POLKADOT
BLOCKCHAIN
ACADEMY

Introduction to Substrate

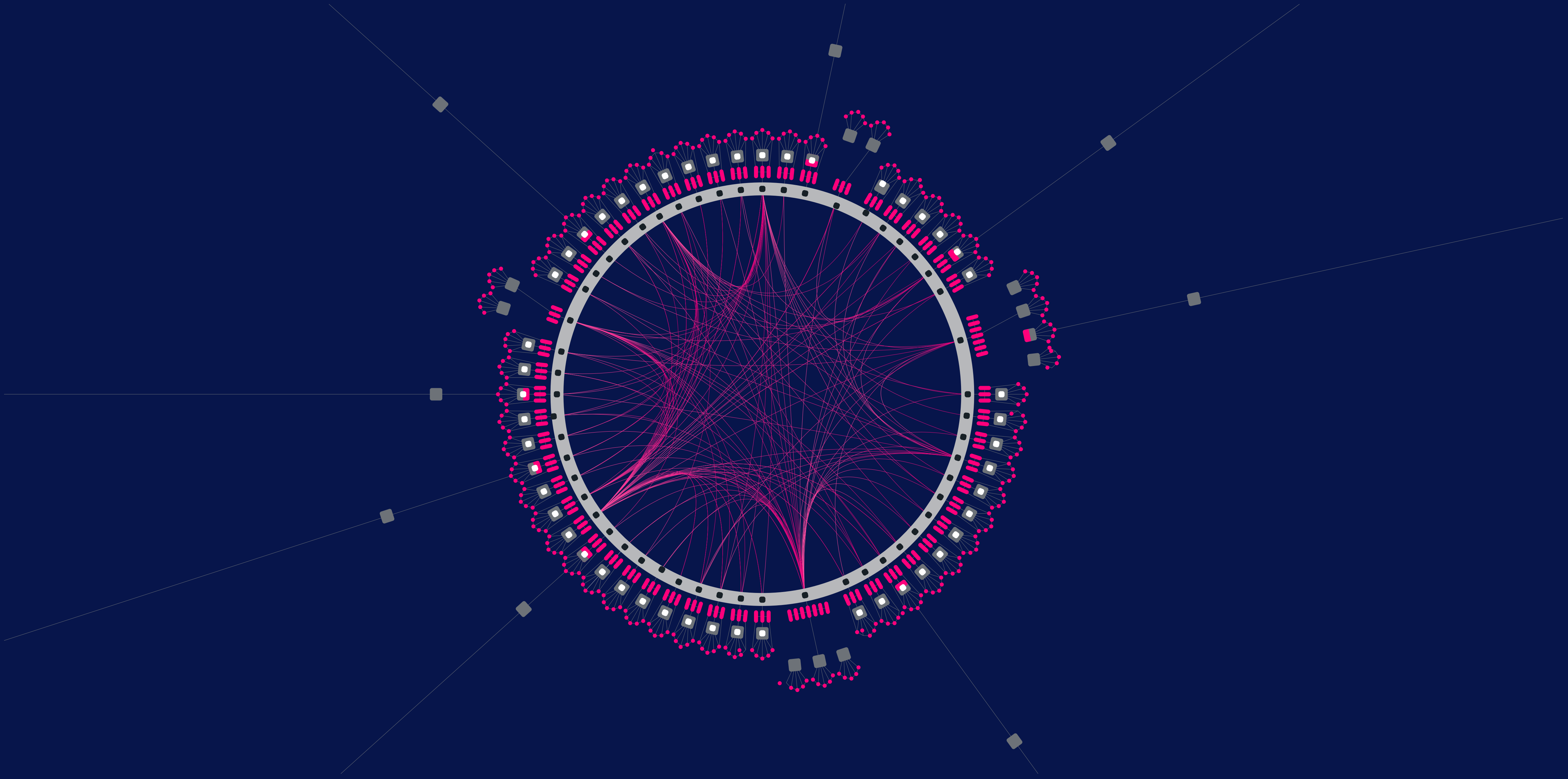
What is Substrate?

Substrate is a Rust framework for building modular and extensible blockchains.

Why Substrate?

Building a blockchain is hard.
Like... really hard.

The Multi-Chain Future

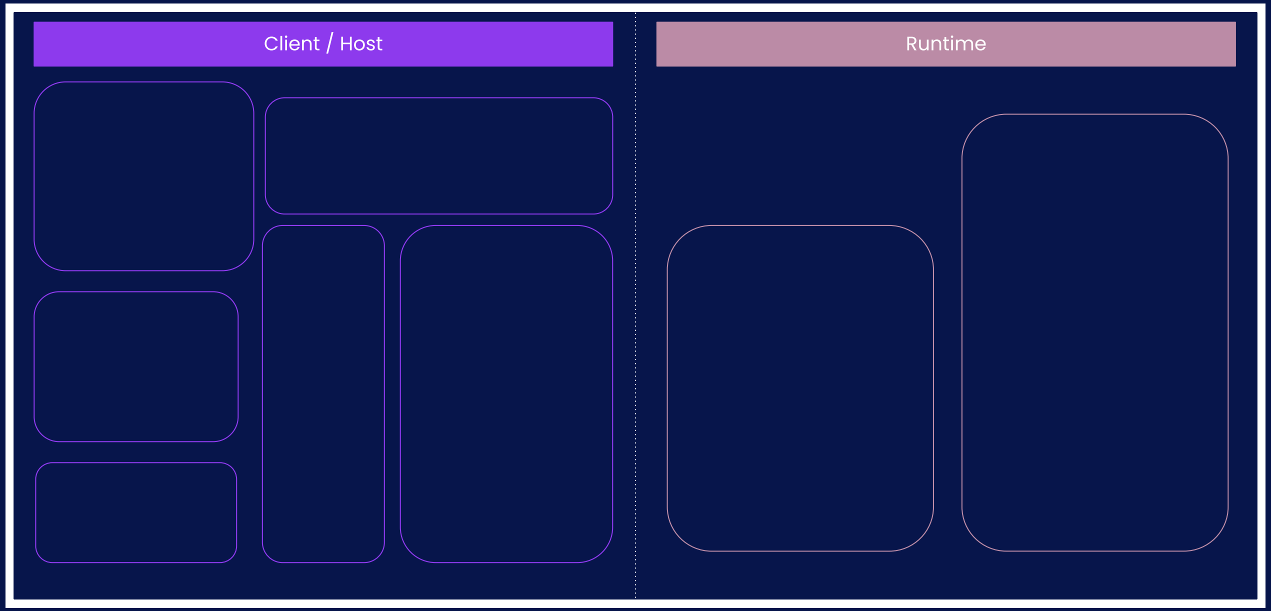


Substrate Architecture

At a very high level, a Substrate node has two parts:

The Client - A Wasm executor.

A Wasm runtime.



What is the Runtime?

The runtime contains all of the business logic for executing the **state transition function** of the blockchain.

Turing-Complete State Machine

- Turing completeness basically means you can implement any computer algorithm.
- Besides limitations from execution time, memory size, or storage limitations... the runtime is a turing-complete state machine.
- The state machine itself is broken into two components:
    - The state itself
    - The state transition function

Runtime as a VM

The Runtime is designed as a Virtual Machine within the Substrate client.

Why?

- Runtime code must execute deterministically.
- Runtime code should be sandboxed.

VMs enable this.

The runtime is always a Wasm binary.

Wasm

- Wasm is short for WebAssembly
- It is a binary instruction format for a stack-based virtual machine.
- Originally built for the web as a faster and better alternative to technologies like JavaScript.
- The open standards for WebAssembly are developed by W3C groups.

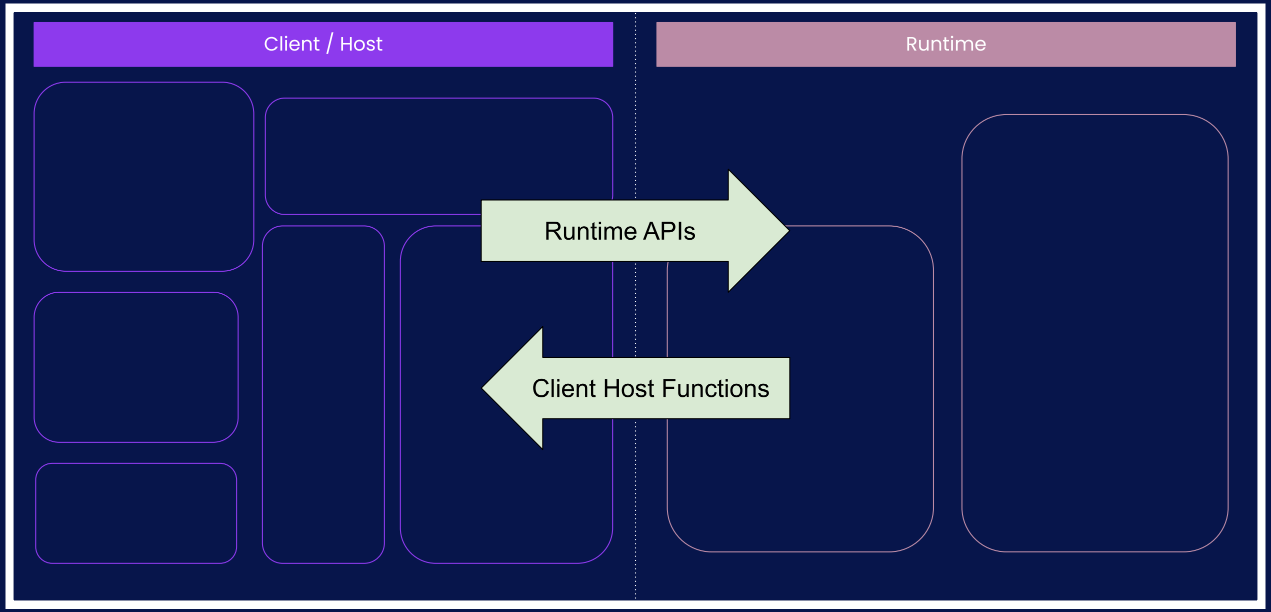
Why Substrate chose Wasm?

- Compact: Designed to be easily transferred over the web.
- Sandboxable: Keeps Wasm Safe, as capabilities have to be exposed explicitly to the Wasm environment.
- Deterministic(-ish): assuming all outputs are defined given some instruction set.
- Performance: direct mapping of operations to machine code.
- Well Supported: WASM is on its way to become a core component of the web, just like JavaScript did.

Runtime Assumptions

To make a Substrate compatible runtime, our only assumptions are:

- It exposes a specific Runtime APIs.
- It has access to specific client-side host functions.

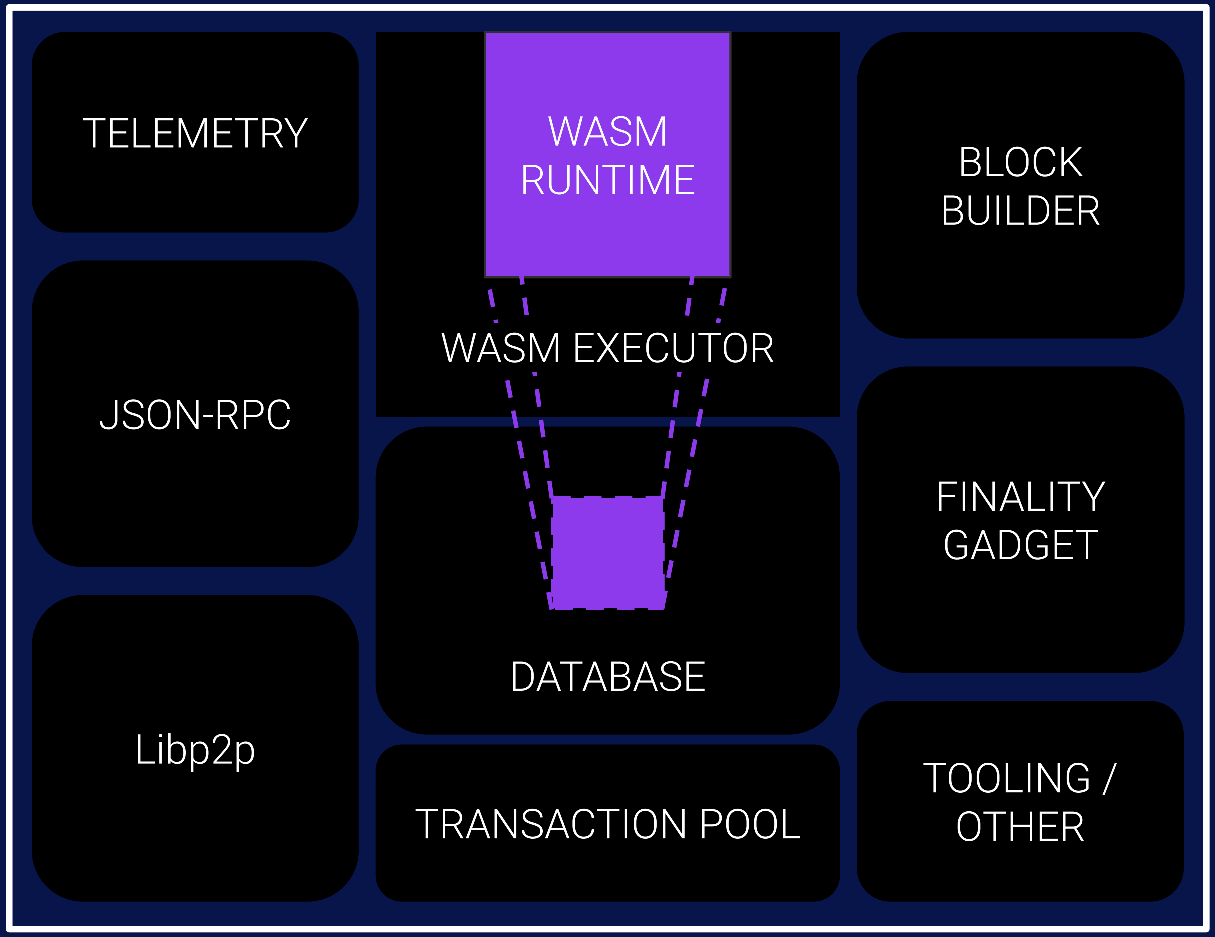


The Client

- This is simply the natively compiled binary which runs on your computer.
- It has access to do much more things then the restrictive Wasm VM environment.
- Generally, determinism is not important at this level.
  - Allows multiple implementations to be created.
  - Allows for compilation to different targets.

Client Components

- Networking
- Database
- Transaction Queue
- Consensus
- Telemetry
- Runtime
- Tools
- And more!

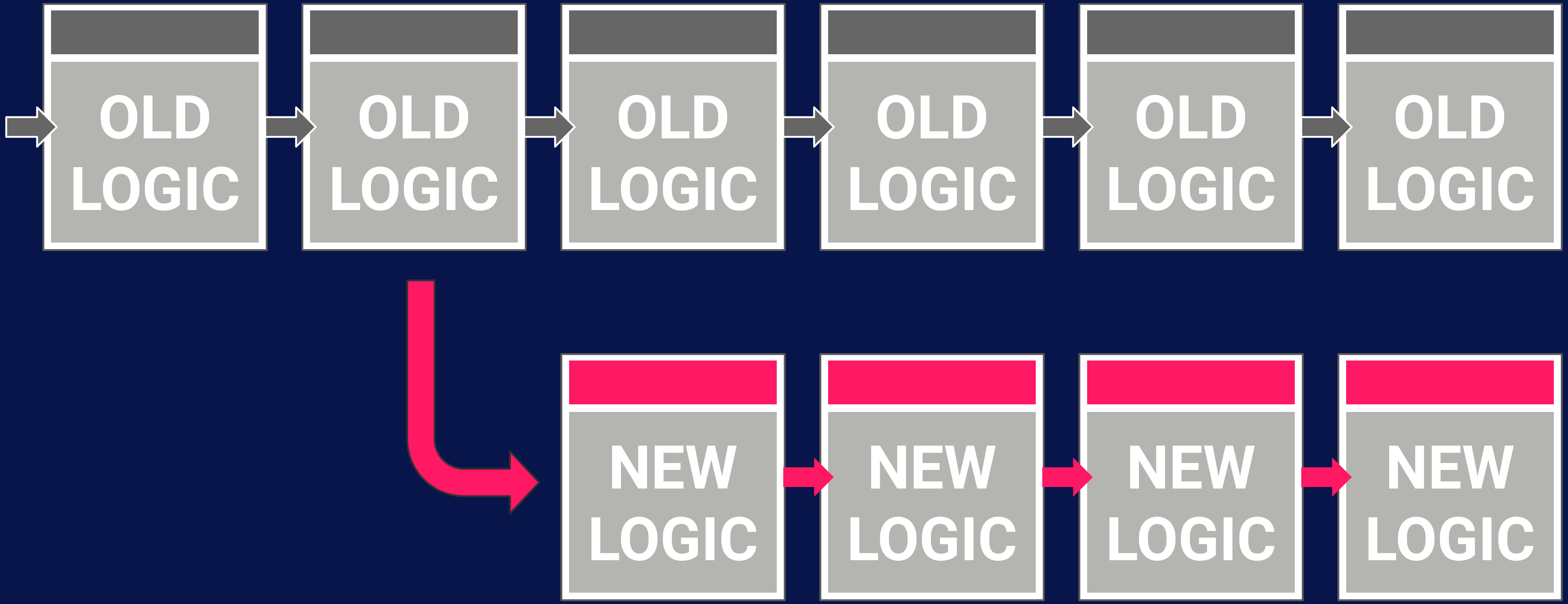


SUBSTRATE CLIENT

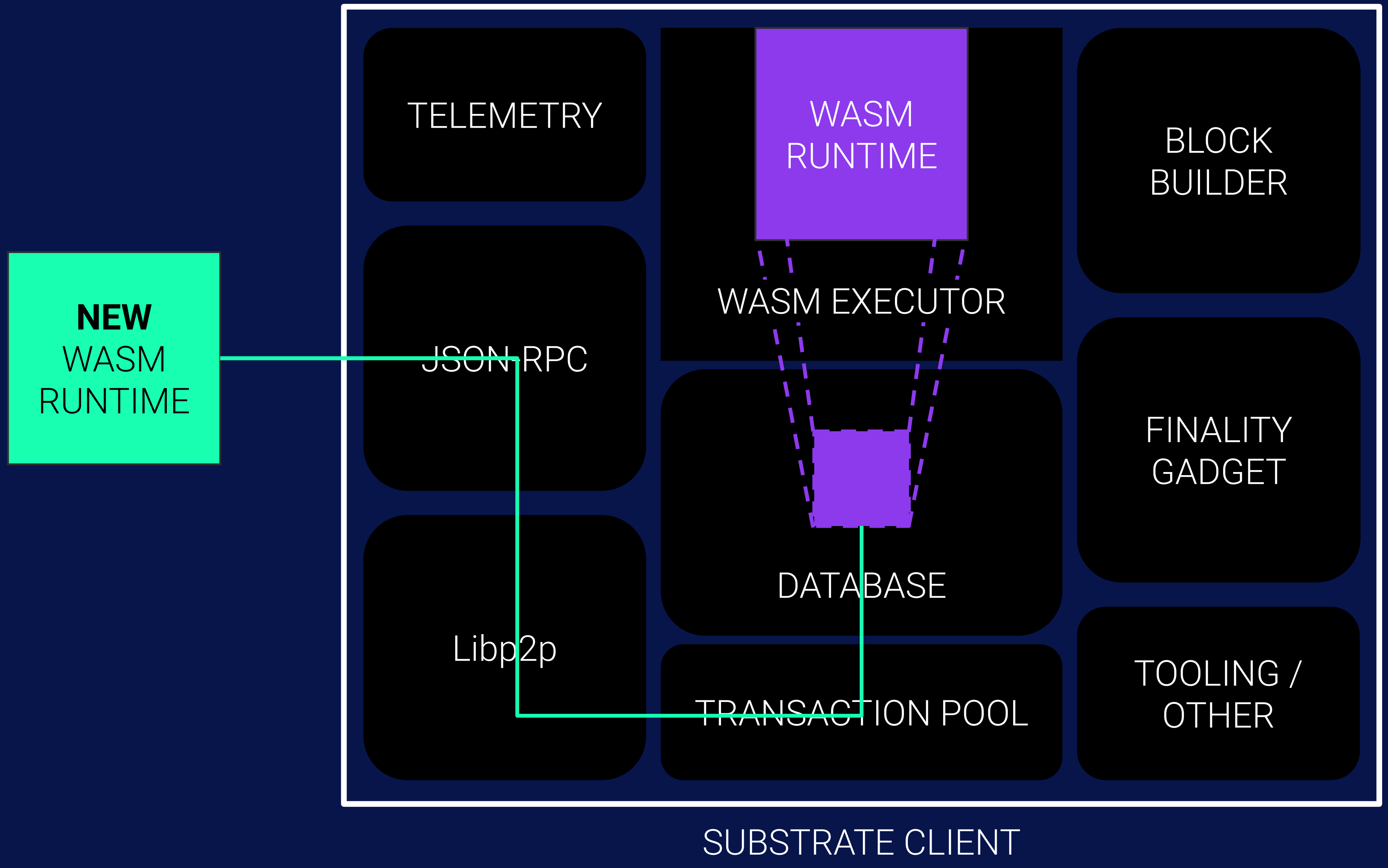
Wasm is stored on chain!

Problems with Hard Forks

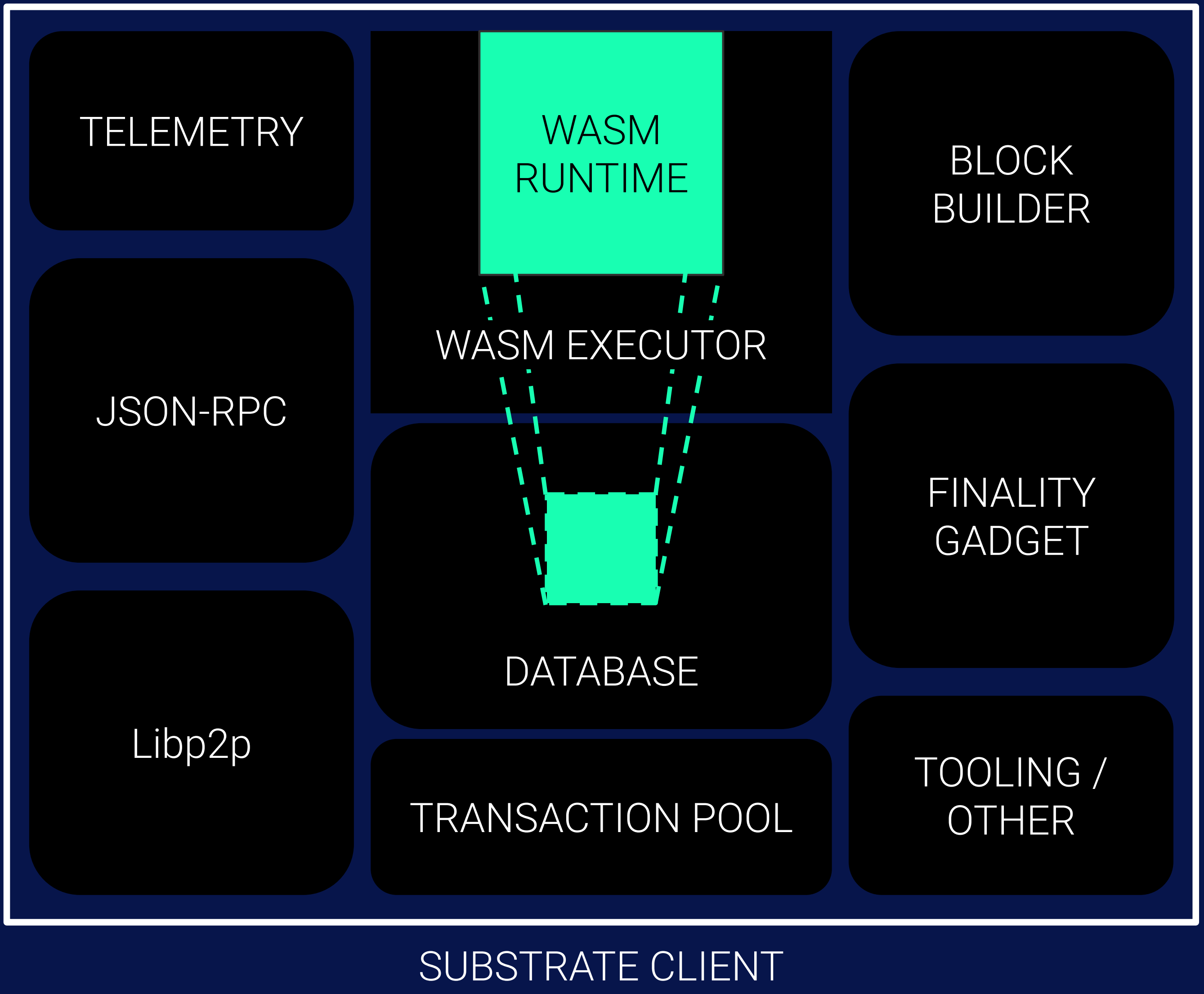
Not everyone updates their client software in time.



Upgrading the Substrate Runtime



Upgrading the Substrate Runtime



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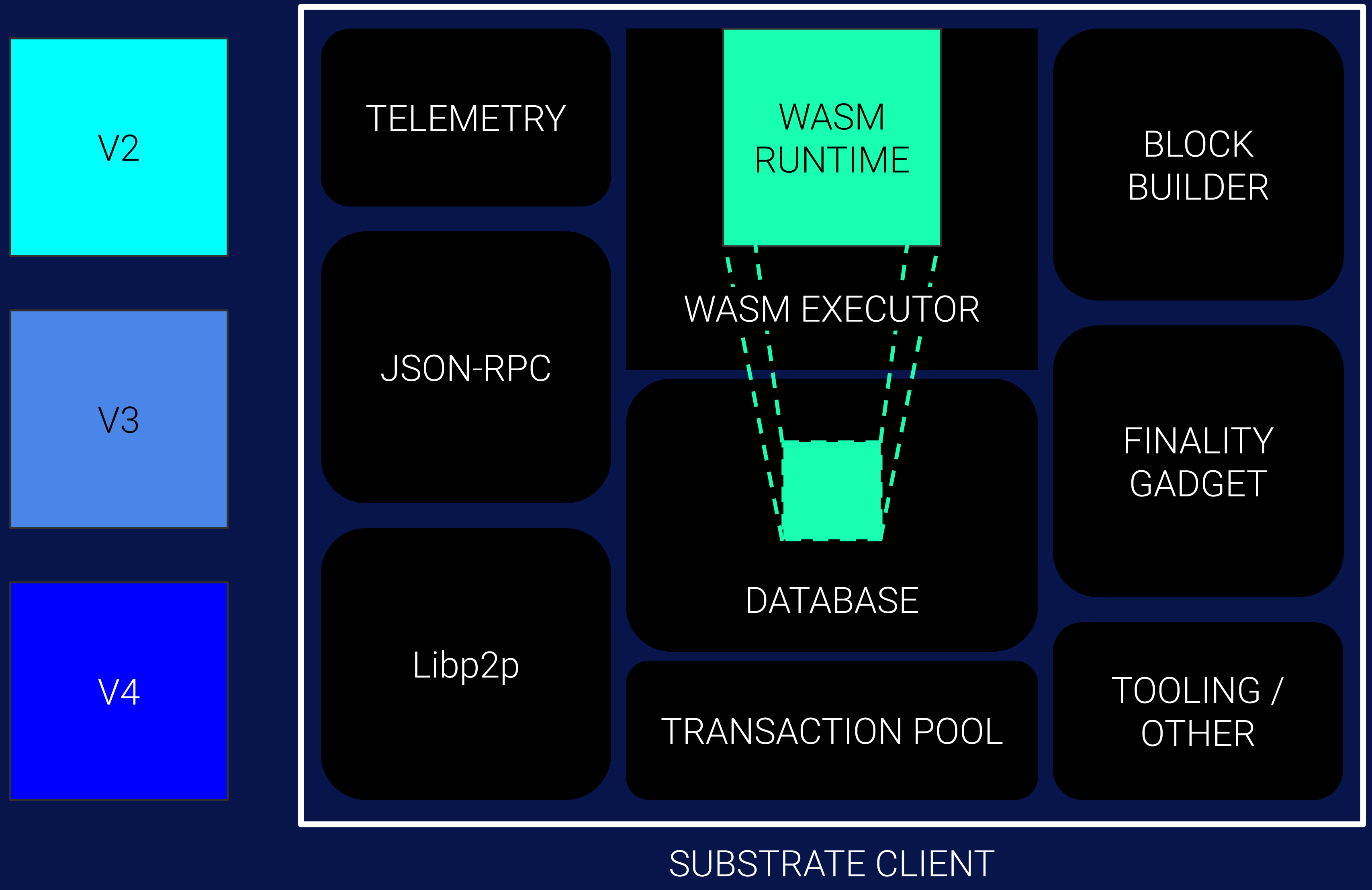
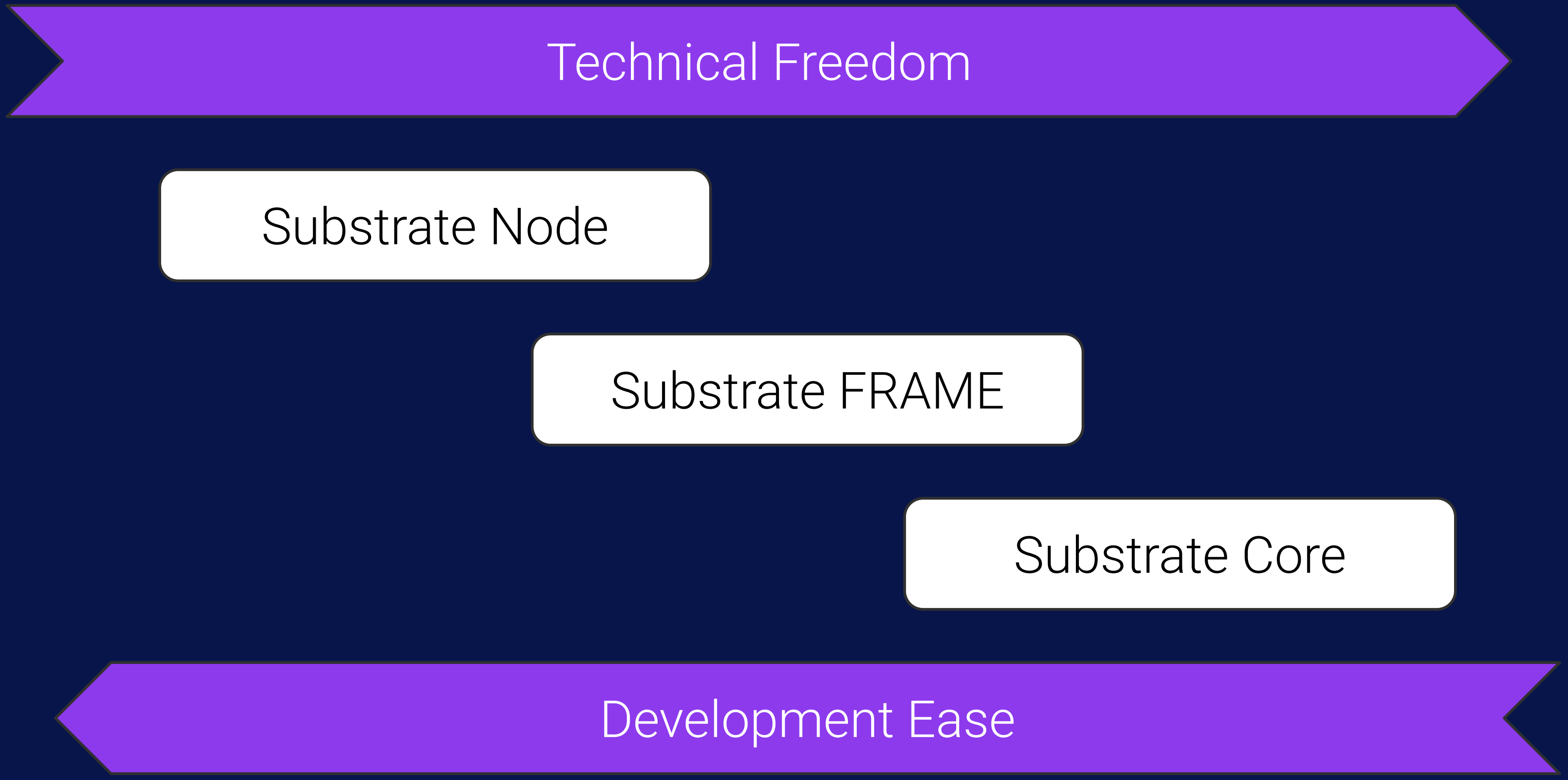


Game Console Analogy

Substrate Client

Substrate Runtime

Technical Freedom vs Ease



License

Substrate Primitives (`sp-*`), Frame (`frame-*`) and the pallets (`pallets-*`), binaries (`/bin`) and all other utilities are licensed under Apache 2.0.
Substrate Client (`/client/*` / `sc-*`) is licensed under GPL v3.0 with a classpath linking exception.

- Apache2 allows teams full freedom over what and how they release, and giving licensing clarity to commercial teams.
- GPL3 ensures any deeper improvements made to Substrate's core logic (e.g. Substrate's internal consensus, crypto or database code) to be contributed back so everyone can benefit.