Secure Computations in Decentralized Environments

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<online version with animations>
Introduction
Scenario

Input
Requestor

Payment

Execution Node
Edge computing

To make edge computing a realistic alternative:
- Security and privacy must be built in the system design
- It must be easy to join the network to submit/execute tasks
- Nodes need to be rewarded for their work
- Fully decentralized without "trusted" 3rd parties
- Building Blocks
  - Rewards
  - Result Verification
  - Privacy
Rewards

- Nodes need to be rewarded for used resources
- It can be the main motivation for nodes to join
- Work need to be proved/verified before payment
- But when should be the payments done?
Result Verification

- Different types of tasks
- Cryptographic proof
  - High cost
  - Not available for every computation
- Parallel execution
  - Partial or complete
  - Highly inefficient
  - How to prevent colluding?
Input/Result Privacy

Input and Result Data must be hidden from the network and from the execution node.

- Homomorphic encryption
  - Introduces overhead
  - Not always possible
- Trusted Execution Environment
  - Creates a trusted environment within an untrusted node
  - Low overhead
  - Requires dedicated hardware
Industry

- Golem, Somn
- Run on Ethereum Blockchain
- Payments using smart contracts
- No automatic, reliable result verification mechanism
- 3rd parties to resolve conflicts
Background
Intel SGX

- Trusted Execution Environment (TEE)
- Enclaves are protected by the CPU against access from other apps/OS/Hypervisor
- Used in Proof of Elapsed Time (PoET)
- Remote Attestation Protocol
  - Verifies the hardware
  - Verifies the code running on a remote node
  - Allows secure communication with the enclave
Blockchain Technologies

- Smart Contracts
  - Allow to logic on top of a blockchain
  - Turing complete language (Solidity)
  - Submitted data is publicly visible
- Payment Channels
  - Process off chain payments
  - Secured by deposits
- Oracles
  - Trusted data feed for Smart Contracts
Overview
Assumptions

- Both the Requestor and the Executing Node know the function and trust its behaviour (i.e. a function does images processing)
- The Requestor and the Executing Node mutually distrust one another
- Both the Requestor and the Executing Node trust the blockchain
- The Executing Node has complete control over its OS/Hypervisor
Conclusion

- System for result verification and payments
- Fully automated
- Orders of magnitude lower overhead than SoA
- No 3rd parties involved
- Limitations
  - Needs Intel hardware
  - Application size limit (up to 100MB)
Open Questions

- How to automatically dispatch tasks?
  - Concerning cost, node capacities price
  - How to define fairness?
- How to estimate cost of computations?
  - CPU, bandwidth, memory, QoS
  - Different node capacities
- How to provide full privacy?
Thank you