ZILLIQA:
A TALE OF SHARDING

THROUGHPUT
OF BLOCKCHAINS

BITCOIN
7 TX/S

THROUGHPUT

OF PAYMENT SYSTEMS

VISA

8000 TX/S

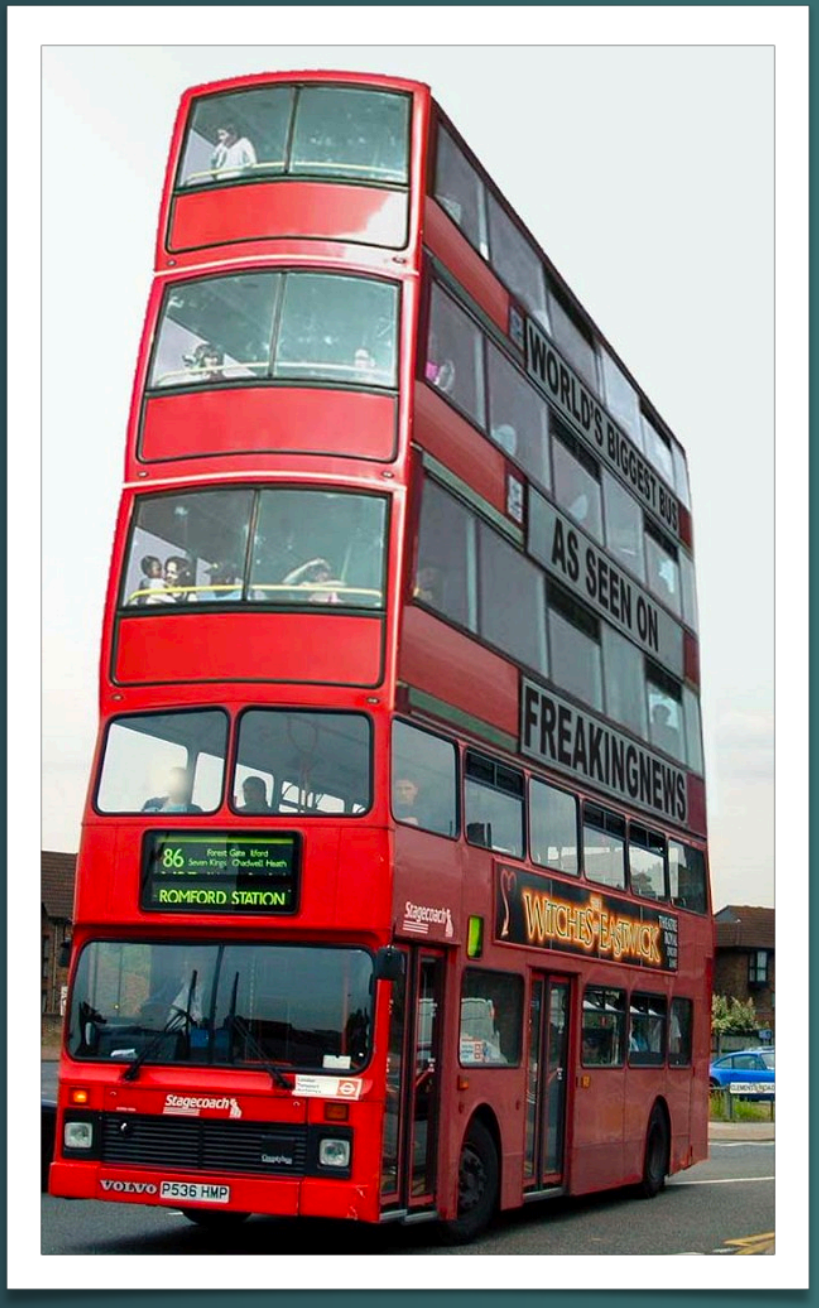
CONGESTION & HIGH GAS

~US$50 Gas Fee

With CryptoKitties

LARGER BLOCKS

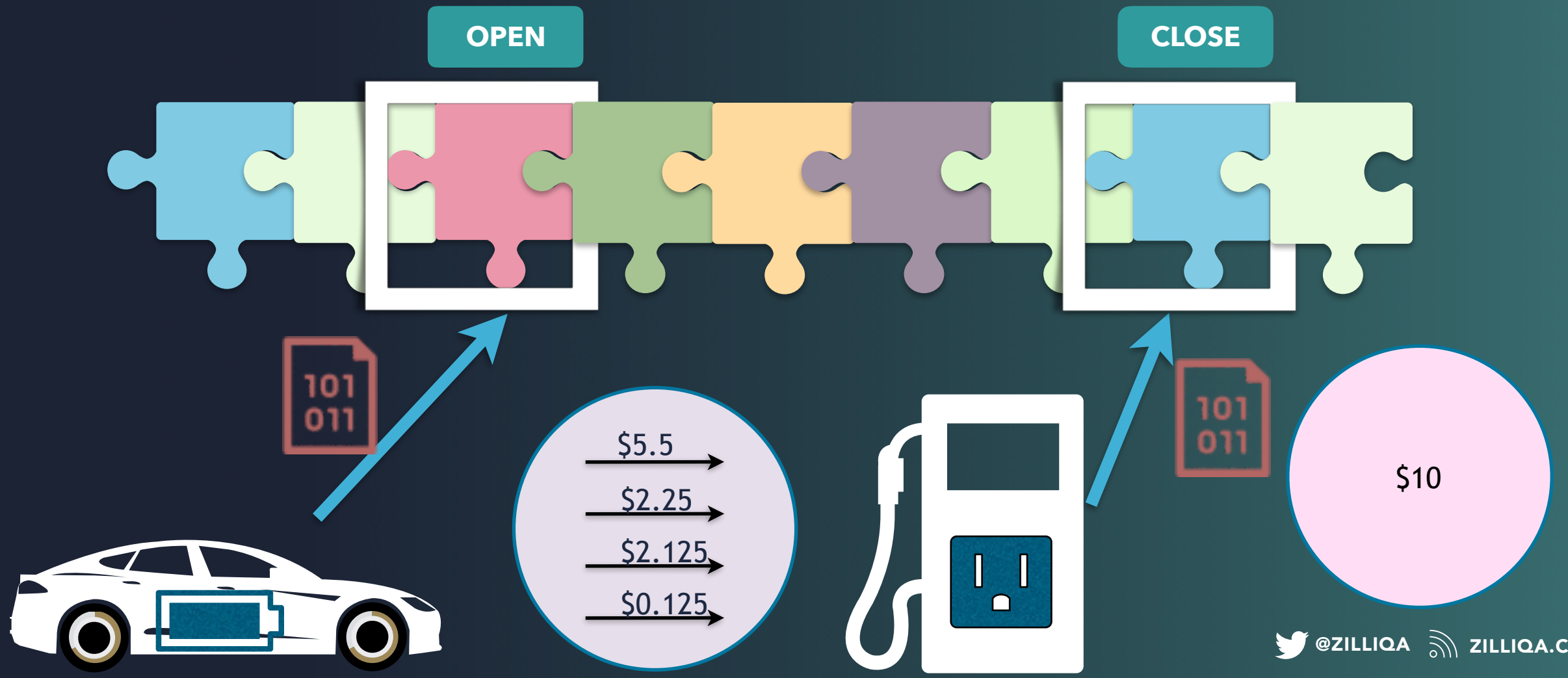
Not a 100x Scaling Factor



DELEGATED CONSENSUS

OFFCHAIN SOLUTIONS

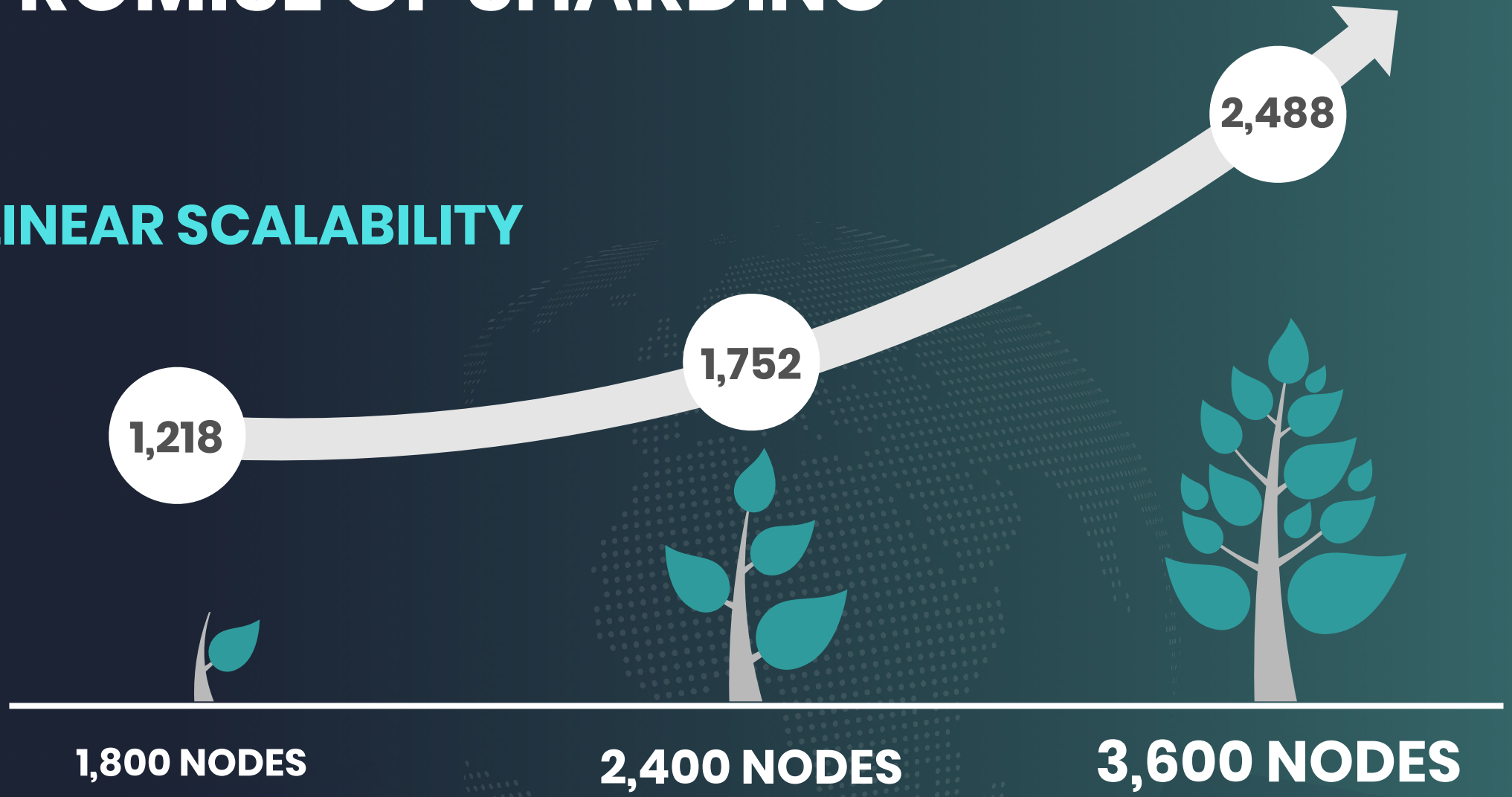
Complementary to onchain scalability



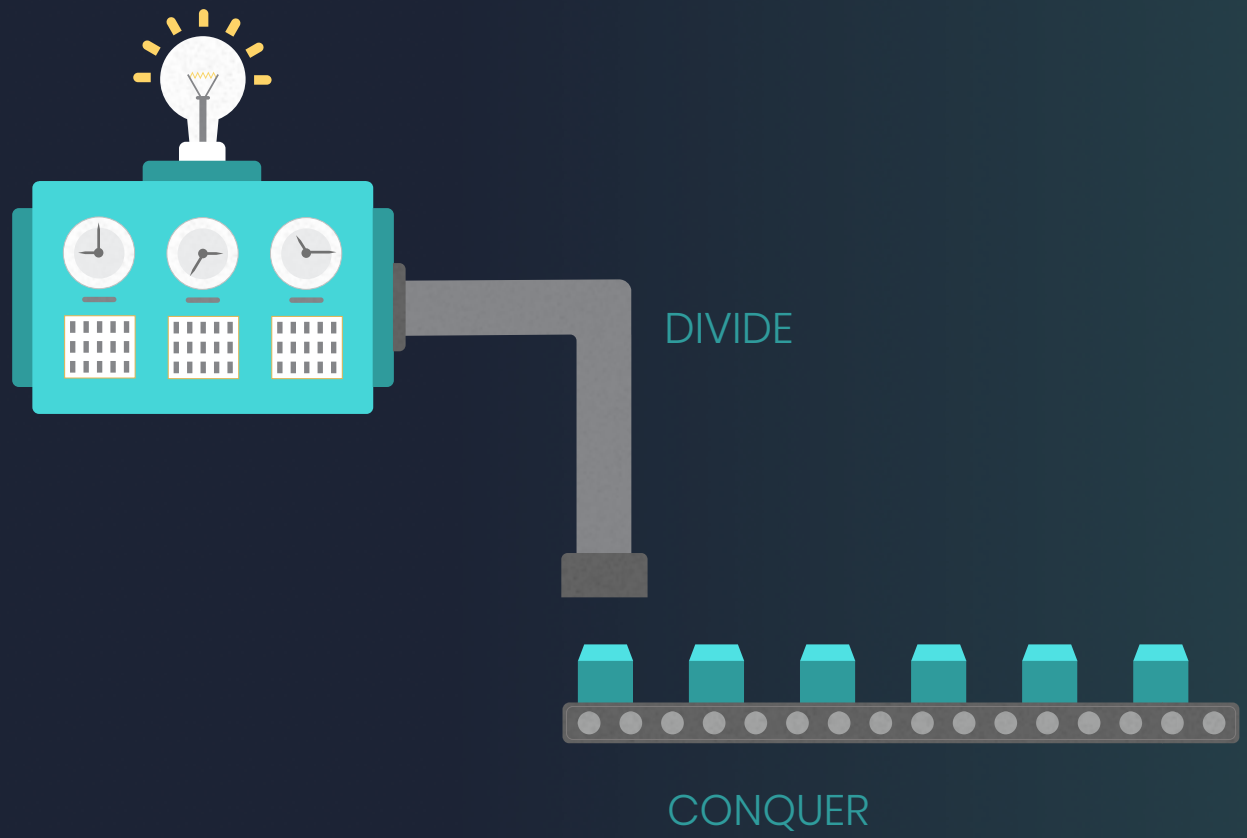
TOWARDS GREATER SCALABILITY

PROMISE OF SHARDING

LINEAR SCALABILITY



CHALLENGES OF SHARDING



Uncompromised ***security***

Strong ***decentralization***

Efficient ***contract*** execution

NETWORK SHARDING

Sybil defense

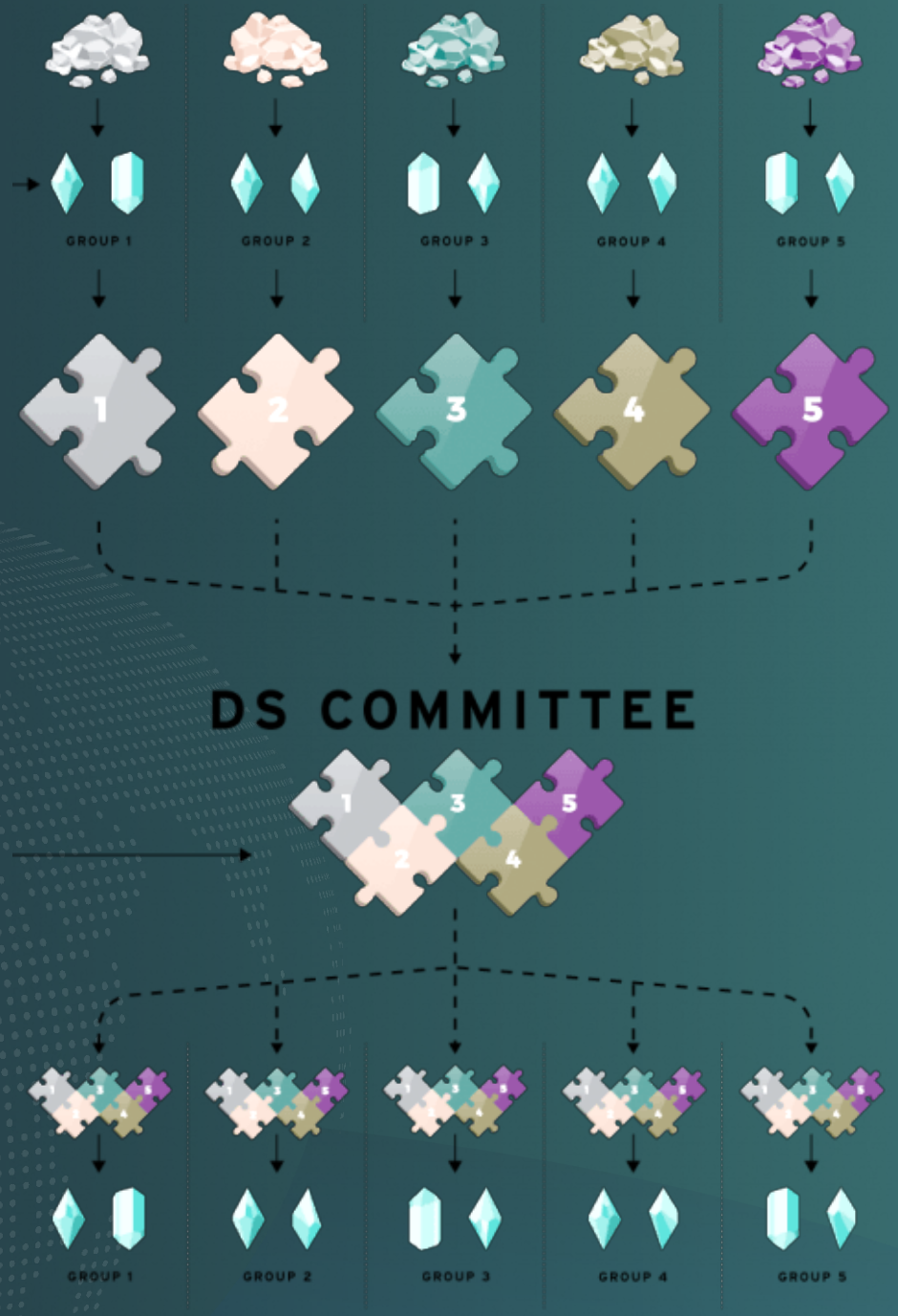
Preventing flooding of malicious nodes

POW

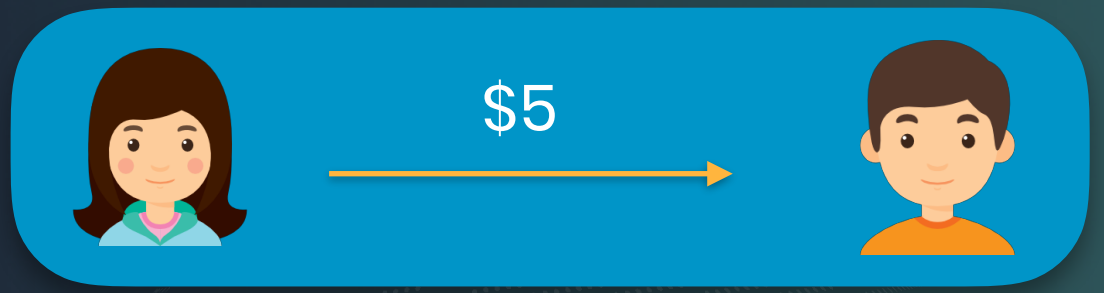
RANDOM SAMPLING

600-node consensus

Secure & decentralized decision making



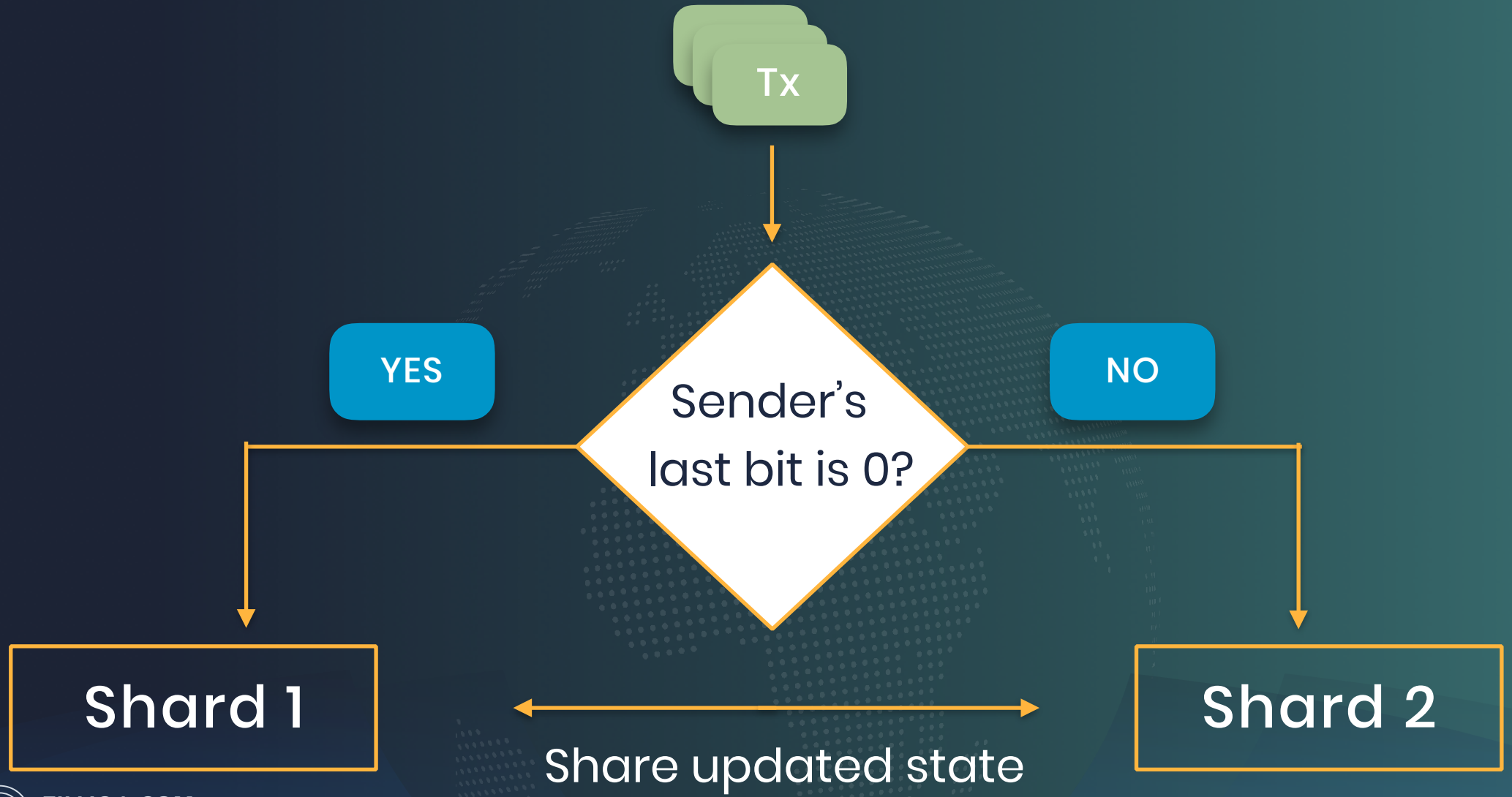
WHAT GOES TO WHICH SHARD?



Shard 1

Shard 2

PAYMENTS WITH SHARDING



DOUBLE SPENDS?

Shard 1

Shard 2

(CONTRACT) STATE MATTERS

REGULAR PAYMENTS

- Only **sender's and recipient's states** are affected.
- Only the **sender can change the states**.

vs

CONTRACT EXECUTION

- Potentially **any account's state** can be affected.
- Potentially **any account can change the state**.

CHALLENGES FROM CONTRACTS

buy_last_token()

TX1

TX2

buy_last_token()

YES

NO

Who gets the last token?

Sold to Alice

Sold to Bob

Shard 1

Shard 2

ONE SOLUTION

State Locking using 2PC

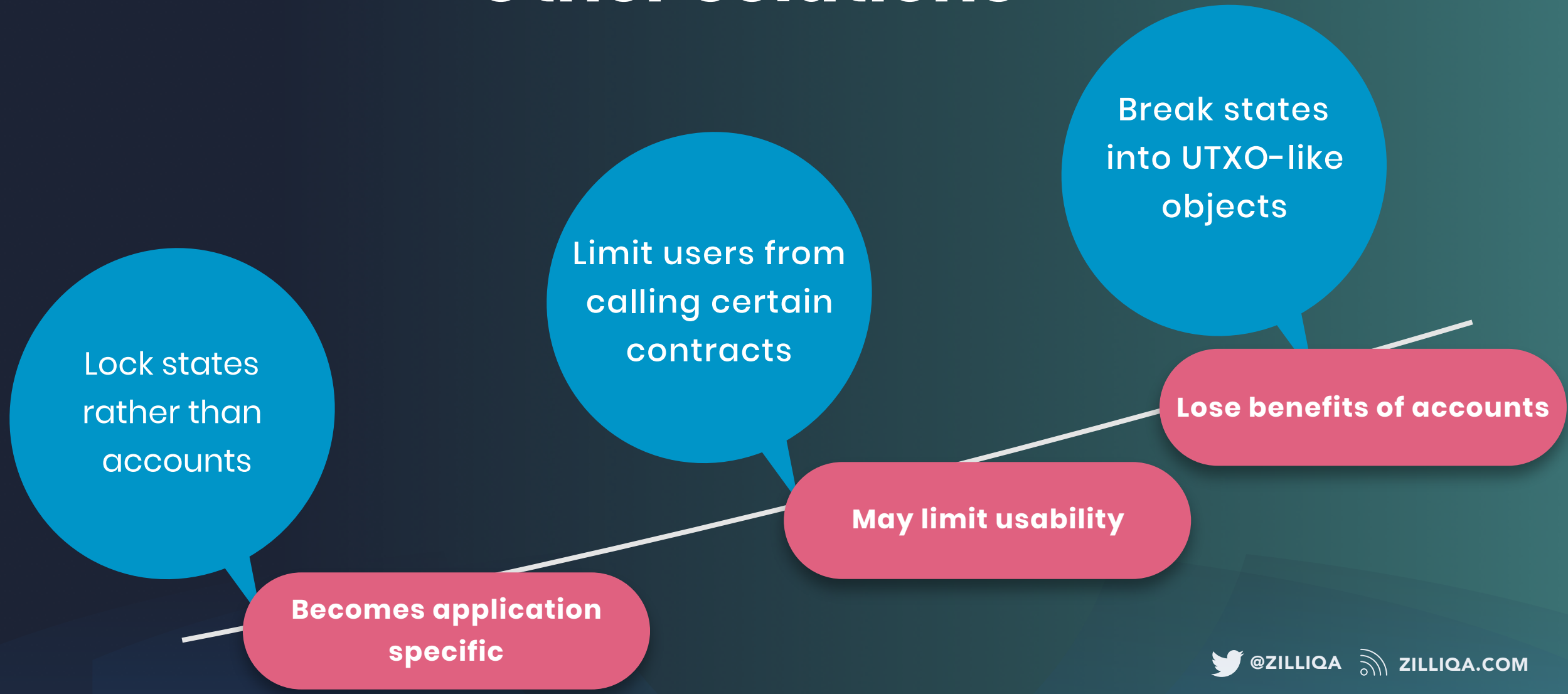
Account Locking limits parallel processing

concurrent changes

Shard 1

Shard 2

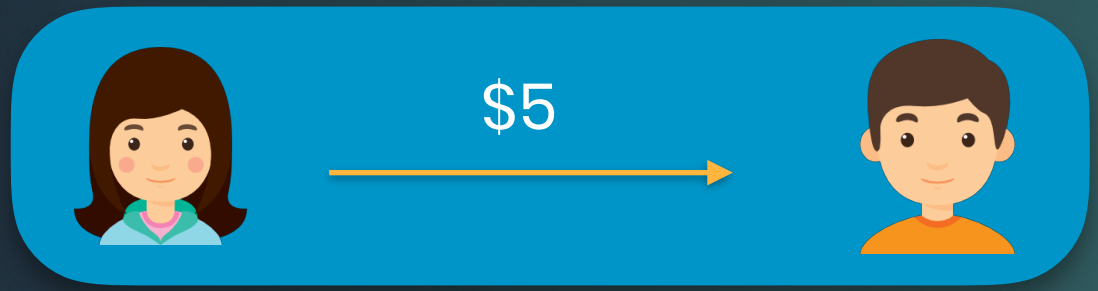
Improved Locking and Other Solutions



CONFLICT RESOLUTION *via* DETERMINISTIC TX ASSIGNMENT

TRANSACTION TYPES

Type I



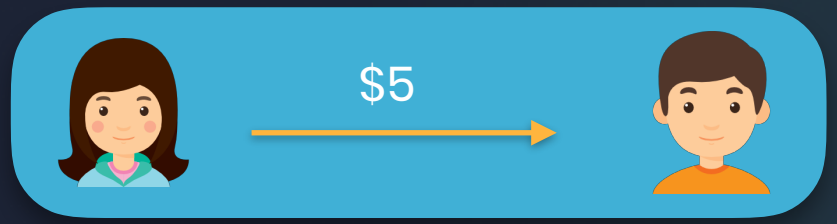
Type II

Type III

TRANSACTION PROCESSING

SHARDING TX & CONTRACTS

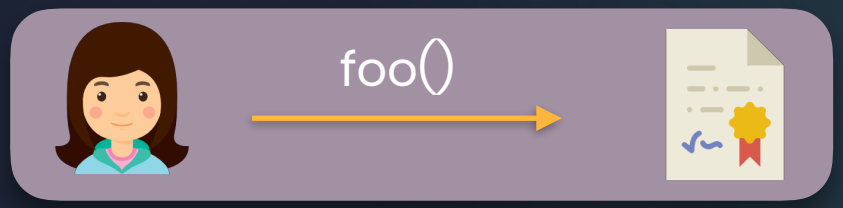
Type I



FROM 0X...0

FROM 0X...1

Type II



FROM & TO 0X...0

FROM & TO 0X...1

Type III

OTHERS

Shard 1

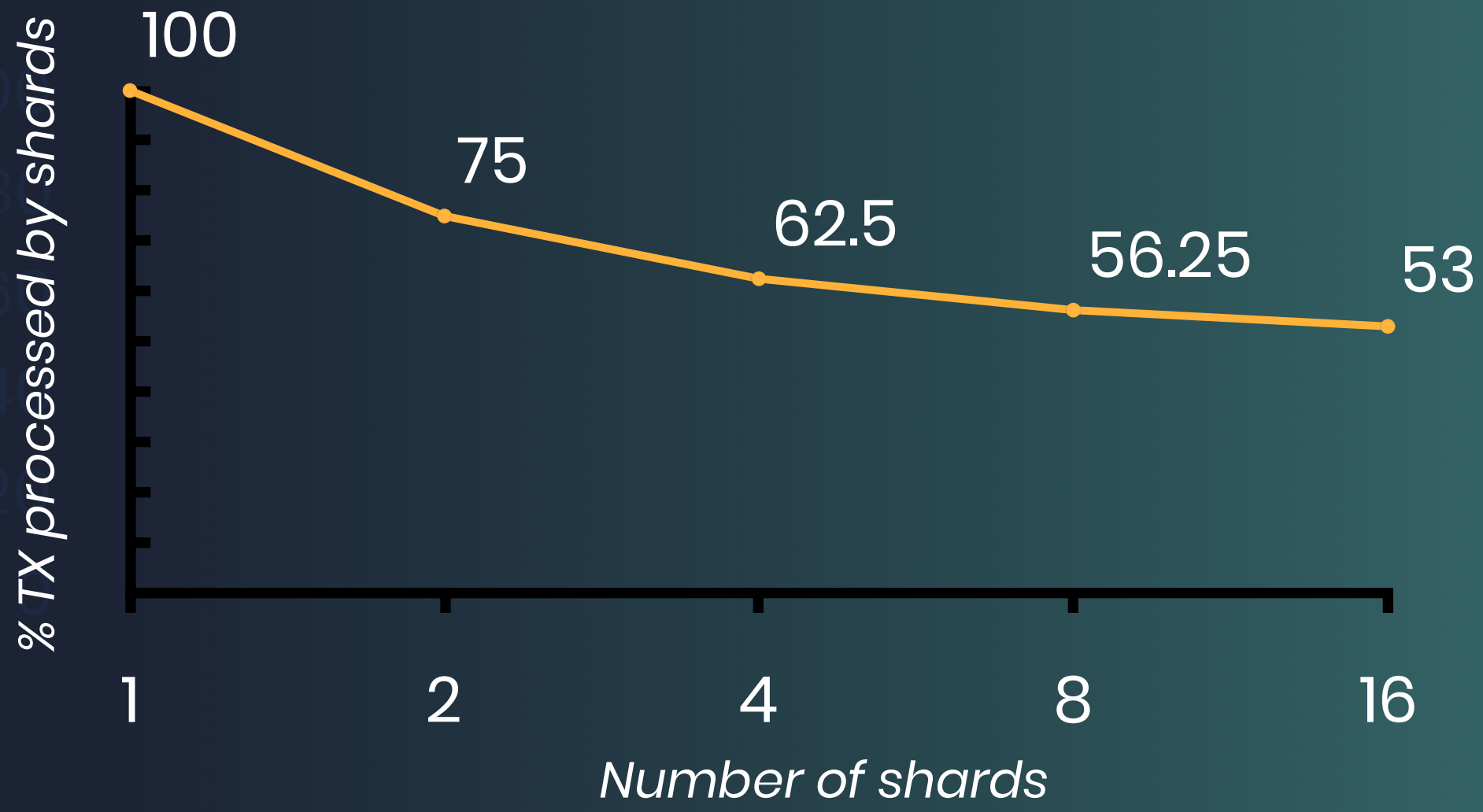
Shard 2

DS Committee

Example

Sender \ Recipient	U1(0)	U2(0)	U3 (1)	U4(1)	C1(0)	C2(0)	C3(1)	C4(1)
U1(0)	S1	S1	S1	S1	S1	S1	DS	DS
U2(0)	S1	S1	S1	S1	S1	S1	DS	DS
U3(1)	S2	S2	S2	S2	DS	DS	S2	S2
U4(1)	S2	S2	S2	S2	DS	DS	S2	S2

TX PROCESSED BY SHARDS



FUTURE WORK

Optimisations for Type II & III

Language support for greater parallelism

Client support for better efficiency

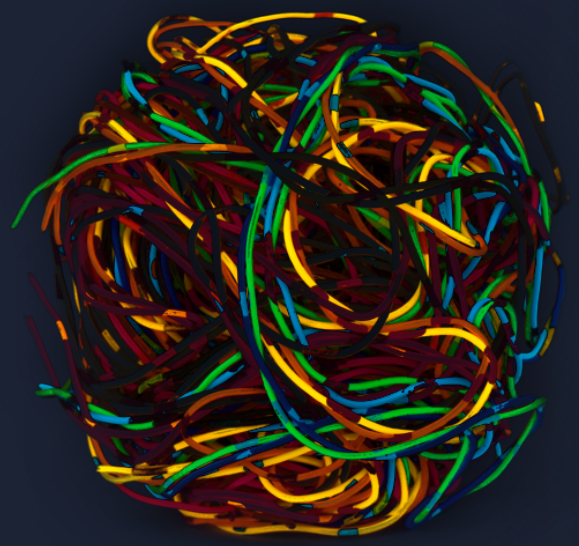
SCILLA

INCIDENTS WITH SMART CONTRACTS

$60 MIL
STOLEN

$300 MIL
FROZEN

UNDERLYING CAUSES



COMPLEXITY

EXPECTED VS
UNEXPECTED BEHAVIOR

NO FORMAL
VERIFICATION

SCILLA

SMART CONTRACTS ON ZILLIQA

NON-TURING COMPLETE

DECIDABLE CONTRACTS

AMENABLE TO FORMAL VERIFICATION

CLEAN SEPARATION: COMMUNICATION VS COMPUTATION

KICKSTARTER IN SCILLA

IMMUTABLE PARAMS

```
contract Crowdfunding
         (owner    : ByStr20,
          deadline : BNum,
          goal     : Uint128)
```

MUTABLE STATE

```
field backers : Map Address ⇒ Uint128 = Emp
field success : Bool = False
```

STATE TRANSITIONS

```
transition Donate ()
```

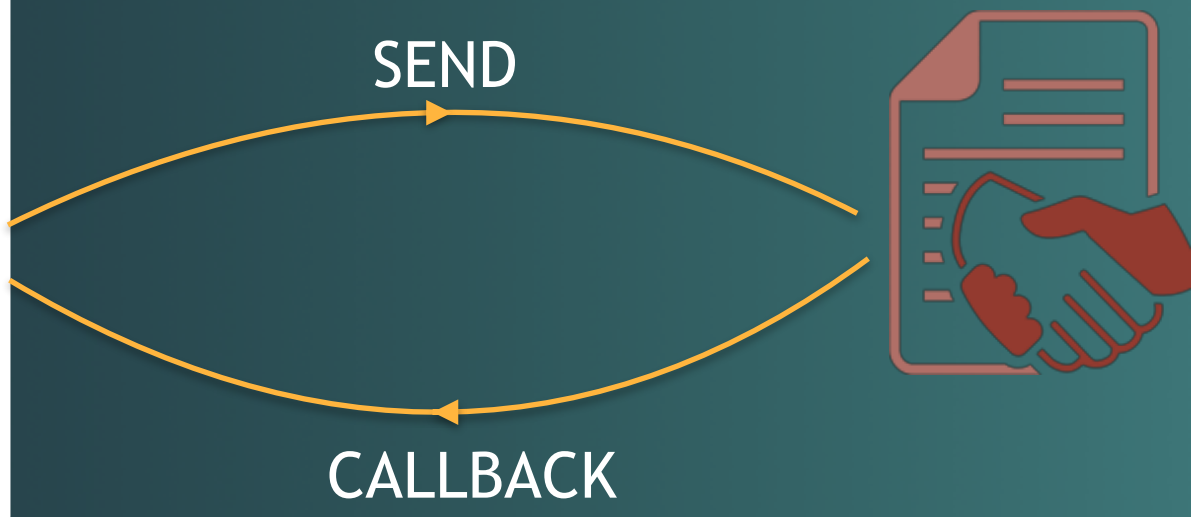
```
transition GetFunds ()
```

```
transition ClaimBack ()
```

DAO INCIDENT

SOLIDITY

```
function reclaim
{
    uint amount = contributors[msg.sender]
    if(msg.sender.call.value(amount) == false)
        throw
    // reset the amount for sender
    contributors[msg.sender] = 0;
}
```



INSTRUCTION NEVER EXECUTED

PREVENTING DAO INCIDENT

SECURITY RECOMMENDATION

```
// THIS CONTRACT HAS A BUG, DO NOT USE
function reclaim
{
    uint amount = contributors[msg.sender];
    if(msg.sender.call.value(amount) == false)
        throw
    // reset the amount for sender
    contributors[msg.sender] = 0;
}
```

```
// SAFE TO USE

function reclaim
{
    uint amount = contributors[msg.sender];
    contributors[msg.sender] = 0;
    msg.sender.transfer(amount);
}
```

CHECK-EFFECTS-INTERACTIONS

PREVENTING DAO INCIDENT

AT THE LANGUAGE LEVEL

SOLIDITY

```
// SAFE TO USE

function reclaim
{
    uint amount = contributors[msg.sender];
    contributors[msg.sender] = 0;
    msg.sender.transfer(amount);
}
```

SCILLA

```
transition Reclaim
        // Check if the sender is eligible to
        reclaim
    if ( … )
        send (<to → sender, amount → 0,
              tag  → “main", msg → "failure">)
    else
        // remove sender from the list
        let v = get(contributors, sender) in
        contributors := remove(contributors,
        sender);
        send (<to → sender, amount → v,
                  tag → “main", msg → "refunded">)
```

HACKS ON PARITY MULTISIG CONTRACT

```
contract UnsafeContract2{
    address owner;

    function initowner(address _owner) { owner = _owner; }

    function transferTo(uint _amount, address _recipient) {
        if (msg.sender == owner)
            _recipient.transfer(_amount);
    }
}
```

Anyone can set `_owner`

Transfer once `_owner` is set

INTEGER OVERFLOW ATTACKS

```
function batchTransfer(address[]receivers, uint256
(bool) {
  uint cnt = _receivers.length;
  uint256 amount = uint256(cnt) * _value;
  require(_value > 0 && balances[msg.sender] >= amount);
  balances[msg.sender] = balances[msg.sender].sub(amount
   for (uint i = 0; i < cnt; i++) {
        balances[_receivers[i]] = balances[_receivers[i
        Transfer(msg.sender, _receivers[i], _value);
   }
   return true;
}
```

What if:

```
_value = 2^255
cnt    = 2
```

```
amount = 0
```

Becomes possible to transfer a large number of tokens

SECURITY FEATURES

Structured recursion instead of loops

Handles arithmetic underflows and overflows

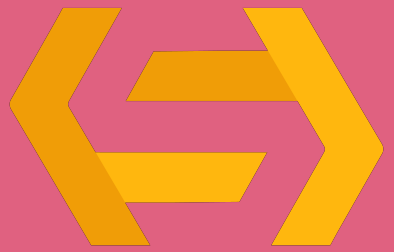
Clean separation between mutable and immutable params

All programs terminate and easier resource analysis

No need for external safe math like libs

Prevents Parity like incidents

FORMAL VERIFICATION



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COQ

LEMMA 1: CONTRACT WILL HAVE ENOUGH FUNDS TO REFUND.

LEMMA 2: CONTRACT WILL NOT ALTER ITS CONTRIBUTION RECORDS.

LEMMA 3: EACH CONTRIBUTOR IS REFUNDED THE RIGHT AMOUNT.

SCILLA DEMO

THANK YOU!

Gitter Channel

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