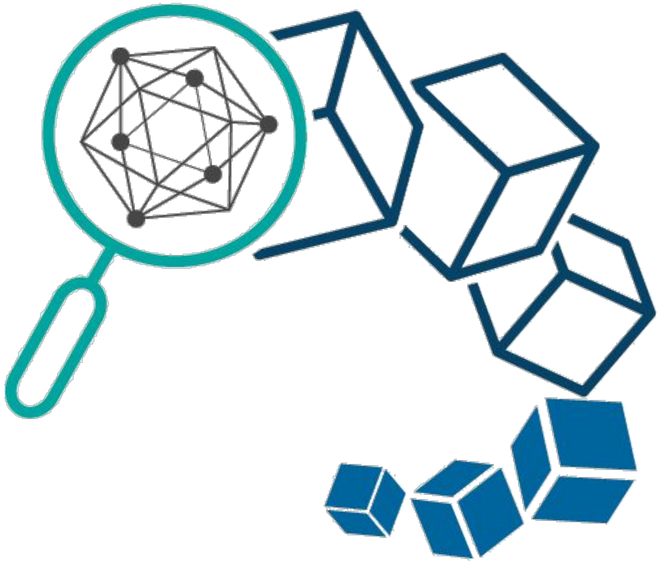
VQL: Providing Query Efficiency and Data Authenticity in Blockchain Systems



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Query Design Motivation

- Blockchain techniques (cryptocurrency, business transactions, supply chain, insurance, medical care, etc.)

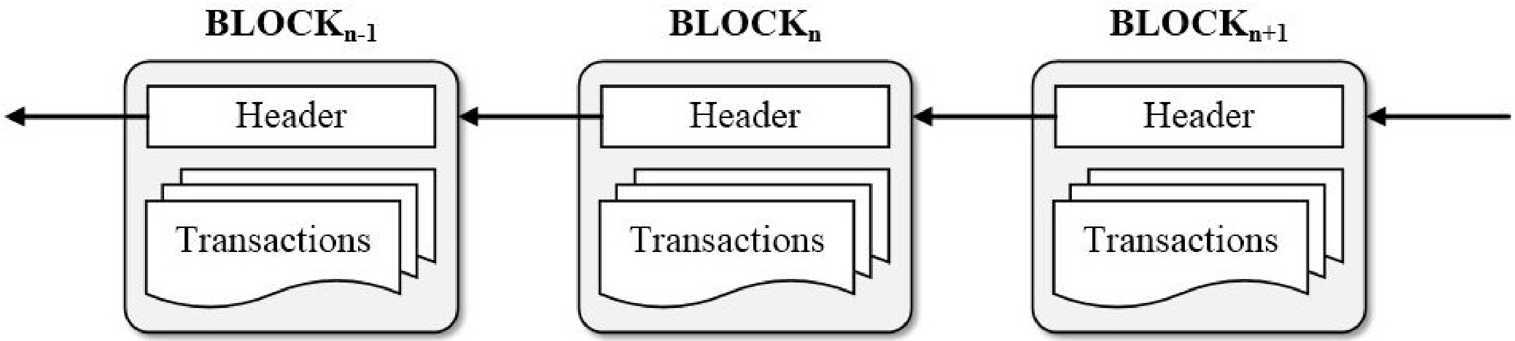


Illustration of blockchain structure

Immutability and verifiability in trustless and distributed environment !

Low query efficiency !

Previous Work

- Existing query supported blockchain systems:
  - Toshi [1]: provide basic query of **block information** in Bitcoin
  - Ethereum [2]: maintain the **current balance of each account** in each node
  - Etherchain [3]: extend Ethereum basic API to **query block time and count transactions**
  - ECBC [4]: build a tree structure to efficiently **query historical transactions** of an account

Limited query services

[1] Coinbase: Toshi project. https://github.com/coinbase/toshi
[2] Wood, G.: Ethereum: a secure decentralised generalised transaction ledger. In Ethereum Project Yellow Paper, 2014.
[3] Etherchain. https://etherchain.org/
[4] Y. Xu, S. Zhao, L. Kong, Y. Zheng, S. Zhang, and Q. Li, "ECBC: A High Performance Educational Certificate Blockchain with Efficient Query," in *International Colloquium on Theoretical Aspects of Computing*, 2017.

Previous Work

➢ Various data analytical tasks focus on the blockchain:

- [5] analyses Bitcoin **transactions** and proves that Bitcoin is **not** a fully **anonymous** system
- [6] proposes a multi-variant relation model with time series dataset to **detect money laundering**
- [7] builds a reputation network for blockchain users to **reduce transaction risks**

[5] Ron, Dorit, and Adi Shamir. "Quantitative analysis of the full bitcoin transaction graph." in *International Conference on Financial Cryptography and Data Security*. Springer, Berlin, Heidelberg, 2013.
[6] MCA, G. Krishnapriya, and M. Prabakaran. "An multi-variant relational model for money laundering identification using time series data set." in *the International Journal of Engineering and Science (IJES),* vol. 3, pp. 43-47, 2014.
[7] Buechler, Matthew, et al. "Decentralized reputation system for transaction networks." in *Technical report, University of Pennsylvania*, 2015.

Motivation

- A query supported blockchain system:
  - How to efficiently support various data analytical tasks on top of blockchain systems?
  - How to provide trusted query results?

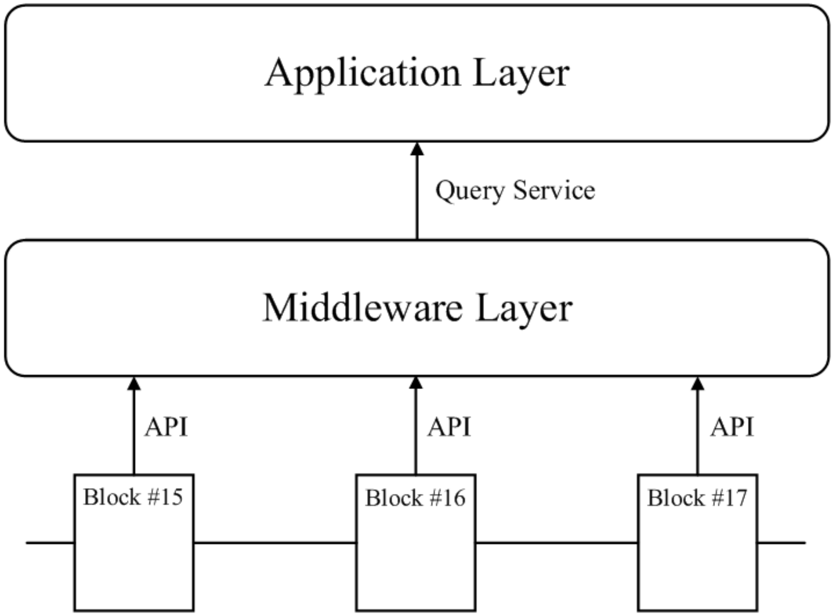
Problem

- How to provide efficient query services with verifiability guarantees for blockchain system:
  - Verifiability of querying results by public
  - Querying efficiency
  - Data storage efficiency

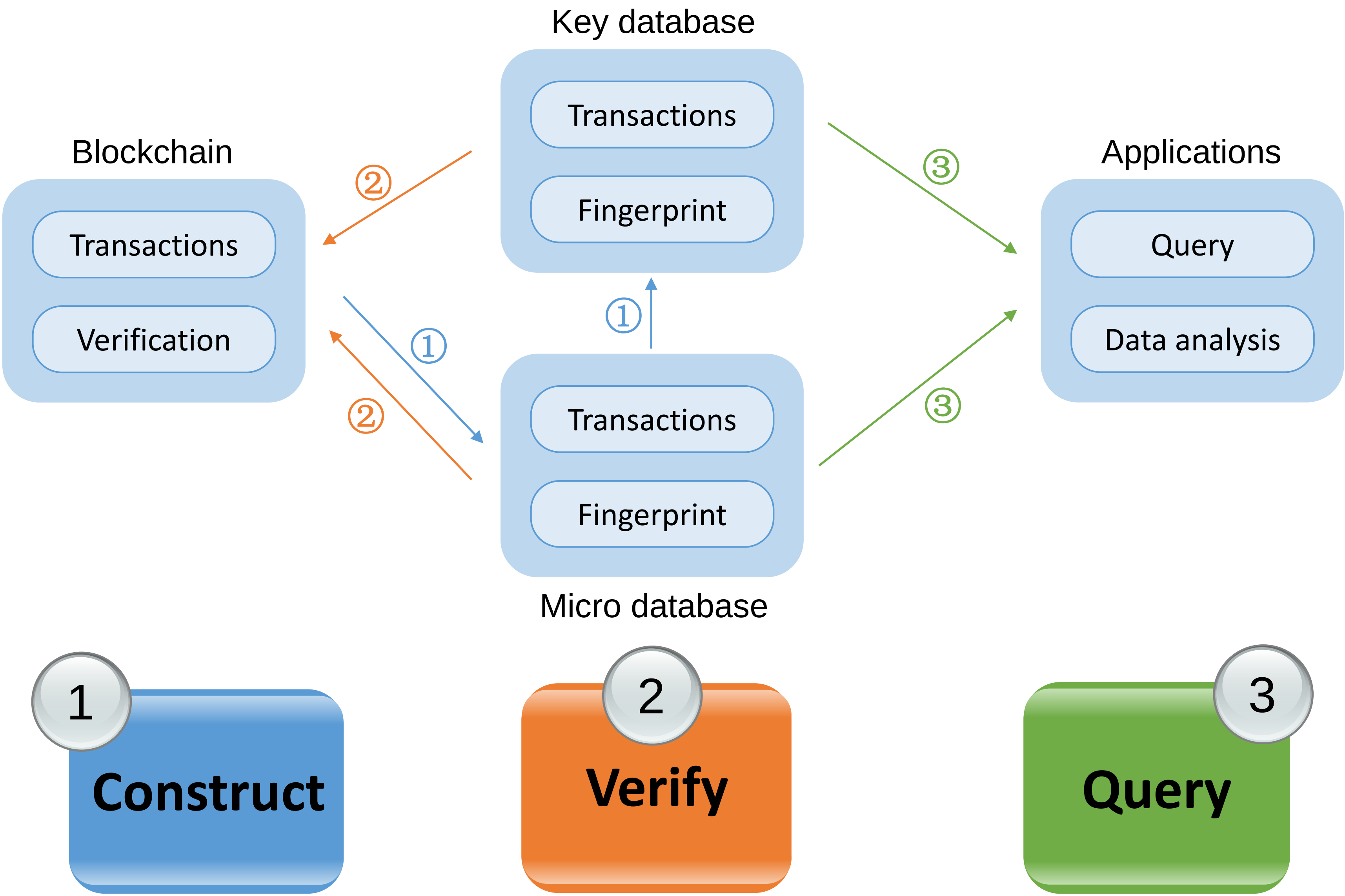
Architecture

Service model

- Blockchain, Middleware layer, Application layer



System Overview



Key database

Transactions

Fingerprint

Blockchain

Transactions

Verification

Applications

Query

Data analysis

Micro database

Transactions

Fingerprint

①

②

③

1 Construct

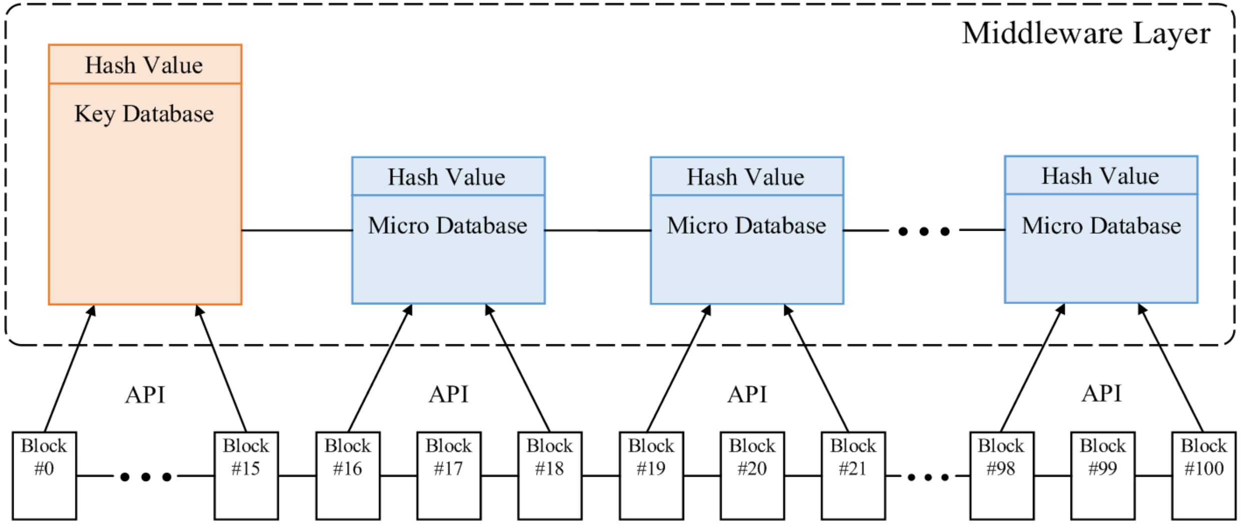
2 Verify

3 Query

System Design

➢ Middleware architecture

- Key database, Micro database with hash values
  - Store hash values in blockchain
  - Integrity and authenticity functions
- Hash value of database can be verified by miners
- Databases are dynamically updated and merged



Middleware Update Algo.

- Middleware update every month
  - Each day
    - Construct a new Micro database
    - Calculate its hash
  - End of each month
    - Merge all Micro databases into Key database
    - Calculate Key database’s hash
    - Delete all Micro databases

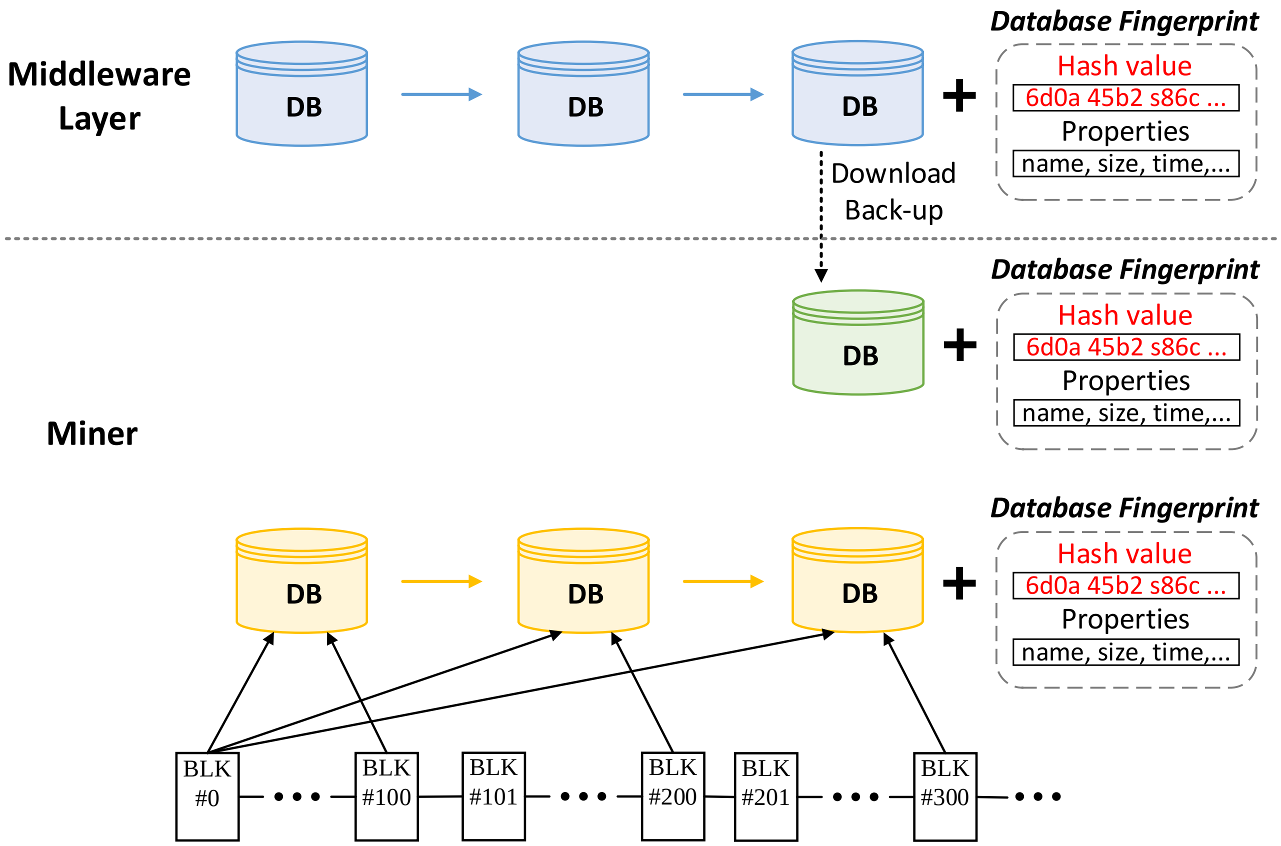
System Design

- Efficient query services
  - Data Query
    - Block
    - Transaction
- Data storage efficiency
  - Periodically store snapshot and hash value of database
  - Merge databases to save space

System Design

➢ Database verification

- Data in the middleware are consistent with the blockchain



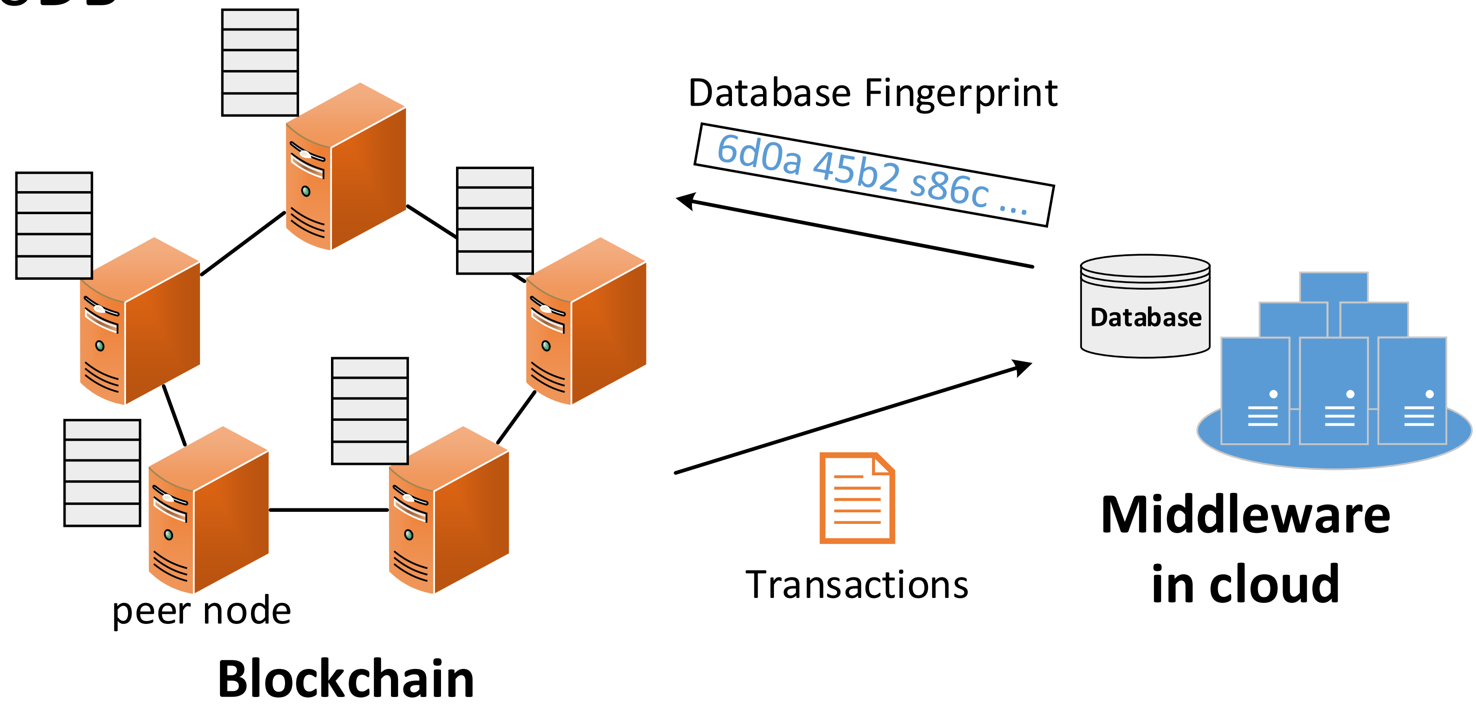
Database Verification Algo.

➢ Miner Database verification

- Download and re-construct databases
  - Data files will be published by the middleware layer
- Calculate fingerprints and compare
  - hash value published by the middleware layer
  - hash value calculated based on the re-constructed database
  - hash value calculated based on the blockchain data
- Write verified fingerprints into blocks

Experimental Implementation

- Blockchain
  - Ethereum
- Middleware layer
  - MongoDB



Performance Evaluation

- Throughput
- Block query time by number of blocks
- Transaction query time by number of transactions

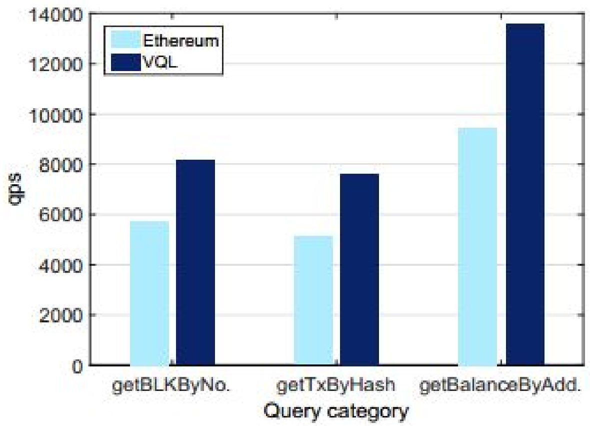


Fig. 4: Throughput comparison between Ethereum and VQL.

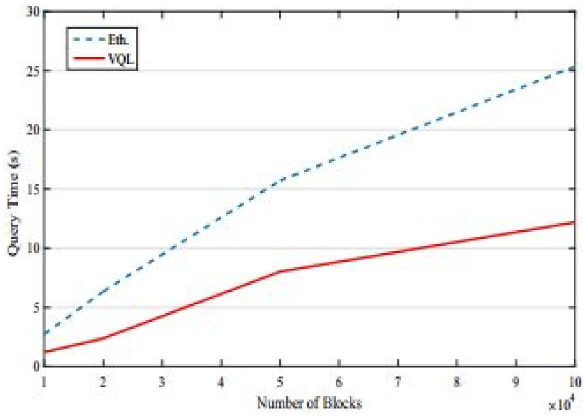


Fig. 5: Comparison of block query time with Ethereum and VQL.

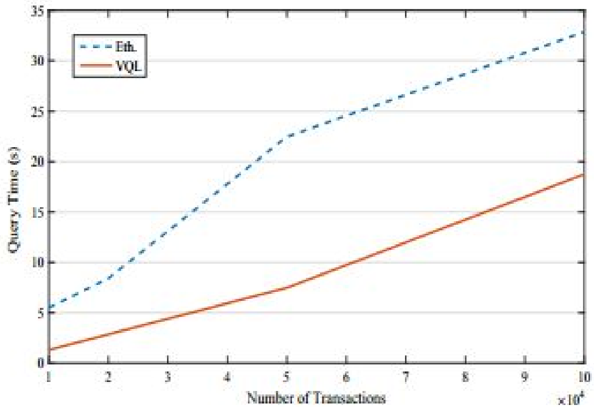


Fig. 6: Comparison of transaction query time with Ethereum and VQL.

Conclusion

- ***Query problems*** in blockchain system
    - Querying efficiency
    - Verifiability of querying results by public
- Our solution: A Verifiable Query Layer
    - The ***middleware layer***
    - Dynamically construct, update, and merge databases
    - Verify the consistency of constructed databases
- Experimental analysis

Thank You!!!