HyperService: Interoperability and Programmability Across Heterogeneous Blockchains

Make Web3.0 Connected!

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Blockchain Proliferation

Payment Network

Smart Contract Platform

Total # of Projects Listed on CoinMarketCap

2.3K
“Make Blockchains Great”

- Consensus Protocols
- Blockchain X
- Sharding & Layer-II Channels
- Blockchain Y
- Privacy & Program Analysis
- Blockchain Z

- Privacy
- Security
- Scalability
- Decentralization
In a world deluged with isolated blockchains, *interoperability* is power.

Atomic Token Swap is NOT the complete scope
Blockchain interoperability is complete only with programmability ...

Passive Distributed Ledgers → Programmable State Machine

Blockchain X

pragma solidity 0.4.22;

contract Broker {
    uint constant public MAX_OWNER_COUNT = 50;
    uint constant public MAX_VALUE_PROPOSAL_COUNT = 5;

    // The authoritative output provided by this Broker contracts.
    uint public StrikePrice;  // StrikePrice = $10

    @public
    @payable
    def CashSettle(shareCount: uint256, genuinePrice: wei_value):
        assert self.remainingFund > MIN_STAKE
        assert self.optionBuyers[msg.sender].valid
        assert not self.optionBuyers[msg.sender].executed

        if genuinePrice > self.strikePrice:

Blockchain Y

function CashSettle(unit shareCount, uint genuinePrice) public
optionAvailable
{
    require(optionBuyers[msg.sender].valid & optionBuyers[msg.sender].executed);

    if (genuinePrice > strikePrice) {
Challenge I: A virtualization layer to abstract away heterogeneity

Cross-chain dApps: how to uniformly define operations among heterogeneous contracts and accounts ...

Contract Languages

Consensus Efficiency & Finality

Transactions Not-Synchronized

Blockchain X

Blockchain Y

Blockchain Z
Challenge II: Cryptography protocols to realize cross-chain dApps

Cross-chain dApps in the era of Web3.0

dApp Executables

How to realize transactions via decentralized protocols?

Transactions on different Blockchains;
Transactions in specific order;
Downstream transactions depend on state resulted from upstream transactions;

Contain more complex operations than just token transfers
Our Proposal — HyperService

- A developer-facing programming framework
  - Universal State Model: a blockchain-neutral model to describe dApps
  - HyperService Language: a high-level language to program dApps

- A blockchain-facing cryptography protocol to realize dApps on-chain
  - Network Status Blockchain: a decentralized trust anchor
  - Insurance Smart Contract: a trust-free code arbitrator

A universal platform for developing and executing dApps across heterogeneous Blockchains
Programming Framework — Universal State Model

\[ M = \{ E, P, C \} = \{ \text{Entities, Operations, Constraints} \} \]

**Entitites**: objects extracted from underlying blockchains

<table>
<thead>
<tr>
<th>Entities</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>account</td>
<td>address, balance, unit</td>
</tr>
<tr>
<td>contract</td>
<td><strong>state variables[], interfaces[],</strong> source</td>
</tr>
</tbody>
</table>

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pragma solidity 0.4.22;

contract Broker {
    uint constant public MAX_OWNER_COUNT = 50;
    uint constant public MAX_VALUE_PROPOSAL_COUNT = 5;

    // The authoritative output provided by this Broker contracts.
    uint public StrikePrice;
}

@public @ payable
def CashSettle(shareCount: uint256, genuinePrice: wei_value):
assert self.remainingFund > MIN_STAKE
assert self.optionBuyers[msg.sender].valid
assert not self.optionBuyers[msg.sender].executed
if genuinePrice > self.strikePrice:

Blockchain X

Blockchain Y
```
Programming Framework — Universal State Model

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Operations: computation performed over several entities

<table>
<thead>
<tr>
<th>Operations</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>payment</td>
<td>from, to, value, exchange rate</td>
</tr>
<tr>
<td>invocation</td>
<td>interface, parameters[], invoker</td>
</tr>
</tbody>
</table>

An example invocation operation:
Y::Option.CashSettle(10, X::Broker.StrikePrice)
### Programming Framework — Universal State Model

\[ M = \{ E, P, C \} = \{ \text{Entities, Operations, Constraints} \} \]

**Entities:** objects extracted from underlying blockchains

**Operations:** computation performed over several entities

**Constraints:** dependencies among operations

<table>
<thead>
<tr>
<th>Entities</th>
<th>Attributes</th>
<th>Operations</th>
<th>Attributes</th>
<th>Dependency</th>
</tr>
</thead>
<tbody>
<tr>
<td>account</td>
<td>address, balance, unit</td>
<td>payment</td>
<td>from, to, value, exchange rate</td>
<td>precondition</td>
</tr>
<tr>
<td>contract</td>
<td>state variables[], interfaces[], source</td>
<td>invocation</td>
<td>interface, parameters[], invoker</td>
<td>deadline</td>
</tr>
</tbody>
</table>
HyperService Language (HSL): A high-level programming language

**import**: include the source code of all contracts defined in the HSL program

**account & contract**: defining entities extracted from underlying blockchains

**payment & invocation**: defining operations among entities

**before, after & deadline**: defining dependencies among operations

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1. // Import the source code of contracts written in different languages.
2. import ("broker.sol", "option.vy", "option.go")
3. # Entity definition.
4. # Attributes of a contract entity are implicit from its source code.
5. account a1 = ChainX::Account(0x7019..., 100, xcoin)
6. account a2 = ChainY::Account(0x47a1..., 0, ycoin)
7. account a3 = ChainZ::Account(0x61a2..., 50, zcoin)
8. contract c1 = ChainX::Broker(0xbba7...)
9. contract c2 = ChainY::Option(0x917f...)
10. contract c3 = ChainZ::Option(0xefed...)
11. # Operation definition.
12. op op1 invocation c1.GetStrikePrice() using a1
13. op op2 payment 50 xcoin from a1 to a2 with 1 xcoin as 0.5 ycoin
14. op op3 invocation c2.CashSettle(10, c1.StrikePrice) using a2
15. op op4 invocation c3.CashSettle(5, c1.StrikePrice) using a3
16. # Dependency definition.
17. op1 before op2, op4; op3 after op2
18. op1 deadline 10 blocks; op2, op3 deadline default; op4 deadline 20 mins

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Figure 2: A cross-chain Option dApp written in HSL.
Programming Framework Core -- HSL Program Compilation

- Extract state variables and interfaces from imported contracts
- Unify different contract languages
- Compatibility: type check
- Verifiability: state variables
- Feasibility: no dep-loop

<table>
<thead>
<tr>
<th>Unified Type</th>
<th>Solidity</th>
<th>Vyper</th>
<th>Go</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>bool</td>
<td>bool</td>
<td>bool</td>
</tr>
<tr>
<td>Numeric</td>
<td>int, unit</td>
<td>int128, decimal, ...</td>
<td>int, float, ...</td>
</tr>
<tr>
<td>Array</td>
<td>array, bytes</td>
<td>array, bytes</td>
<td>array, slice</td>
</tr>
</tbody>
</table>

Figure 3: Workflow of HSL Compilation.
Transaction Dependency Graph (TDG) — HSL Program Executables

- Each vertex defines:
  - Full information for computing a blockchain-executable transaction
  - Metadata to ensure correct execution
- Edges define the transaction order

- Resulting state of T1 is used subsequently
- A state proof needs to be collected after T1 is finalized.

Transaction T1 on ChainX:
from: a1.address
to: c1.address
Meta:
data: c1.getStrikePrice
amt, dst>: <0.1 ncion, 0x1...>
state_proof: collect from NSB

Transaction T2 on ChainX:
from: a1.address
to: VES.relayX.address
Meta:
value: 50 xcoin
amt, dst>: <25 ncion, 0x2...>
deadline: 4 NSB blocks

Transaction T3 on ChainY:
from: VES.relayY.address
to: a2.address
Meta:
value: 25 ycoin
amt, dst>: <5 ncion, 0x3...>
deadline: 6 NSB blocks

Transaction T4 on ChainY:
from: a2.address
to: c2.address
Meta:
data: c2.CashSettle(10, c1.StrikePrice)
amt, dst>: <0.1 ncion, 0x4...>
value_proof: T1.meta.state_proof
HyperService Architecture

Developer-facing Programming Framework

Universal Inter-Blockchain Protocol
Universal Inter-Blockchain Protocol (UIP) Overview

- A protocol spoken by all parties to co-execute cross-chain dApps
- Fully decentralized: no authorities and no mutual trust among parties

- Provable security properties
  - Correctness assurance, financial atomicity, and accountability

- Network Status Blockchain: a decentralized trust anchor
- Insurance Smart Contract: a trust-free code arbitrator
UIP Security Properties

Security properties of dApps executed by UIP (Proved in UC-Framework)

- **TDG is realized as desired**
  - dApp execution either finishes correctly or being financially reverted
- **Accountability**
  - Regardless of at which stage the execution fails, the misbehaved parties are held accountable for the failure
- **Correctness Guarantee**
  - If blockchains are modeled with bounded transaction finality latency, dApps are guaranteed to finish correctly if all parties are honest

**Financial Atomicity**
NSB: Provide unified and objective views on the status of dApp executions

- Consolidate transactions and state from underlying blockchains
- Provide unified representations for transaction status and state in form of verifiable Merkle proofs

Proof of Actions (PoAs): allow parties to construct proofs to certify their actions taken during executions

Status Merkle Tree

Action Merkle Tree

Figure 5: The architecture of NSB blocks.
Insurance Smart Contract (ISC)

Merkle Proofs

if CorrectExecution:
    Pay service fee
else:
    Revert effective fund
    Enforce accountability

Decision Logic
Implementation and Source Code Release (as of March 2020)

- Incorporate Ethereum and a permissioned blockchain built on Tendermint
  - Different consensus efficiency and transaction finality definition
  - Different contract languages: Solidity VS. Go

- Three categories of cross-chain dApps
  - Financial derivative, asset movement and federated computing

- Released source code: https://github.com/HyperService-Consortium

60K Lines of Code
Demo: End-to-end executions on HyperService

1. Invoke E::Broker.ComputeStrikePrice()
2. Invoke T::Option.cash_settle(E::Broker.StrikePrice)
3. Invoke E::Option.CashSettle(E::Broker.StrikePrice)
HyperService: A universal platform for developing and executing dApps across heterogeneous Blockchains

Q & A
Thank You
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