

# Measurements, Analysis and Modeling of Hyperledger Fabric

**Abstract**—Bitcoin network

**Index Terms**—Bitcoin Network, Mining Pools, Malthusian Trap, Incentive Mechanism

## 1 INTRODUCTION

**B**ITCOIN [1] is a decentralized peer to peer (P2P) cryptocurrency that was first proposed by Satoshi Nakamoto in 2008. Without resorting to any trusted third party, Bitcoin adapts a cryptographic proof mechanism that enables anonymous peers to complete transactions through the P2P network. Blockchain is the core mechanism of the Bitcoin system. It not only records historical transactions from Bitcoin clients, but also prevents the Bitcoin network from double spending attacks [2]. The Bitcoin network participants, who maintain and update the ongoing chain of blocks, are called miners. These miners compete in a mining race driven by an incentive mechanism [3], [4], where the one who first solves the Bitcoin cryptographic puzzle [5] has the right to collect unconfirmed transactions into a new block, append the new block to the main chain, i.e., the longest chain of blocks, and gain some BTCs [6] as a mining reward.

## 2 PRELIMINARY

### 2.1 Cluster Configuration

This is about cluster configuration

### 2.2 MSP

Certificates

### 2.3 TLS

TLS secure protocol description

## 3 ENVIRONMENT

Hyperledger Fabric version 1.4  
Fabric SDK v1.0.0  
Jmeter

## 4 BLOCKTIME SOLO ORDERER MODE

### 4.1 Model Definition

### 4.2 Model of Orderer's Configuration

The configuration file, i.e., configtx.yaml, configures the orderer service as follows.

TABLE 1  
Configuration Notations

Notations	Descriptions
$N_{msg}$	MaxMessageCount
$S_{max}$	AbsoluteMaxBytes
$S_{pref}$	PreferredMaxBytes
$T_{batch}$	Time to generate a block when MaxMessageCount is not satisfied

TABLE 2  
Customized Notations

Notations	Descriptions
$T_{\sigma}$	Time to generate a block when MaxMessageCount is satisfied
$TAR$	Transaction arrival rate
$BlockTime$	Time it takes to generate a block
$TxDelay$	Time it takes to issue a transaction
$S_{payload}$	Size of transaction payload
$Throughput$	Throughput of transactions

```

1 BatchTimeout: 2s
2 BatchSize:
3   MaxMessageCount: 10
4   AbsoluteMaxBytes: 98 MB
5   PreferredMaxBytes: 512 KB

```

Case Study 1 without considering block size, we have the following model, Given a  $TAR$  of which  $\Delta t = 1$ , the time it costs is given as follows, the average block time is,

$$BlkTime = \begin{cases} \infty & TAR = 0 \\ \frac{T_{batch} N_{msg}}{TAR} & 0 < TAR \leq \frac{N_{msg}}{T_{batch}} \\ \left\lfloor \frac{TAR}{N_{msg}} - 1 \right\rfloor \cdot T_{\sigma} & \frac{N_{msg}}{T_{batch}} < TAR \leq \frac{N_{msg}}{T_{\sigma}} \\ \left\lfloor \frac{TAR}{N_{msg}} - 1 \right\rfloor \cdot T_{\sigma} + T_{batch} & otherwise \end{cases} \quad (1)$$

If  $TAR = 0$ , then  $BlockTime = \infty$ . It means that if there are no transactions, there are no blocks.

If  $0 < TAR \leq \frac{MaxMessageCount}{BatchTimeout}$ . It means that the number of transactions are less than MaxMessageCount

given a BatchTimeout. Therefore, blocks are created for each BatchTimeout.

If  $\frac{MaxMessageCount}{BatchTimeout} < TAR$ . It means that the number of transactions are larger than MaxMessageCount in each BatchTimeout. Therefore, blocks are created as soon as possible and  $\sigma$  is a small value.

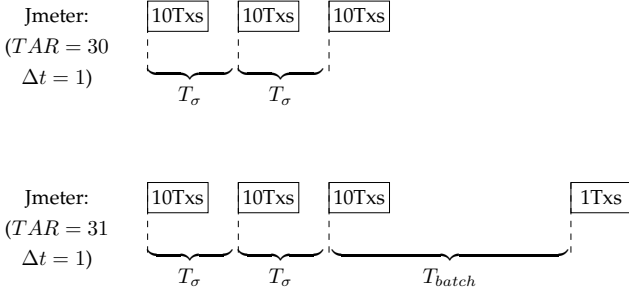


Fig. 1. The  $TAR$  Configurations

#### 4.2.1 Experiment 1: How $TAR$ affects $T_{sigma}$ and Throughput

In this section, we focus on how  $TAR$  affects the block time when MaxMessageCount is satisfied.

Experiment 1 – Setup: for normal TAR we can use workload generators “Thread Group” on Ubuntu 01; while for small TAR we can use other workload generators “Ultimate Thread Group” on Ubuntu 01.

Experiment 1 – Setup: for experiment analysis, we can check with logs in a peer. We have a program to analyze the log data, see *readdata.py* at Github benchmark module at the *q3v14* folder.

Experiment 1 – Observation 1: when TAR achieves a high value (e.g., 80 tps, 90 tps), then a block cannot be fully make used (e.g., 8 transactions per block + 2 transactions per block, instead of 10 transactions per block).

Experiment 1 – Observation 2: when TAR achieve a very high value (e.g., 200 tps), then a peer cannot handle such a high frequent event, and the SDK client will be rejected by the peer. See more error about  $TAR=200$  per peer, Error “peer0.org2.example.com:7051, PKIdid:6830efc127d4818973edd435ee7df6fa6fdf3e23286479b1e34092906659b5 isn’t responsive: EOF”. – To solve this problem, we need more distributed machines.

TO DO – why 70 tps to 80 tps, much not-full used blocks are created?

Experiment 2 – Observation 1: for small TAR (e.g., 20 tps, 30 tps, 40 tps, 60 tps), setting of  $TAR$  (e.g., 11 tps, 21 tps, 31 tps, 51 tps) highly affect the  $T_{sigma}$ .

TODO –: for large TAR (e.g., 80 tps, 90 tps, 140 tps), why experiment 2 is much lower than experiment 1?

TO DO –: why  $TAR=91$  results in fewer null-fully used blocks than  $TAR=90$ ?

#### 4.2.2 Endorsement Policy (OR) on Transaction Delay

Experiment 3 - Setup: Endorsement Policy (OR) the source code is at Ubuntu 01 - nodeTest invoke3.js.

Experiment 3 - Setup: we can calculate with timestamps at invoke3.js.

Experiment 3 - Setup: we save the timestamp results with Jmeter in a res.xml file.

Experiment 3 - Setup: we can summary the timestamp results with readxml.py at nodeTest in ubuntu01.

Experiment 3 - Setup: get proposal approval from local-host, see invoke3.js nodeTest in ubuntu 01.

Experiment 3: Set up: transaction payload size 2 bytes

Experiment 3 - Observation 1: when  $TAR$  are higher than 10 transactions per second, the transaction delay will increase up, since the length of the waiting line is longer.

Experiment 3 - Observation 2: when Tx Orderer Delay are larger than 3 seconds, the transaction proposal will be rejected.

Experiment 3 - Observation 3: transaction proposal delay increases linearly with transaction arrival rate, while orderer transaction delay is not.

Experiment 3 - Observation 4: why these 14 transactions are rejected? It is nothing about orderer. It is limited to the capacity of ubuntu01 local peer. While the next experiment 4, the ubuntu00 remote peer has more powerful computing capacity.

Optimal Solution to this problem: try to let different peers to help to send transaction proposals at the same time.

#### 4.2.3 Endorsement Policy (OR) on Transaction Delay

Experiment 4 - Setup: Endorsement Policy (OR) the source code is at Ubuntu 01 - nodeTest invoke3a.js.

Experiment 4 - Setup: we can calculate with timestamps at invoke3a.js.

Experiment 4 - Setup: we save the timestamp results with Jmeter in a res.xml file.

Experiment 4 - Setup: we can summary the timestamp results with readxml.py at nodeTest in ubuntu01.

Experiment 4: Set up: get proposal approval from remote peer, see invoke3a.js nodeTest in ubuntu 01.

Experiment 4: Set up: transaction payload size 2 bytes

Experiment 4 - Observation 1: we can not find any performance difference between local proposers and remote proposers.

#### 4.2.4 Endorsement Policy (AND) on Transaction Delay

Experiment 5 - Setup: Endorsement Policy (AND) see Github benchmark module the config7.md and the con-

Experiment 5 - Setup: Endorsement Policy (AND) see invoke5.js at nodeTest folder in Ubuntu01 machine.

Experiment 5 - Observation 1: endorsement policy (AND) will have relatively small larger in transaction delay than endorsement policy (OR), when there are only two peers.

Experiment 5 - Observation 2: if the endorsement policy (AND), we will have more responses say two times, and the peer ubuntu00 will have double burdens, resulting in peer channel problem.

Experiment 5 - Next Steps: if we have more peers say 16 peers using the endorsement policy (AND), then how about the transaction delay?

Experiment 5: Next Steps: what is the technical solutions to the error problem with the eventhub? the eventhub shutdown problem see <https://stackoverflow.com/questions/52773529/hyperledger-fabric-nodejs-sdk-eventhub-has-been-shutdown>. Then try to build up your own queue on the peer nodes.

TABLE 3

Experiment 1:  $TAR$  affects  $T_{sigma}$ ,  $numberoftransactionsofablock$  and  $numberoftransactionsrejected$ 

$TAR$	20	30	40	50	60	70	80	90	100	150
$BlkTime.AVG$	0.338	0.3828	0.4151	0.4035	0.5730	0.4866	<b>1.1803</b>	<b>1.1792</b>	<b>1.0968</b>	<b>1.0285</b>
$BlkTime.MAX$	0.325	0.4040	0.5727	0.5260	0.6412	0.5290	<b>1.5029</b>	<b>1.5668</b>	<b>1.3033</b>	<b>1.4904</b>
$BlkTime.MIN$	0.35	0.3715	0.3337	0.3362	0.4634	0.4492	0.6994	0.4832	0.7277	0.7244

TABLE 4

Experiment 2: how batch of  $TAR$  affects  $T_{sigma}$ 

$TAR$	11	21	31	41	51	61	71	81	91	141
$BlkTime.AVG$	2.2673	1.2507	1.0408	0.9152	0.7564	0.7073	0.7243	<b>0.9656</b>	<b>0.7010</b>	<b>nll</b>
$BlkTime.MAX$	2.4900	1.2920	1.3040	1.1757	0.8044	0.8395	0.9021	<b>1.3219</b>	<b>0.8963</b>	<b>nll</b>
$BlkTime.MIN$	2.0030	1.1800	0.8203	0.7715	0.7222	0.6288	0.5626	0.5490	0.5187	nll

TABLE 5

Experiment 3: Endorsement Policy "OR", with local proposer

$TAR$	Phase 1: Tx Proposal Delay		Phase 2: Tx Orderer Delay		Total Tx Delay	Rounds	Accepted TxS	Rejected TxS
	Delay (s)	Proportion (%)	Delay (s)	Proportion (%)				
5	0.75	24.67	2.29	75.33	3.04	5	25	0
10	1.52	71.69	0.60	28.31	2.12	5	50	0
30	4.58	82.67	0.96	17.33	5.54	5	150	0
50	7.88	85.65	1.32	14.35	9.2	5	250	0
70	11.19	88.11	1.51	11.89	12.70	5	350	0
<b>90</b>	<b>14.39</b>	<b>89.10</b>	<b>1.76</b>	<b>10.90</b>	<b>16.15</b>	<b>5</b>	<b>436</b>	<b>14</b>

TABLE 6

Experiment 4: Endorsement Policy "OR", with remote proposer

$TAR$	Phase 1: Tx Proposal Delay		Phase 2: Tx Orderer Delay		Total Tx Delay	Rounds	Accepted TxS	Rejected TxS
	Delay (s)	Proportion (%)	Delay (s)	Proportion (%)				
5	0.80	26.05	2.27	73.95	3.07	5	25	0
10	1.52	73.07	0.56	26.93	2.08	5	50	0
30	4.51	83.82	0.87	16.18	5.38	5	150	0
50	7.60	86.75	1.16	13.25	8.76	5	250	0
70	10.88	88.62	1.41	11.48	12.29	5	350	0
90	14.33	89.67	1.65	10.33	15.98	5	450	0

TABLE 7

Experiment 5: Endorsement Policy "AND", with remote proposer

$TAR$	Phase 1: Tx Proposal Delay		Phase 2: Tx Orderer Delay		Total Tx Delay	Rounds	Accepted TxS	Rejected TxS
	Delay (s)	Proportion (%)	Delay (s)	Proportion (%)				
5	0.74	24.74	2.25	75.25	2.99	5	25	0
10	1.56	71.88	0.61	28.12	2.17	5	50	0
30	4.65	82.88	0.96	17.12	5.61	5	150	0
50	7.82	86.12	1.26	13.88	9.08	5	250	0
70	11.09	87.59	1.57	12.41	12.66	5	347	3
90	14.34	88.62	1.84	11.37	16.18	5	438	12

Solutions to the eventhub problem: build up your own queue <https://stackoverflow.com/questions/52773529/hyperledger-fabric-nodejs-sdk-eventhub-has-been-shutdown>. See Event hub with read-write conflict transactions <https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8751453>.

[6] BTC. [Online]. Available: <https://en.bitcoin.it/wiki/Bitcoin>, Accessed on 31 January 2019.

#### 4.2.5 Transaction Size on Transaction Delay

Experiment 6 - Setup: Transaction size 1 KB

Experiment 6 - Setup: invoke3.js in "nodeTest" folder in ubuntu 01.

#### 4.2.6 Transaction Size on Transaction Delay

Experiment 7 - Setup: Transaction size 10 KB

Experiment 7 - Setup: invoke3.js in "nodeTest" folder in ubuntu 01.

### 4.3 Transaction Delay (For Peer)

Here we need to discuss something about transaction delay in this section.

#### 4.3.1 Transaction Size

How transaction size affects transaction delay, transaction loss

#### 4.3.2 Experiment 1: Transaction Size 1 byte

#### 4.3.3 Experiment 2: Transaction Size 300 byte

#### 4.3.4 Experiment 3: Transaction Size 10 Mbyte

#### 4.3.5 Endorsement Policy

#### 4.3.6 Experiment 1: Policy a

#### 4.3.7 Experiment 2: Policy b

#### 4.3.8 Experiment 3: Policy c

Here we need to know how endorsement policy affect transaction delay

## 5 KAFKA ORDERER MODE

### 5.1 Model of Kafka Orderer's Configuration

The configuration file of Kafka

## REFERENCES

- [1] S. Nakamoto, "Bitcoin: A peer-to-peer electronic cash system," 2008.
- [2] G. O. Karame, E. Androulaki, M. Roeschlin, A. Gervais, and S. Čapkun, "Misbehavior in bitcoin: A study of double-spending and accountability," *ACM Transactions on Information and System Security (TISSEC)*, vol. 18, no. 1, p. 2, 2015.
- [3] Y. Lewenberg, Y. Bachrach, Y. Sompolinsky, A. Zohar, and J. S. Rosenschein, "Bitcoin mining pools: A cooperative game theoretic analysis," in *Proceedings of the 2015 International Conference on Autonomous Agents and Multiagent Systems*. International Foundation for Autonomous Agents and Multiagent Systems, 2015, pp. 919–927.
- [4] O. Schrijvers, J. Bonneau, D. Boneh, and T. Roughgarden, "Incentive compatibility of bitcoin mining pool reward functions," in *International Conference on Financial Cryptography and Data Security*. Springer, 2016, pp. 477–498.
- [5] I. Giechaskiel, C. Cremers, and K. B. Rasmussen, "On bitcoin security in the presence of broken cryptographic primitives," in *European Symposium on Research in Computer Security*. Springer, 2016, pp. 201–222.

TABLE 8  
Experiment 6: Transaction Size on Transaction Delay 1 KB

$TAR$	Phase 1: Tx Proposal Delay	Phase 2: Tx Orderer Delay	Total Tx Delay	Rounds	Accepted Txs	Rejected Txs
5	0.78	2.33	3.11	5	25	0
10	1.54	0.68	2.22	5	50	0
30	4.67	0.94	5.61	5	150	0
50	7.83	1.25	9.08	5	250	0
70	11.14	1.48	12.62	5	350	0
90	14.54	1.86	16.4	5	449	1