LYU1803:

Opensource E-voting System for 8 million mobile devices

ESTR4999 Graduation Thesis Presentation

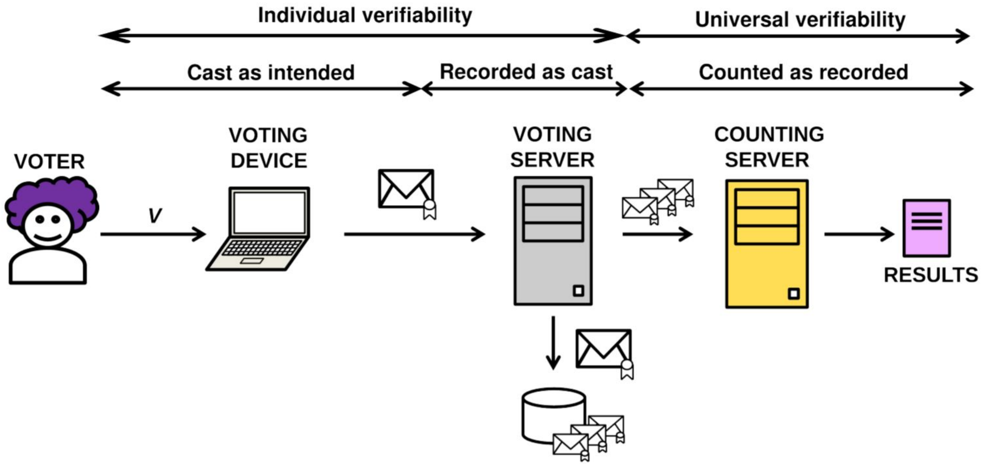
Maxwell Chan presents

supervised by **Prof. Michael Lyu**

Review of Term 1

Motivation

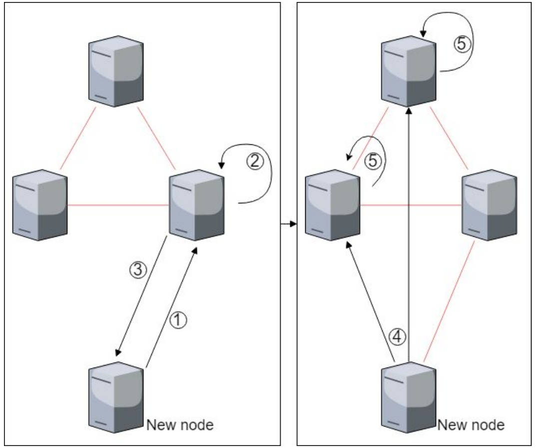
- Disadvantage of paper-based voting
- Blockchain
- End-to-end verifiable voting



Design

- Helios

- Permissioned blockchain

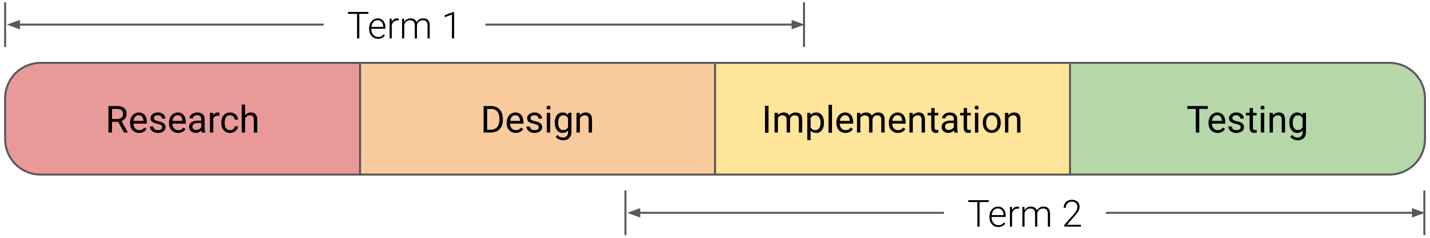


Implementation

- Election encryption & decryption
- “Backbone” of blockchain
- Draft user interface

Objective

Overall schedule



Objective of Term 2

- Zero-knowledge proof
- Communication full verification
- User interface design
- Load test

Protocol design

Zero-knowledge proof

- Sigma protocol

- Non-interactive mode

Trustee knowledge on private key

- Need all private key for decryption
- Malicious example:

Trustee public key: y_i private key: x_i

Submit public key as: $y_i/(y_1y_2y_3\ldots y_n)$

Election public key = $(y_1y_2y_3\ldots y_n) \times y_i/(y_1y_2y_3\ldots y_n) = y_i$

Trustee honest decryption

- Must use the private key
- Malicious example: $x_i g^1$ or $x_i g^{-1}$
- Ballot aggragation

Voter honest encryption

- Encrypt only 0 or 1
- Limit number of selection
- Use "simulated proof" for other values
  - Reverse the Sigma protocol
  - Verify sum of "Challenge"

Q1 (1-3 selection)	1 real, 2 simulated
Choice 1	1 real, 1 simulated
Choice 2	1 real, 1 simulated
Choice 3	1 real, 1 simulated

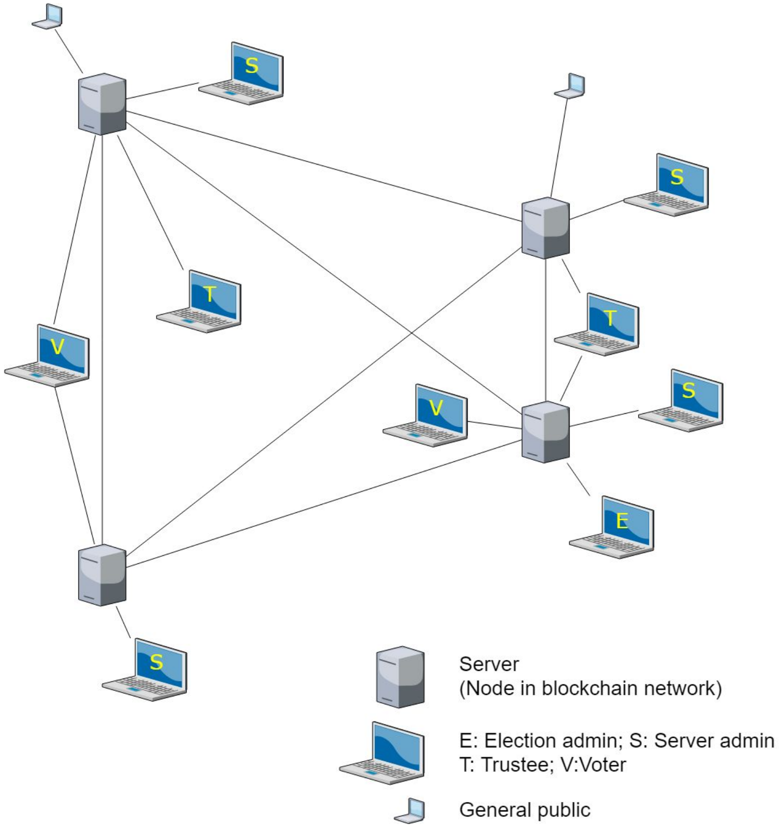
Authentication method

- Signature bound with ballot
- Key generation problem
  - Server generate, send via email
  - Voter self-enrollment
  - Election administrator upload directly

Roles and permission

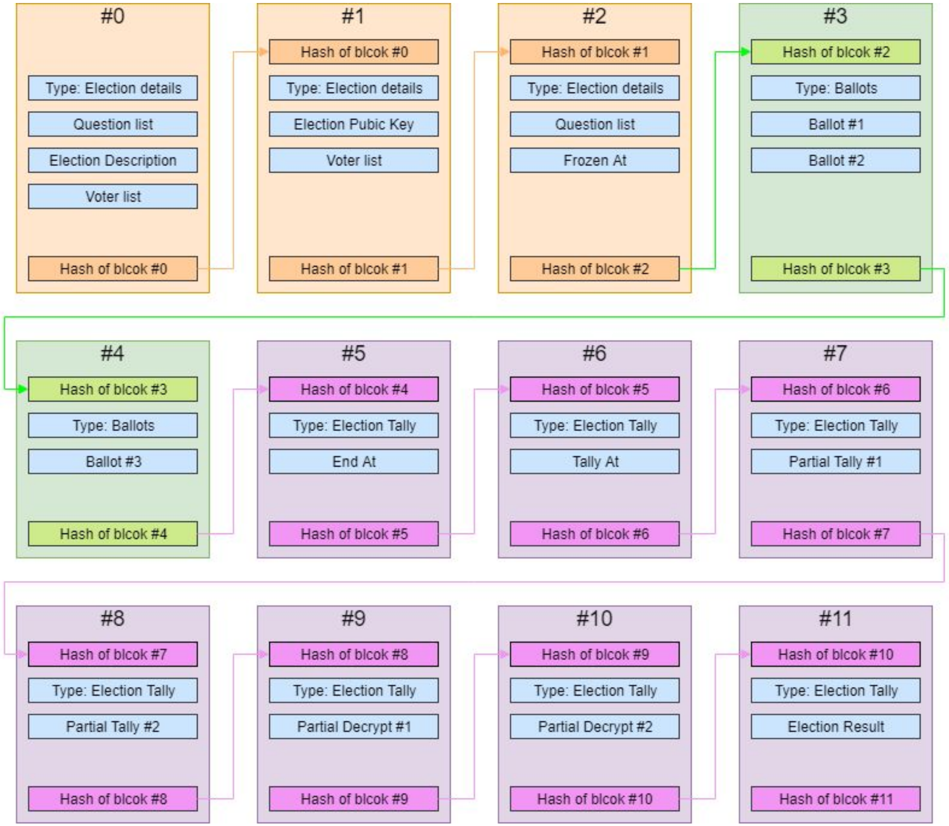
Different type of administrator:

- Server administrator
- Election administrator
- Trustee



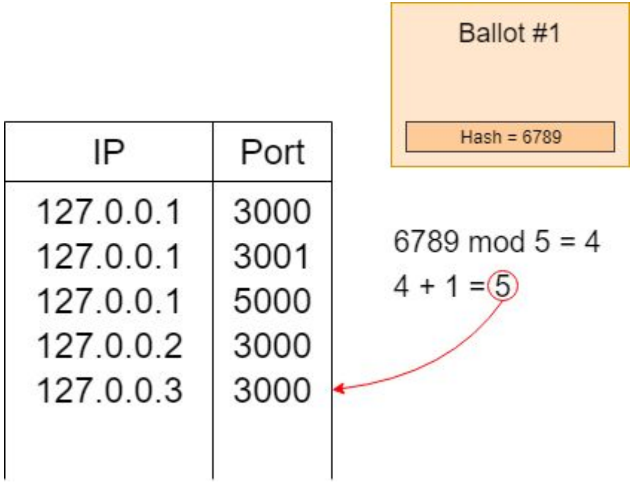
Block design

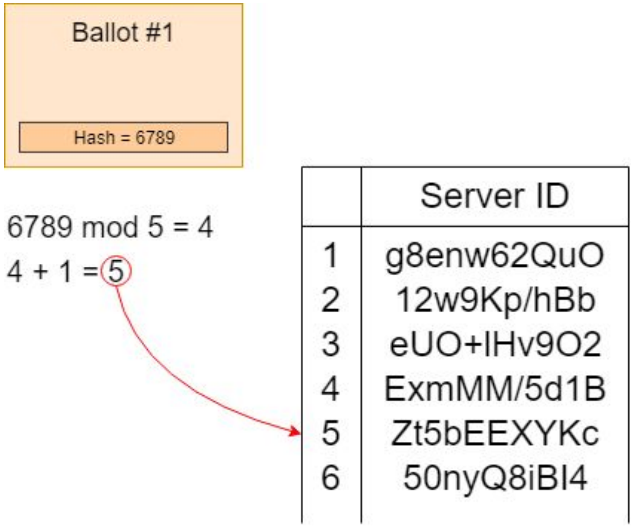
1. Election details
2. Ballots
3. Election tally



Block generation - Node selection

- Use Server ID instead of address
- Unique ID for each server key pair

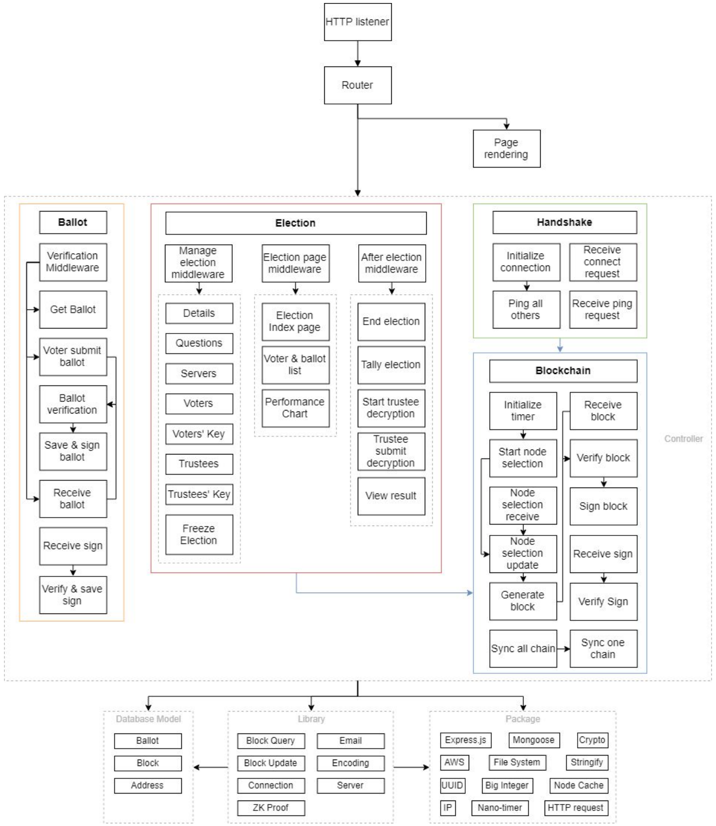




Implementation

System architecture

- Modularized design



Demo

1. Vote in a prepared election
2. Tally the election
3. Decrypt the election
4. Show result

Testing

Overview

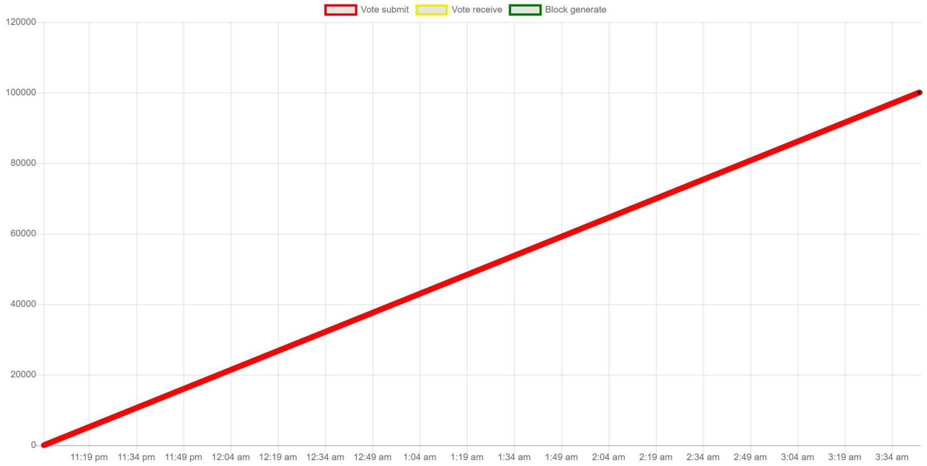
- Aim: Bottleneck of scaling up
- Load test (2 round)
    - Block length test
    - Arrival rate test
    - Ballot aggregation test
- Reliability test

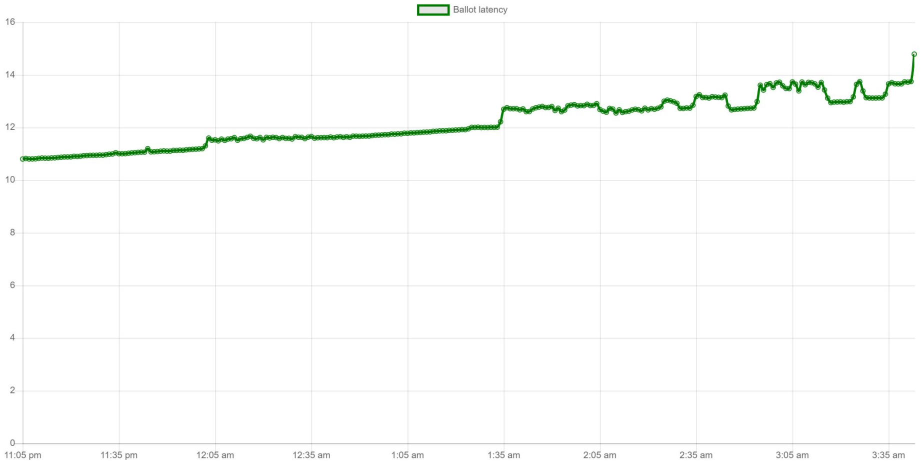
Environment

- CSE machine x3
  - 4 CPU @ 2.8GHz
  - 8GB RAM
- Google Cloud Virtual Machine
  - 8 CPU @ 2.5GHz
  - 56GB RAM

Block length test - CSE machine

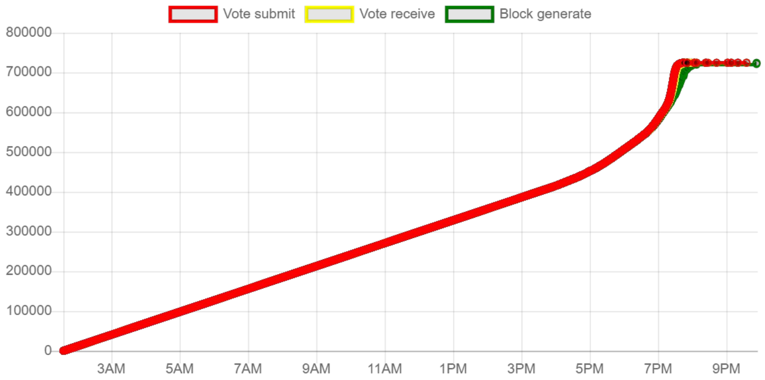
- Case of 100,000 ballots

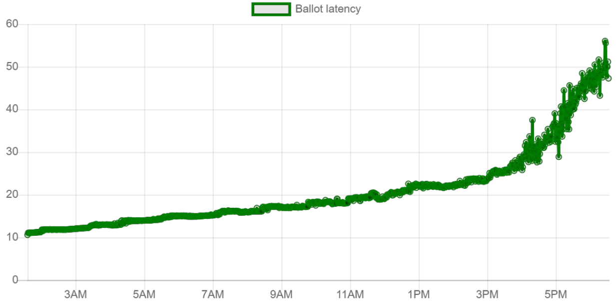




Block length test - CSE machine

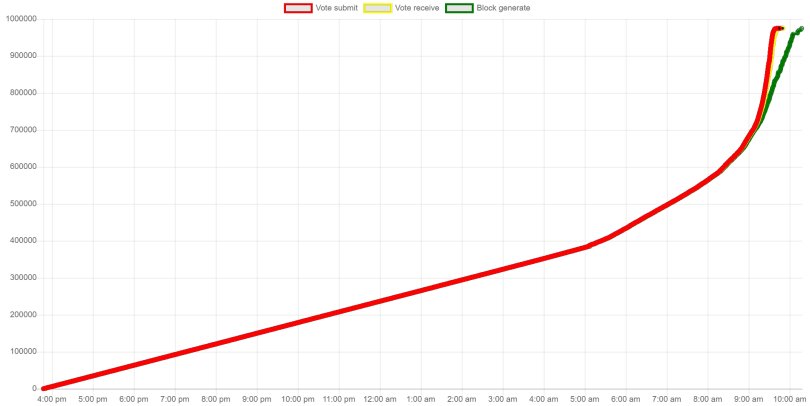
- Case of 1,000,000 ballots
  - Database out of memory
  - Some ballots in multiple blocks

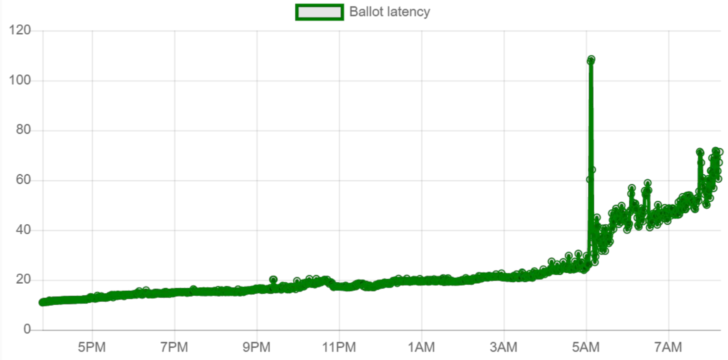




Block length test - Google VM

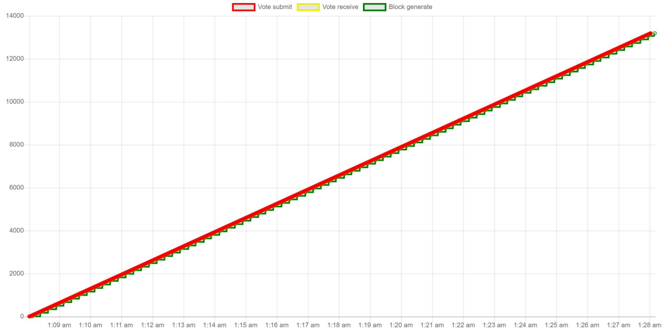
- Case of 1,000,000 ballots
    - Processing time increase

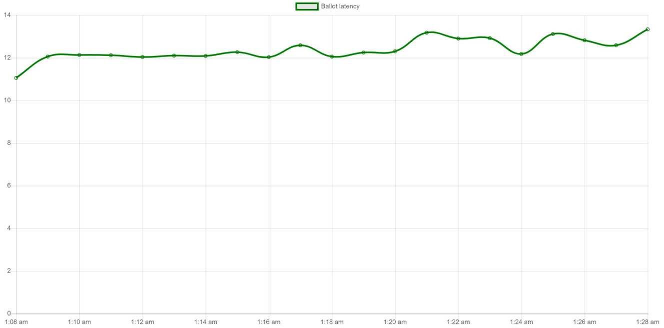




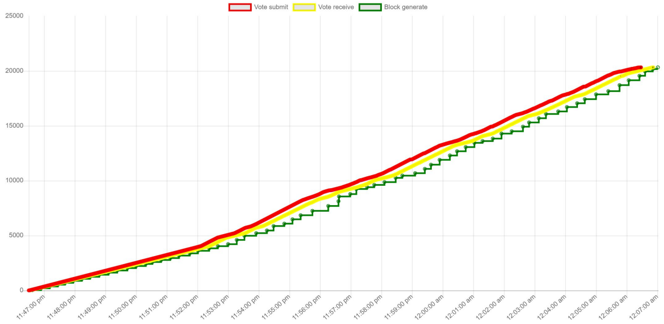
Arrival rate test - 1 node - CSE machine

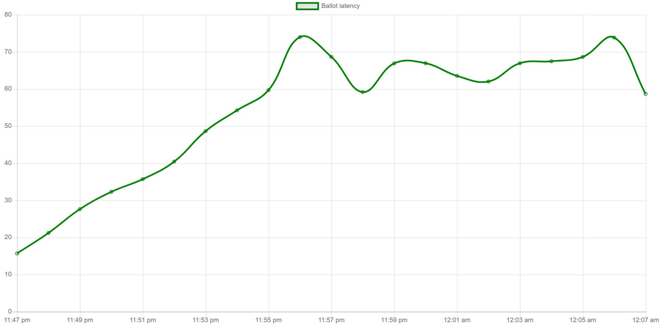
- 11 Ballots per second





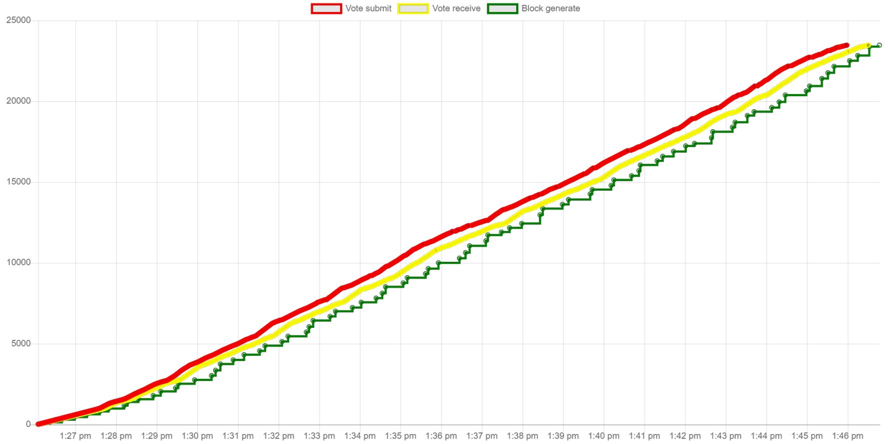
- 12 Ballots per second

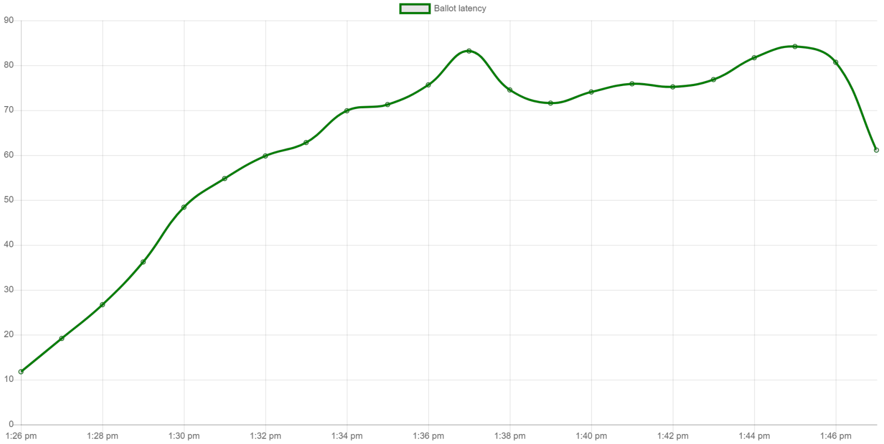




Arrival rate test - 1 node - Google VM

- 12 Ballots per second



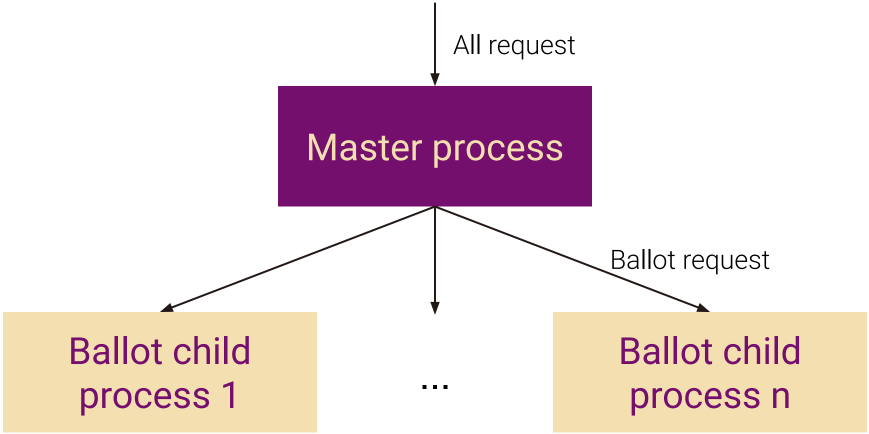


Ballot aggreagtion test - CSE machine

- 3 nodes on same machine
- 100 Ballots: 0.07 second
- 1000 Ballots: 0.6 second
- 10000 Ballots: 72 seconds

Summary & Improvement

- Cannot scale up
- Single thread → Low CPU utilization
    - Fork child processes for ballot processing

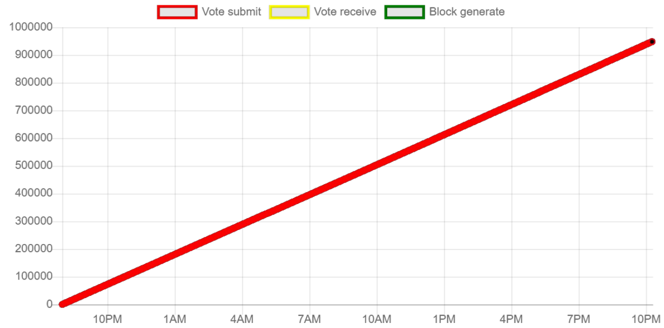


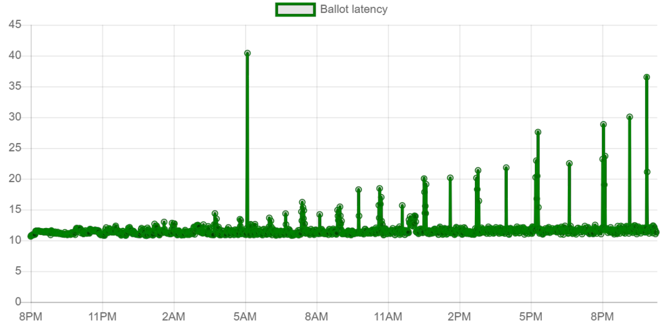
Summary & Improvement

- High database memory usage → Long response time
    - More index
        - electionID ↑, blockType ↑, blockSeq ↓, data.voters.id ↑
        - electionID ↑, blockSeq ↓

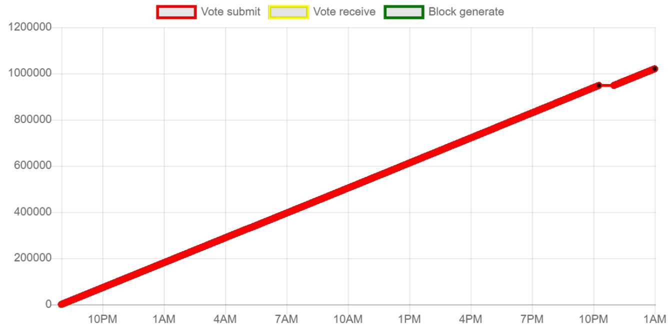
Block length test - Google VM

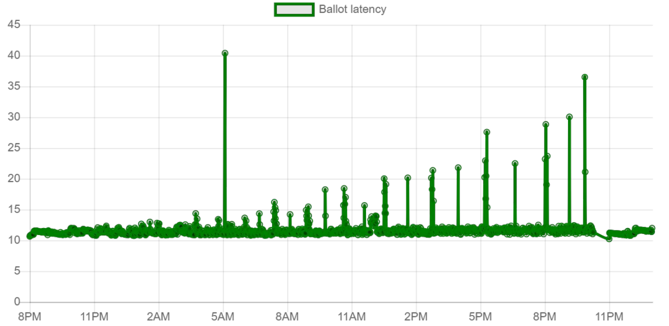
- Case of 1,000,000 ballots
  - Crash at ~950,000 ballots





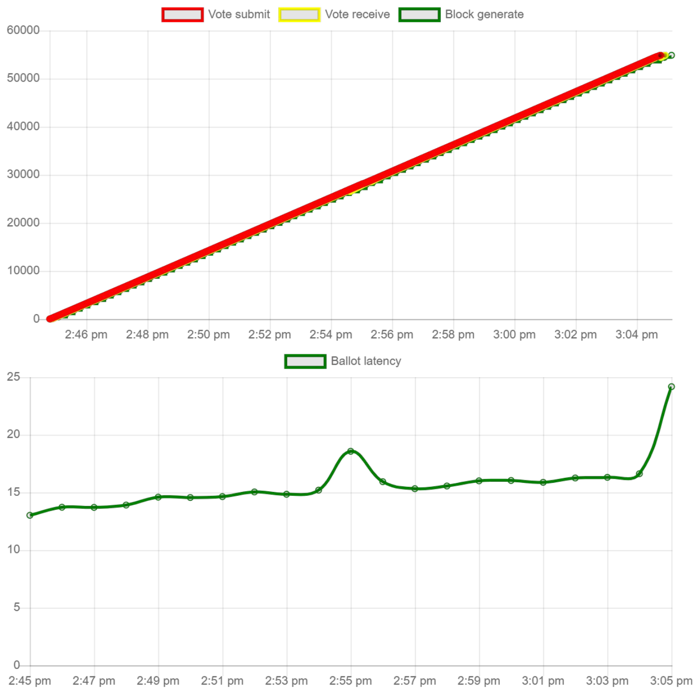
- Extended test



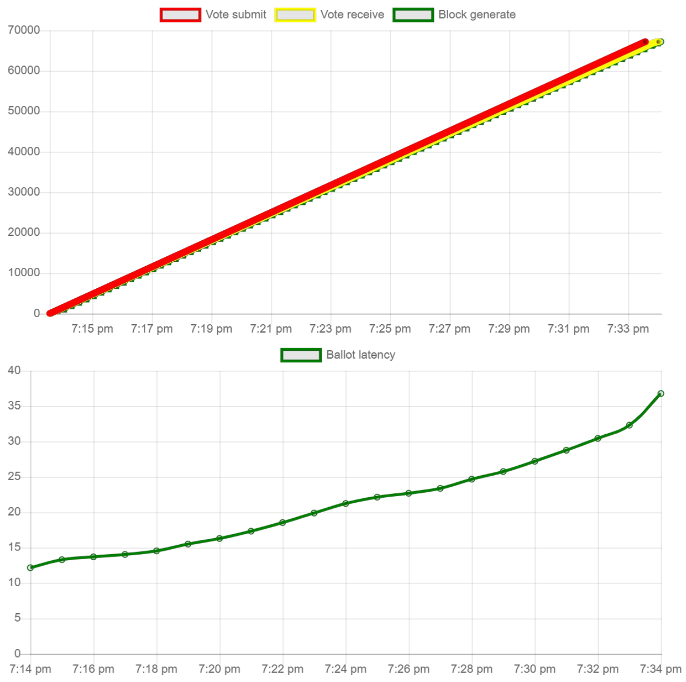


Arrival rate test - 1 node - Google VM

- 48 Ballots per second



- 56 Ballots per second



Arrival rate test - 1 node - Google VM

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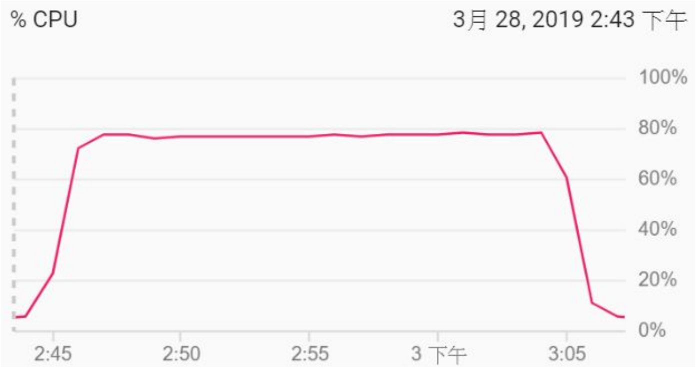
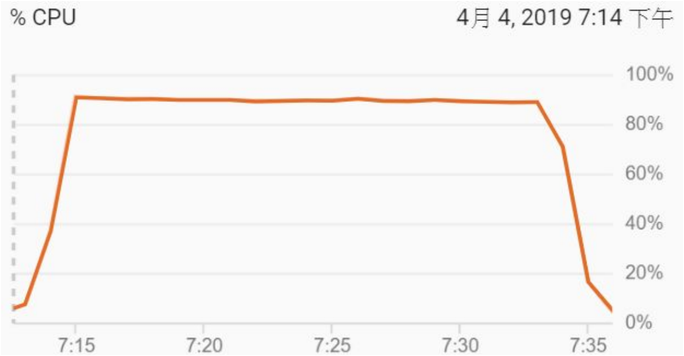


- 56 Ballots per second

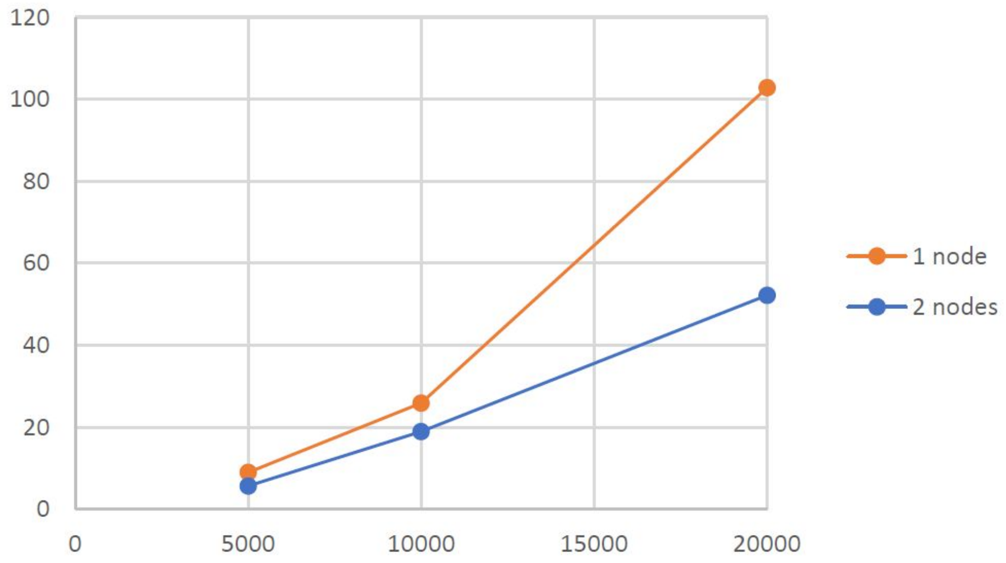


Arrival rate test - CSE machine

- 1 node
  - 30-31 Ballots per second
- 2 nodes
  - 28-29 Ballots per second

Ballot aggregation test

- With 1 or 2 node(s) on CSE machine

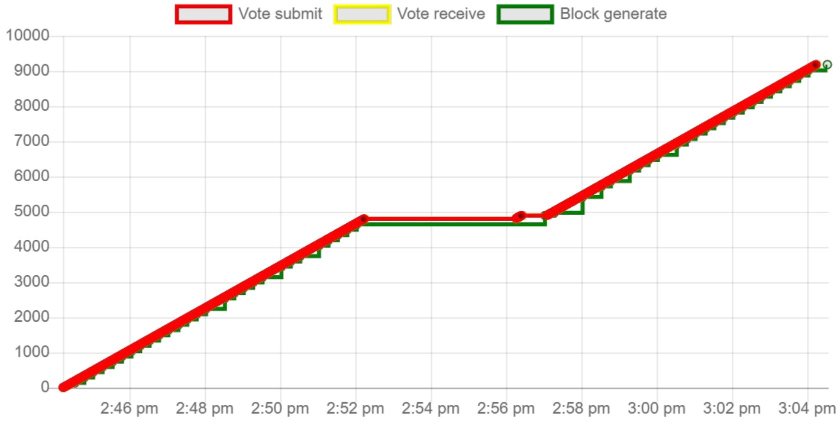


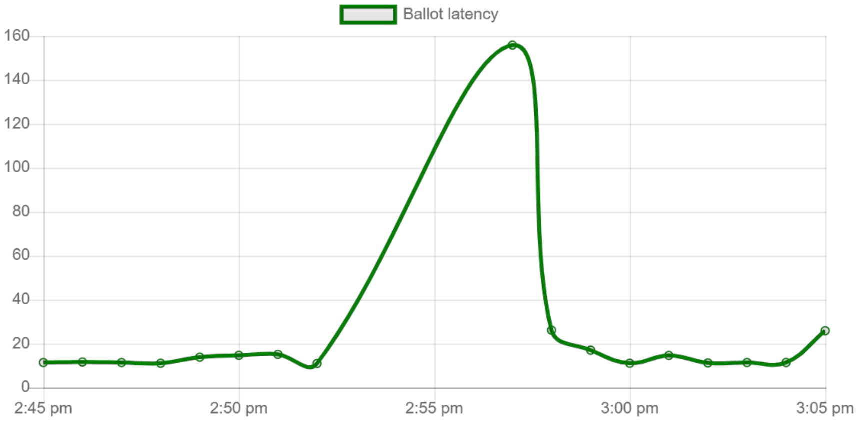
Summary & Improvement

- Great improvement
- Able to scale up
- Memory leakage problem
    - Fixed (on block generation)

Reliability test

- 3 nodes on the same CSE machine
- Able to adapt the situation
- Need time to sync

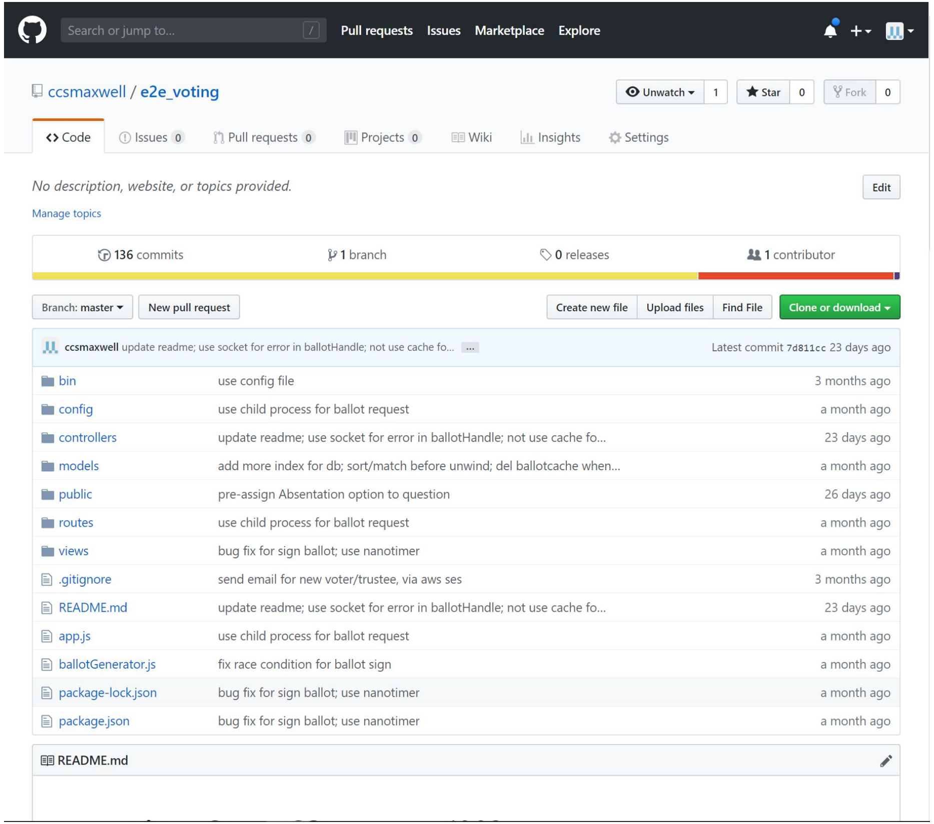




Conclusion

Overview of Term 2

- Zero-knowledge proof
- Reviced design
  - Authenication
  - Blockchain
- Implementation
  - Full verification between nodes
  - User interface & authenication
- Testing & improvement
- Opensource



Possible application

Legislative Council Election

- 5 geographical constituencies (GC)
- 1 million voters per GC
- 100,000 votes per hour
- 28 ballots per second

Future work

- Improvement on scalability
- Improvement on reliability
- Full implementation of the proposed design
- Enforce more security measure
- Use newer communication protocols
- Possibility of enabling “Voting-as-a-service”

Improvement on scalability

- More Child processes
    - Blockchain, Election, Handshake
- Partially broadcasting ballots
    - nodes with same database

Improvement on reliability

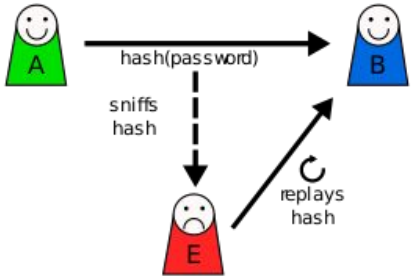
- Ballot re-broadcasting
  - Voter experience
- Smarter blockchain synchronization
  - Sequence of ‘invalid blocks’
- Clock synchronization
  - For block generation

Full implementation of the proposed design

- Kiosk voting
- Authentication method

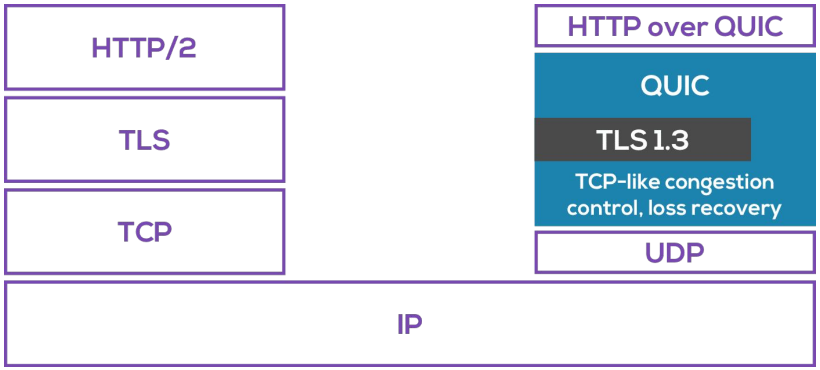
Enforce more security measure

- Removed for the ease of testing
- **Replay attack → Nonce**
- Secure connection → HTTPS



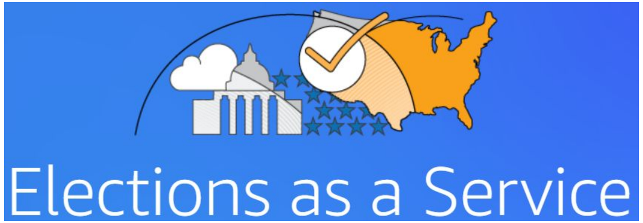
Use newer communication protocols

- **Current**: All via HTTP
- **Improvement**: Some via TCP
- **Future**: Use QUIC



Possibility of enabling “Voting-as-a-service”

- Pay for computation power used
- Earn by hosting as a node



Q & A