Algorand

Algorand School

2022

Open Source: github.com/cusma/algorand-school

Algorand

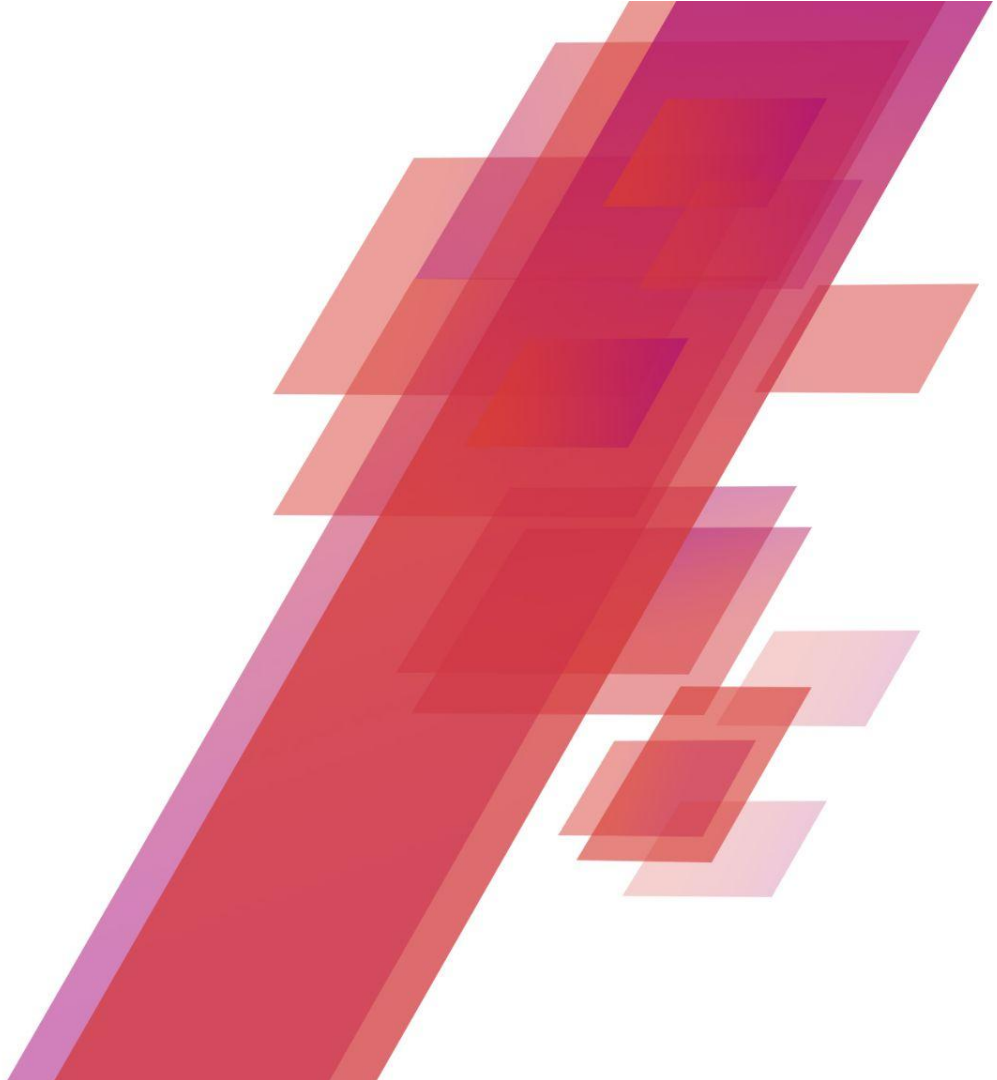
Our journey today:

understanding Algorand Consensus and Algorand Networks, how to use Algorand Dev Tools, how to develop decentralized applications on the Algorand Virtual Machine

Algorand

Agenda

- Blockchain as an infrastructure
- Analog properties for Digital things
- Algorand Consensus
- Algorand Sustainability
- Algorand Networks
- Algorand Interoperability
- Algorand Transactions
- Algorand Accounts
- Algorand Standard Assets & ARCs
- Algorand Virtual Machine
- Algorand Smart Contracts on Layer-1
- Smart Signatures & Smart Contracts
- TEAL
- PyTEAL
- Algorand ABI
- Beaker



Algorand

Introduction to Algorand

An efficient public infrastructure for digital value

Cosimo Bassi
Solutions Architect at Algorand

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Algorand


Blockchain *is a digital infrastructure* for value
"The ability to create something which is not duplicable in the digital world has enormous value."
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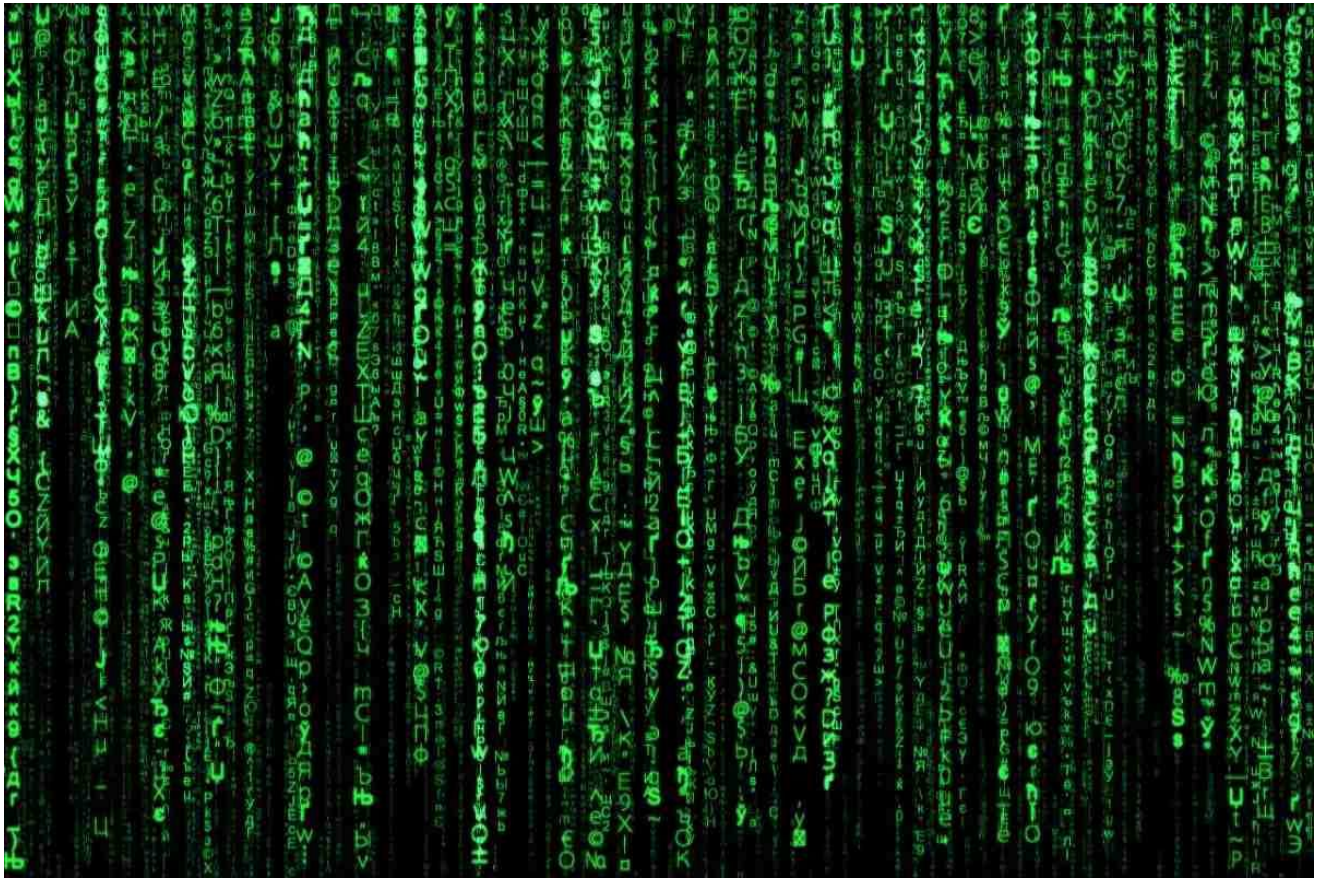
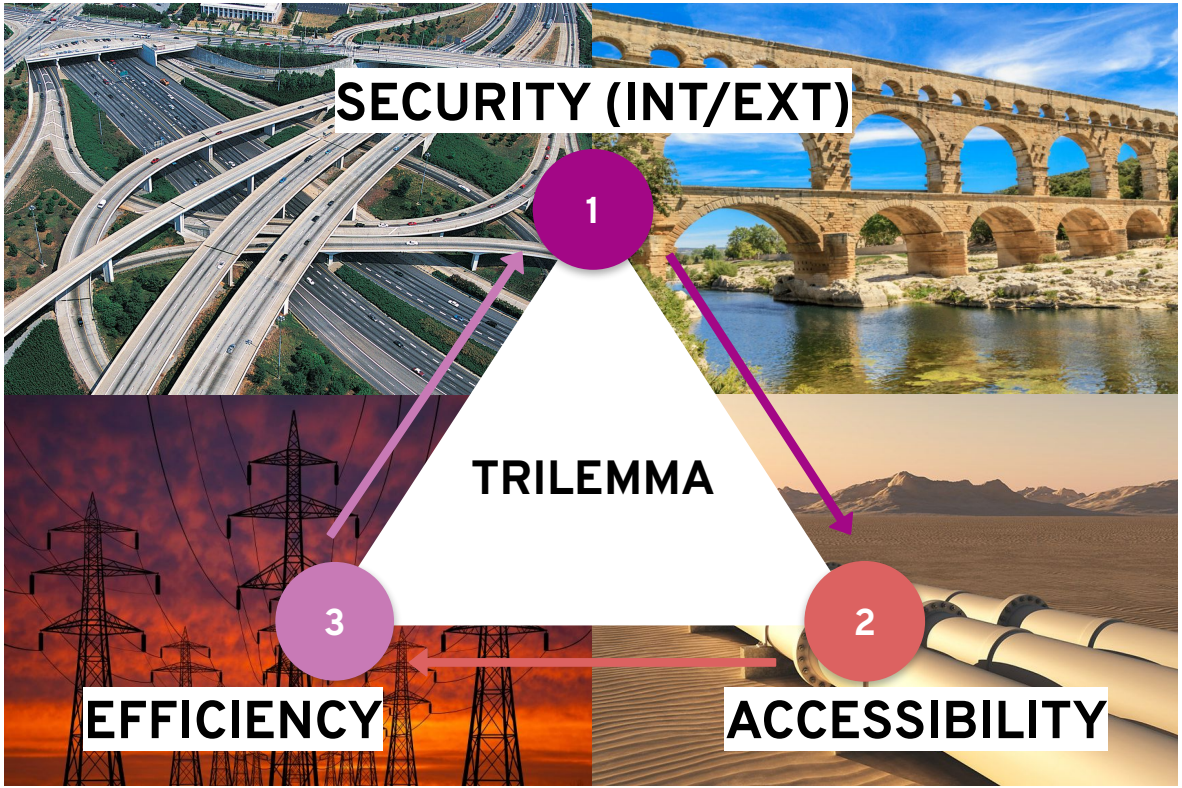
Blockchain *is a digital infrastructure* for value



"The ability to create something which is not duplicable in the digital world has enormous value."

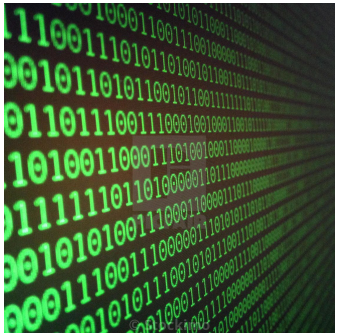
Eric Schmidt

The *infrastructure trilemma*



Public or private? Who has the control? Duty and responsibility? Aligned incentives?

The problem of *native digital value*



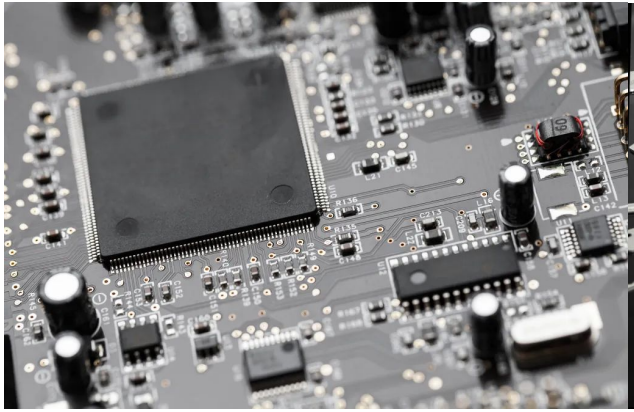
In the digital age
everything can be represented in bits
as a string of 0 and 1

Strings of 0 and 1 are useful
because you can
duplicate them easily

Value is therefore difficult to represent in the digital age:
SCARCITY, AUTHENTICITY, UNICITY

How to build such infrastructure? *Protocol* is the answer

This is not just an *information technology* problem



DISTRIBUTED SYSTEMS

CRYPTOGRAPHY

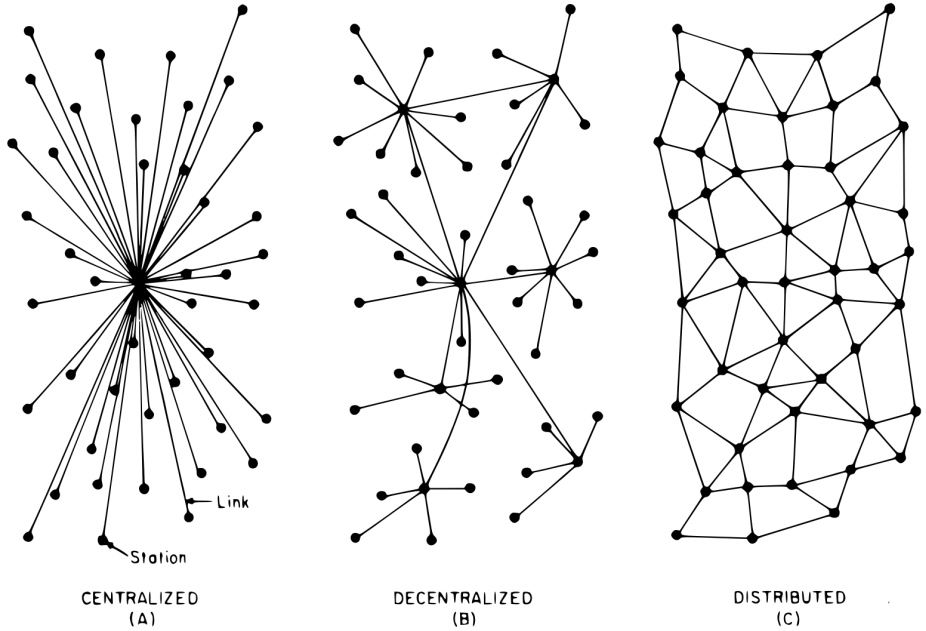
GAME THEORY

PUBLIC
TAMPER-PROOF
TRANSPARENT
TRUSTLESS
LEDGER

Who controls the system? Nobody… everybody!

DISTRIBUTED SYSTEMS

PAST

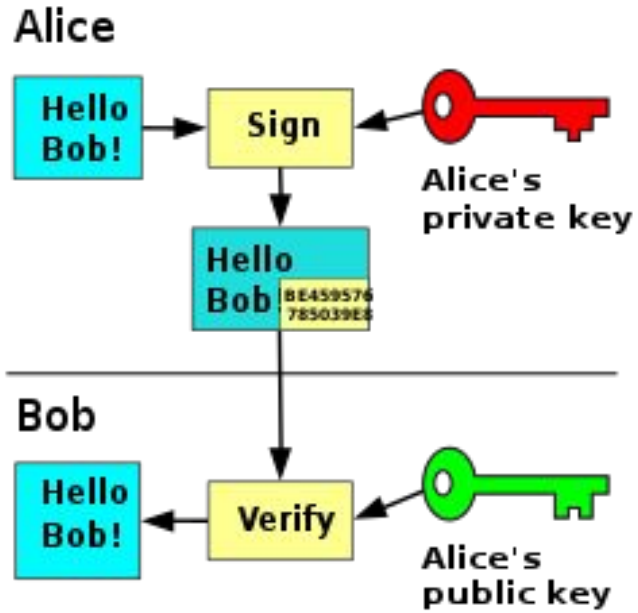


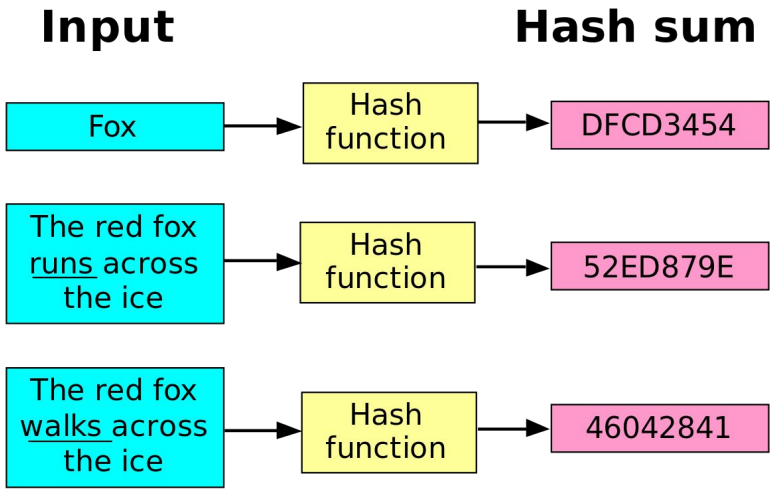
FUTURE

No absolute power, no single point of failure.

Don’t trust, verify!

CRYPTOGRAPHY





Nobody can break the rules…

and

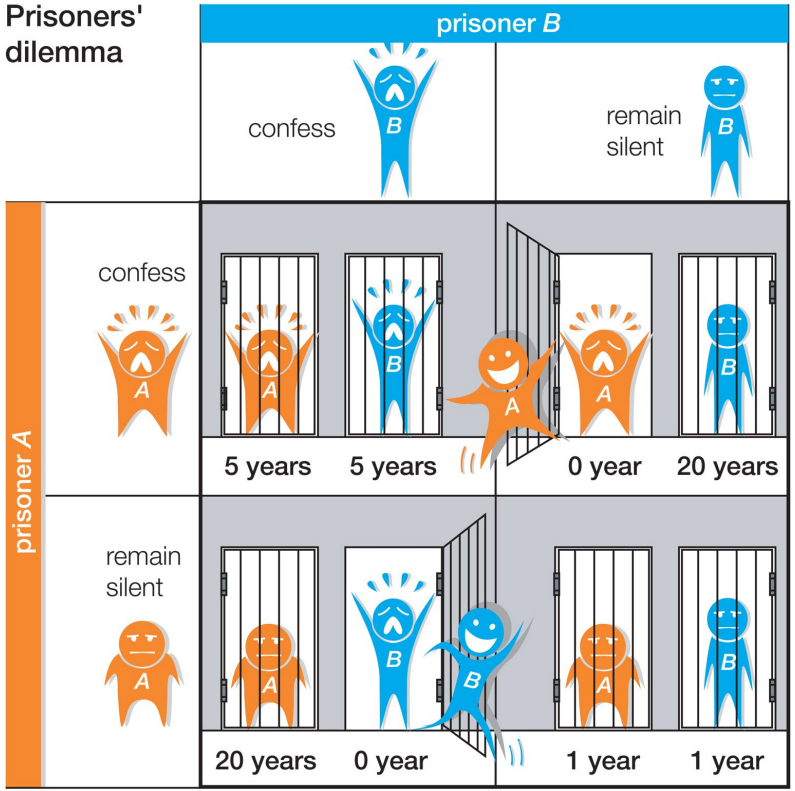
…everybody can verify.

Align incentives: collective self-protecting system

GAME THEORY

Equilibrium in which **attacking** the system is **less convenient than protecting** it.

Cost of the attack: make malicious behaviours expensive.



Algorand

ANALOG PROPERTIES FOR DIGITAL THINGS

Consensus as “law of Physics” for digital world

Who owns what? Let's write it down!

A **blockchain** is a **public ledger** of transactional data.

WHO

OWNS

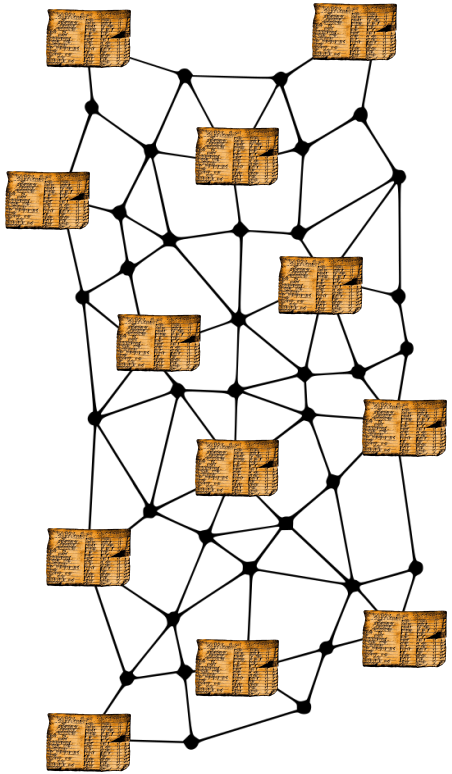
WHAT

World's first writing — cuneiform — traces its beginnings back to an ancient system of accounting.

More copies are better than one!

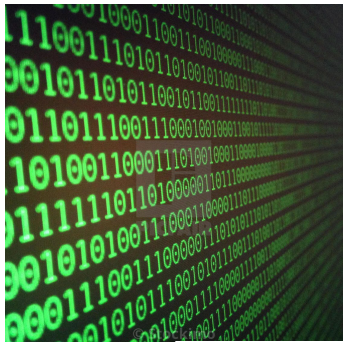
Distributed and **replicated** across a **system of multiple nodes** in a network.

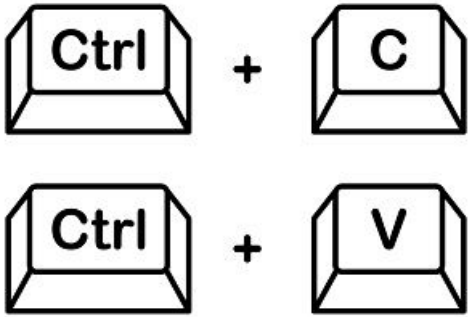
All *"ledger keepers"* should work together, using the **same set rules**, to **verify** the transactions to add to each copy of the finalized ledger.

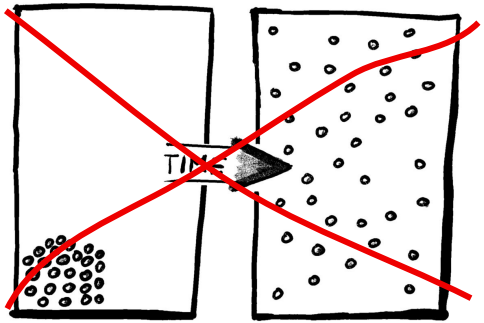


Entropy, irreversibility and the arrow of time

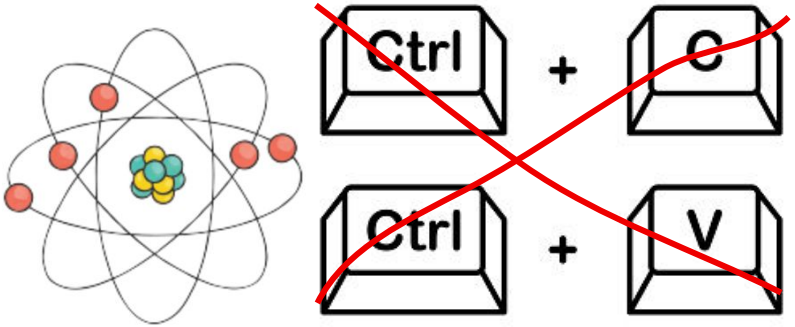
Bits can be copy & pasted and **are not obliged** to follow the **arrow of time**!

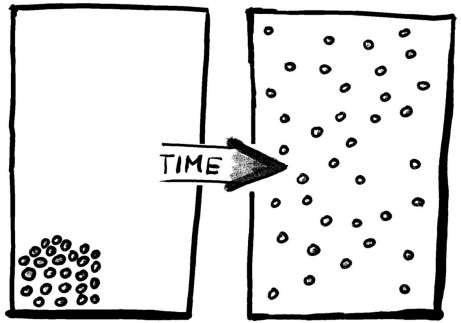






Atoms can't be copy & pasted and **are obliged** to follow the **arrow of time**!

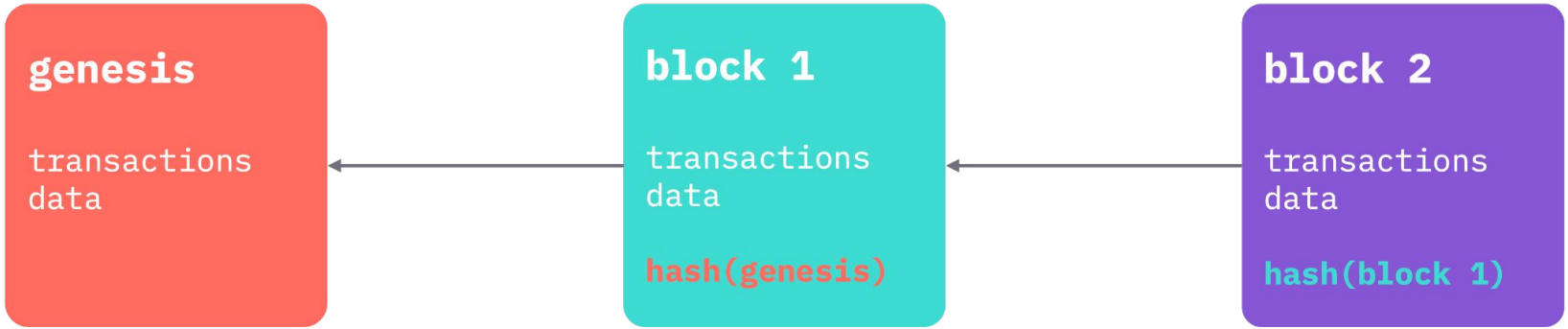




A chain of transactions organized in blocks

The “**block**” refers to a set of transactions that are proposed and verified by the other nodes and eventually added to the ledger (**no copy & paste**).

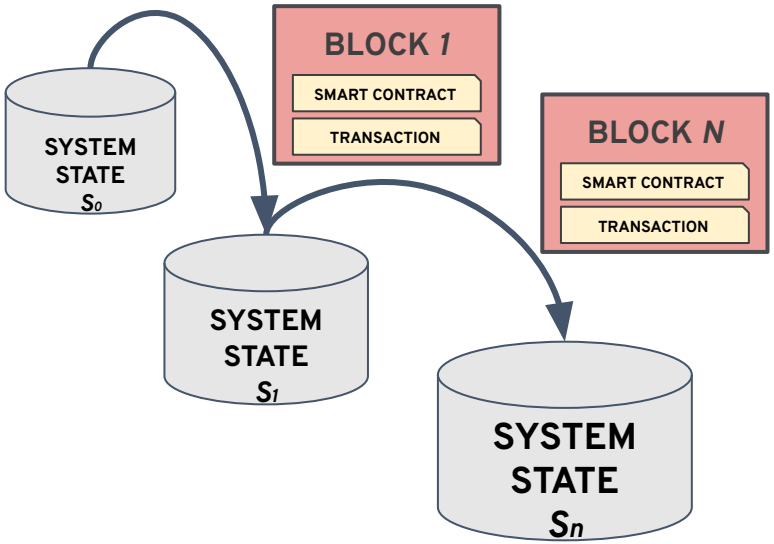
The “**chain**” refers to the fact that each block of transactions contains proof (a cryptographic hash) of what was in the previous block (**arrow of time**).



Can transactions be reverted or modified ex-post? No! *Dura lex, sed lex!*

A distributed state machine

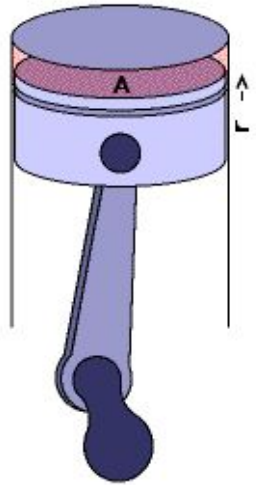
The **evolution** of the **states of the system** is determined...

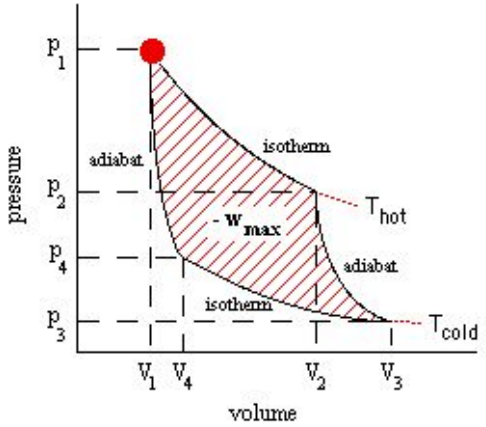


...**acting on bits**, through **what?**

A machine

The **evolution** of the **states of the system** is determined...



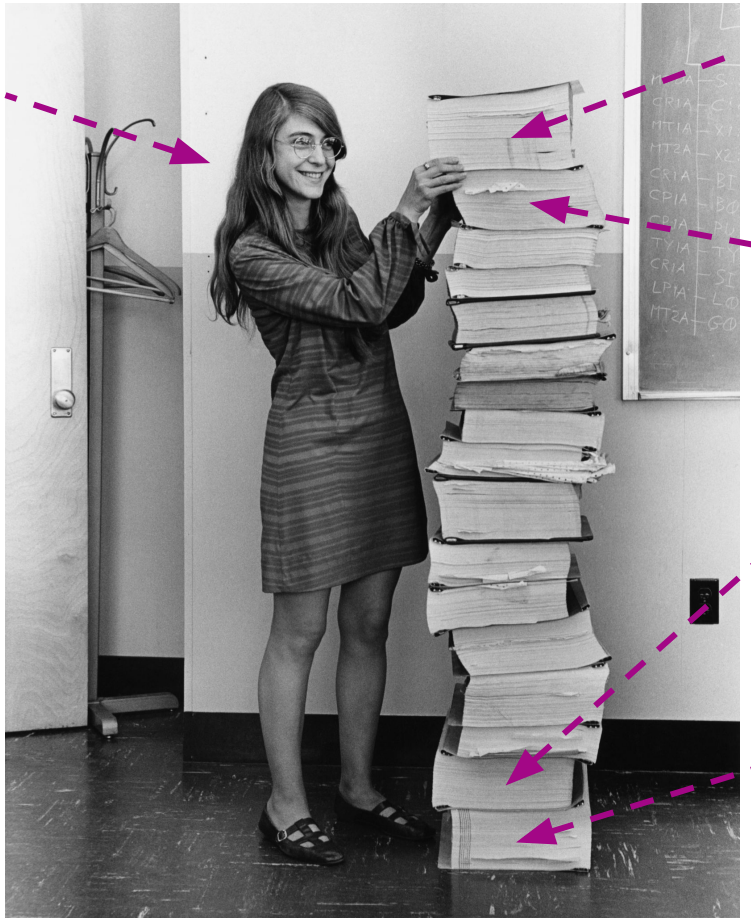


...**acting on atoms**, through the **inviolable laws of Physics!**

The responsibility of correct information

How should we **replace** the role played by the **law of Physics** in evolving the state of a machine?

With a **set of software rules**, called **Consensus Protocol** that evolves the **state** of the system.



Margaret Hamilton in 1969, standing next to listings of the software she and her MIT team produced for the Apollo project.

The architecture of consensus

1. How to choose the **proposer for the next block** for a **public and permissionless** blockchain?

2. How to ensure that **there is no ambiguity** in the choice of the next block?

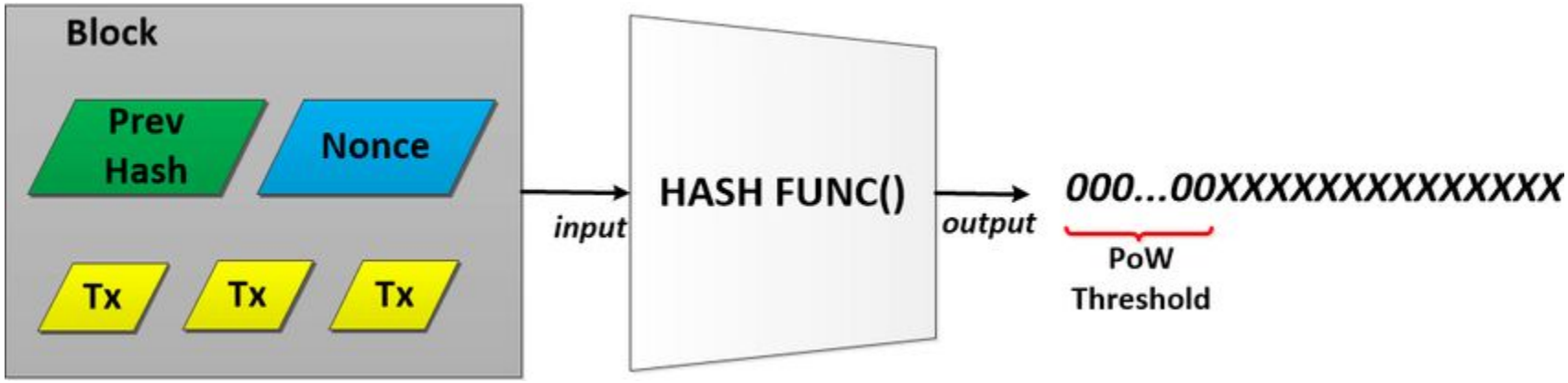
3. How to ensure that the **blockchain stays unique** and has **no forks**?

4. How to ensure that **consensus mechanism itself can evolve** over time while the blockchain is an immutable ledger?

Temple of Concordia

Valley of Temples (Agrigento), 440-430 B.C.

Proof of Work consensus mechanism



Miners **compete with each other** to append the next block and **earn a reward for the effort**, fighting to win an **expensive computational battle**.

The **more computational power**, the **higher the probability** of being elected as block proposer.

Proof of Work limits

- Huge electrical consumption
- Concentration of governance in few mining farms
- Soft-forking of the blockchain

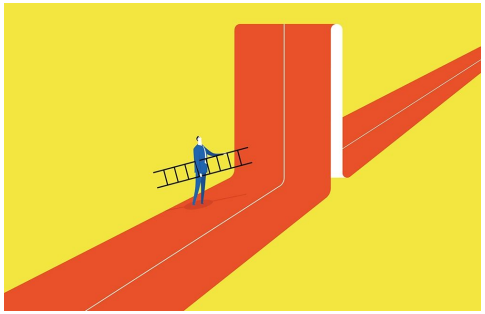
Proof of Stake consensus mechanism

Network participants **show their commitment and interest** in keeping the ledger safe and secure **proving the ownership of value stored on the ledger itself**.

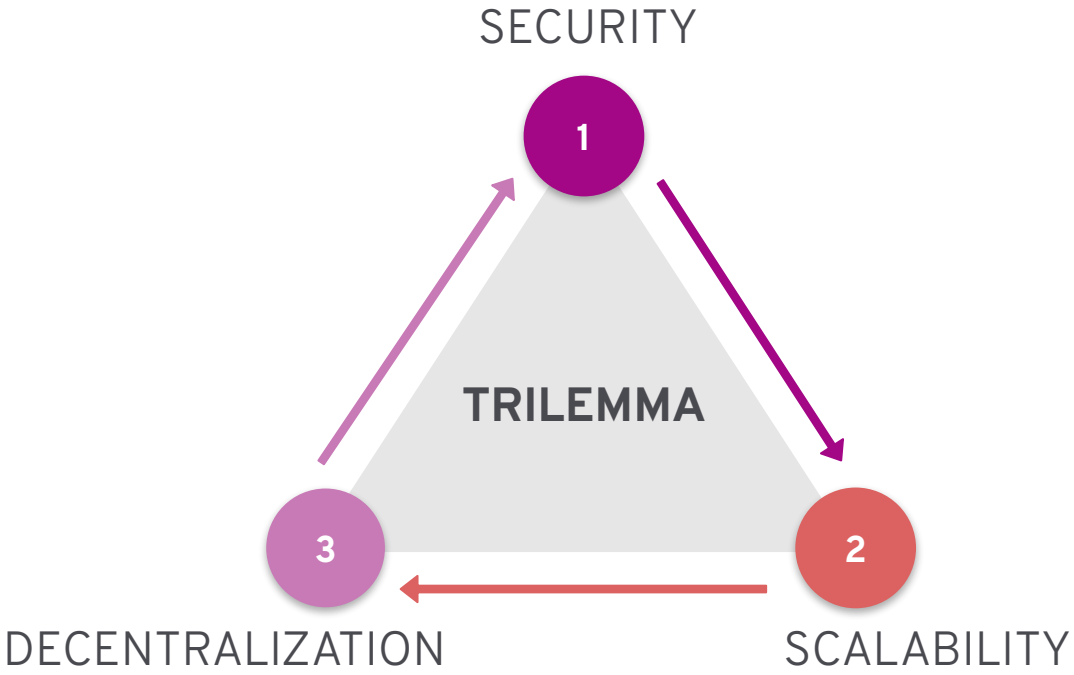
The **higher the skin in the game** the **higher the probability** of being elected as block proposer.

Proof of Stake limits

	CRITICAL ISSUES
BPoS **BONDED PROOF OF STAKE** Validators **bind their stake**, to **show their commitment** in validating and appending a new block. Misbehaviors are punished.	• Participating in the consensus protocol makes users' stakes illiquid • Risk of economic barrier to entry
DPoS **DELEGATED PROOF OF STAKE** Users **delegate the validation** of new blocks to a **fixed committee**, through weighted voting based on their stakes.	• Known delegate nodes, therefore exposed to DDoS attacks • Centralization of governance



Is the *Blockchain Trilemma* unsolvable?



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ALGORAND CONSENSUS

Pure Proof of Stake (PPoS)

Algorand PPoS Consensus

- **Scalable** 6000 TPS, billions of users
- **Fast** < 3.9 s per block
- **Secure** 0 downtime for over 23M blocks
- **Low fees** 0.001 ALGO per txn
- **No Soft Forks** prob. < 10^{-18}
- **Instant Transaction Finality**
- **Carbon neutral**
- **Minimal hardware node requirements**
- **No delegation or binding of the stake**
- **No minimum stake**
- **Secure with respect DDoS**
- **Network Partitioning resilience**

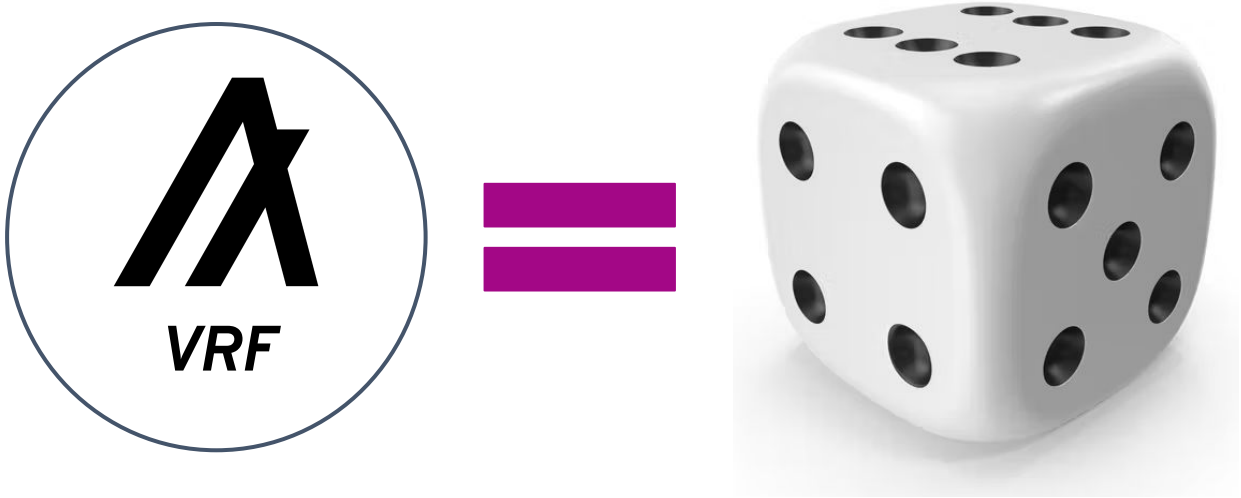
Silvio Micali

Algorand Founder

Professor MIT, Turing Award, Gödel Prize

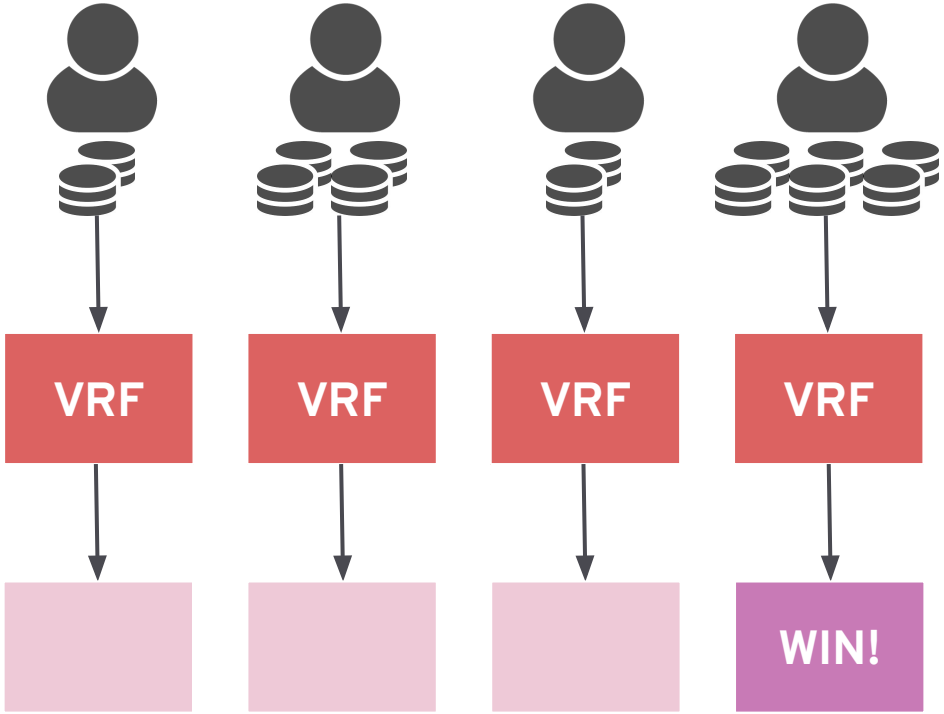
Digital Signatures, Probabilistic Encryption, Zero-Knowledge Proofs, Verifiable Random Functions and other primitives of modern cryptography.

Tamper-proof, unique and verifiable dices



1. Dices are **perfectly balanced** and **equiprobable**, nobody could tamper their result!
2. Keep **observing dice rolls** by no means increases the chance of guessing the next result!
3. Each dice is **uniquely signed** by its owner, nobody can roll someone else dices!
4. Dices are **publicly verifiable**, everybody can read the results of a roll!

Who chose the *next block*?



1. Each **ALGO** could be assimilated to a **tamper-proof dice** participating in a safe and secret **cryptographic dice roll**. More ALGOs more dices to roll.

2. For **each new block**, dice rolls are performed in a **distributed, parallel and secret** and manner, directly on online accounts' hardware (in microseconds).

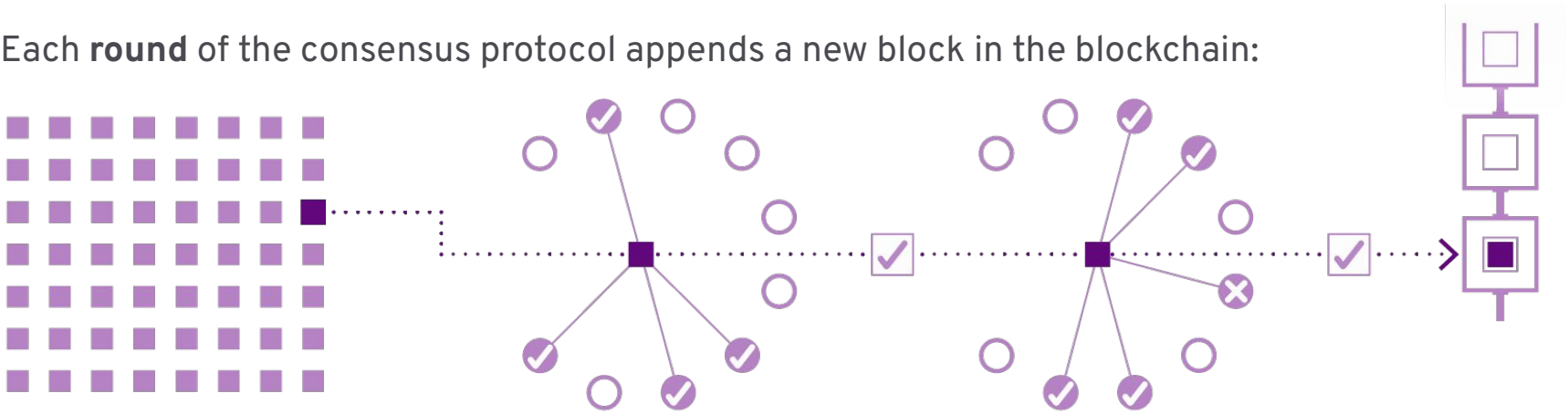
3. The **winner is revealed** in a safe and **verifiable way** only after winning the dice roll, proposing the next block.

A glimpse on “simplified” VRF sortition

1. A **secret key (SK) / public verification key (VK)** pair is associated **with each ALGO in the account**
2. For each new round ***r*** of the **consensus protocol** a **threshold *L(r)*** is defined
3. **Each ALGO** in the account **performs a VRF**, using its own **secret key (SK)**, to generate:
   a. a pseudo-random number: $Y = VRF_{SK}(seed)$
   b. the verifiable associated proof: $\rho_{SK}(seed)$
4. If $Y = VRF_{SK}(seed) < L(r)$, that specific ALGO **“wins the lottery”** and **viraly propagates the proof** of its victory $\rho_{SK}(seed)$ to other **network’s nodes**, through “gossiping” mechanism
5. Others node can use the **public verification key (VK)** to verify, through $\rho_{SK}(seed)$, that the number **Y** was generated by **that specific ALGO, owned by the winner of the lottery**

Pure Proof of Stake, in short

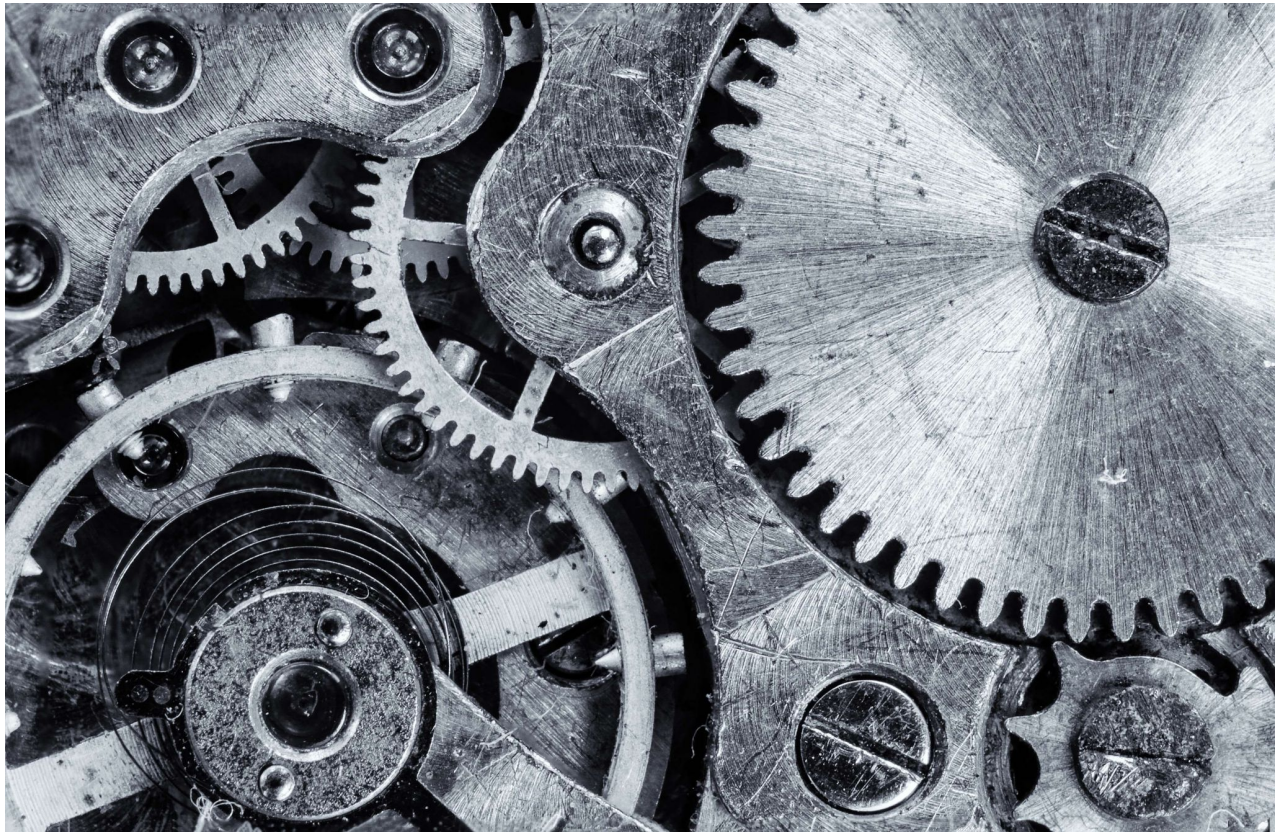
Each **round** of the consensus protocol appends a new block in the blockchain:



An account is elected to **propose** the **next block**	A **committee** is elected to **filter** and **vote** on the **block proposals**	A **new committee** is elected to reach a quorum and **certify** the **block**	The **new block** is **appended** to the **blockchain**

Through the **cryptographic lottery**, an **online account** is elected with probability directly proportional to its stake: **each ALGO corresponds to an attempt** to win the lottery!

Ok, but… how long does it take?



Less than 3.9 seconds!

Pure Proof of Stake security

Algorand's decentralized Byzantine consensus protocol can tolerate an **arbitrary number of malicious users** as long as honest users hold a **super majority of the total stake** in the system.

1. The adversary **does not know which users he should corrupt**.
2. The adversary **realizes which users are selected too late** to benefit from attacking them.
3. Each **new set of users will be privately and individually elected**.
4. During a network partition in Algorand, the adversary is **never able to convince two honest users to accept two different blocks** for the same round.
5. Algorand is able to **recover shortly after network partition** is resolved and guarantees that new blocks will be generated at the same speed as before the partition.

Pure Proof of Stake: the output pre-upgrade!

BLOCKS	> 23M with 0 downtime
BLOCKCHAIN SIZE	~ 1 TB
ADDRESSES	> 27M with ~ 2M monthly active addresses
AVG. BLOCK FINALIZATION	~ 3.8 sec per block
TXNS WEEKLY VOLUME	~ 11M transactions (March 2022)
TPS WEEKLY PEAK	~ 6000 transactions per second

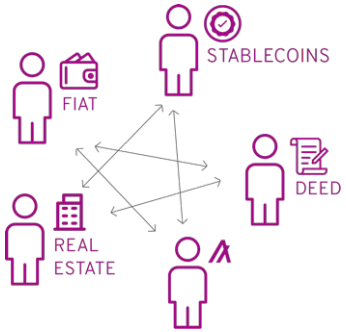
** up to August 2022*

Algorand Layer-1 primitives

Algorand Standard Assets (ASA)

- SECURITIES
- CURRENCIES
- STABLECOINS
- UTILITY TOKENS
- CERTIFICATIONS
- REAL ESTATE

Atomic Transfers (AT)



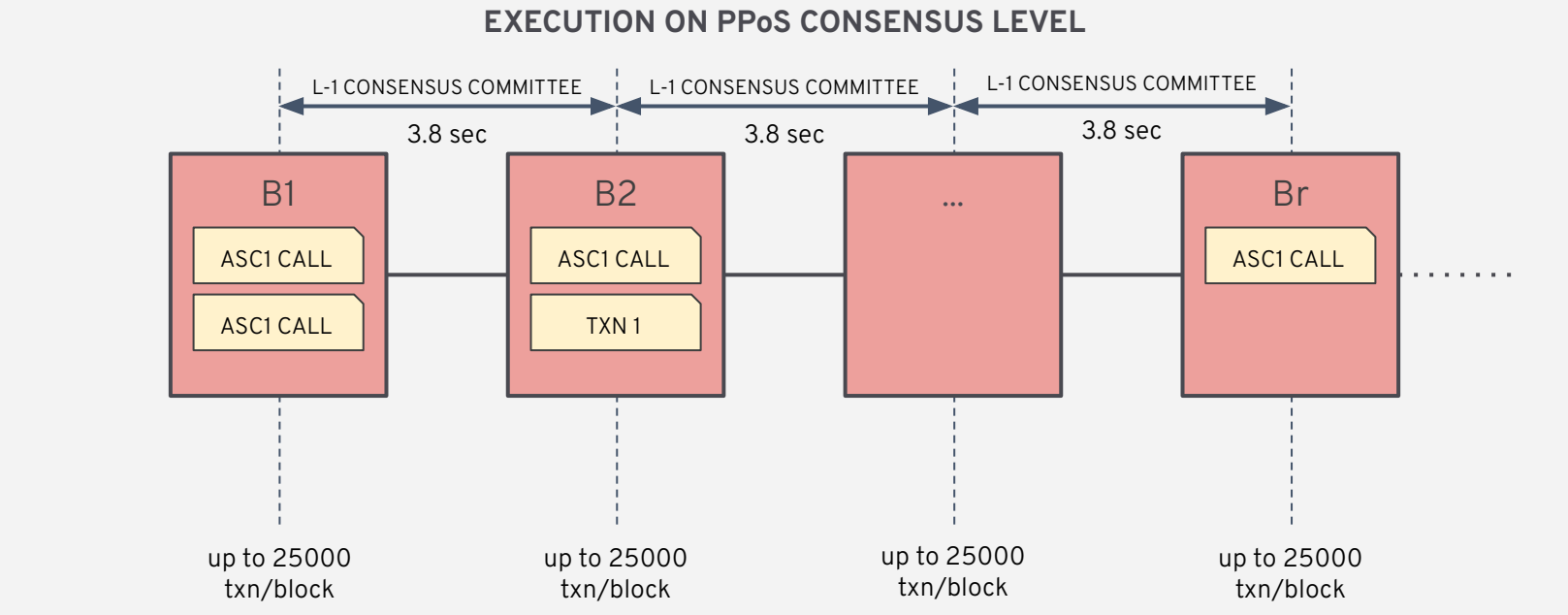
Algorand Virtual Machine (AVM)

- FAST
- SECURE
- LOW COST

Algorand State Proof (ASP)

- TRUSTLESS
- INTEROPERABLE
- POST-QUANTUM SECURE

What does *execution on Layer-1* mean?



AVM execution does not slow down the whole blocks production!

What does *execution on Layer-1* mean?

- Smart Contracts are executed *“at consensus level”*
- Benefit from network's speed, security, and scalability
- Fast trustless execution (~3.8 seconds per block)
- Low cost execution (0.001 ALGO regardless SC’s complexity)
- Instant Finality of Smart Contracts’ effects
- Native interoperability with Layer-1 primitives
- Safe high level languages (PyTeal, Reach, Clarity)
- Low energy consumption

Algorand

ALGORAND SUSTAINABILITY

"Permission-less" is not "Responsibility-less"

Full paper: "Proof of Stake Blockchain Efficiency Framework"

“Permission-less” is not *“Responsibility-less”*

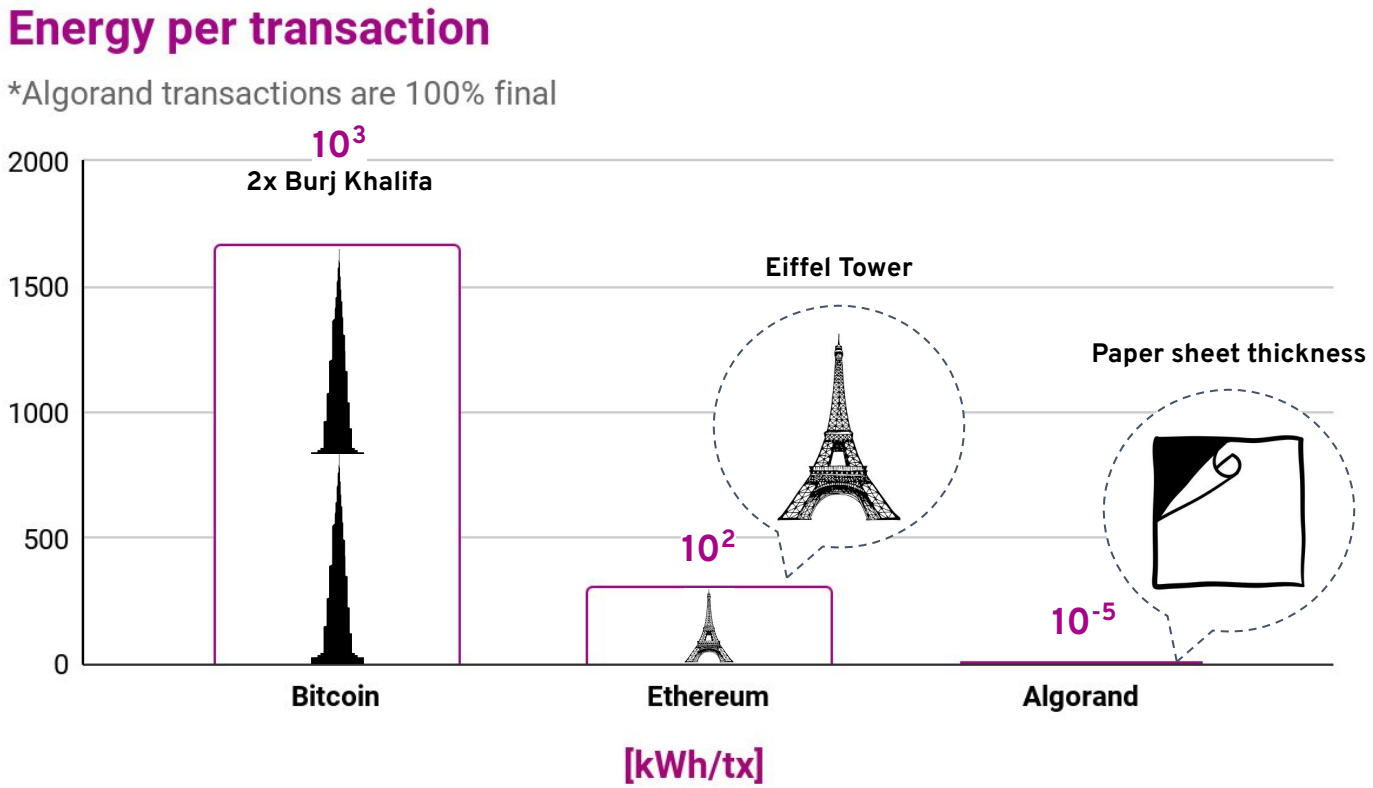
- Algorand is a *permission-less* network 🕸️, so **no centralized authority can know or impose** how node runners should power their nodes 💻.
- As decentralized infrastructure, Algorand is **responsible for its impact** on Planet Earth 🌏, although no centralized authority controls it.
- Algorand **should acts proactively** (not hiding behind the *“permission-less excuse”*) and set blockchains’ sustainability bar high 🌱.

Proof of unsustainable Work

- **Proof of Work** is a planetary **wasteful computational battle**, in which miners **MUST burn energy** to secure the blockchain.
- Showing off personal commitment in the ecosystem through the **consumption of computational and energetic resources** is at the **core of PoW** consensus mechanism.

Our planet Earth can no longer afford unsustainable technologies.

A matter of orders of magnitude (PoW vs PPoS)



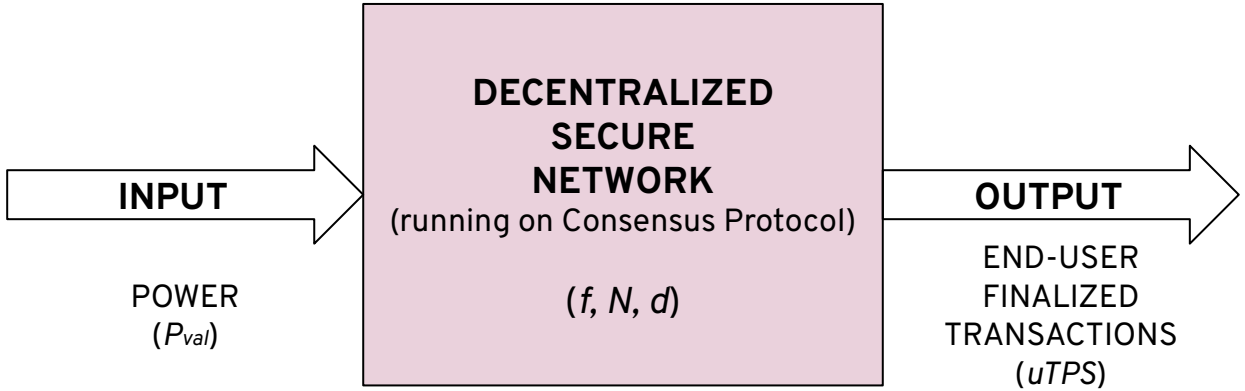
Full paper: "Proof of Stake Blockchain Efficiency Framework"

You like to win easy!

What about others Proof of Stake?

When the going gets tough, the tough get going (PoS vs PPoS)

Blockchain **sustainability** must consider **scalable end-user transactions** (*uTPS*) **finality** (*f*), **nodes hardware** (*N*), and **secure network decentralization** (*d*).



Being sustainable while centralized, insecure or not scalable is worthless!

Reframing the question

Is Algorand blockchain efficient
at consuming energy
to finalize end user useful transactions
in a secure, scalable and decentralized way?

Algorand solves *blockchain trilemma* sustainably

- **Algorand transactions are 100% available to end-users**

  (other PoS blockchains consume their own transactions for consensus)
- **Algorand transactions are 100% instantly final**

  (other PoS must consume the energy of several blocks to ensure transactions' finality)
- **Algorand transactions are secured by a very decentralized network**

  (some PoS blockchain have only few validators)
- **Algorand security is a feature of its own efficiency**

  (Algorand never experienced downtime since the genesis block)

Full paper: "Proof of Stake Blockchain Efficiency Framework"

Algorand

ALGORAND NETWORKS

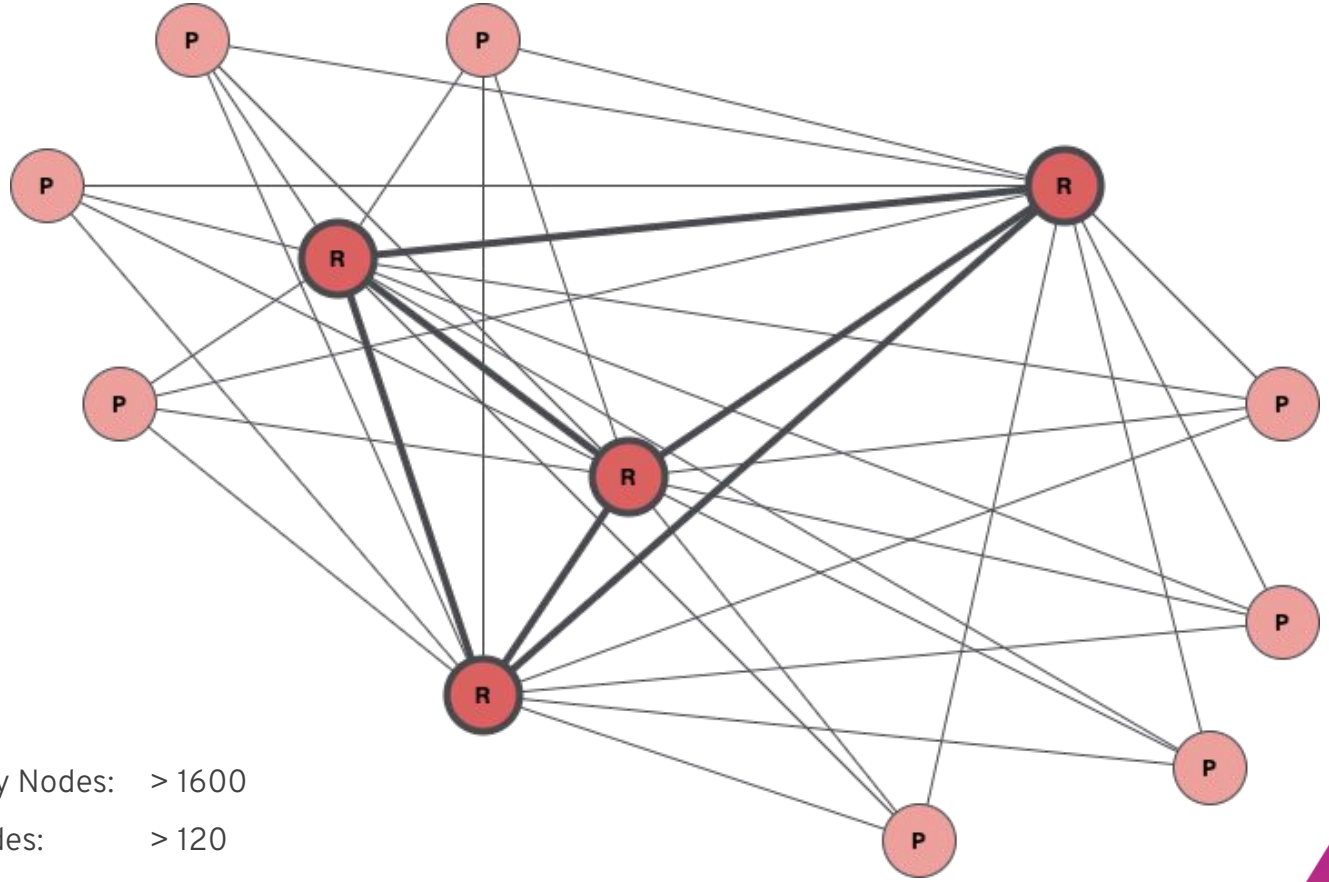
Nodes, Indexer and APIs

Algorand Node configurations

1. **Non-Relay Nodes**
   - Participate in the PPoS consensus (if hosting participation keys)
   - Connect only to Relay Nodes
   - Light Configuration: store just the lastest 1000 blocks (Fast Catch-Up)
   - Archival Configuration: store all the chain since the genesis block

2. **Relay Nodes**
   - Communication routing to a set of connected Non-Relay Nodes
   - Connect both with Non-Relay Nodes and Relay Nodes
   - Route blocks to all connected Non-Relay Nodes
   - Highly efficient communication paths, reducing communication hops

Example of Algorand Network topology



Node Metrics

- Non-Relay Nodes: > 1600
- Relay Nodes: > 120

Access to Algorand Network

The **Algorand blockchain is a distributed system of nodes** each maintaining their **local state** based on validating the history of blocks and the transactions therein. **Blockchain state integrity** is maintained by the **consensus protocol** which is implemented within the **Algod daemon** (often referred to as the node software).

An application **connects to the Algorand blockchain** through an **Algod client**, requiring:

- **a valid Algod REST API endpoint IP address**
- **an Algod token from an Algorand node connected to the network you plan to interact with**

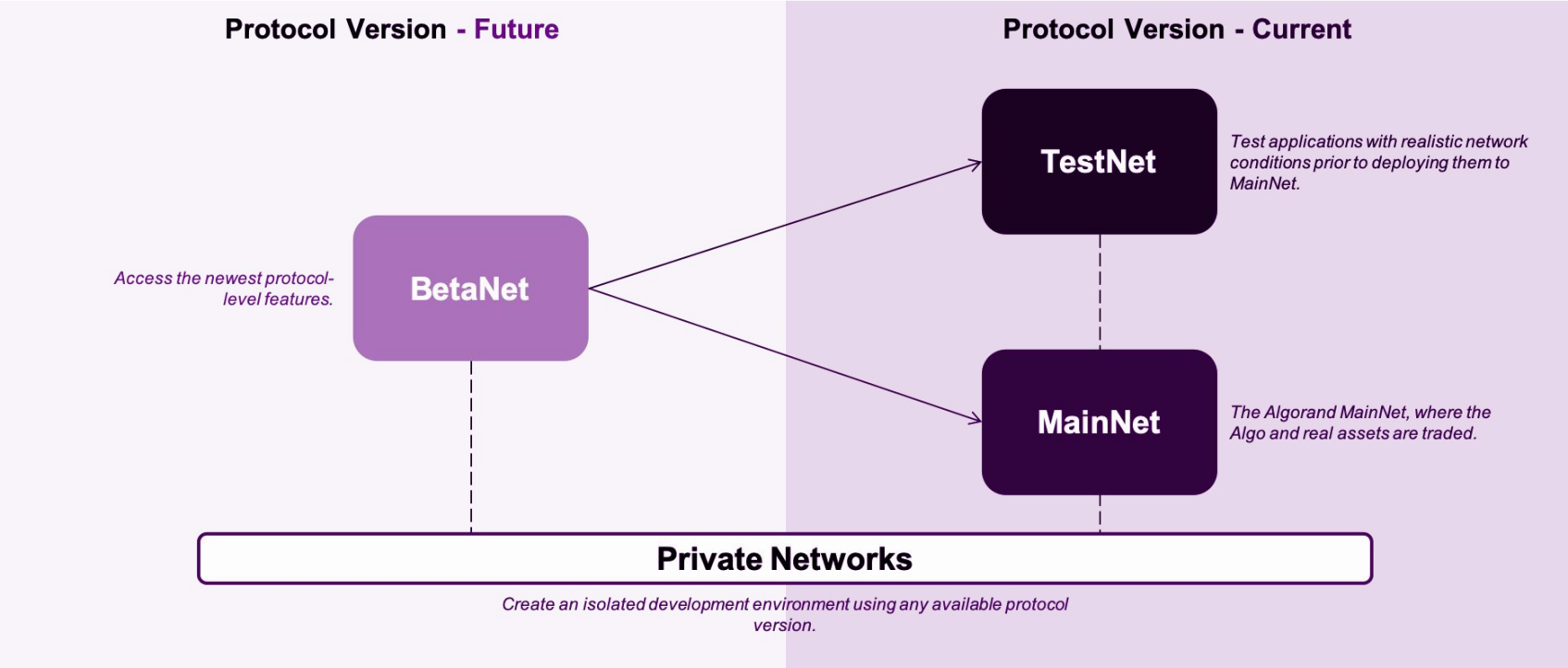
These **two pieces of information** can be provided by **your local node** or by a **third party node aaS**.

How to get an Algod Client?

There are **three ways** to get a REST API Algod **endpoint IP address / access token**, each with their respective pros and cons depending on development goals.

	Use a third-party service	Use Docker Sandbox	Run your own node
Time	**Seconds** - Just signup	**Minutes** - Same as running a node with no catchup	**Days** - need to wait for node to catchup
Trust	1 party	1 party	Yourself
Cost	Usually free for development; pay based on rate limits in production	Variable (with free option) - see node types	Variable (with free option) - see node types
Private Networks	❌	✅	✅
`goal`, `algokey`, `kmd`	❌	✅	✅
Platform	Varies	MacOS; Linux	MacOS; Linux
Production Ready	✅	❌	✅

Algorand Networks



Algorand Node - Writing on the blockchain

1. Install (Linux, MacOS, Windows)
2. Choose a **network** (MainNet, TestNet, BetaNet, PrivateNet)
3. Start & Sync with the network, Fast Catchup

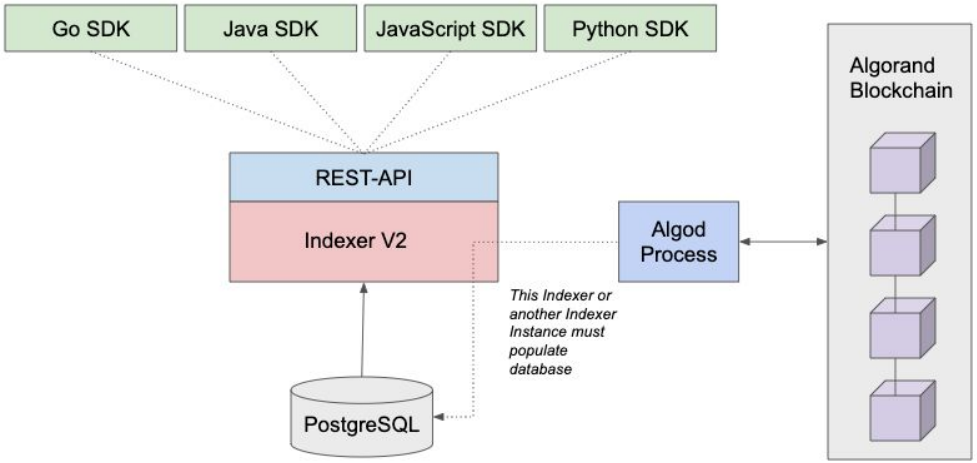
genesis.json (mainnet)


```
{
  "alloc": [
    {
      "addr": "7377777777777777...77777777UFEJ2CI",
      "comment": "RewardsPool",
      "state": {
        "algo": 10000000000000,
        "onl": 2
      }
    },
    {
      "addr": "Y76M3MSY6DKBRHBL7C3...F2QWNPL226CA",
      "comment": "FeeSink",
      "state": {
        "algo": 1000000,
        "onl": 2
      }
    },
    ...
  ],
  "fees": "Y76M3MSY6DKBRHBL7C3NNDX...F2QWNPL226CA",
  "id": "v1.0",
  "network": "mainnet",
  "proto":
"https://github.com/algorandfoundation/specs/tree/5615ad
c36bad610c7f165fa2967f4ecfa75125f0",
  "rwd": "737777777777777777777...77777777UFEJ2CI",
  "timestamp": 1560211200
}
```


Interacting with Algorand Nodes

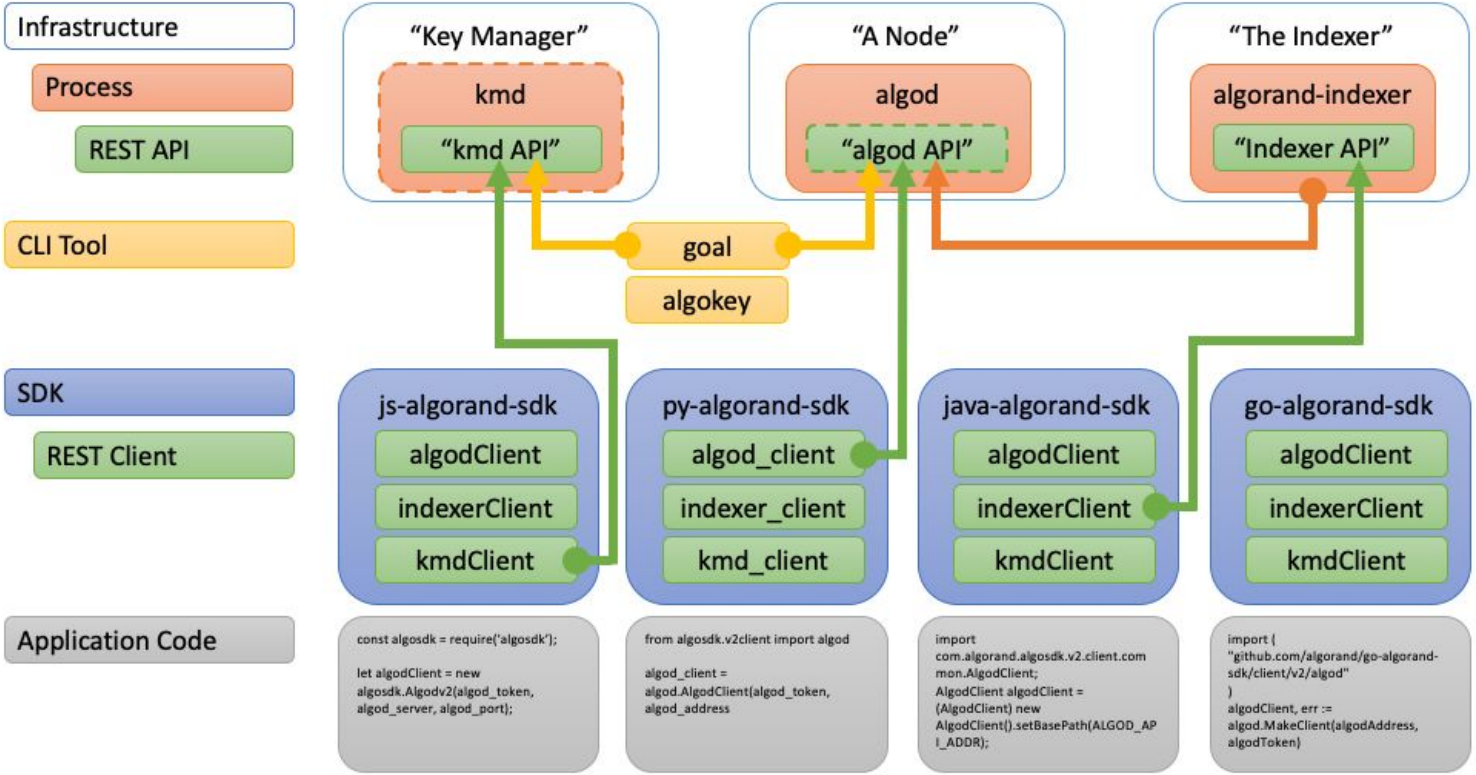
1. CLI utilities: **goal**, **kmd** and **algokey**
2. REST API interface: **algod V2**, **kmd**, **indexer**
3. Algorand SDKs: **JavaScript**, **Python**, **Java** o **Go**

Algorand Indexer - Reading from the blockchain



The **Indexer** provides a **REST API interface** of API calls to **query the Algorand blockchain**. The Indexer REST APIs retrieves blockchain data from a **PostgreSQL database**, populated using the Indexer instance connected to an **Archival Algorand node that reads blocks' data**. As with the Nodes, the Indexer can be used as a **third-party service**.

How to interact with Algorand Node and Indexer

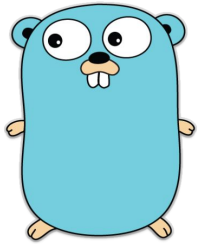


Algorand SDKs

Java

JavaScript

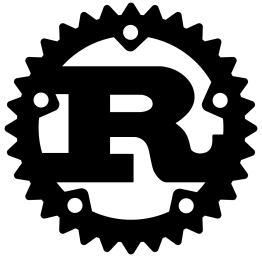
Python



Go

Algorand Community SDKs

C#



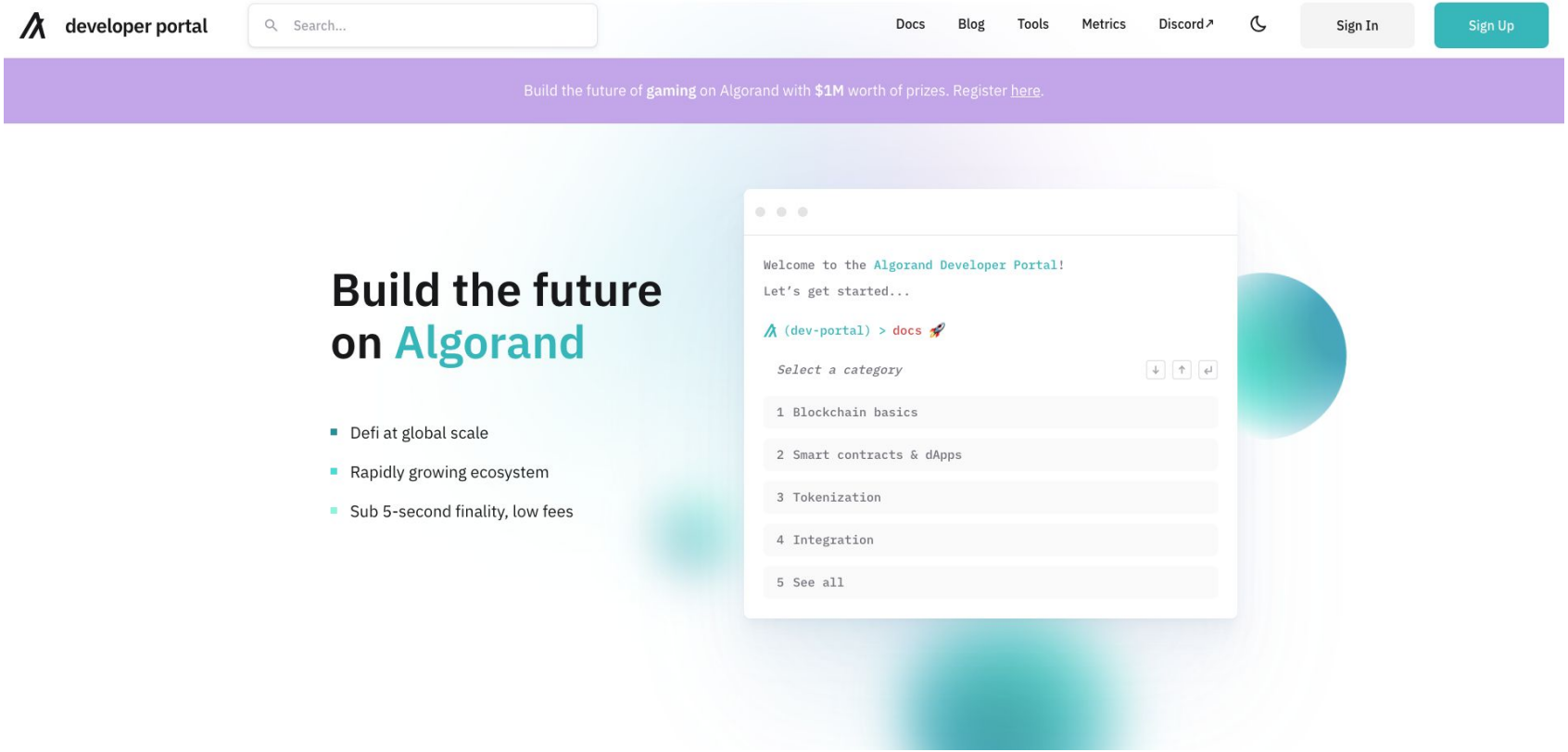
Rust

Dart

PHP

Swift

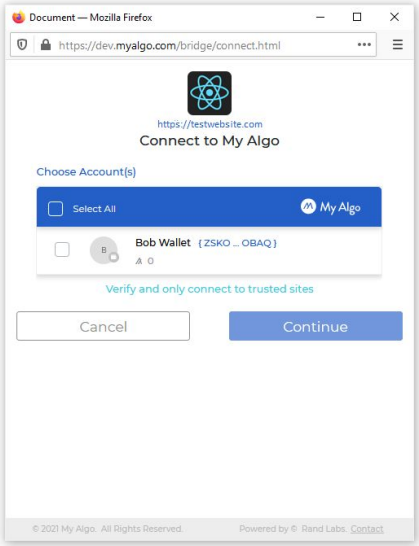
Algorand Developer Portal



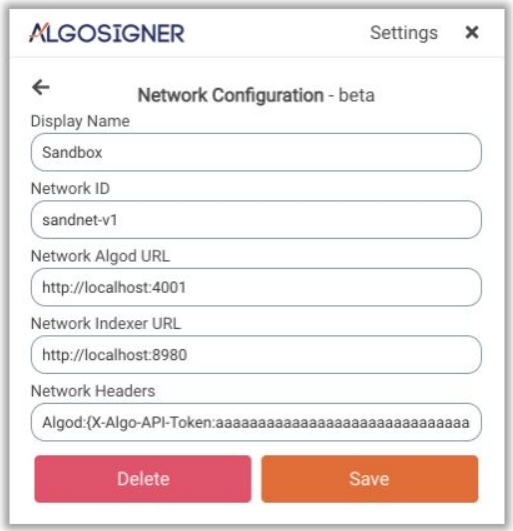
Awesome Algorand

Algorand Wallets

[Pera Wallet](#) + [Wallet Connect](#)



[MyAlgo Wallet](#)



[AlgoSigner](#)

Algorand Explorers

Dappflow

Algo Explorer

GOALSEEKER

Algorand

ALGORAND INTEROPERABILITY

State Proofs and Post-Quantum Security

Credits to Noah Grossman for contents

Trustless interoperability

Algorand approach to interoperability:

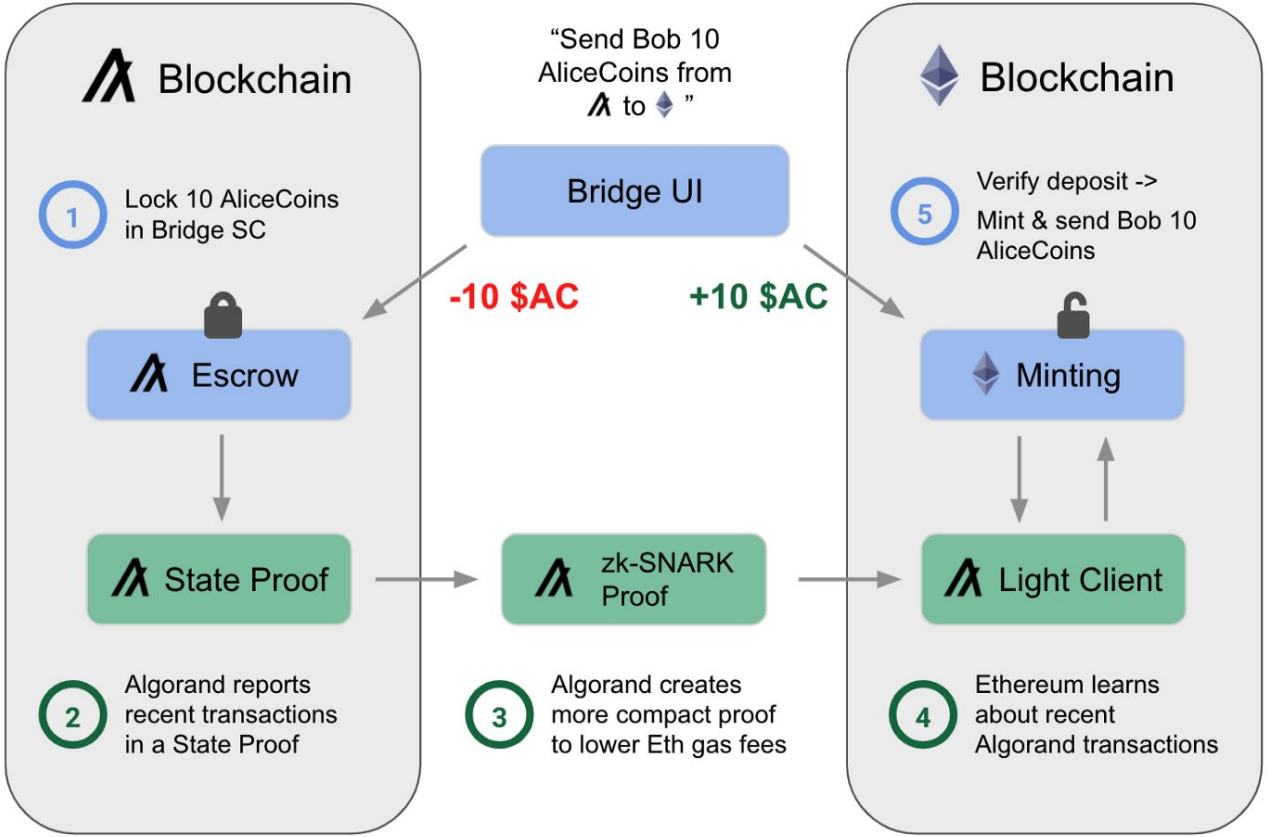
cross-chain transactions should rely just on

1. Trust in **departing** consensus protocol
2. Trust in **arrival** consensus protocol

without centralized bridges or validator networks, to handle the assets.

Algorand State Proofs remove trusted centralized operators becoming the **first trustless post-quantum secure L1 interoperability standard**.

Post-Quantum Secure Algorand State Proofs



Post-Quantum secure and **immutable proofs**, attesting blockchain state, generated by Pure Proof of Stake consensus protocol.

Algorand

ALGORAND TRANSACTIONS

Core element of blocks

Changing blockchain state

Transactions are the **core element of blocks**, which define the **evolution** of distributed ledger **state**. There are **six transaction types** in the Algorand Protocol:

1. Payment
2. Key Registration
3. Asset Configuration
4. Asset Freeze
5. Asset Transfer
6. Application Call

These six transaction types can be specified in particular ways that result in more granular perceived transaction types.

Signature, fees and round validity

In order to be approved, Algorand's transactions must comply with:

1. **Signatures**: transactions must be correctly signed by its sender, either a **Single Signature**, a **Multi Signature** or a **Smart Signature / Smart Contract**
2. **Fees**: in Algorand transactions fees are a way to protect the network from DDoS. In Algorand Pure PoS fees are not meant to pay "validation" (as it happens in PoW blockchains). In Algorand you can **delegate fees**.
3. **Round validity**: to handle transactions' idempotency, letting Non-Archival nodes participate in Algorand Consensus, transactions have an intrinsic validity of 1000 blocks (at most).

Browse through a transaction

Transactions are characterized by two kind of **fields** (codec):

- **common** (header)
- **specific** (type)

Field	Required	Type	codec	Description
Fee	*required*	uint64	`"fee"`	Paid by the sender to the FeeSink to prevent denial-of-service. The minimum fee on Algorand is currently 1000 microAlgos.
FirstValid	*required*	uint64	`"fv"`	The first round for when the transaction is valid. If the transaction is sent prior to this round it will be rejected by the network.
GenesisHash	*required*	[32]byte	`"gh"`	The hash of the genesis block of the network for which the transaction is valid. See the genesis hash for MainNet, TestNet, and BetaNet.
LastValid	*required*	uint64	`"lv"`	The ending round for which the transaction is valid. After this round, the transaction will be rejected by the network.
				the account that pays the fee and amount.
				ype of transaction. This value is automatically generated e developer tools.

Field	Required	Type	codec	Description
Receiver	*required*	Address	`"rcv"`	The address of the account that receives the amount.
Amount	*required*	uint64	`"amt"`	The total amount to be sent in microAlgos.
CloseRemainderTo	*optional*	Address	`"close"`	When set, it indicates that the transaction is requesting that the Sender account should be closed, and all remaining funds, after the fee and amount are paid, be transferred to this address.

Payment Transaction example

Here is a transaction that sends 5 ALGO from one account to another on MainNet.


```
{
  "txn": {
    "amt": 5000000,
    "fee": 1000,
    "fv": 6000000,
    "gen": "mainnet-v1.0",
    "gh": "wGHE2Pwdvd7S12BL5FaOP20EGYesN73ktiC1qzkkit8=",
    "lv": 6001000,
    "note": "SGVsbG8gV29ybGQ=",
    "rcv": "GD64YIY3TWGDMCNPP553DZPPR6LDUSFQOIJVFDPPXWEG3FVOJCCDBBHU5A",
    "snd": "EW64GC6F24M7NDSC5R3ES4YUVE3ZXXNMARJHDCCCLIHZU6TBEOC7XRSBG4",
    "type": "pay"
  }
}
```

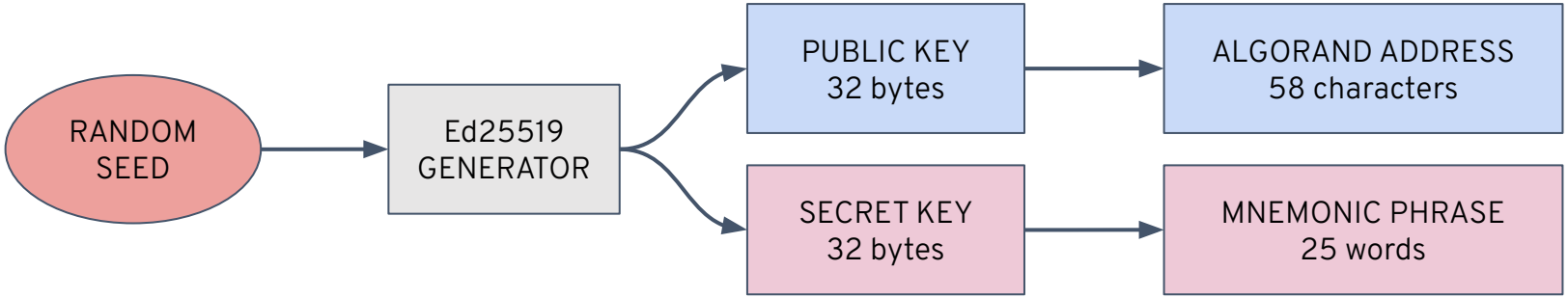
Algorand

ALGORAND ACCOUNTS

Transactions' Authorization

Signatures

Algorand uses **Ed25519** high-speed, high-security elliptic-curve signatures.

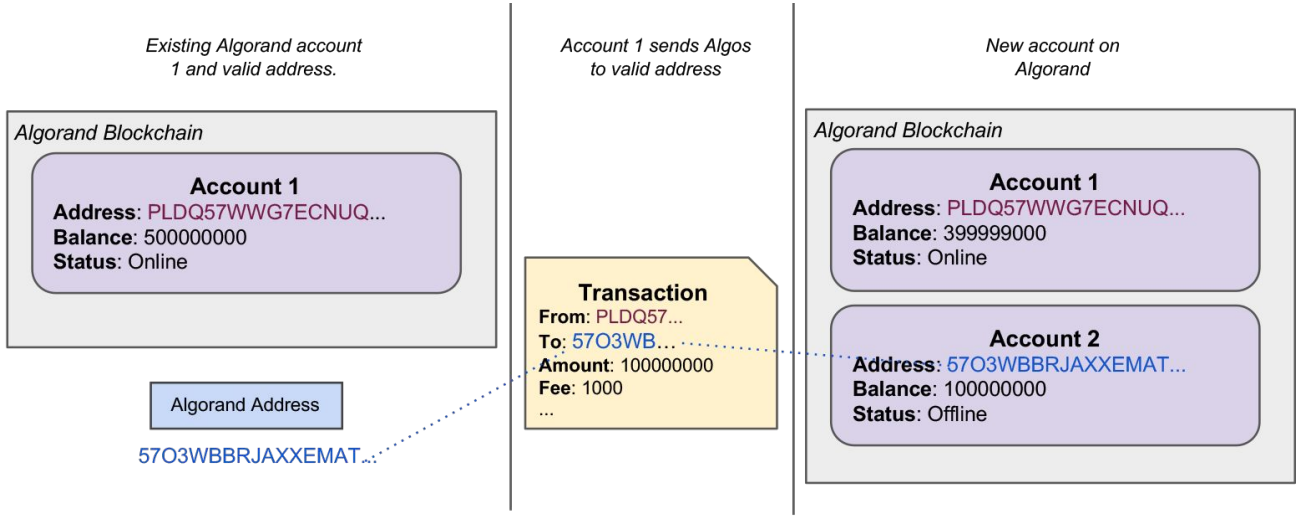


- **ADDRESS:** the **public key** is transformed into an **Algorand Address**, by adding a 4-byte checksum to the end of the public key and then **encoding it in base32**.

- **MNEMONIC:** the 25-word **mnemonic** is generated by converting the **private key bytes** into **11-bit integers** and then **mapping** those integers to the bip-0039 English word list.

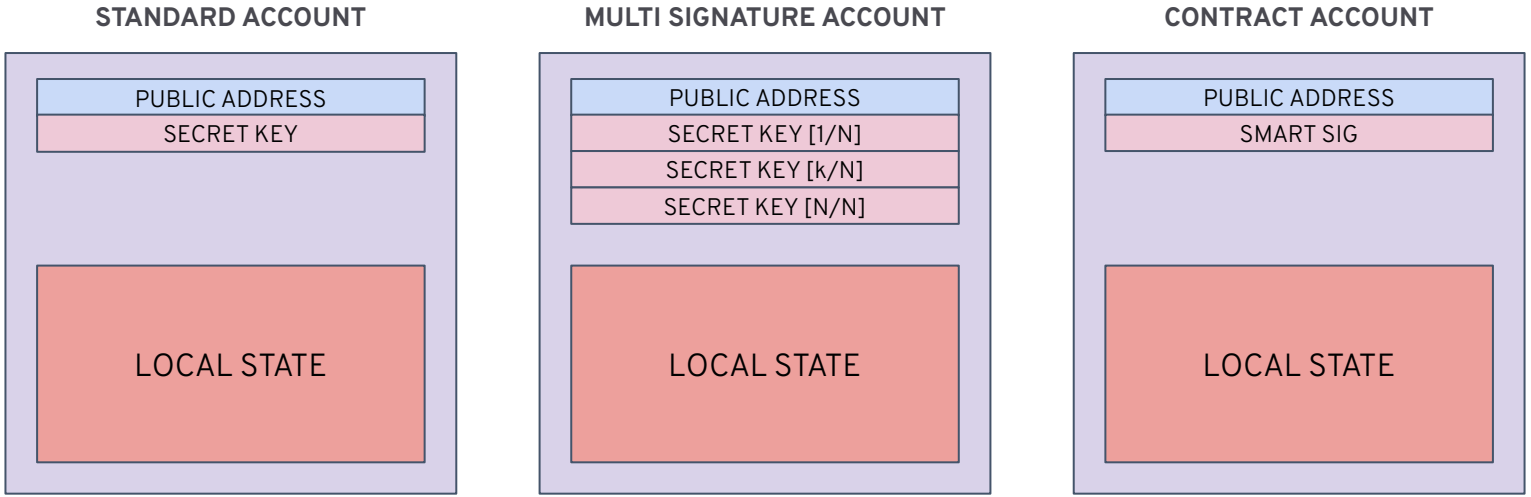
Algorand Accounts

Accounts are **entities on the Algorand blockchain** associated with specific **on-chain local sate**. An **Algorand Address** is the **unique identifier** for an **Algorand Account**.



All the potential keys pairs "already exists" mathematically, we just keep discovering them.

Transactions Authorization and Rekey-To



Algorand Rekeying: powerful **Layer-1 protocol feature** which enables an Algorand account to **maintain a static public address** while dynamically **rotating the authoritative private spending key(s)**. Any Account can Rekey either to a Standard Account, MultiSig Account or LogicSig Contract Account.

Account State Minimum Balance

Name	Current value	Developer doc	Consensus parameter name in (.go)	Note
Default	0.1 Algos	reference	MinBalance	
Opt-in ASA	+ 0.1 Algos	reference	MinBalance	
Created ASA	+ 0.1 Algos	reference	MinBalance	creator of ASA does not need to opt in

Name	Current value	Developer doc	Consensus parameter name in (.go)	Note
Per page application creation fee	0.1 Algos	reference	AppFlatParamsMinBalance	
Flat for application opt-in	0.1 Algos	reference	AppFlatOptInMinBalance	
Per state entry	0.025 Algos	reference	SchemaMinBalancePerEntry	
Addition per integer entry	0.0035 Algos	reference	SchemaUintMinBalance	
Addition per byte slice entry	0.025 Algos	reference	SchemaBytesMinBalance	

Algorand

ASA

Algorand Standard Assets on Layer-1

ARC-3

Algorand Standard Asset Parameters Conventions for Fungible and Non-Fungible Tokens

- Status: *Final*
- Defines **Fungible Tokens**, **Pure NFT**, **Fractional NFTs**
- Very comprehensive definition of NFT's metadata (e.g. images, videos, audio tracks, etc.) and traits as JSON structure
- Binding between the ASA and the JSON structure **uploaded on external storage** (e.g. IPFS, Arweave, etc.)
- Circulating tokens: ~ 42,000
- Generators: https://arc3.xyz/, https://app.algodesk.io/
- Example: https://www.nftexplorer.app/asset/429087615

ARC-69

Community Algorand Standard Asset Parameters Conventions for Digital Media Tokens

- Status: *Living*
- Adopted both in art and games (https://algoseas.io/)
- Simple and succinct definition of NFT's metadata and traits as JSON structure. Allows tratits configuration after minting
- Binding between the ASA and the JSON structure **uploaded directly on-chain** as *transaction notefield*
- Circulating tokens: ~ 565,000 (most popular standard)
- Generators: https://app.algodesk.io/
- Example: https://www.nftexplorer.app/asset/420625533

ARC-19

Templating of NFT ASA URLs for mutability

- Status: *Final*
- Has been adopted as building block of **non-fungible-domain** standard proposed by NFDomains
- Makes use of ASA Reserve Address to **update the NFT metadata binding** over time.
- Circulating tokens: ~ 26,000
- Generators: https://app.nf.domains/
- Example: https://app.nf.domains/name/john.algo

ARC-20 / ARC-18

Smart ASA / Royalty Enforcement Specification

- Status: ARC-18 (*Draft*), ARC-20 (*Draft*)
- Binds a native ASA with a Smart Contract creating a *"Smart ASA"*, useful whenever a **decentralized transferability policy** must be enforced on-chain (e.g. *royalties*, *vesting*, *limited amount per day*, etc.)
- Allows ASA programmable full reconfigurability on the AVM (e.g. enforcing a rule to upgrade a trait of a NFT character in game, etc.)
- ARC-20 Reference Implementation
- ARC-18 Reference Implementation (using *Beaker*)

Algorand

Algorand Virtual Machine

Programming on Algorand

Cosimo Bassi
Solutions Architect at Algorand

cosimo.bassi@algorand.com



Algorand

What's a *Smart Contract*?

Smart Contracts are **deterministic** programs through which complex **decentralized** trustless **applications** can be executed on the **AVM**.

What's the *AVM*?

The **Algorand Virtual Machine** is a **Turing-complete** secure **execution environment** that runs on Algorand **consensus layer**.

What the AVM *actually* does?

Algorand Virtual Machine purpose: **approving** or **rejecting** transactions' effects **on the blockchain** according to Smart Contracts' logic.

AVM **approves** transactions' effects if and only if:

1. There is a single non-zero value on top of AVM's stack;

AVM **rejects** transactions' effects if and only if:

1. There is a single zero value on top of AVM's stack;
2. There are multiple values on the AVM's stack;
3. There is no value on the AVM's stack;

How the AVM *works*?

Suppose we want the AVM to **check** the following assertion:

$$1 + 2 = 3$$

How the AVM *works*?

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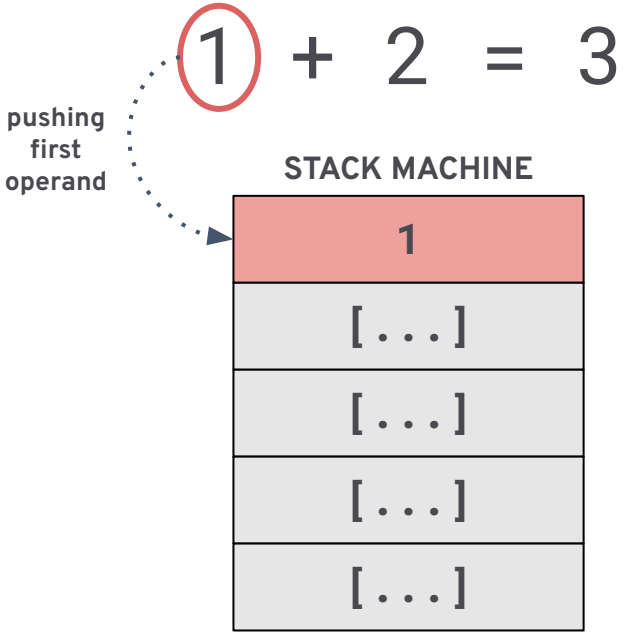

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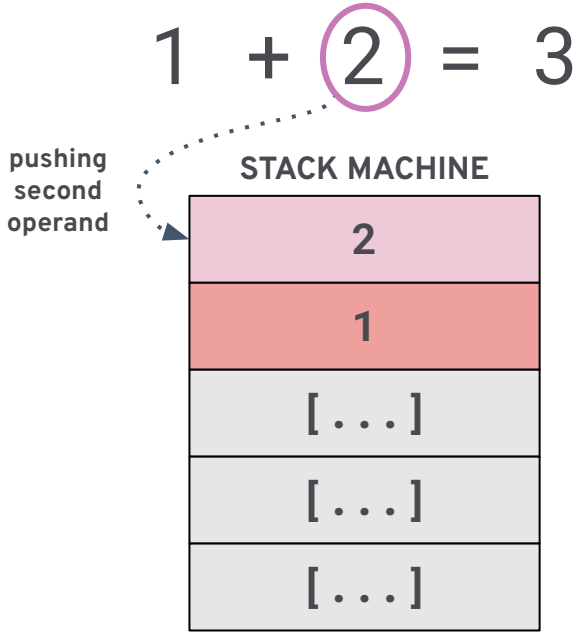

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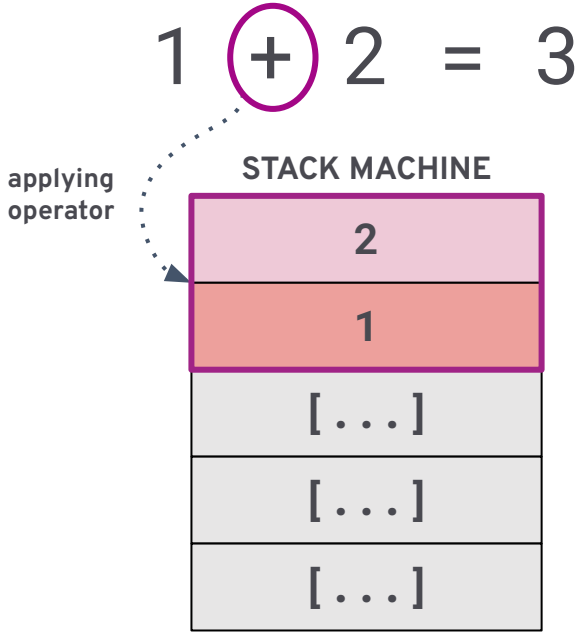

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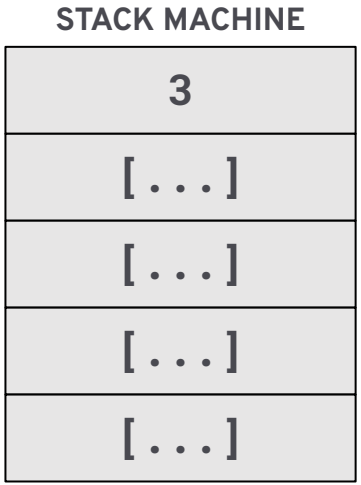

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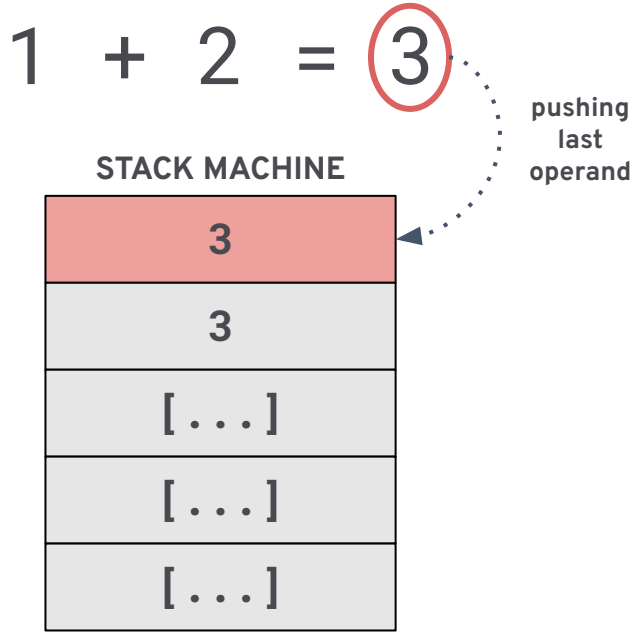

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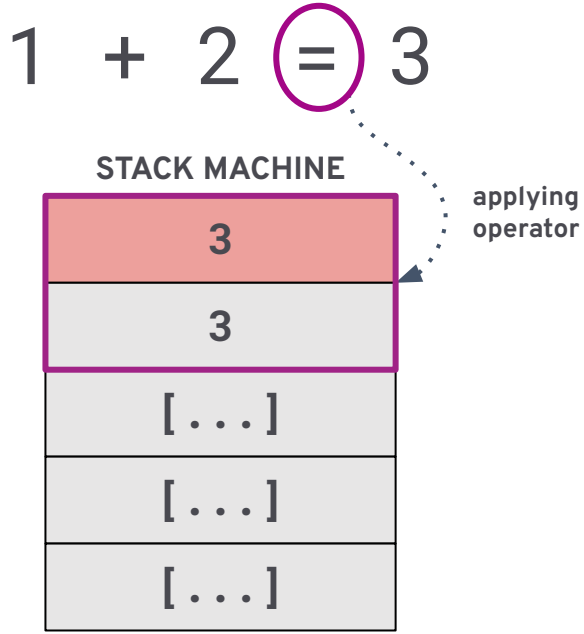

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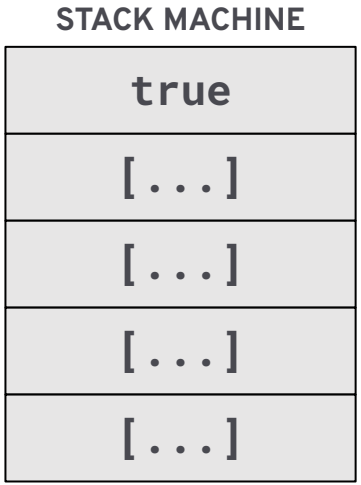


AVM architecture

TRANSACTION

1. Sender
2. Receiver
3. Fee
4. FirstValid
5. LastValid
6. Amount
7. Lease
8. Note
9. TypeEnum
10. …

TRANSACTION ARGS

[0]:	Bytes
[i]:	Bytes
[255]:	Bytes

Stateless properties

APP ARG ARRAY

[0]:	UInt64/ Bytes
[i]:	UInt64/ Bytes
[15]:	UInt64/ Bytes

ACCOUNT ARRAY

[0]:	Bytes
[i]:	Bytes
[3]:	Bytes

ASSET ARRAY

[0]:	UInt64
[i]:	UInt64
[7]:	UInt64

APP IDs ARRAY

[0]:	UInt64
[i]:	UInt64
[7]:	UInt64

APP GLOBAL K/V PAIRS

[0]:	UInt64 / Bytes
[i]:	UInt64 / Bytes
[63]:	UInt64 / Bytes

APP LOCAL K/V PAIRS

[0]:	UInt64 / Bytes
[i]:	UInt64 / Bytes
[15]:	UInt64 / Bytes

Max Key + Value size: 128 bytes

ACCOUNT STATE VARS

ALGO / ASA Balance
...

BLOCK GLOBAL VARS

Block Number
Block Timestamp
...

Stateful properties

PROGRAM

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
&&
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
txn Amount
int 42
==
txn Amount
int 77
==
||
&&
```

Processing

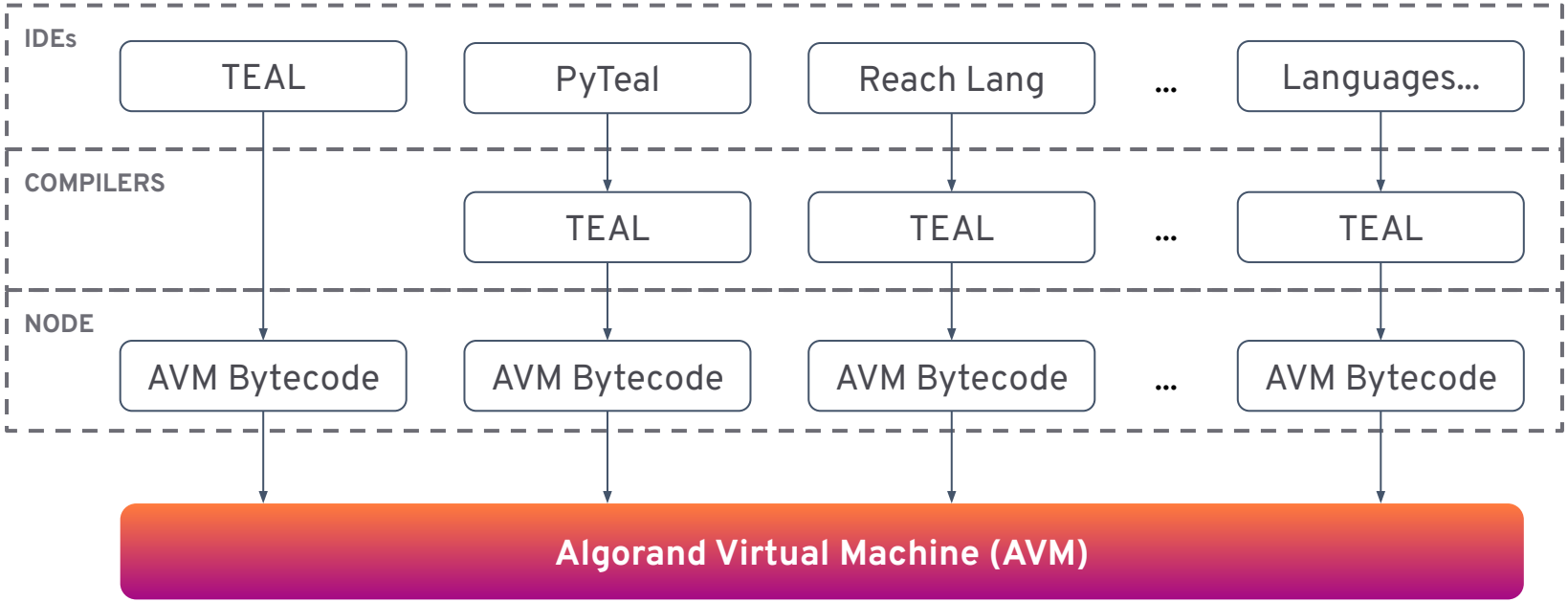
STACK MACHINE

[0]:	UInt64 / Bytes
[i]:	UInt64 / Bytes
[999]:	UInt64 / Bytes

SCRATCH SPACE

[0]:	UInt64 / Bytes
[i]:	UInt64 / Bytes
[255]:	UInt64 / Bytes

How to program the AVM?

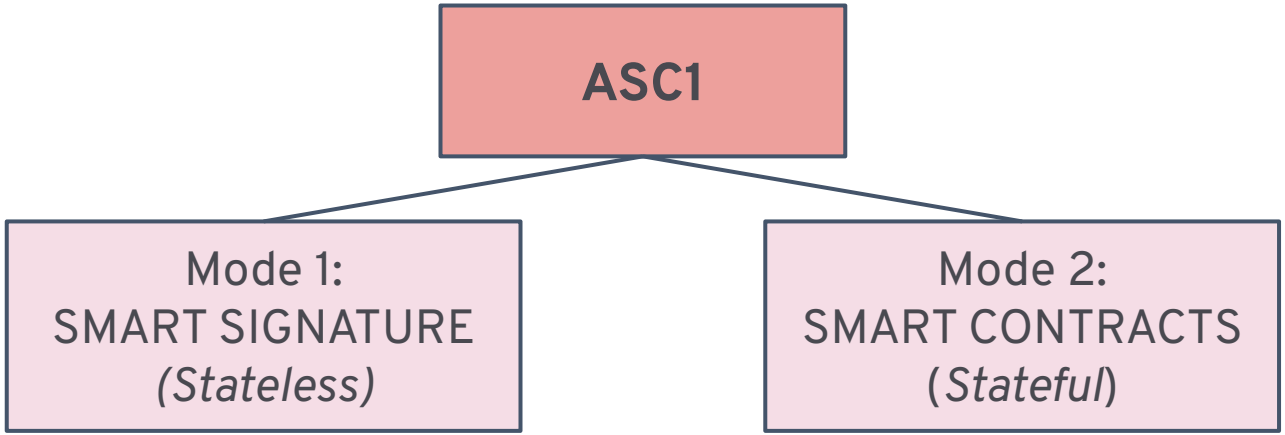


Algorand

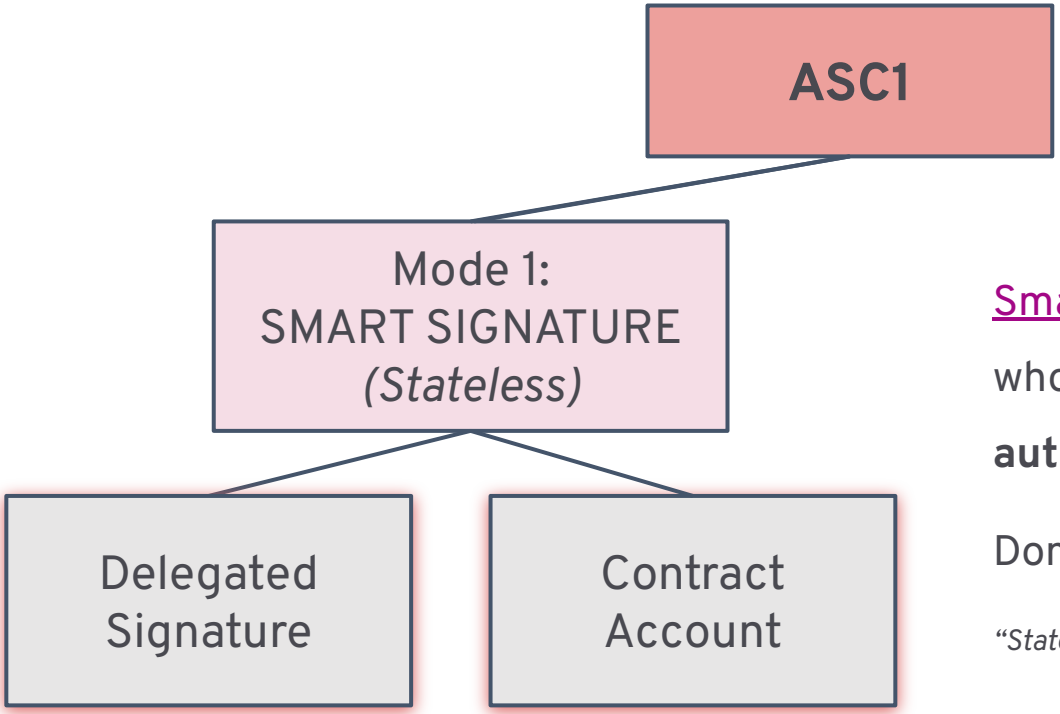
ASC1

Algorand Smart Contracts on Layer-1

AVM Modes


ASC1
Mode 1:
SMART SIGNATURE
(Stateless)
Mode 2:
SMART CONTRACTS
(Stateful)

Stateless ASC1

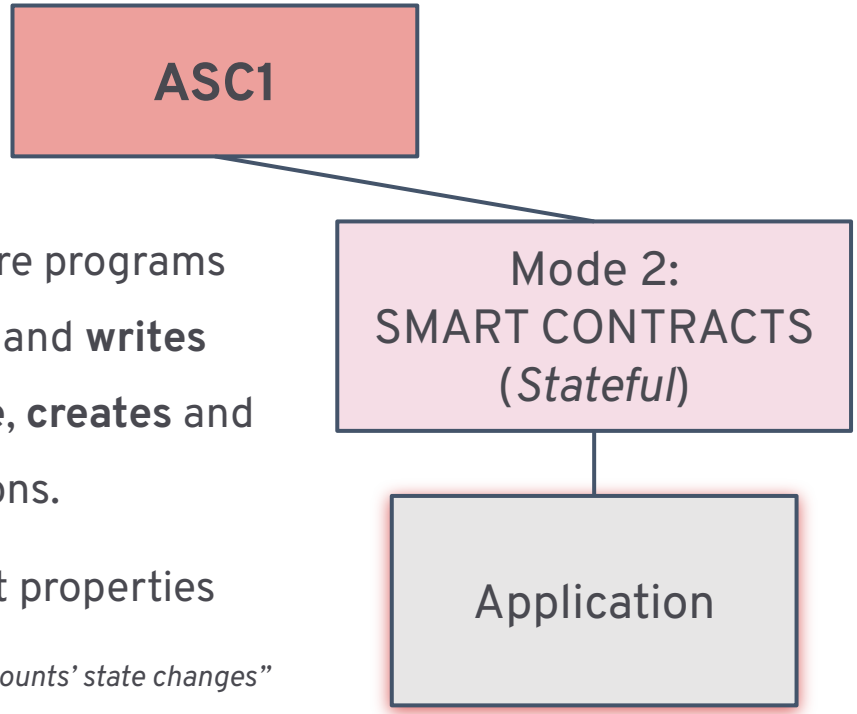


Smart Signatures are programs whose logic **governs transactions' authorization.**

Domain: transient properties

"Stateless ASC1 deal with assets' spending approvals"

Stateful ASC1



Smart Contracts are programs whose logic **reads** and **writes blockchain's state**, **creates** and **submits** transactions.

Domain: persistent properties

"Stateful ASC1 deal with accounts' state changes"

Algorand

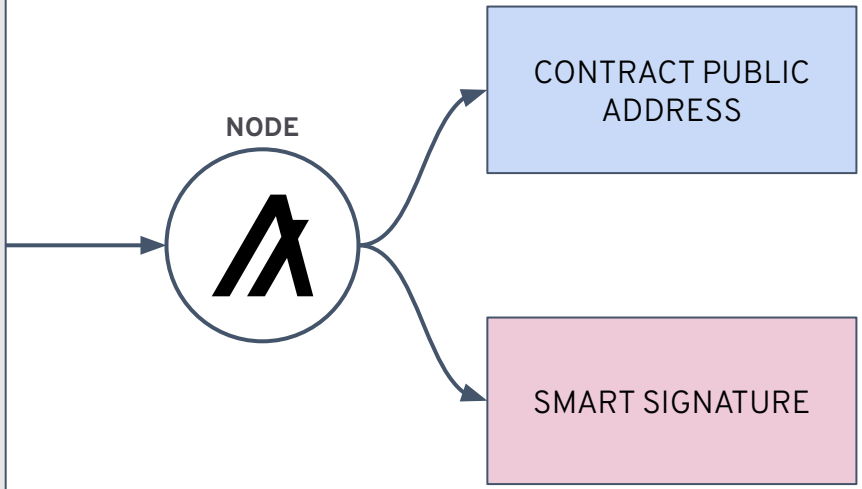
SMART SIGNATURES

Authorizing transactions through TEAL logic

Creating Smart Signature

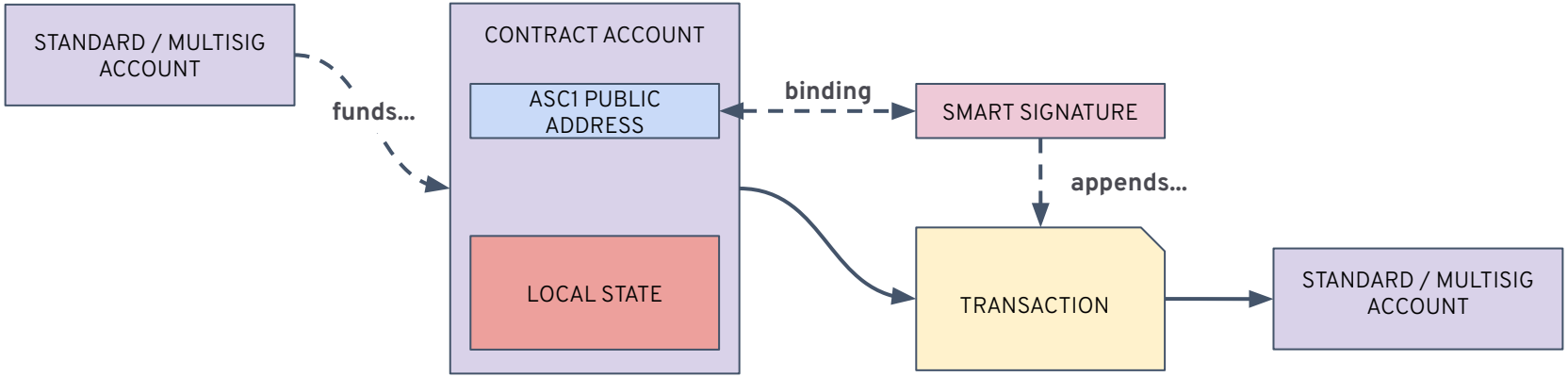
PROGRAM

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
&&
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
txn Amount
int 42
==
txn Amount
int 77
==
||
&&
```

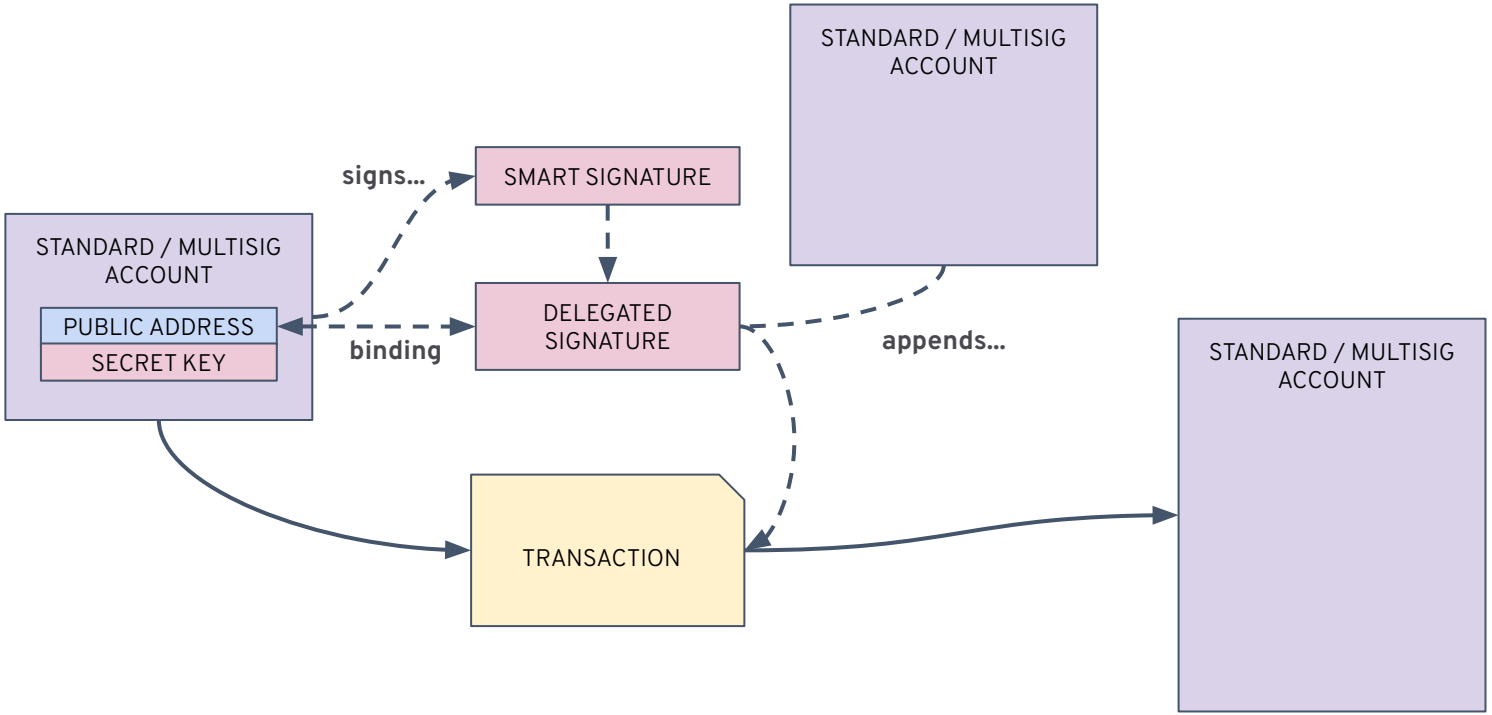


Compiled TEAL Max Size: 1000 bytes
OpCode Max Budget: 20.000

Contract Account



Delegated Signature

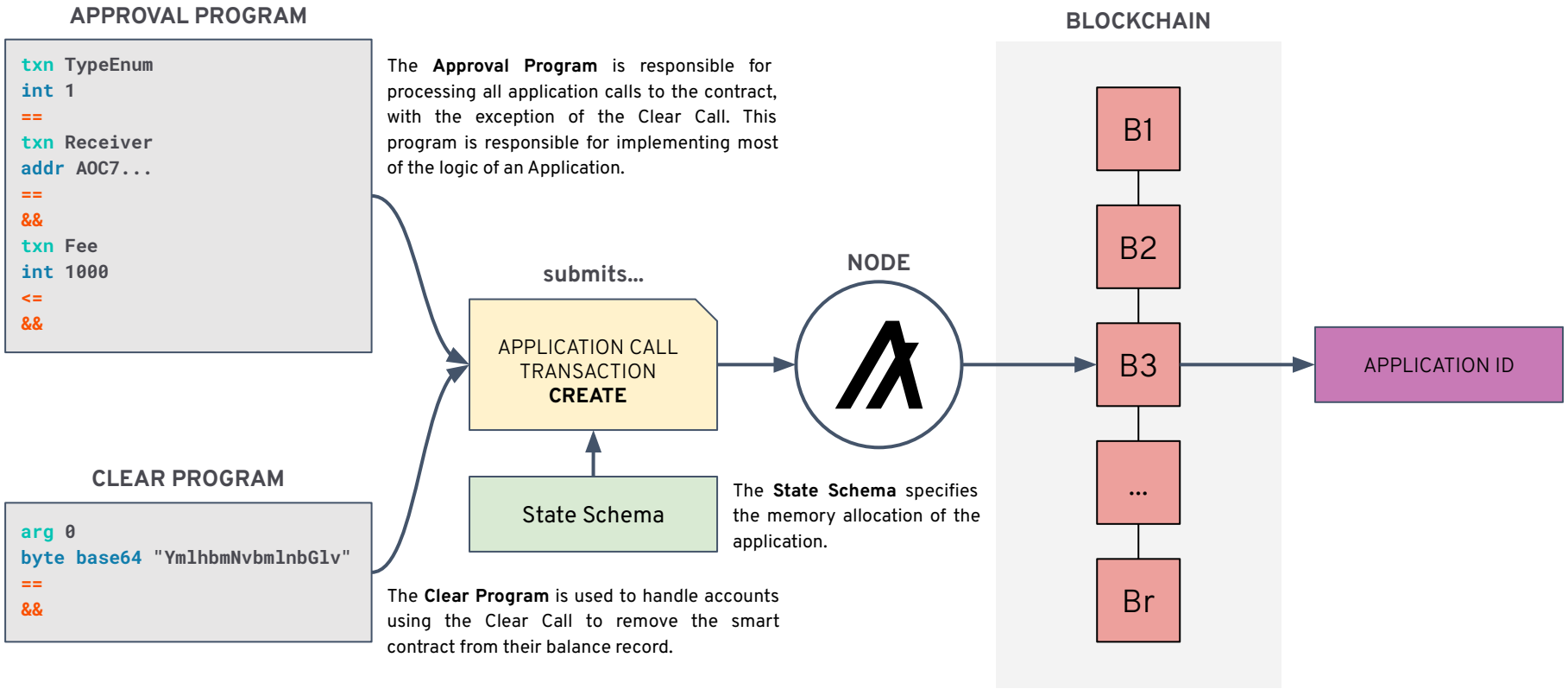


Algorand

SMART CONTRACTS

Decentralized Applications on Algorand

Deploying Applications on chain

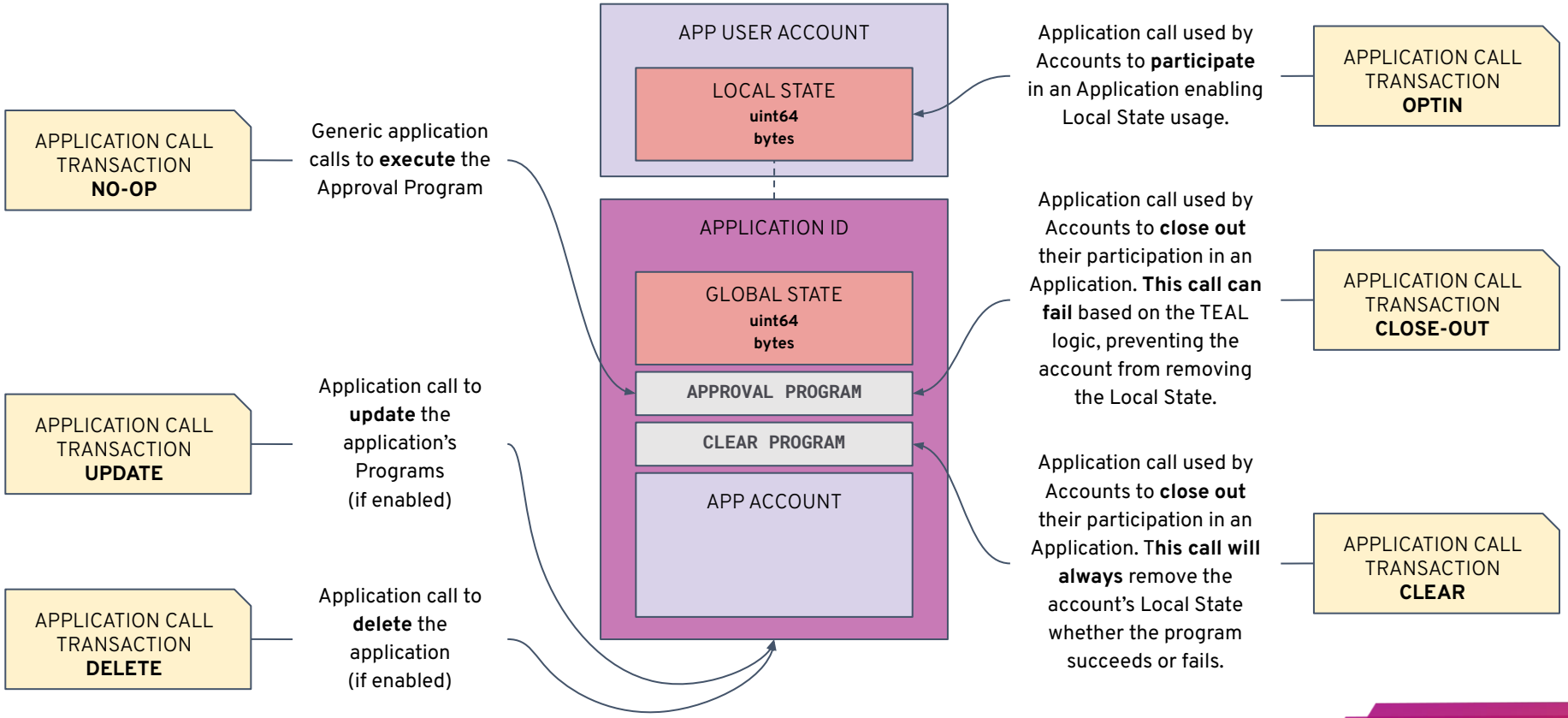


Compiled TEAL Max Size: 2048 bytes (+3 Extra Pages)
OpCode Max Budget: 700 (x16 Atomic Calls)

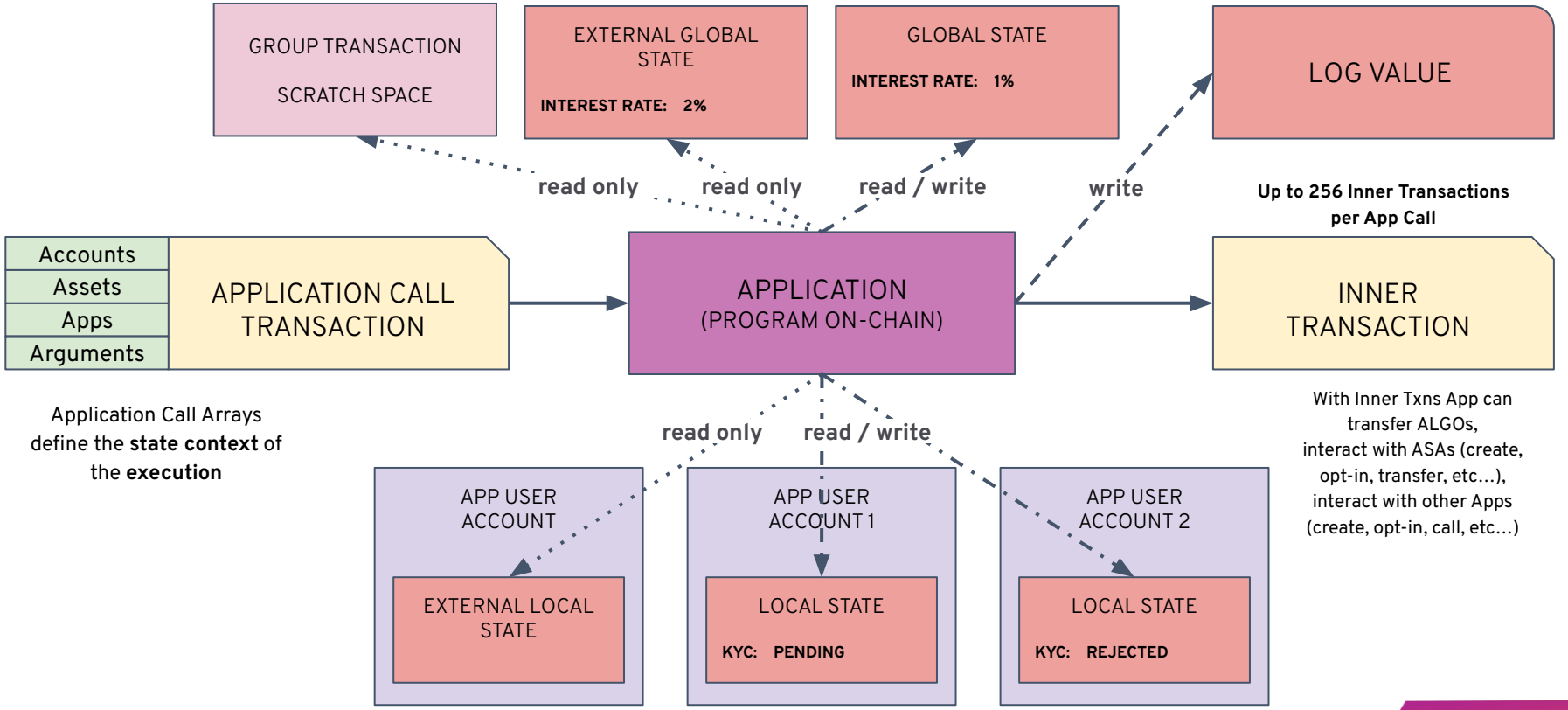
Application Minimum Balance requirements

Name	Current value	Developer doc	Consensus parameter name in (.go)	Note
Per page application creation fee	0.1 Algos	reference	AppFlatParamsMinBalance	
Flat for application opt-in	0.1 Algos	reference	AppFlatOptInMinBalance	
Per state entry	0.025 Algos	reference	SchemaMinBalancePerEntry	
Addition per integer entry	0.0035 Algos	reference	SchemaUintMinBalance	
Addition per byte slice entry	0.025 Algos	reference	SchemaBytesMinBalance	

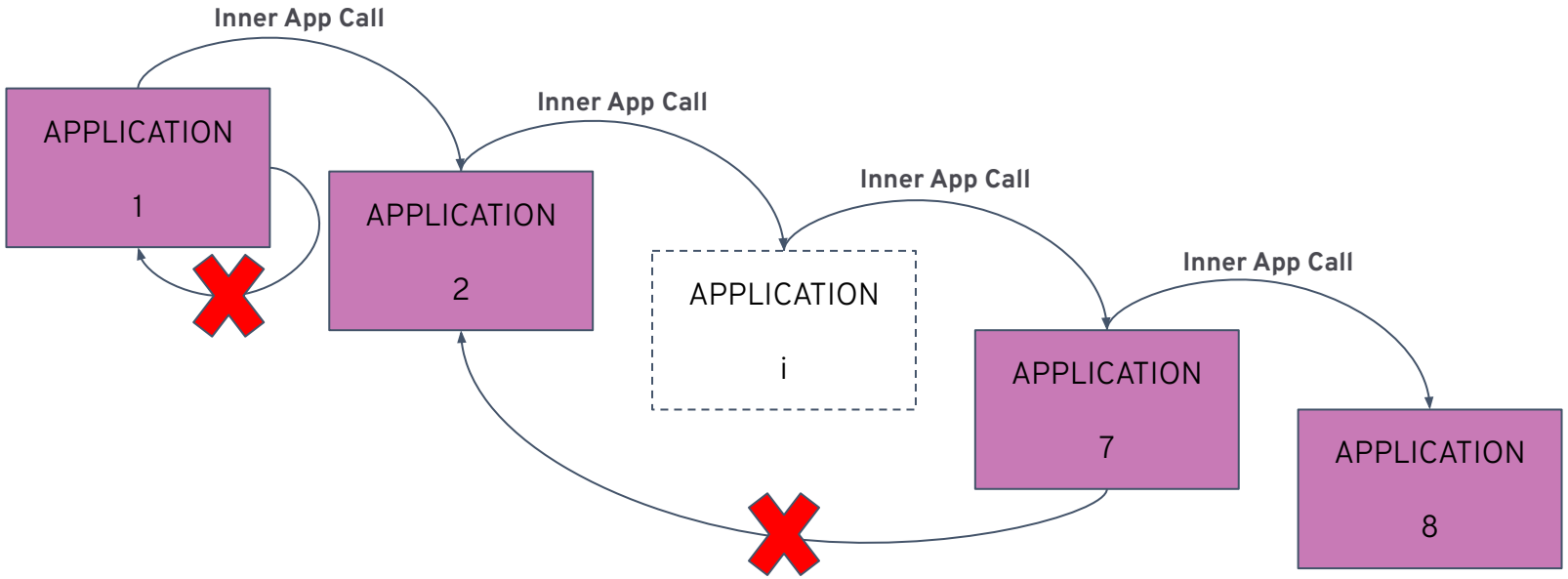
Calling Applications



Interacting with Applications



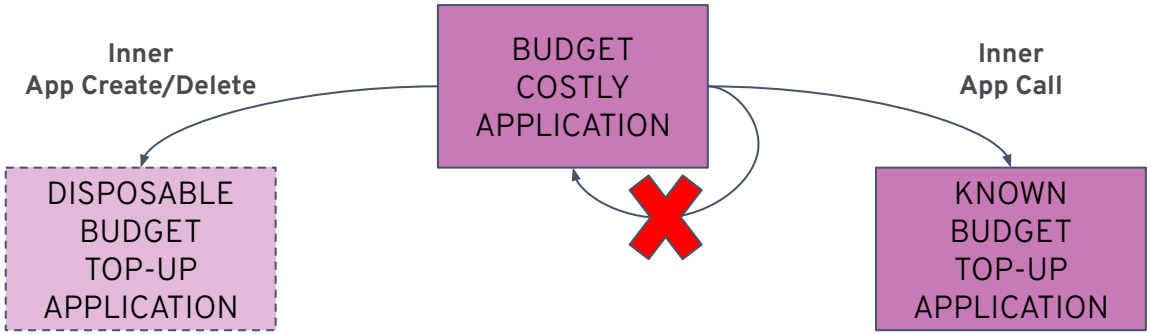
Contract 2 Contract interaction



1. An application may not call itself, even indirectly. This is referred to as **re-entrancy** and is explicitly forbidden.
2. An application may only call into other applications **up to a stack depth of 8**.

Smart Contract Execution: op-code budget

The **op-code budget** is consumed during execution of every Algorand Smart Contract according to the op-code cost. In order for the evaluation to succeed, the budget must not exceed 700 points. Each App Call (also as Inner Transactions) provides an additional budget of 700 points to the whole execution.



An application may issue **up to 256 inner transactions** to increase its **budget** (max budget of 179.2k!), but **the max call budget is shared** for all applications **in the group**.

Smart Contract Interface: ABI

The **ABI** (*Application Binary Interface*) defines the **encoding/decoding of data types** and a standard for **exposing and invoking methods** in a Smart Contract. The specification is defined in ARC-4.

```
{
    "name":"super-awesome-contract",
    "networks":{
        "MainNet":{
            "appID": 123456
        }
    },
    "methods":[
        {
            "name":"add",
            "desc":"Add 2 integers",
            "args":[ { "type":"uint64" }, { "type":"uint64" } ],
            "returns": {"type":"uint64"}
        },
        {
            "name":"sub",
            "desc":"Subtract 2 integers",
            "args":[ { "type":"uint64" }, { "type":"uint64" } ],
            "returns": {"type":"uint64"}
        },
```

At a high level, the ABI allows contracts to define an API so clients know exactly what the Smart Contract is expecting to be passed (like a "*Smart Contract Swagger*").

Algorand

TEAL

AVM assembly-like language

Smart Signature Example

Suppose we want to develop a **Smart Signature** that approves a transaction **if and only if**:

1. is "*Payment*" **type** transaction;
2. the **receiver** is a specific "*ADDR*";
3. **fees** are less or equal to "*1000 microALGO*";
4. first **argument** is equal to "*bianconiglio*";
5. **amount** is equal to "*42 ALGO*";
6. or **amount** is equal to "*77 ALGO*";

Where do we start?

Smart Signature as “Transaction Observer”

Smart Signatures can be defined as a *“transactions’ observers”*: programs that meticulously check all **fields in the transaction** (or in a group of transactions) that intend to *“approve”* or *“reject”* based on TEAL logic.

To translate those 6 **semantically defined** example’s conditions into **TEAL** we need to check which transaction fields are going to be controlled by Smart Signature’s logic.

Let's start with the translation...

Translating conditions into TEAL...

1. is "*Payment*" **type** transaction;

TxType	*required*	string	`"type"`	Specifies the type of transaction. This value is automatically generated using any of the developer tools.

```
txn TypeEnum
int 1
==
```

1

Translating conditions into TEAL...

2. the **receiver** is a specific "*ADDR*";


```
txn Receiver
addr AOC7...
==
```

2

Translating conditions into TEAL…

3. **fees** are less or equal to "*1000 microALGO*";

Fee	*required*	uint64	`"fee"`	Paid by the sender to the FeeSink to prevent denial-of-service. The minimum fee on Algorand is currently 1000 microAlgos.

```
txn Fee
int 1000
<=
```

3

Translating conditions into TEAL...

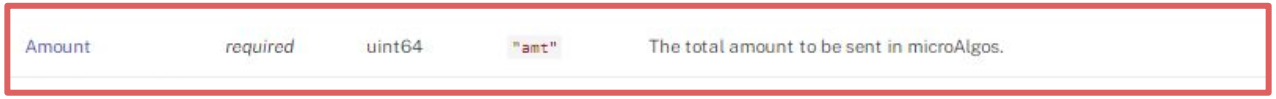
4. first **argument** is equal to "*bianconiglio*";

`arg`	push Args[N] value to stack by index

```
arg 0                                    4
byte base64 "YmlhbmNvbmlnbGlv"
==
```

Translating conditions into TEAL…

5. **amount** is equal to “*42 ALGO*”;



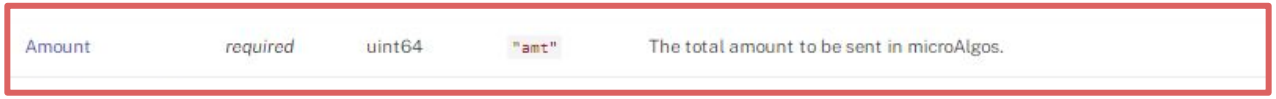
Amount	*required*	uint64	`"amt"`	The total amount to be sent in microAlgos.

```
txn Amount
int 42000000
==
```

5

Translating conditions into TEAL…

6. **amount** is equal to “*77 ALGO*”;



Amount	*required*	uint64	`"amt"`	The total amount to be sent in microAlgos.

```
txn Amount
int 77000000
==
```

6

Logic connectors...

```
txn TypeEnum
int 1
==                                          1

txn Receiver
addr AOC7...
==                                          2

txn Fee
int 1000
<=                                          3

arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==                                          4

txn Amount
int 42000000
==                                          5

txn Amount
int 77000000
==                                          6
```

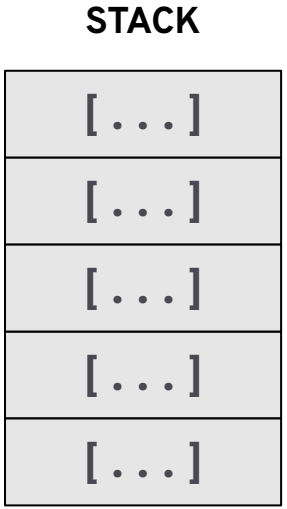
STACK

Logic connectors...

```
txn TypeEnum
int 1
==                                          1
txn Receiver
addr AOC7...
==                                          2
&&
txn Fee
int 1000
<=                                          3
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==                                          4
&&
&&
txn Amount
int 42000000
==                                          5
txn Amount
int 77000000
==                                          6
||
&&
```

This is probably the most complex phase in **TEAL** programming, because you need to keep in mind the **state of the stack**.

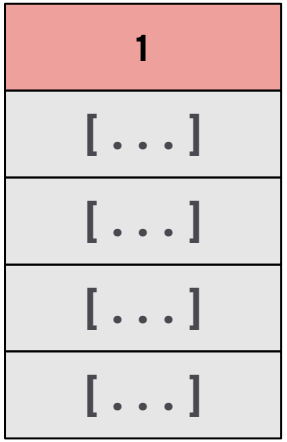
This phase is drastically simplified with the use of **PyTEAL**, Python binding for TEAL, which automatically performs this concatenation, saving us the effort of thinking about the state of the stack.



Execution...

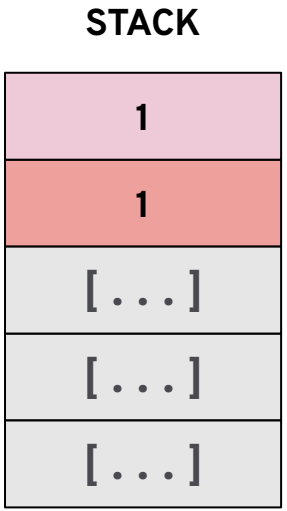
```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```

STACK



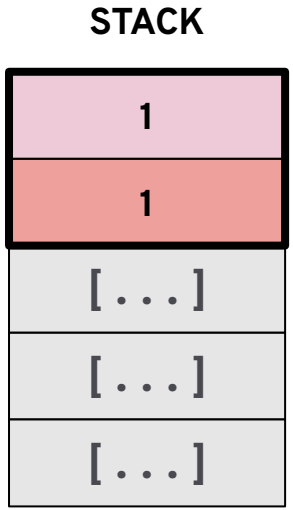
Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```



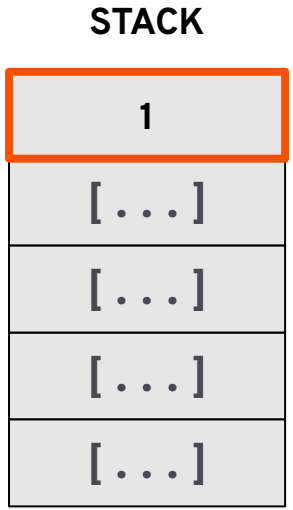
Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```



Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```



Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```

STACK

AOC7...
1
[. . .]
[. . .]
[. . .]

Execution...

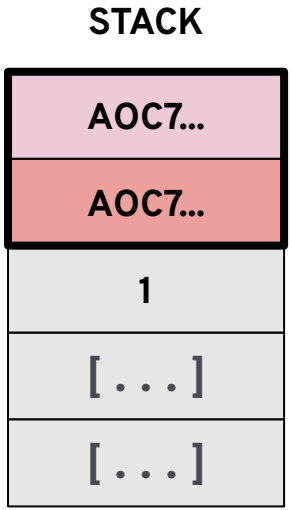
```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```

STACK

AOC7...
AOC7...
1
[. . .]
[. . .]

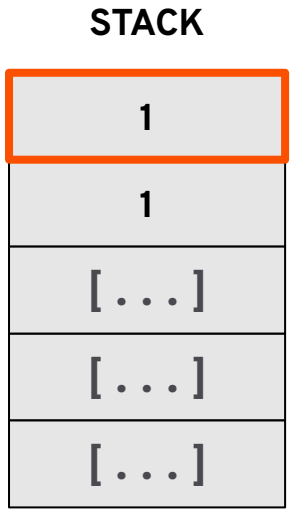
Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```



Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```



Execution...

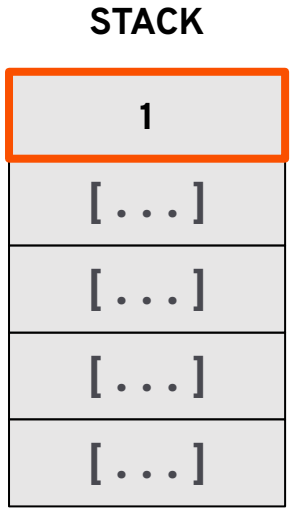
```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```

STACK

1
1
[...]
[...]
[...]

Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```



Execution...

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txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```

STACK

1000
1
[. . .]
[. . .]
[. . .]

Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```

STACK

1000
1000
1
[. . .]
[. . .]

Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
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==
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int 77000000
==
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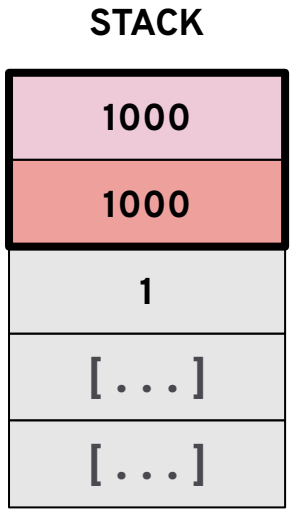
```



Execution...

```
txn TypeEnum
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byte base64 "YmlhbmNvbmlnbGlv"
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int 42000000
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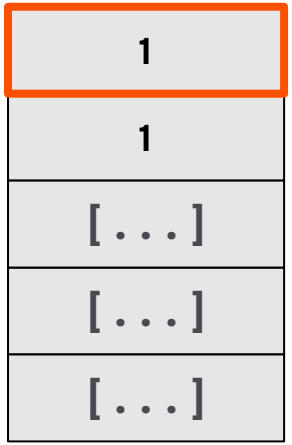
&&
```

STACK



Execution...

```
txn TypeEnum
int 1
==
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txn Fee
int 1000
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arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```

STACK

bianconiglio
1
1
[. . .]
[. . .]

Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```

STACK

bianconiglio
bianconiglio
1
1
[. . .]

Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```

STACK

Execution...

```
txn TypeEnum
int 1
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txn Receiver
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&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
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txn Amount
int 42000000
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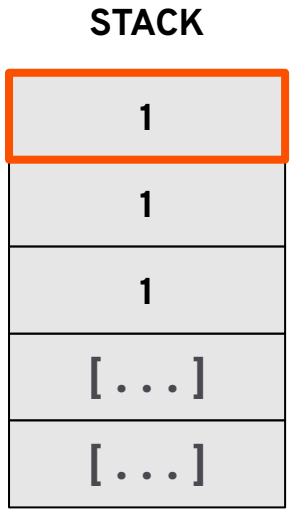
txn Amount
int 77000000
==
||
&&
```



Execution...

```
txn TypeEnum
int 1
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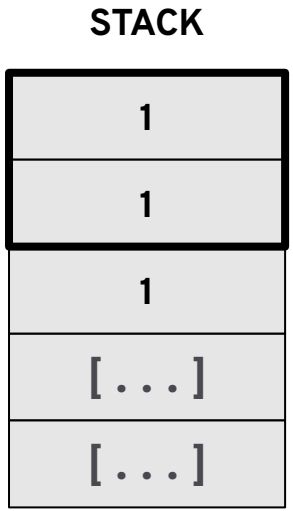
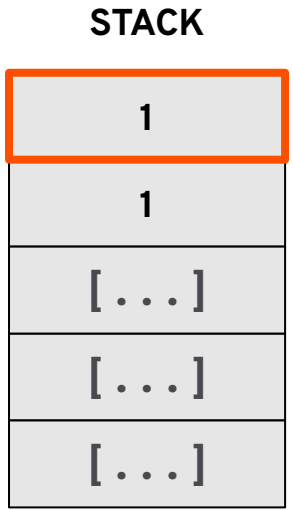
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```



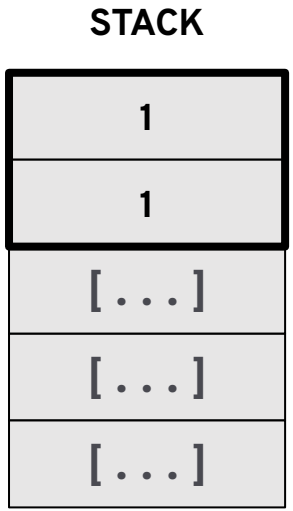
Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```



Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```



Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
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byte base64 "YmlhbmNvbmlnbGlv"
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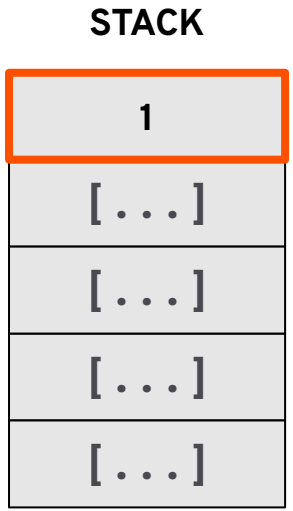
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```



Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```

STACK

42000000
1
[...]
[...]
[...]

Execution...

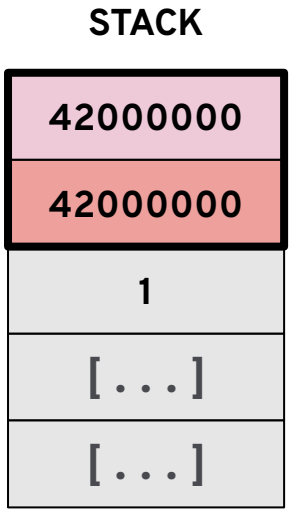
```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```

STACK

42000000
42000000
1
[. . .]
[. . .]

Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```



Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
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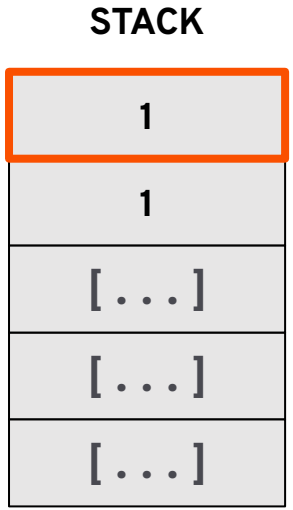
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```



Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```

STACK

42000000
1
1
[. . .]
[. . .]

Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```

STACK

77000000
42000000
1
1
[. . .]

Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
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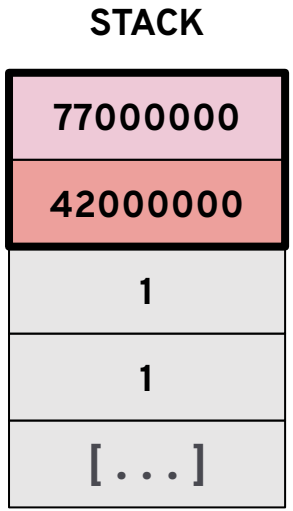
==
||
&&
```



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txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
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int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
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==
||
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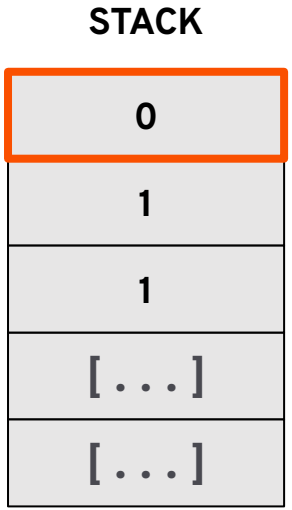
```



Execution...

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txn Receiver
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txn Fee
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&&
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==
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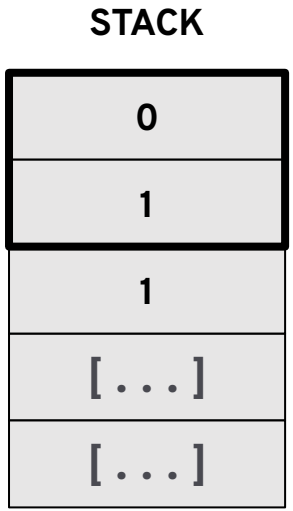
int 77000000
==
||
&&
```



Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
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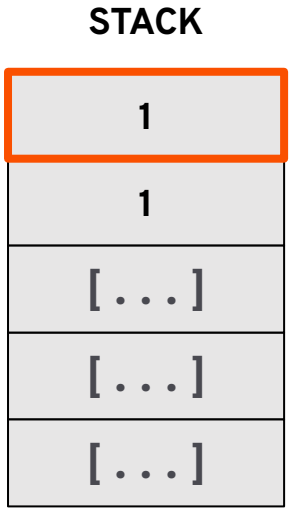
txn Fee
int 1000
<=
arg 0
byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```



Execution...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
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byte base64 "YmlhbmNvbmlnbGlv"
==
&&
&&
txn Amount
int 42000000
==
txn Amount
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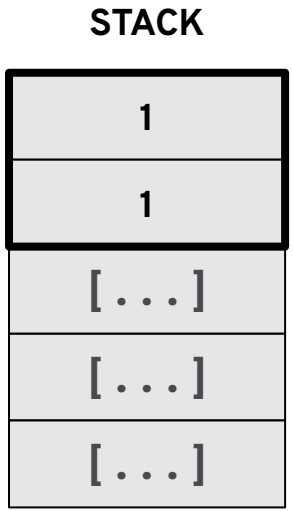
==
||
&&
```



Execution...

```
txn TypeEnum
int 1
==
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==
&&
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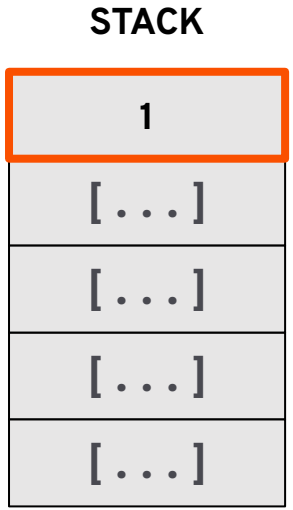
&&
&&
txn Amount
int 42000000
==
txn Amount
int 77000000
==
||
&&
```



Conclusion...

```
txn TypeEnum
int 1
==
txn Receiver
addr AOC7...
==
&&
txn Fee
int 1000
<=
arg 0
byte base64 "[illegible]"
==
&&
&&
txn Amount
int [illegible]
==
txn Amount
int [illegible]
==
||
&&
```

Smart Signature written in PyTEAL

```python
import base64
from pyteal import *

"""Esempio ASC1 in PyTeal"""


def asc1(tmpl_receiver):
    is_payment = Txn.type_enum() == Int(1)
    is_correct_receiver = Txn.receiver() == Addr(tmpl_receiver)
    max_fee = Txn.fee() <= Int(1000)
    follow_the = Arg(0) == Bytes(
        "base64", str(base64.b64encode('bianconiglio'.encode()), 'utf-8'))
    amount_option1 = Txn.amount() == Int(42000000)
    amount_option2 = Txn.amount() == Int(77000000)
    is_correct_amount = Or(amount_option1, amount_option2)
    asc1_logic = And(is_payment,
                     is_correct_receiver,
                     max_fee,
                     follow_the,
                     is_correct_amount)
    return asc1_logic
```

Algorand

PyTEAL

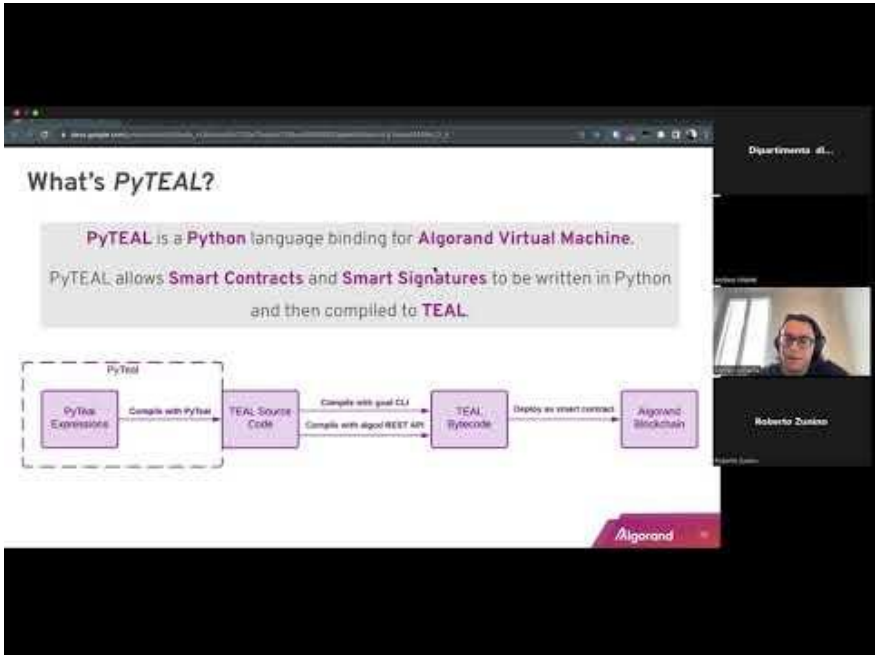
Writing Smart Contracts with Python

Jason Paulos
Senior Software Engineer at Algorand


Matteo Almanza
Blockchain Engineer at Algorand



Algorand

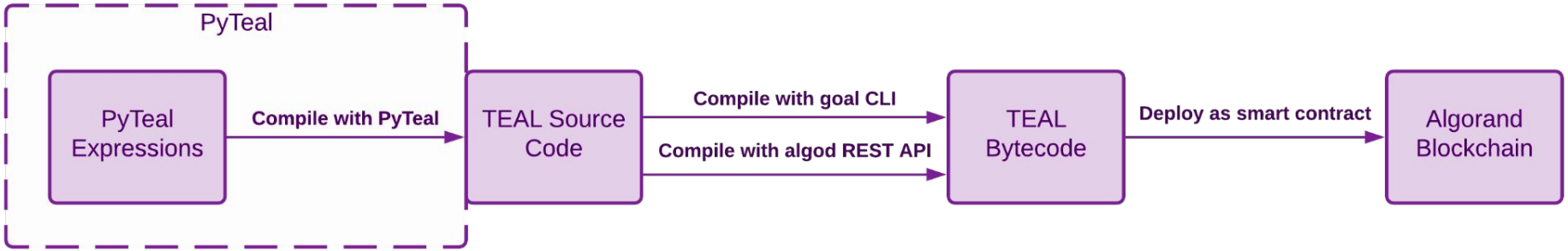

What's PyTEAL?
PyTEAL is a Python language binding for Algorand Virtual Machine.
PyTEAL allows Smart Contracts and Smart Signatures to be written in Python and then compiled to TEAL.
PyTeal
PyTeal Expressions
Compile with PyTeal
TEAL Source Code
Compile with goal CLI
Compile with algod REST API
TEAL Bytecode
Deploy as smart contract
Algorand Blockchain
Roberto Zunino
Algorand


Algorand
NOV2021
of the Algorand Virtual Machine (AVM),
a more powerful Python library (PyTeal) to
tracts. In this talk, Jason Paulos, Software
Lead, will explain how to make use of the
strate building subroutines, using loops,
DeCipher
JASON PAULOS
Software Engineer and PyTeal Lead - Algorand
ustrating how to
The Power
d blockchains
DeCipher

What's *PyTEAL*?

PyTEAL is a **Python** language binding for **Algorand Virtual Machine**.

PyTEAL allows **Smart Contracts** and **Smart Signatures** to be written in Python and then compiled to **TEAL**.



It’s easier with PyTEAL!

TEAL Source Code

```
txn Receiver
addr AOC7...
==
txn Amount
int 1000
<=
&&
```

COMPILE...

AVM bytecode

PyTEAL Source Code

```
And(
        Txn.Receiver == Addr(AOC7...),
        Txn.Amount <= Int(1000),
)
```

COMPILE...

TEAL Source Code

```
txn Receiver
addr AOC7...
==
txn Amount
int 1000
<=
&&
```

COMPILE...

AVM bytecode

PyTEAL Basics - Intro

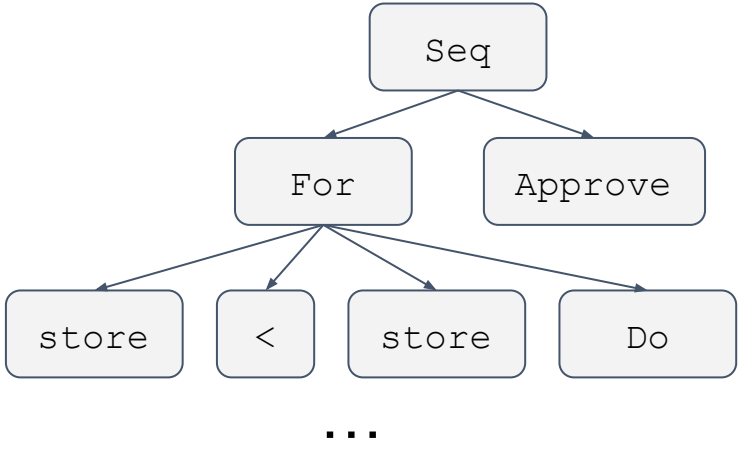
You're writing **Python code** that produces **TEAL code**.

```
from pyteal import *

program = ... # a pyteal expression
teal_source = compileTeal(program, mode=Mode.Application, version=7)

>>> teal_source
"#pragma version 7\nintcblock 0 1\ntxn NumAppArgs\nintc_0 //
0\n==\nbnz main_l4\ntxna ApplicationArgs 0\npushbytes 0x90e75c9d..."
```

PyTEAL Basics - Intro

PyTEAL expressions represent an **abstract syntax tree** (AST)

```
# [...]
program = Seq(
    For(
        i.store(Int(0)),
        i.load() < Int(16),
        i.store(i.load() + Int(1)))
    .Do(
        App.globalPut(
            Concat(Bytes("index"), Itob(i.load())),
            Int(1))
    ),
    Approve(),
)
```



PyTEAL Basics - Types (1/2)

Two basic types:

- **uint64**
- **byte strings**

```
i = Int(5)

x = Bytes("content")
y = Bytes(b"\x01\x02\x03")
z = Bytes("base16", "05")
```

PyTEAL Basics - Types (2/2)

Conversion between types

- **Itob** - integer to bytes (8-byte big endian)
- **Btoi** - bytes to integer

```
Itob(i) # produces the byte string 0x0000000000000005
Btoi(z) # produces the integer 5
```

PyTEAL Basics - Math operators

Math and **logic** operators (uint as boolean: 0 is false, non zero is true)

```
    i = Int(10)
    j = i * Int(2) + Int(1) # => Add(Mul(i, Int(2)), Int(1))
    k = And(Int(1), Or(Int(1), Int(0)))


    # Expressions are not optimized
    z = j * j # => Mul(Add(Mul(i, Int(2)), Int(1)), Add(Mul(i, Int(2)),
Int(1)))
```

PyTEAL Basics - Byte string manipulation

Byte string **manipulation**

```
x = Bytes("content")
y = Concat(Bytes("example "), x) # "example content"
z = Substring(y, Int(2), Len(y)) # "ample content"
```

PyTEAL Basics - Crypto utilities

Built-in **crypto** utilities

```
h_sha256 = Sha256(z)
h_sha512_256 = Sha512_256(z)
h_keccak = Keccak256(z)
```

PyTEAL Basics - Fields (1/3)

Fields from the **current transaction**

```
Txn.sender()
Txn.accounts.length()
Txn.application_args.length()
Txn.accounts[1]
Txn.application_args[0]
Txn.group_index()
```

PyTEAL Basics - Fields (2/3)

Fields from transactions in the **current atomic group**

```
Gtxn[0].sender()
Gtxn[Txn.group_index() - Int(1)].sender()
Gtxn[Txn.group_index() - Int(1)].accounts[2]

# Gtxn (and other globals) indexes can be both (python) int and expr
```

PyTEAL Basics - Fields (3/3)

Fields from **execution context**

```
Global.group_size()
Global.round() # current round number
Global.latest_timestamp() # UNIX timestamp of last round
```

PyTEAL Basics - Logs

Log publicly viewable messages to the chain

```
Log(Bytes("message"))
```

PyTEAL Basics - State (1/2)

Global - one instance per application

```
App.globalPut(Bytes("status"), Bytes("active")) # write to global key "status"

status = App.globalGet(Bytes("status")) # read global key "status"

App.globalDel(Bytes("status")) # delete global key "status"

# Can also access global state of other smart contracts - no secrets
```

PyTEAL Basics - State (1.5/2)

Global - one instance per application

```
# Remember that we are building expressions, not fetching values

old_status = App.globalGet(Bytes("status")) # read global key "status"
program = Seq(
     # Update status
     App.globalPut(Bytes("status"), Bytes("frozen")), # write to global key "status"
     # Check if was previously active
     If(old_status != Bytes("frozen")).Then(
          Log(Bytes("Was active")) # <= Will never execute
     )
)
```

PyTEAL Basics - State (2/2)

Local - one instance per opted-in account per application

```
App.localPut(Txn.sender(), Bytes("level"), Int(1)) # write to sender's local key
"level"
App.localPut(Txn.accounts[1], Bytes("level"), Int(2))  # write to other account's local
key "level"

sender_level = App.localGet(Txn.sender(), Bytes("level"))  # read from sender's local
key "level"

App.localDel(Txn.sender(), Bytes("level"))  # delete sender's local key "level"
```

PyTEAL Basics - Control Flow (1/5)

Approve the transaction and **immediately exit**

```
Approve()
```

Reject the transaction and **immediately exit**

```
Reject()
```

PyTEAL Basics - Control Flow (2/5)

Multiple expressions can be joined into a **sequence**

```
program = Seq(
    App.globalPut(Bytes("count"), App.globalGet(Bytes("count")) + Int(1)),
    Approve()
)
```

PyTEAL Basics - Control Flow (3/5)

Basic conditions can be expressed with **If**, **Then**, **Else**, **Elself**

```
program = Seq(
    If(App.globalGet(Bytes("count")) == Int(100))
    .Then(
        App.globalPut(Bytes("100th caller"), Txn.sender())
    )
    .Else(
        App.globalPut(Bytes("not 100th caller"), Txn.sender())
    ),
    App.globalPut(Bytes("count"), App.globalGet(Bytes("count")) + Int(1)),
    Approve(),
)
```

PyTEAL Basics - Control Flow (4/5)

Larger conditions can be expressed with **Cond**

```
program = Cond(
    [Txn.application_id() == Int(0), on_create],
    [Txn.on_completion() == OnComplete.UpdateApplication, on_update],
    [Txn.on_completion() == OnComplete.DeleteApplication, on_delete],
    [Txn.on_completion() == OnComplete.OptIn, on_opt_in],
    [Txn.on_completion() == OnComplete.CloseOut, on_close_out],
    [Txn.on_completion() == OnComplete.NoOp, on_noop],
    # error if no conditions are met
)
```

PyTEAL Basics - Control Flow (5/5)

Loops can be expressed with **For** and **While**

```
i = ScratchVar(TealType.uint64)

on_create = Seq(
    For(i.store(Int(0)), i.load() < Int(16), i.store(i.load() + Int(1)))
    .Do(
        App.globalPut(Concat(Bytes("index"), Itob(i.load())), Int(1))
    ),
    Approve(),
)
```

PyTEAL Basics - Subroutines (1/2)

Sections of code can be put into **subroutines** (Python decorators)

```
@Subroutine(TealType.uint64)
def isEven(i):
    return i % Int(2) == Int(0)

App.globalPut(Bytes("value_is_even"), isEven(Int(10)))
```

PyTEAL Basics - Subroutines (2/2)

Recursion is allowed

```
@Subroutine(TealType.uint64)
def recursiveIsEven(i):
    return (
        If(i == Int(0))
        .Then(Int(1))
        .ElseIf(i == Int(1))
        .Then(Int(0))
        .Else(recursiveIsEven(i - Int(2)))
    )
```

PyTEAL Basics - Inner Transactions (1/3)

Every **application** has control of an **account**

```
Global.current_application_address()
```

PyTEAL Basics - Inner Transactions (2/3)

Applications can **send transactions** from this **account** – even to other Apps

Limitation: no reentrancy

```
Seq(
    InnerTxnBuilder.Begin(),
    InnerTxnBuilder.SetFields(
        {
            TxnField.type_enum: TxnType.Payment,
            TxnField.receiver: Txn.sender(),
            TxnField.amount: Int(1_000_000),
        }
    ),
    InnerTxnBuilder.Submit() # send 1 Algo from the app account to the transaction sender
)
```

PyTEAL Basics - Inner Transactions (3/3)

```
appAddr = Global.current_application_address()
Seq(
    InnerTxnBuilder.Begin(),
    InnerTxnBuilder.SetFields(
        {
            TxnField.type_enum: TxnType.AssetConfig,
            TxnField.config_asset_name: Bytes("PyTEAL Coin"),
            TxnField.config_asset_unit_name: Bytes("PyTEAL"),
            TxnField.config_asset_url: Bytes("https://pyteal.readthedocs.io/"),
            TxnField.config_asset_decimals: Int(6),
            TxnField.config_asset_total: Int(800_000_000),
            TxnField.config_asset_manager: appAddr,
        }
    ),
    InnerTxnBuilder.Submit(), # create a PyTEAL Coin asset
    App.globalPut(Bytes("PyTealCoinId"), InnerTxn.created_asset_id()) # remember the asset ID
)
```

PyTEAL Basics - Other operations

See docs at https://pyteal.readthedocs.io/en/stable/overview.html

- Wide math
- Balances, assets holding and parameters
- JSON (limited) parsing
- ...

A pythonic Algorand stack

PyCharm IDE & AlgoDEA plug-in

Algorand Sandbox Docker in dev mode

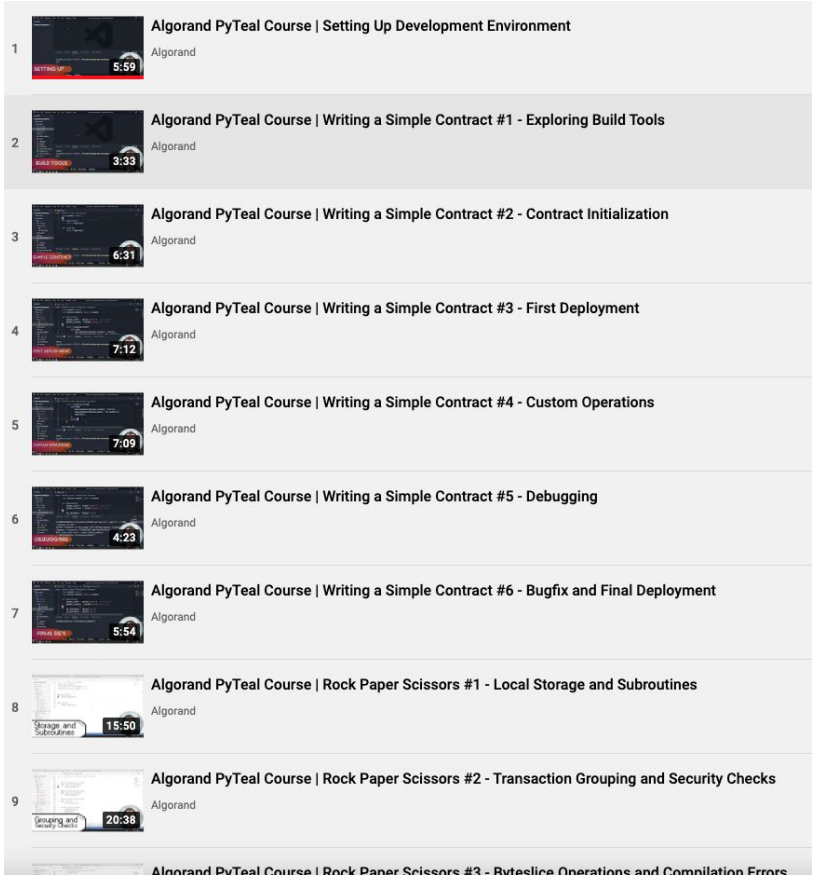
Algorand Python SDK

PyTEAL & Beaker

PyTest for Smart Contracts unit-tests and e2e-tests

TEAL Debugger

"Zero to Hero PyTEAL" crash course



Join and learn in 12 lessons!

Algorand

Algorand ABI

Writing ABI Compliant Smart Contracts with PyTEAL

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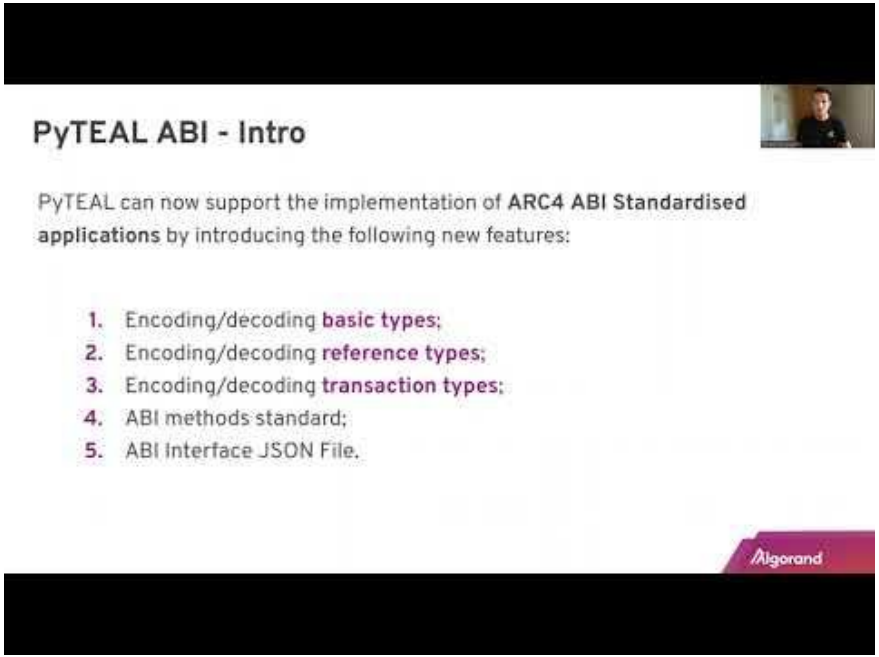
Algorand


PyTEAL ABI - Intro
PyTEAL can now support the implementation of ARC4 ABI Standardised applications by introducing the following new features:
1. Encoding/decoding basic types;
2. Encoding/decoding reference types;
3. Encoding/decoding transaction types;
4. ABI methods standard;
5. ABI Interface JSON File.
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What is an *ABI*?

An **ABI** (*Application Binary Interface*) is an **interface** between two binary program modules, one of which is at the level of *machine code*. The interface defines the **convention of how data is encoded/decoded** into/out of the machine code via computational routines.

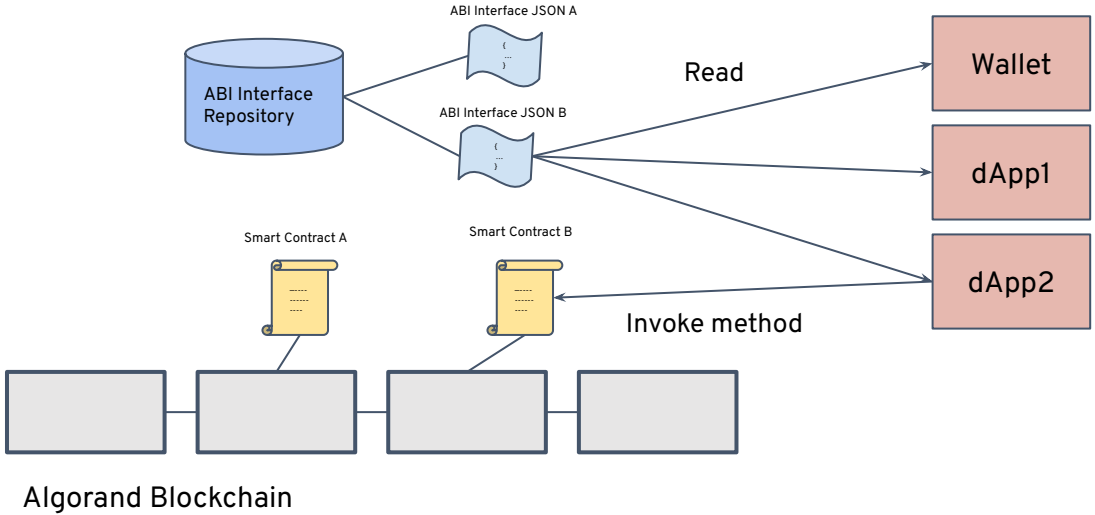
Algorand ABI

Algorand ABI is the interface that defines a standard on **how to call Algorand Smart Contracts**, the **encoding/decoding** of *Application Call* arguments and the return values.

ARC4 is the specification for **Algorand ABI**. It defines a **standard approach to call smart contract methods** and describes the ***ABI interface description object***. It is a human readable and machine readable **JSON** file showing the methods of a smart contracts, the required input parameters and the return values.

Why an Algorand ABI?

Smart Contract developers can publish the **interface JSON file** before deploying the application on the blockchain.
Client applications just need to read the **interface JSON file** and properly call the smart contract methods and process return values.



ABI Interface JSON File (1/3)

The **ABI Interface JSON file** is composed by three distinct JSON types called **Method**, **Interface** and **Contract**.

A **Method** description defines a method with the expected arguments and return type.

```
{
    "name":"add",
    "desc":"method description",
    "args":[{"type":"uint32","desc":"first description"},
            {"type":"uint16","desc":"second description"}],
    "returns":{"type":"uint32","desc":"return description"}
}
```

ABI Interface JSON File (2/3)

An **Interface** description defines a collection of **Methods**. It is a way to represent the set of methods required to implement an **ARC4** compliant Smart Contract. It can be extended with other methods.

```
{
    "name":"interface",
    "methods":[
        {
            "name":"add",
            "args":[{"type":"uint32"},{"type":"uint32"}],
            "returns":{"type":"uint32"}
        },
        {
            "name":"sub",
            "args":[{"type":"uint32"},{"type":"uint32"}],
            "returns":{"type":"uint32"}
        },

    ]
}
```

ABI Interface JSON File (3/3)

A **Contract** description defines a specific Smart Contract that **currently exists on the blockchain**, and specifies all the methods the contract implements. It is an implementation of an **Interface**.

```
{
    "name":"demo-abi",
    "networks": {
        "wGHE2Pwdvd7S12BL5FaOP20EGYesN73ktiC1qzkkit8=": { "appID": 1234 },
        "SGO1GKSzyE7IEPItTxCByw9x8FmnrCDexi9/cOUJOiI=": { "appID": 5678 },
    },

    "methods":[
        {
            "name":"add",
            "description":"Add 2 integers",
            "args":[ { "type":"uint64" }, { "type":"uint64" } ],
            "returns": {"type":"uint64"}
        },
        {
            "name":"sub",
            "description":"Subtract 2 integers",
            "args":[ { "type":"uint64" }, { "type":"uint64" } ],
            "returns": {"type":"uint64"}
        },
        {
            "name":"mul",
            "description":"Multiply 2 integers",
            "args":[ { "type":"uint64" }, { "type":"uint64" } ],
            "returns": {"type":"uint64"}
        }
    ]
}
```

ARC4 ABI Methods standard

The **ARC4** defines a **method signature** as a way to identify a smart contract method. It is expressed as **method name, arguments types, return type.**

add(uint64, uint64)uint128

The **method selector** is the first 4 bytes of the hash of a signature

```
SHA-512/256 hash (in hex): 8aa3b61f0f1965c3a1cbf…70184ff89dc114e877b1753254a

Method selector (in hex): 8aa3b61f
```

The **method selector** to be specified as the **first** argument of an *Application Call* transaction. The smart contract must route to the corresponding method matching the selector.

PyTEAL ABI - Intro

PyTEAL can now support the implementation of **ARC4 ABI Standardised applications** by introducing the following new features:

1. Encoding/decoding **basic types**;
2. Encoding/decoding **reference types**;
3. Encoding/decoding **transaction types**;
4. ABI methods standard;
5. ABI Interface JSON File.

PyTEAL ABI - Basic Types

AVM stack types limited to **uint64**, **bytes**. PyTEAL ABI supports **new basic types** whose **encoding is standardized** to AVM basic types.

PyTeal Type	Description
`abi.UintN`	An N-bit unsigned integer, where 8 <= N <= 64
`abi.Bool`	A boolean value that can be either 0 or 1
`abi.Byte`	An 8-bit unsigned integer used to indicate non-numeric data
`abi.StaticArray[T,N]`	A fixed-length array of `T` with `N` elements
`abi.Address`	A 32-byte Algorand address. This is an alias for `abi.StaticArray[abi.Byte, Literal[32]]`
`abi.StaticBytes[N]`	A fixed-length array with `N` elements of `abi.Byte`
`abi.DynamicArray[T]`	A variable-length array of `T`
`abi.DynamicBytes`	A variable length array of `abi.Byte`
`abi.String`	A variable-length byte array assuming UTF-8 content. This is an alias for `abi.DynamicArray[abi.Byte]`
`abi.TupleN, abi.NamedTuple`	A tuple of multiple types, where 0 <= N <= 5

PyTEAL ABI - Setting Values

To create and instantiate an ABI Type we have the **`abi.make()`** method.

All Basic Types have a **`set()`** method which can be used to assign a value.

```
my_address = abi.make(abi.Address)
my_bool = abi.make(abi.Bool)
my_uint64 = abi.make(abi.Uint64)
my_tuple = abi.make(abi.Tuple3[abi.Address, abi.Bool, abi.Uint64]

program = Seq(
    my_address.set(Txn.sender()),
    my_bool.set(Txn.fee() == Int(0)),
    my_uint64.set(5000),
    my_tuple.set(my_address, my_bool, my_uint64)
)
```

PyTEAL ABI - Getting Values

Basic types have a **`get()`** method which can be used to extract that value.

```
my_address.get() # Returns the 32-byte Algorand address of Txn.sender()
```

PyTEAL ABI - Working with NamedTuples

A **NamedTuple** is a PyTEAL **Tuple** that has named elements.

```
class User(abi.NamedTuple):
    address: abi.Field[abi.Address]
    balance: abi.Field[abi.Uint64]

my_user = User()

program = Seq(
    my_user.set(Txn.sender(), 5000),
    Approve(),
)
```

PyTEAL ABI - Reference Types

Blockchain entities passed to the AVM within the **foreign arrays** of the method call.

PyTeal Type	Description
`abi.Account`	Represents an account stored in the `Txn.accounts` array
`abi.Asset`	Represents an asset stored in the `Txn.assets` array
`abi.Application`	Represents an application stored in the `Txn.applications` array

PyTEAL ABI - Working with Reference Types (1/2)

Reference types expose methods to obtain the **ID** of the object referenced and to access that object's **parameters**

```
@Subroutine(TealType.none)
def check_ref_values(my_user: abi.Account, my_asset: abi.Asset, my_app:
abi.Application):
    return Assert(
        my_user.address() == my_app.params().creator_address(),
        my_asset.asset_id() == Int(5),
    )
```

PyTEAL ABI - Working with Reference Types (2/2)

Asset holding properties can be accessed using reference types

```
@Subroutine(TealType.none)
def ensure_asset_balance_is_nonzero(my_user: abi.Account, my_asset: abi.Asset):
    return Assert(
        my_user.asset_holding(my_asset).balance() > Int(0)),
    )
```

PyTEAL ABI - Transaction Types

Transaction objects which are part of the same **group** of a method call.

A method may have multiple Transaction Type arguments, in which case they must appear in the *same order* as the method's arguments immediately before the method call.

PyTeal Type	Description
`abi.Transaction`	A catch-all for any transaction type
`abi.PaymentTransaction`	A payment transaction
`abi.KeyRegisterTransaction`	A key registration transaction
`abi.AssetConfigTransaction`	An asset configuration transaction
`abi.AssetTransferTransaction`	An asset transfer transaction
`abi.AssetFreezeTransaction`	An asset freeze transaction
`abi.ApplicationCallTransaction`	An application call transaction

PyTEAL ABI - Working with Transaction Types (1/2)

Get the absolute **group index** of a specific transaction in the group

```
@Subroutine(TealType.none)
def handle_txn_args(
    any_txn: abi.Transaction,
    pay: abi.PaymentTransaction,
    axfer: abi.AssetTransferTransaction):
    return Assert(
        any_txn.index() == Txn.group_index() - Int(3),
        pay.index() == Txn.group_index() - Int(2),
        axfer.index() == Txn.group_index() - Int(1),
    )
```

PyTEAL ABI - Working with Transaction Types (2/2)

Transaction Types expose a **`get()`** method which can be used to access **fields** from a transaction in the group

```
@Subroutine(TealType.none)
def check_txn(pay: abi.PaymentTransaction, sender: abi.Account):
    return Assert(
        pay.get().sender() == sender().address(),
        pay.get().receiver() == Global.current_application_address(),
    )
```

PyTEAL ABI - Subroutines

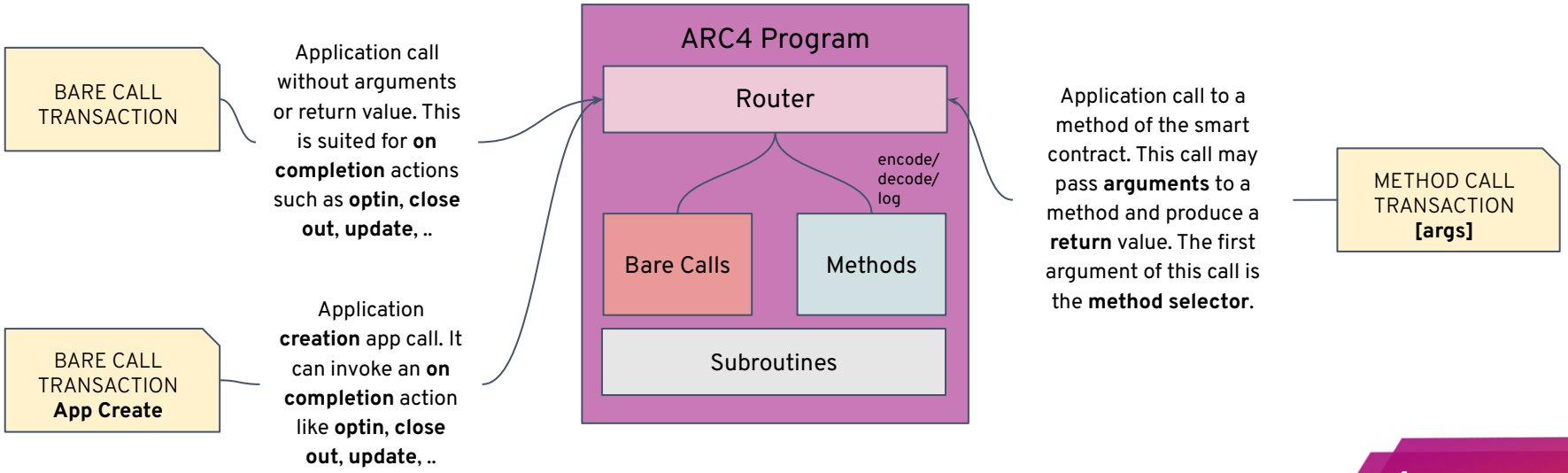
Subroutines can now return ABI values using the **ABIReturnSubroutine** decorator. The **output** keyword is now used to store the return value

```
@ABIReturnSubroutine
def get_account_balance(account: abi.Account, *, output: abi.Uint64) -> Expr:
    return Seq(
        (balance := abi.Uint64()).set(App.localGet(account.get(), Bytes("balance"))),
        output.set(balance),
    )
```

PyTEAL ABI - ARC4 Program

ABI Programs respond to two specific subtypes of application call transactions:

- **Method calls:** which encode a specific method to be called and the method arguments
- **Bare app calls:** which have no arguments and no return values



PyTEAL ABI - Registering Bare Calls

A bare app call handler can be registered with the **router**. The **actions** of a bare call handler can be either an **Expr** or a Subroutine

CallConfig options indicates whether the action is able to be called during an **app creation**, a **non-creation**, or **either**

```
router = Router(
    name = "ExampleApp",
    bare_calls = BareCallActions(
        no_op = OnCompleteAction(action=Approve(), call_config=CallConfig.CREATE),
        opt_in = OnCompleteAction(action=Approve(), call_config=CallConfig.CREATE),
        close_out = OnCompleteAction(action=Approve(), call_config=CallConfig.CALL),
        update_application = OnCompleteAction(
                             action=Assert(Txn.sender() == Global.creator_address()),
                             call_config=CallConfig.CREATE),
        delete_application = OnCompleteAction(action=Reject(),
call_config=CallConfig.CALL),
    )
)
```

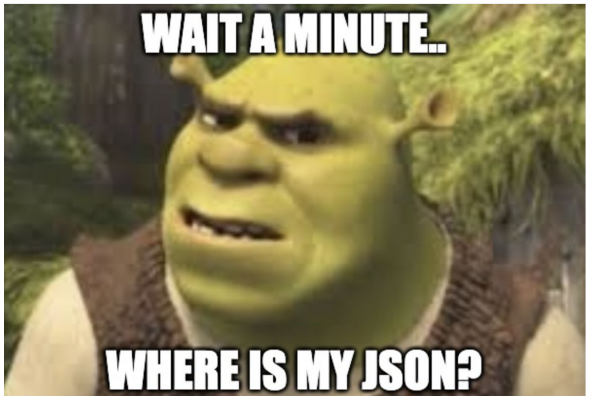
PyTEAL ABI - Registering Methods

A **method** decorator placed on top of the method subroutine can be used to register that method with the application router

CallConfig options can be specified within the decorator directly

```
@router.method(no_op=CallConfig.CALL, opt_in=CallConfig.CALL)
def my_method(a: abi.Uint64, b: abi.Uint64):
    return Seq(
        ...
    )
```

Nice, we finally know how to implement **ARC4 programs**!
Uhm?



PyTEAL ABI - Compiling ARC4 Programs

The PyTEAL **router** object provides the **compile_program()** method to compile an ARC4 program into **TEAL** code.

This method generates the **approval** and **clear state** programs, along with an auto-generated **Contract** object which represents the contract interface!

```
router = ...

approval_program, clear_state_program, contract = router.compile_program(
    version=6, optimize=OptimizeOptions(scratch_slots=True))

with.open("example.json", "w") as f:
    f.write(json.dumps(contract.dictify(), indent=4))
```

Pump my JSON: docstrings!

```python
@router.method(no_op=CallConfig.CALL, opt_in=CallConfig.CALL)
def deposit(payment: abi.PaymentTransaction, sender: abi.Account) -> Expr:
    """This method receives a payment from an account opted into this app and records it as a deposit.

    The caller may opt into this app during this call.

    Args:
        payment: A payment transaction containing the amount of Algos the user wishes to deposit.
            The receiver of this transaction must be this app's escrow account.
        sender: An account that is opted into this app (or will opt in during this method call).
            The deposited funds will be recorded in this account's local state. This account must
            be the same as the sender of the `payment` transaction.
    """
    return Seq(
        Assert(payment.get().sender() == sender.address()),
        Assert(payment.get().receiver() == Global.current_application_address()),
        App.localPut(
            sender.address(),
            Bytes("balance"),
            App.localGet(sender.address(), Bytes("balance")) + payment.get().amount(),
        ),
    )
```

Pump my JSON: docstrings!


```
{
    "name": "ExampleApp",
    "methods": [
        {
            "name": "deposit",
            "args": [
                {
                    "type": "pay",
                    "name": "payment",
                    "desc": "A payment transaction containing the amount of Algos the user wishes to deposit. The receiver of this transaction must be this app's escrow account."
                },
                {
                    "type": "account",
                    "name": "sender",
                    "desc": "An account that is opted into this app (or will opt in during this method call). The deposited funds will be recorded in this account's local state. This account must be the same as the sender of the `payment` transaction."
                }
            ],
            "returns": {
                "type": "void"
            },
            "desc": "This method receives a payment from an account opted into this app and records it as a deposit.\nThe caller may opt into this app during this call."
        }
        ...
    ],
    "networks": {}
}
```

PyTEAL ABI - Calling an ARC4 Program (1/2)

ARC4 programs can be called *of-chain* with the **SDKs**

Atomic Transaction Composer is an SDK utility to construct transactions, transaction groups, and ABI method calls with the functions `addTransaction()` and `addMethodCall()`

We can also use the **goal CLI**

Bare calls can be invoked with either `goal app create` or `goal app <action>` commands, where actions are **optin**, **closeout**, **clear**, **update**, or **delete**.

Method calls can be triggered via the `goal app method` command

PyTEAL ABI - Calling an ARC4 Program (2/2)

ARC4 programs can be also called *on-chain* with a **contrat-to-contract call**

Inner transactions can invoke other applications' ABI methods using the **Inner Transaction Builder** utility with the **ExecuteMethodCall()** function

```
InnerTxnBuilder.ExecuteMethodCall(
    app_id=56,
    method_signature="add(uint64,uint64)uint128",
    args=[5, 8],
)
```

AlgoBank Demo!

AlgoBank is your first **ARC4 Program**.

It acts as a **escrow** for users' funds. It exposes three **ABI methods**

1. **deposit()**: Deposit some funds in the AlgoBank;
2. **getBalance()**: Retrieve the user's funds locked in;
3. **withdraw()**: Claim back funds from the deposit

Deployment environment:

- **Algorand Sandbox**: Dockerized private network!
- **DappFlow**: Algorand blockchain explorer

Algorand

Beaker

Algorand dApp Has Never Been Easier

Chris Kim
Developer Advocate at Algorand

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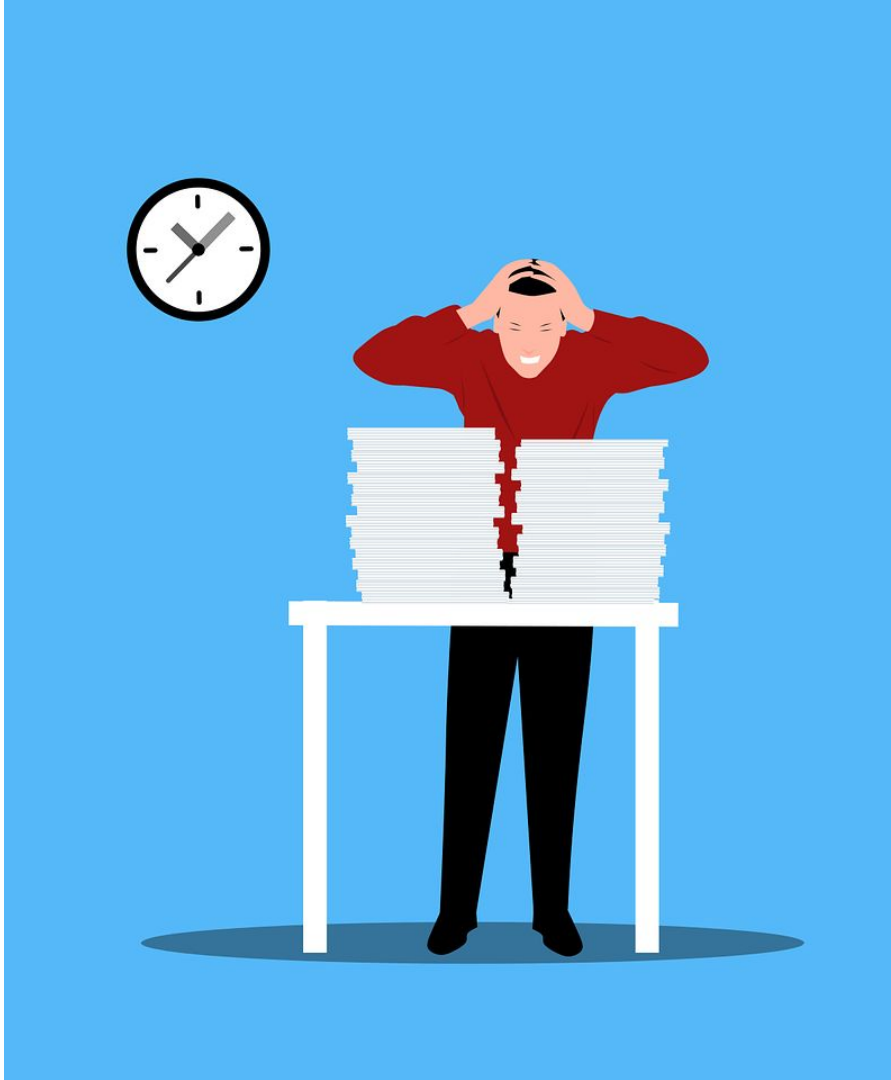
Algorand

PyTeal, SDK may feel...

- **Unfamiliar**
- **Complex**
- **Overwhelming**




UPGRADE

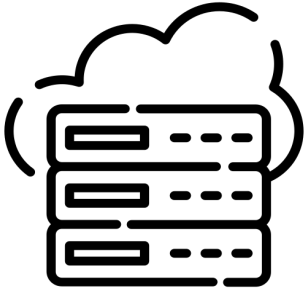
Algorand

Algorand dApp Architecture

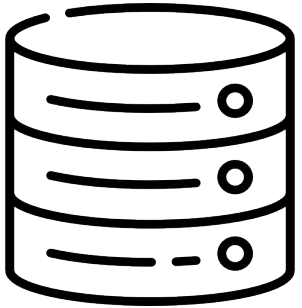
Web2 App Architecture

Frontend

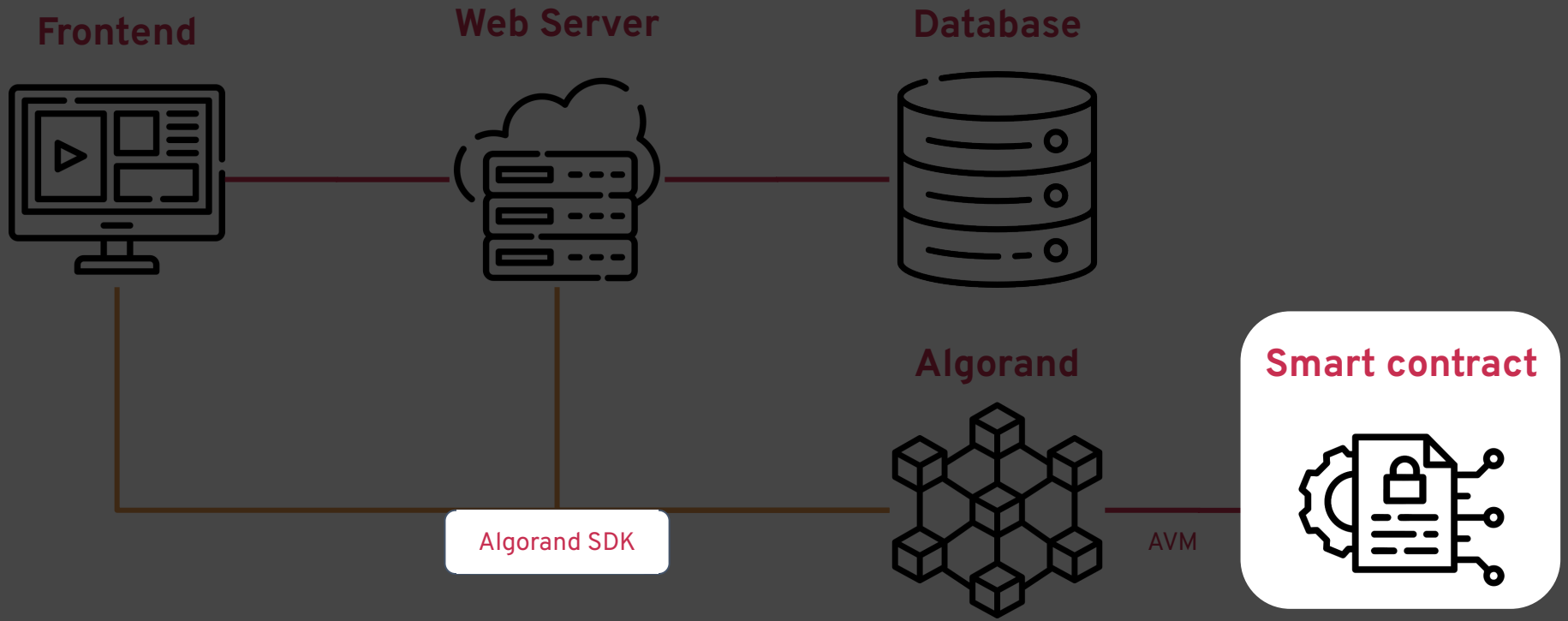
Web Server



Database



Algorand Dapp Architecture



Algorand

Introducing Beaker: The Way dApp development should be

Python smart contract framework

- Code Organization (**PyTeal**)
- Deploy/ Call (**Algorand SDK**)
- Debugging

In short, it handles all the **heavy lifting** for you

Algorand

Let’s see a direct comparison

Comparison Recap

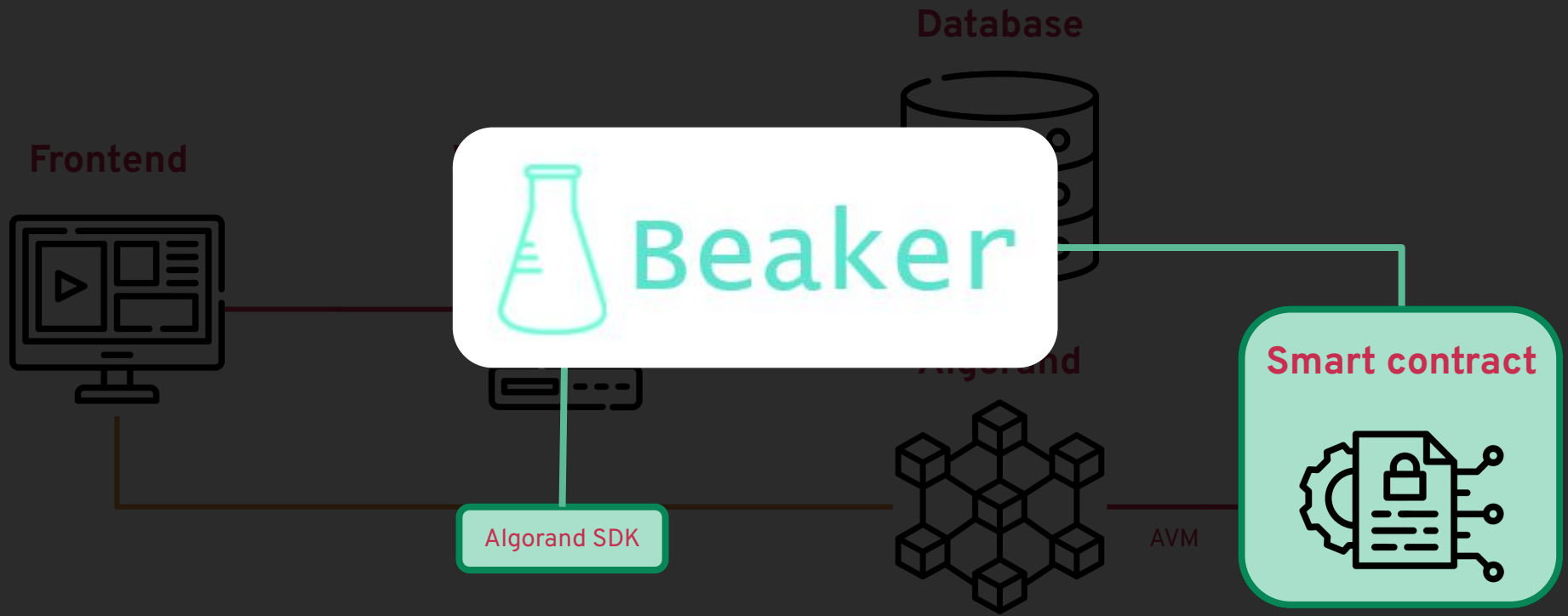
Bare Pyteal

- Smart contract code is **unfamiliar**
- Need to **manually** define helper functions
- Frontend setup is **lengthy**

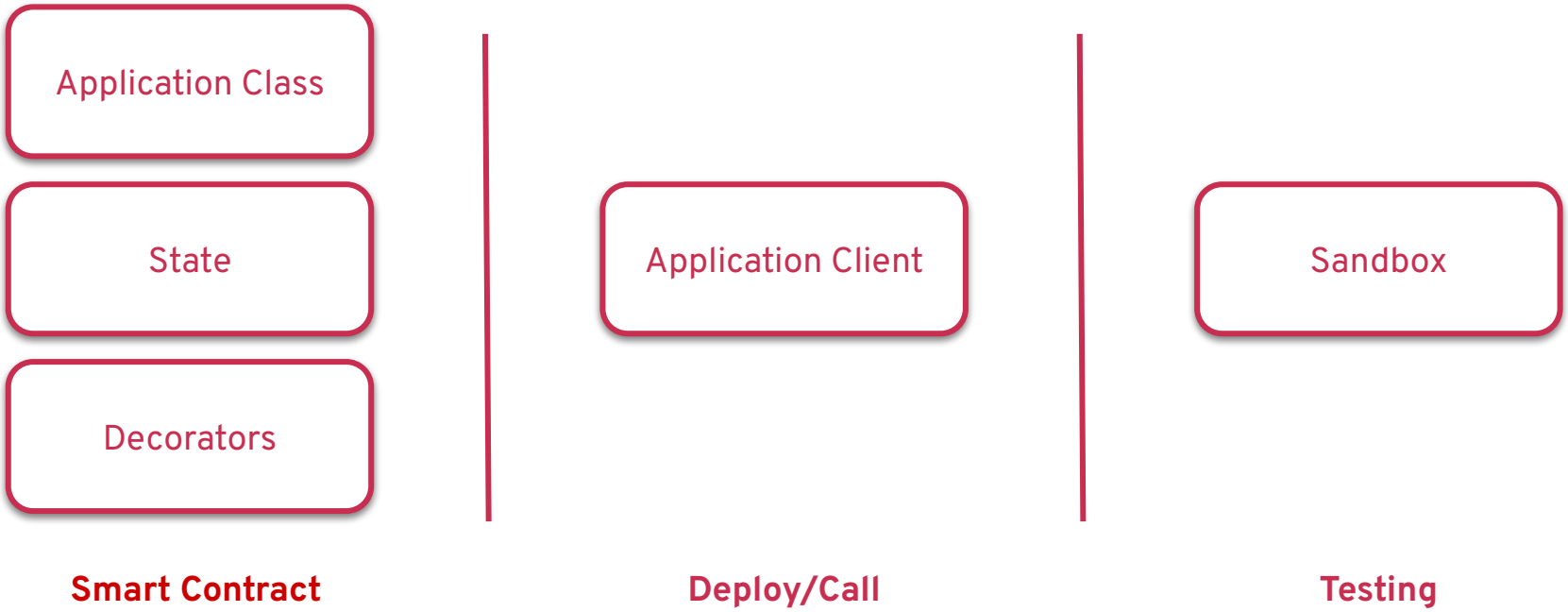
Beaker

- Smart Contract organization is **familiar**
- helper methods **defined** for you
- **Easier** to deploy/call contract

Algorand Dapp Architecture



Beaker Components



Algorand

Developer Environment Setup

Packages to Install

- **Sandbox**

```
git clone https://github.com/algorand/sandbox.git
```

- **Pyteal**

```
$ pip3 install pyteal
```

- **Python Algorand SDK**

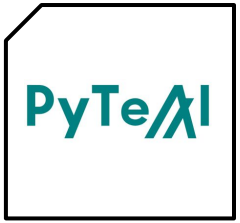
```
$ pip3 install py-algorand-sdk
```

- **Beaker**

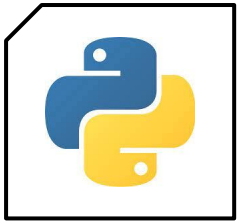
```
(.venv)$ pip install beaker-pyteal
```

Packages to Install

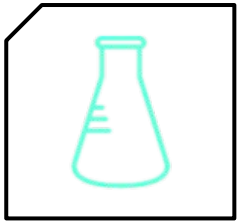
Sandbox



PyTeal



Python SDK



Beaker

Beaker Starter Kit

1. **Launch Sandbox / Git Clone**

```
./sandbox up dev
git clone [beaker-starter-kit url]
```

2. **Create Virtual Environment**

```
python3 venv venv
source ./venv/bin/activate
```

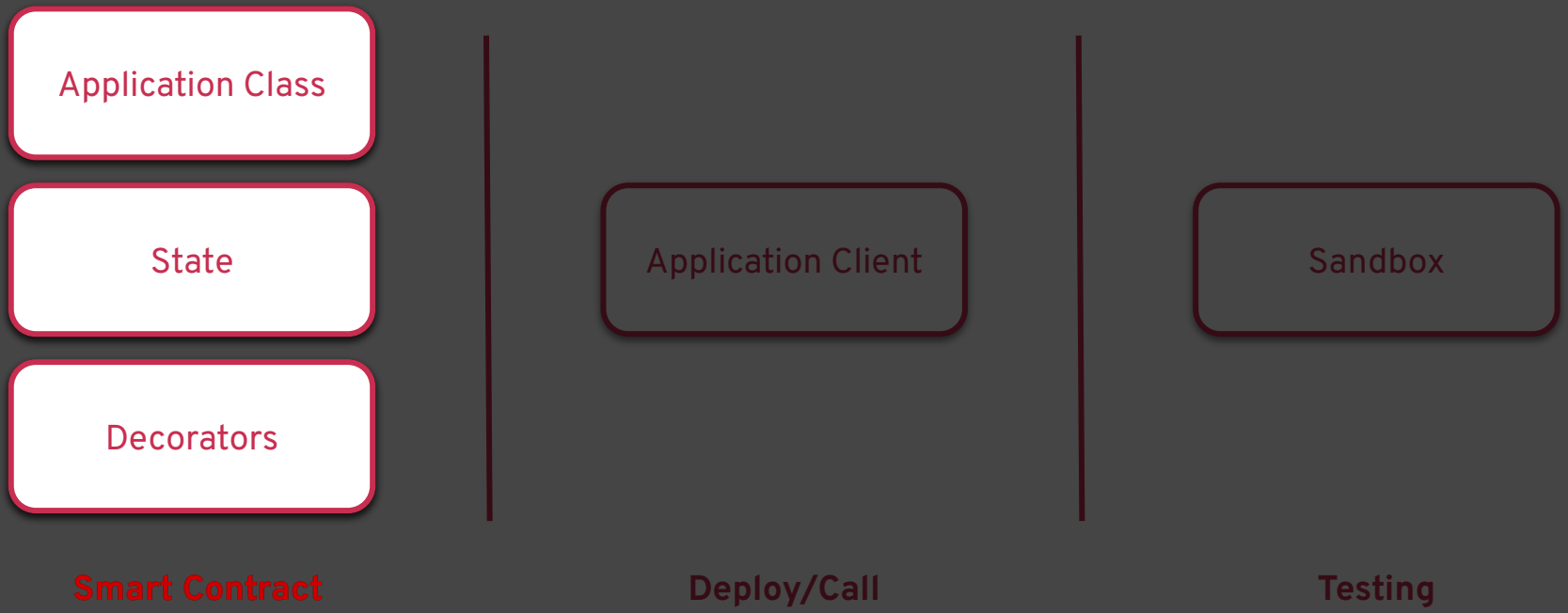
3. **install All Required Packages**

```
pip install -r requirements.txt
```

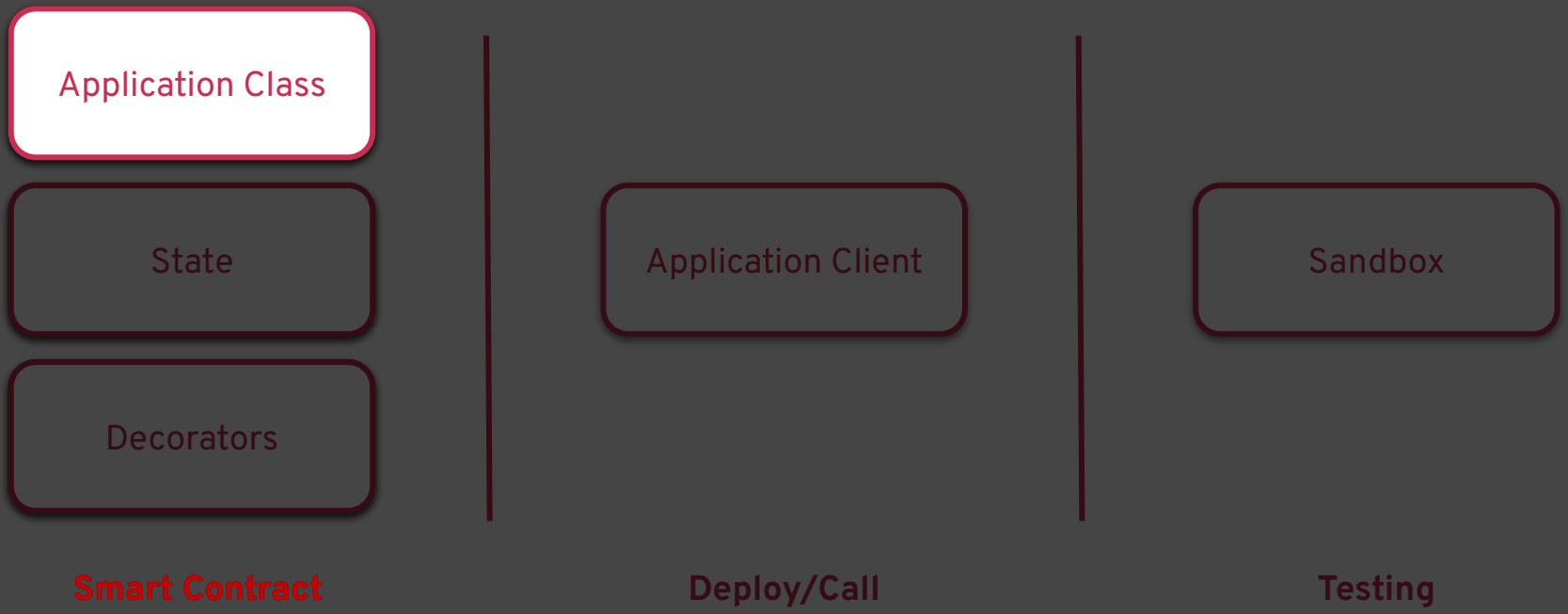
Algorand

Beaker: Smart Contract (PyTeal)

Beaker Components



Beaker Components



Class

Base class that all Beaker Applications should **inherit** from

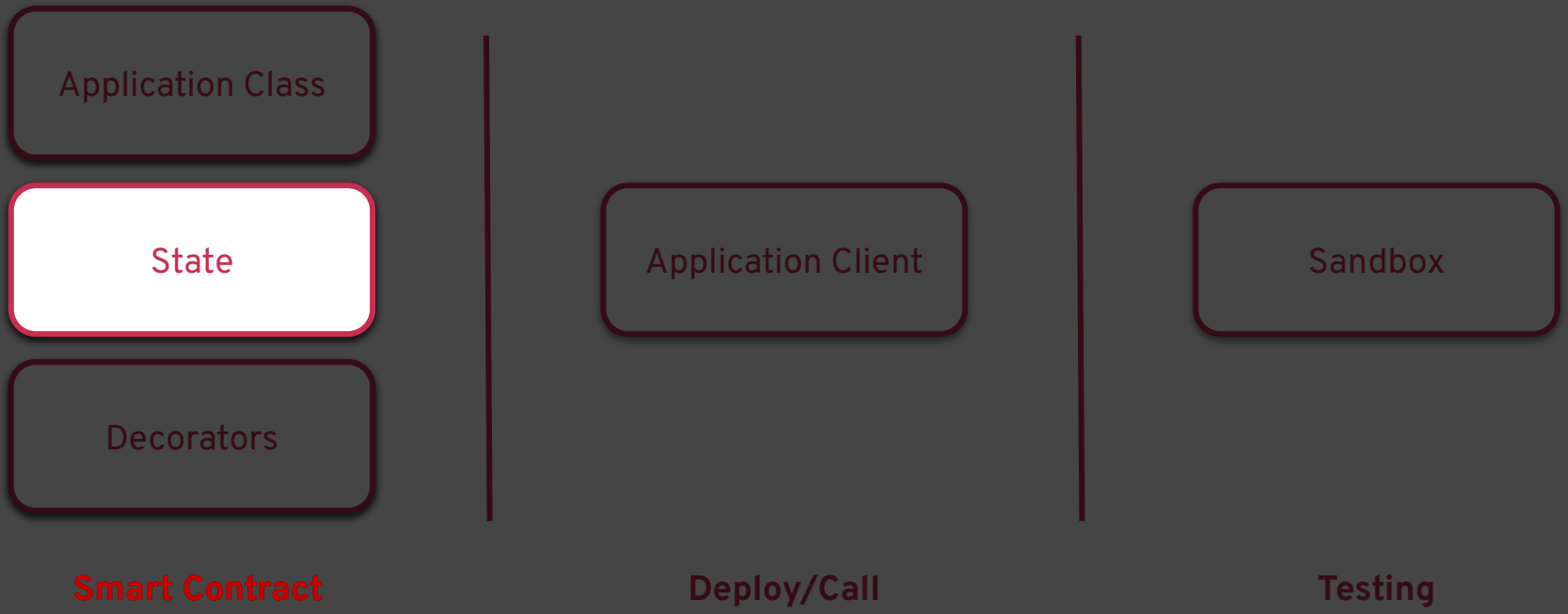
```
class Simple(Application):

    @external
    def hello(self, name: abi.Stri                ):
        # Set output to the result
        return output.set(Concat(B                ()))
```

Included logic

- Detect State Variables
- OnComplete methods
- ABI Methods
- internal subroutines

Abstraction = Simple Code

Beaker Components



Ap

Use Final typing construct that **prevents re-assigning** of the variable name as good practice

```
class StateExample(Ap

    ################
    # Application Sta
    ################

    declared_app_value: Final[ApplicationStateValue] = ApplicationStateValue(
        stack_type=TealType.bytes,
        default=Bytes(
            "This value is immutable!"
        ),
        static=True,
        descr="A static declared variable",
    )

    dynamic_app_value: Final[
        DynamicApplicationStateValue
    ] = DynamicApplicationStateValue(
        stack_type=TealType.uint64,
        max_keys=32,
        descr="A dictionary-like dynamic app state variable, with 32 possible keys",
    )
```

Specify state characteristics here:

- **stack_type**
- key (optional)
- default (optional)
- static (optional)
- descr (optional)

```
declared_app_value: Final[ApplicationStateValue] = ApplicationStateValue(
    stack_type=TealType.bytes,
    default=Bytes(
        "This value is immutable!"
    ),
    static=True,
    descr="A static declared variable",
)
```

ABI json File

```
"global": {
  "declared": {
    "declared_app_value": {
      "type": "bytes",
      "key": "declared_app_value",
      "descr": "A static declared variable"
    }
  },
```

Application(Global) State

Specify state characteristics here:

- **stack_type**
- **max_keys**
- key_gen (optional)
- descr (optional)

ABI json File

```
"dynamic": {
  "dynamic_app_value": {
    "type": "uint64",
    "max_keys": 32,
    "descr": "A dictionary-like dynamic app state variable, with 32 possible keys"
  }
}
```

```
dynamic_app_value: Final[
    DynamicApplicationStateValue
] = DynamicApplicationStateValue(
    stack_type=TealType.uint64,
    max_keys=32,
    descr="A dictionary-like dynamic app state variable, with 32 possible keys",
)
```

Specify state characteristics here:

- **stack_type**
- key (optional)
- default (optional)
- static (optional)
- descr (optional)

```
class StateExample(Applic

    ################
    # Account States
    ################

    declared_account_value: Final[AccountStateValue] = AccountStateValue(
        stack_type=TealType.uint64,
        default=Int(1),
        descr="Account state storing integer values",
    )

    dynamic_account_value: Final[DynamicAccountStateValue] = DynamicAccountStateValue(
        stack_type=TealType.bytes,
        max_keys=8,
        descr="A dynamic state value, allowing 8 keys to be reserved, in this case byte type",
    )
```

Account(Local) State

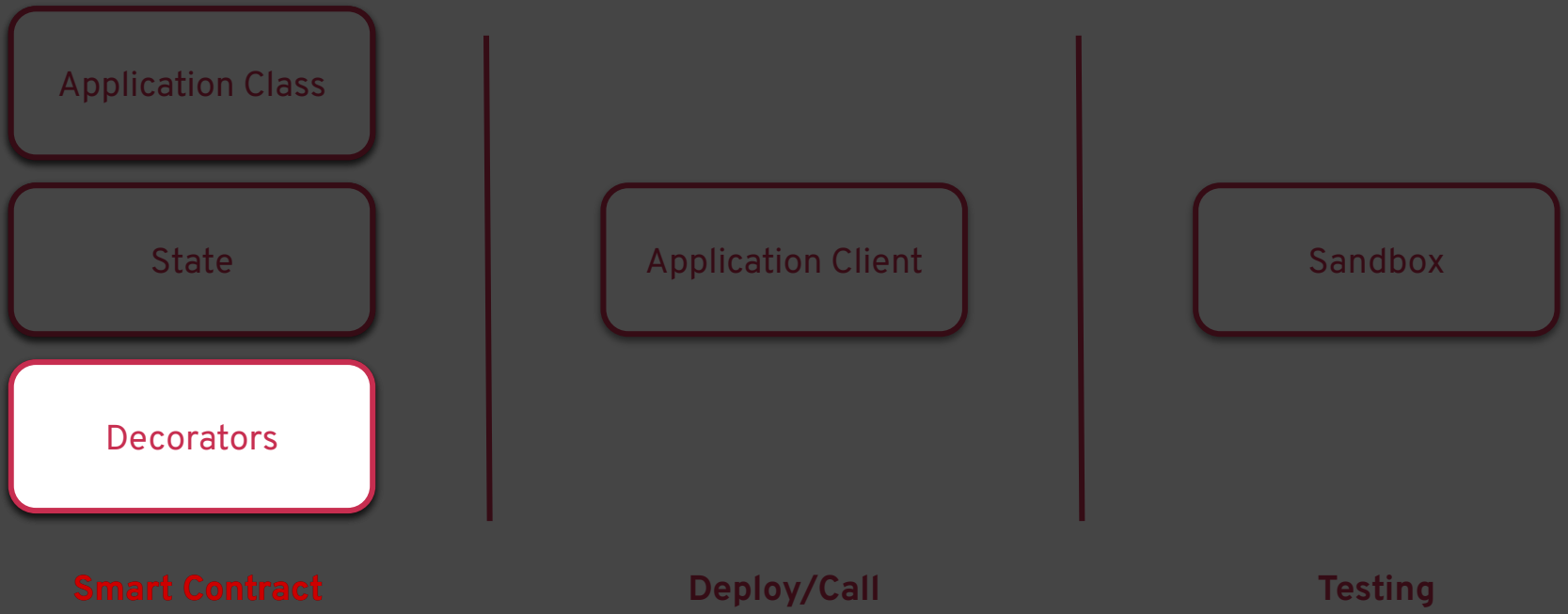
```
class StateExample(Application):

    ################
    # Account States
    ################

    declared_account_valu                                    alue(
        stack_type=TealTy
        default=Int(1),
        descr="Account st
    )
```

Specify state characteristics here:

- **stack_type**
- **max_keys**
- key_gen (optional)
- descr (optional)

```
dynamic_account_value: Final[DynamicAccountStateValue] = DynamicAccountStateValue(
    stack_type=TealType.bytes,
    max_keys=8,
    descr="A dynamic state value, allowing 8 keys to be reserved, in this case byte type",
)
```

Beaker Components



Decorators

@external

- expose methods as ABI methods
- automatically add the method to router

@internal

- Used internally in the contract
- Can access state variables

OnComplete externals

- create
- opt_in
- delete
- update
- clear_state
- close_out

Support **Authorization** to only allow certain accounts to execute the method

Decorators: @external

- expose methods as ABI methods
- automatically add the method to router

```
@external
def add(self, a: abi.Uint64, b: abi.Uint64, *, output: abi.Uint64):
    return output.set(a.get() + b.get())
```

Decorators: @internal

```python
@external
def add_with_internal(self, a: abi.Uint64, b: abi.Uint64, *, output: abi.Uint64):
    return output.set(self.internal_add(a, b))
```

```python
@internal(TealType.uint64)
def internal_add(self, a: abi.Uint64, b: abi.Uint64):
    return a.get() + b.get()
```

- returns Tealtype uint64
- Not exposed to ABI

Decorators: @internal

```python
@external
def add_with_internal(self, a: abi.Uint64, b: abi.Uint64, *, output: abi.Uint64):
    return output.set(self.internal_add(a, b))
```

```python
@internal(TealType.uint64)
def internal_add(self
    return a.get() +
```

- Access internal methods like this
- useful for repeated complex computation

Decorators: OnComplete Externals

```
@create
def create(self):
    return Approv

@delete(authorize                    reator_address()))
def delete(self):
    return Approv
```

Available OnComplete Externals

- create
- opt_in
- delete
- update
- clear_state
- close_out

Decorators: Bare Externals

```
@create
def create(self):
    return Approve()

@delete(authorize=Authorize.only(Global.creator_address()))
def delete(self):
    return Approv
```

- **Only creator** of the contract can call this method
- Authorize accounts that **hold certain tokens**
- Authorize account **opted in**

Smart Contract Recap

Application Class

- **Base class** that Beaker Apps **inherit** from
- Provide Basic functionalities

State

- Application = Global
- Account = Local
- Exposed to ABI

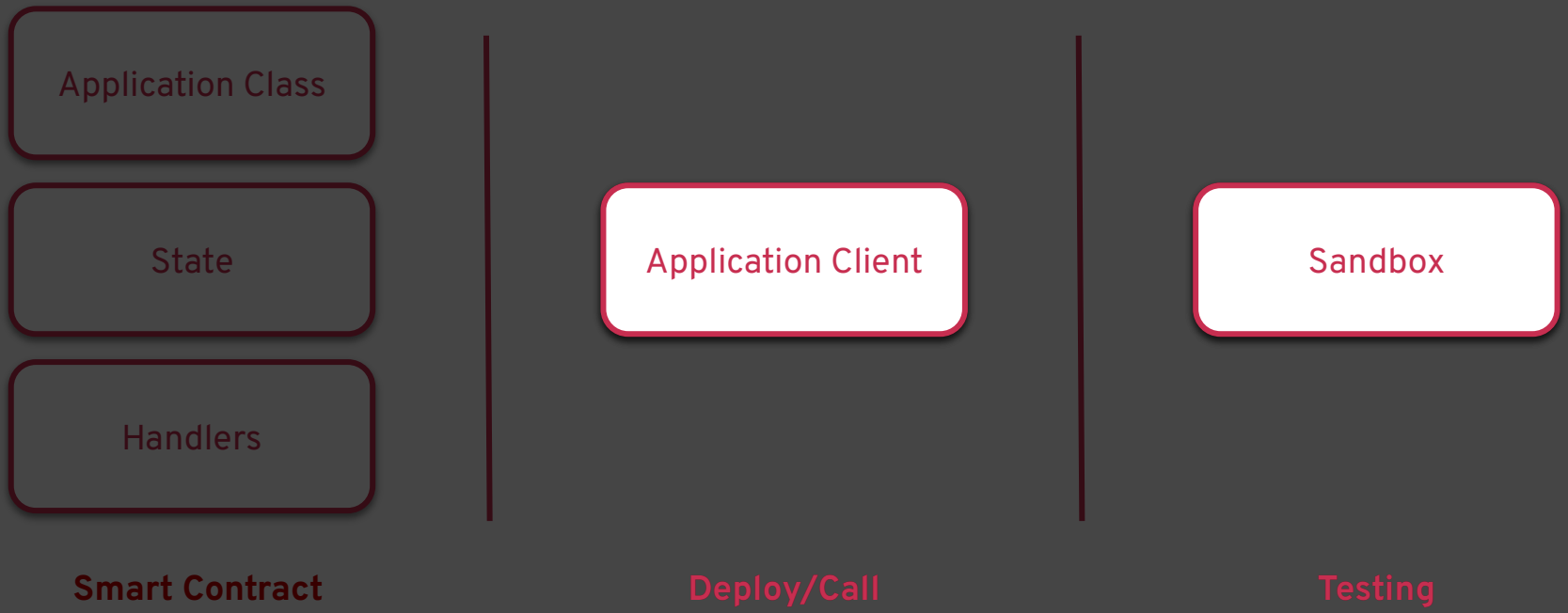
Decorators

- @external
- @internal
- OnComplete Externals
- Authorization

Algorand

Beaker: Deploy / Call Smart Contract

Beaker components



Sandbox

```
from beaker import sandbox

# get_accounts method gives the list of sandboxAccount objects
accts = sandbox.get_accounts()
print(*accts, sep = "\n\n")
```

```
SandboxAccount(address='BIPWSF5UMY5SB2EAML63HV4B2CDUWH7FJDKVTN7DHY2KF5DFPOTBMKZ7MQ', private_key='zMPs3ZEnSiSrlzAdcXATlgY4fOb7Y1cqmD3nQ4+KQvMKH2kXtGY7IOiAYv2z14HQh0sf5UjVWbfjPjSi9GV7pg==', signer=<algosdk.atomic_transaction_composer.AccountTransactionSigner object at 0x10286af20>)

SandboxAccount(address='QY5G6R7U7ZGO5U266XN6QX62DW6D2FVHGZ7EYNZSBH45TXPLQGSU5X45PY', private_key='3TajNhMFn2u5SnG7M6lJIK4+6QLI1Zgic8tYlVtwNj6GOm9H9P5M7tNe9dvoX9odvD0WpzZ+TDcyCfnZ3euBpQ==', signer=<algosdk.atomic_transaction_composer.AccountTransactionSigner object at 0x10289c430>)

SandboxAccount(address='2ZRGL3TOGXZTQLDH4WI35S6AFA6SOIEKZZENIZOWRSBCBAEMSHBRIBTWSM', private_key='AtZNP0JQ1SVDoBzrH24AbTV+mBzmAjcM7zmkWgxRO7zWYmXubjXzOCxn5ZG+y8AoPScgis5I1GXWjIIggIyRww==', signer=<algosdk.atomic_transaction_composer.AccountTransactionSigner object at 0x10289c550>)
```

```
# detecting your sandbox configuration
client = sandbox.get_algod_client()
sp = client.suggested_params()
print(f"suggested fee is {sp.min_fee} microAlgos")
```

Algorand

Sandbox

```
from beaker import sandbox

# get_accounts method gives the list of sandboxAccount objects
accts = sandbox.get_accounts()
print(*accts, sep = "\n\n")
```

```
# sandboxAccount objects
acct1 = accts.pop()
print(f"acct1 address is {acct1.address}")
print(f"acct1 private key is {acct1.private_key}")
print(f"acct1 signer is {acct1.signer}\n")
```

```
acct1 address is 35STM6MN67Q5PQNISP624JYCZHMGOHL7QF7ZB3QH3RFZQ6RXOQRHWPXDBU
acct1 private key is XGpqaRSxLY4jlTalKIqDqxO09al1vxaRwSAst0TNt7vfZTZ5jffh18Gok/2uJwLJ2Gcdf4F/kO4H3EuYejd0Ig==
acct1 signer is <algosdk.atomic_transaction_composer.AccountTransactionSigner object at 0x1036c8640>
```

```
client = sandbox.get_algod_client()
sp = client.suggested_params()
print(f"suggested fee is {sp.min_fee} microAlgos")
```

Sandbox

```
from beaker import sandbox

# get_accounts method gives the list of sandboxAccount objects
accts = sandbox.get_accounts()
print(*accts, sep = "\n\n")

# sandboxAccount objects
acct1 = accts.pop()
print(f"acct1 address is {acct1.address}")
print(f"acct1 private key is {acct1.private_key}")
print(f"acct1 signer is {acct1.signer}\n")
```

```
# get_algod_client creates a client object by automatically
# detecting your sandbox configuration
client = sandbox.get_algod_client()
sp = client.suggested_params()
print(f"suggested fee is {sp.min_fee} microAlgos")
```

```
suggested fee is 1000 microAlgos
```

Algorand

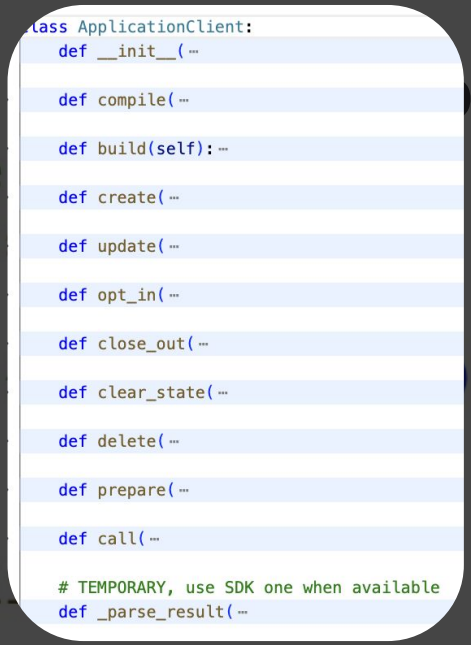
Application Client

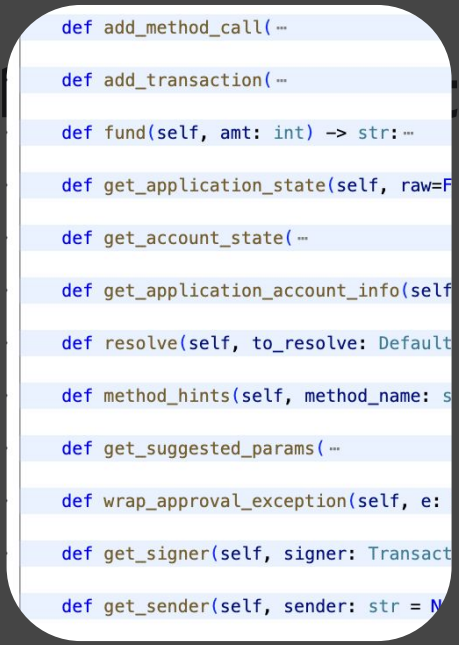
```
# Set up accounts we'll use
accts = sandbox.get_accounts()
acct1 = accts.pop()
print(f"account 1 address: {acct1.address}")

# Set up Algod Client
client=sandbox.get_algod_client()
```

```
# Create Application client
app_client1 = ApplicationClient(
    client, app=ClientExample(), signer=acct1.signer
)
```

Saving 750 lines of code!

Convenient way to interact with your smart contract






```
# Create Application client
app_client1 = ApplicationClient(
    client, app=ClientExample(), signer=acct1.signer
)
```

Algorand

Application Client

```python
# Create the app on-chain (uses signer1)
app_client1.create()
print(f"Current app state: {app_client1.get_application_state()}\n")

# Fund the app account with 1 algo
app_client1.fund(1 * consts.algo)

# Opt in to contract
app_client1.opt_in()

# Set nickname of acct1
app_client1.call(ClientExample.set_nick, nick="first")
print("account 1 local state:")
print(app_client1.get_account_state(), "\n")

# Show application account information
print("application acct info:")
app_acct_info = json.dumps(app_client1.get_application_account_info(), indent=4)
print(app_acct_info)

# Close out from contract
app_client1.close_out()

# Delete the contract
app_client1.delete()
```

No more manually

- **creating** transaction
- **signing** transaction
- **submitting** transaction
- **waiting for confirmation**

Application client handles it for you

Recap

Sandbox

Easily set up **testing** with helper methods that:

- create algod **client**
- get list of sandbox **accounts**
- and more

Application Client

Provides over 20 helper methods you can leverage to easily **deploy / call** your smart contract

Complete RSVP App

- Create RSVP Event
- Guest RSVP
- Guest Check in
- Guest Refund
- Funds Withdrawal
- Event Delete

RSVP Features

Algorand

What Did We Learn Today?

- Algorand dApp Architecture
- What Beaker is
- Complete RSVP Example

Beaker is Amazing

Algodevs Resources

FOLLOW ME!

Algorand

Algorand

Thanks to the contributors!

- Cosimo Bassi
- Jason Paulos
- Pietro Grassano
- Matteo Almanza
- Stefano De Angelis
- Chris Kim