Distributed Ledgers and Smart Contracts

• Distributed Ledger Technology (aka “blockchain”) enables trustworthy sharing and updating of tamper-proof data between untrusting parties
  – Currencies, digital (or tokenized) assets, ...

• Smart contracts enable flexible and expressive logic to govern updates

• Combination enables exciting new use cases
  – Payment triggered by agreed conditions (on-time delivery, IoT device confirms shipping conditions within agreed parameters)
  – ...
  – Decentralized Autonomous Organization (DAO)
    • Crowd funding, proposals approved via voting by token holders, no (biased, corruptible) humans
    • Proposals can generate income for the DAO, effectively a decentralized investment fund
“The” DAO

• Launched on public Ethereum in May 2016
• Raised equivalent of > US $160M
• Quickly attacked, resulting (kind of) in loss of > US $50M
• (Subset of) community rallied to create “hard fork” that special-cased recovery of lost funds
• Now we have two Ethereums (Etherea?)
Ooops! What went wrong with the DAO?

• Ethereum platform behaved correctly, as specified
• DAO smart contract contained multiple bugs, did not reflect authors’ intent or (presumably) investors’ understanding
• Written in Solidity (new Javascript-like language) for Ethereum VM
• Choice and design of programming language can be debated, but...
• … any general-purpose language is difficult to understand for most people
• If experts did not catch bugs, what hope is there for a human (e.g. potential investor) to understand exactly what s/he is trusting?
Oracle ® Policy Automation (OPA)

- Express business rules and policies in human-readable language
- Rules compiled to machine-readable format
- OPA engine applies rules to data
  - Input attributes + inference => Goal attributes

Top-Level Conditions for Approving Imports

- the shipment is cleared for import if
  - the shipment’s import duty has been paid and
  - the shipment has all the necessary certifications

- the shipment’s import duty has been paid if
  - for all the items in the shipment
  - the appropriate import duty for the item has been paid

- the shipment has all the necessary certifications if
  - for all the items in the shipment
  - the item has a notarized certification transaction
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- We explore integration to enable OPA rules as smart contracts

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Inspection Certifications  Duty Payments  Import Approval  Funds Released
Blockchain Nodes
OPA as Smart Contract Language?

• Human readable
• Deterministic
• Guaranteed to terminate (may not reach conclusion if configured to stop too soon, but deterministic)
• These qualities address significant challenges for smart contracts
Juno

• Open source blockchain platform
• Implemented in Haskell
• “BFT hardened” Raft protocol for consensus
• Built-in DSL for money transfers
Generalizing Juno

• We modified Juno to support “pluggable” smart contract engines
  – Engine defines ledger state type, initial state, command processor for updating state

• Smart contract engine for OPA
  – State: key-value map
  – Command processor:
    • Sends input attributes and metadata from application command to “servlet”
    • To be continued...
OPA Servlet

• Has registered OPA rule set
• Receives a request containing:
  – Rule set ID
  – Input attributes
  – Scope ID (e.g., identify customer, case, etc.)
• Invokes OPA engine via Java API, provides input attributes
• Receives result from OPA engine, including inferred goal attributes(s)
• Produces transaction and sends it back to Juno:
  – read set contains input attributes, write set contains goal attributes
  – keys derived from data model, attribute names, scope ID, etc.
Generalizing Juno (continued)

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• Smart contract engine for OPA
  – State: key-value map
  – Command processor:
    • Sends input attributes and metadata from application command to “servlet”
    • Receives results from servlet in form of a transaction (read and write sets)
    • Validates read set against key-value store; if successful...
    • ... updates key-value store based on write set
Benefits

• Tamper-proof record of transaction in blockchain
• Transactions driven by human-understandable policies
• OPA can “explain” reasoning, providing valuable audit trail
  – Can be reproduced on demand after the fact, as OPA is stateless
• No trusted party, no single point of failure
Concluding Remarks

• This is an experimental prototype for research
• Demonstrates feasibility of integrating human-readable policies with a blockchain platform
• More work needed to achieve/assess practicality for real use cases
Questions?

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