
business logic	manage access between different users
arithmetic	interface with humans

POSIX is dynamically typed

Quiz! 😮

What's the difference between this:

```
$ foo < content.txt
```

and this:

```
$ cat content.txt | foo
```

Can you `lseek` on stdin in POSIX?

- If it's a normal file redirected with < : ✅
- If it's a pipe: ❌

WebAssembly has a static typesystem. Let's use it!

Virtualization 🤯

I/O Types

Wasm-native I/O 🚀

I/O Types

Virtualization 🤯

I/O Types

What is an I/O Type?

- An abstraction for a common I/O pattern
- Expose data, hide metadata

Strategy: Define a few simple I/O types now, add more over time.

I/O Streams

Overview:

- Reliable in-order delivery of bytes
  - or in the future, of arbitrary type
- Examples: sockets, pipes, character devices, files*
- Prototype: https://crates.io/crates/io-streams, https://crates.io/crates/nameless

Operations:

- `read` (input)
- `write` (output)
- `skip` (input) - like `read` but discards data
- `write_zeros` (output) - like `write` but just writes zeros
- `flush` (output) - flush buffers, report errors
- `media_type` - return a `string` with the IANA Media Type (eg. "image/jpeg")
- `pseudonym` - return a handle to an identifier
- `write_pseudonym` - (output) write the name of a pseudonym to the output
- `forward` - `read` from an input and `write` the data to another 👊

Constructors:

- `pipe`
- `null` - (output) bit bucket
- `from_array` - form a stream from an I/O array at a given offset

I/O Arrays

Overview:

- Dynamic array of bytes
  - or in the future, of arbitrary type
- Examples: disk partitions, memory buffers, device memory, files*
- Prototype: https://crates.io/crates/io-arrays

Operations:

- `read_at`
- `write_at`
- `len` - current length
- `set_len` - set current length, truncating or appending zeros
- `advise` - optimization hints
- `flush` - flush buffers, report errors
- `media_type` - return a `string` with the IANA Media Type (eg. "image/jpeg")
- `pseudonym` - return a handle to an identifier
- `copy` - `read_at` from one I/O array and `write_at` the data to another 👊

Constructors:

- `anonymous`
- `from_stream` - read all the data from an input stream and write it into an anonymous I/O array

Typed Main

Typed main functions will be able to take I/O Types as arguments.

Programs which operate this way are independent of:

- Network stacks
- Filesystems
- Case sensitivity, Unicode normalization, path separators, the behavior of `..`, how symlinks work, non-Unicode filenames, filename length limitations, trailing whitespace, ...

Errors

Report partial success along with failure.

- Wasm has multiple return values!

Error types:

- Applications usually don't care why `read` or `write` failed
- Detailed errors expose host information
- Options:
  - Success/Failure
  - Opaque handle

No `EINTR`

- Wasm has no signals! 😎
- No need to wrap `read` and `write` in retry loops

Don't be a file or a socket API:

- Errors and `EOF` are sticky!
- No `ETIMEDOUT`
- Atomicity? Seek higher-level APIs that preserve intent

Relationship to filesystem and sockets

The wasi-filesystem and (anticipated) wasi-sockets proposals will continue:

- Now with less pressure to provide perfect portability
- Can now more easily expand in scope

Some use cases will always need the extra functionality of wasi-filesystem and wasi-sockets.

Some host environments won't support that functionality.

WASI can accommodate both.

Other WASI APIS

wasi-clocks and wasi-random - convert to handles

- Add a Clock I/O type?

wasi-poll - add support for polling I/O Types

In Depth

Are files I/O Streams or I/O Arrays?

Both! (like POSIX)

With separate handles! (unlike POSIX)

What about `lseek`?

- POSIX `lseek` bridges between array and stream
- Emulate `lseek` in libc

What about directories?

Directories have wildly differing semantics between platforms.

Alternative: stream of lazy streams

Write-Once Run Anywhere?

What's different between I/O Types and other common WORA approaches?

- Start with compute, not whole applications
- Push metacompute to the boundaries
- At the boundaries, maybe we still have filenames, or even GUIs

Compatibility with existing code

A libc mode that uses I/O streams and I/O arrays will be able to support:

- `read`, `write`, `pread`, `pwrite`
  - and everything build around them
- all non-I/O things
- `lseek`
- Emulation for `open`, `mmap`, `socket`, etc.

Continue to support the libc mode that uses wasi-filesystem and wasi-sockets.

Let developers chose!

Zero copy

- Ways to do zero-copy
  - `forward`, `skip`, `write_zeros`, `copy`
  - `io-array`'s `read_at` skips intervening data
  - create an I/O Array and pass around a handle
- `read` is not zero-copy
  - shared pages require protocols, synchronization
    - not virtualizable
- What can we do instead?
  - Avoid bringing data into an instance that doesn't need it
  - Use direct calls instead of shared-memory protocols where appropriate

Async

WebAssembly is starting a subgroup to talk about stack switching:

https://github.com/WebAssembly/meetings/blob/master/main/2021/CG-03-16.md#agenda-items

https://docs.google.com/presentation/d/1teI1N282B7Dog314G22Emmaur2XCVtqYwwq5c_AK-BE/edit#slide=id.p

Like the rest of WASI, I/O Types are independent of sync/async.

Data parallelism

That's a separate talk!

Things to come

- Vectored I/O - Maybe interface types can enable this automatically
- Multiplexed connections (QUIC, etc.)
- I/O Windows
- Interactive streams
- Text streams
- Terminal I/O
- A way to do `fsync` / `fdatasync` which preserves intent