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About Quorum Performance Verification Using Hyperledger Caliper

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NTT DATA Corporation
Shumpei Shimizu

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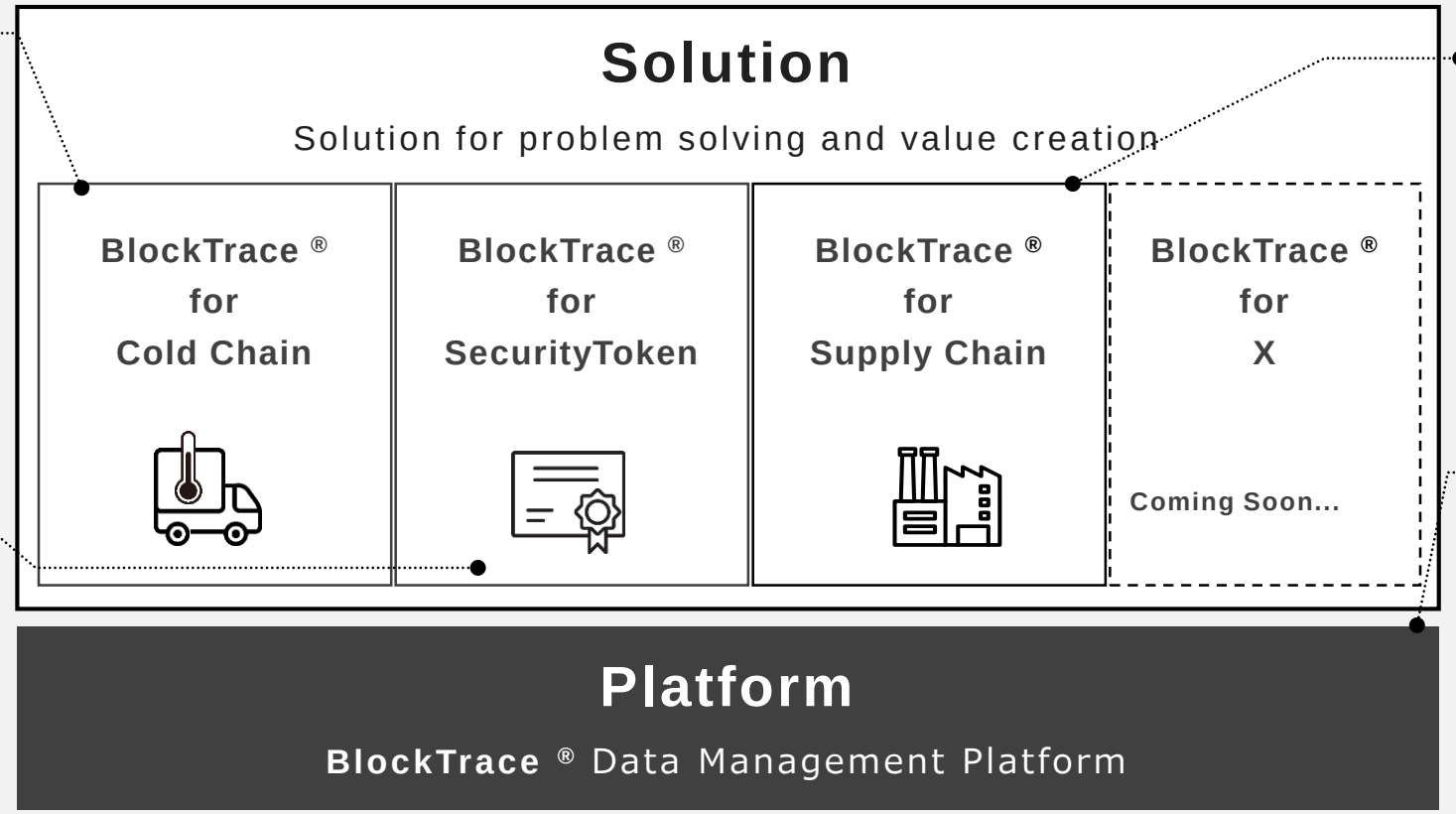

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Quorum Performance Verification

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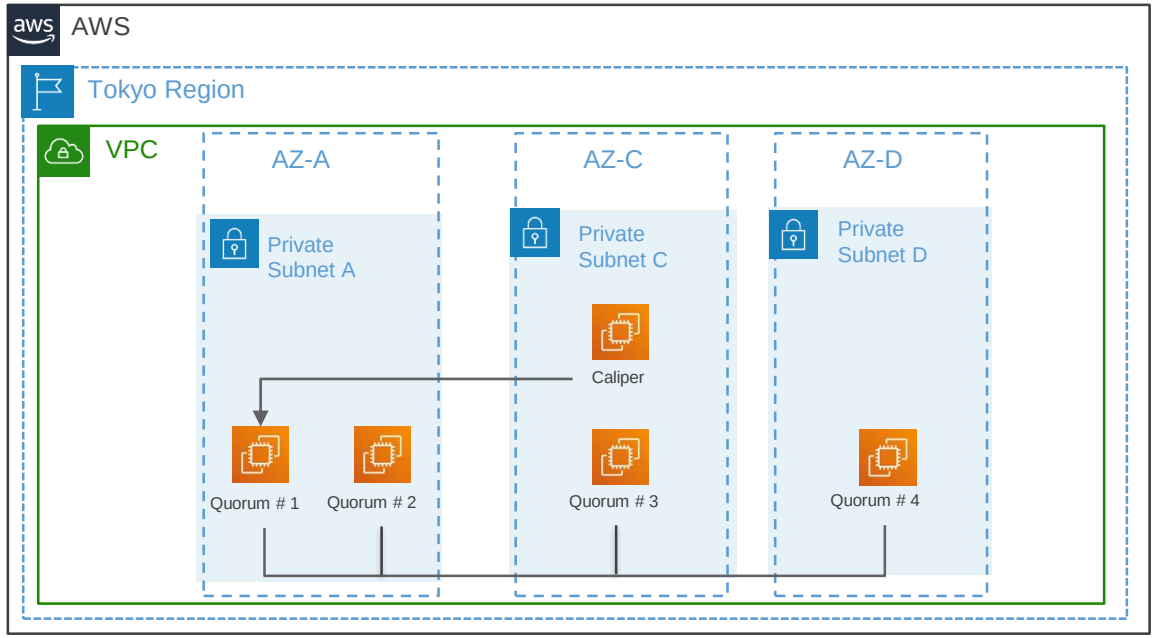
1. Configuration diagram of verification environment (1)

The configuration information of the Quorum shall be as follows:.
This configuration information is equivalent to a white paper.

Category	Items	Definition	Value
Information About Blockchains	Blockchain Client Name	Blockchain Client Name	Go quorum (v 21.7.1)
	Consensus Algorithm	A method of network-wide agreement in a blockchain.	IBFT
	Transaction Method	A state transition method that changes data in a blockchain from one value to another. The content of the processing subject to performance measurement.	Open Query Transfer
	Network Size Node Count	Number of validator nodes participating in consensus building.	4 units
	Block Generation Interval	Interval at which blocks are generated	10 s

1. Configuration diagram of verification environment (2)

The following configuration was constructed on AWS as a measurement environment.



Category	Items	Quorum Instance	Caliper Instance
Hardware Information	OS	Ubuntu 20.04 LTS	Ubuntu 20.04 LTS
	Instance Type	m5a.large	m5a.large
	vCPU (number of cores)	2	2
	Memory (GB)	8	8
	Processor	Intel Xeon ® Platinum 8175/3.1 GHz	Intel Xeon ® Platinum 8175/3.1 GHz
	Instance Storage	EBS only	EBS only
	network bandwidth	Up to 10 GiB/s	Up to 10 GiB/s
	EBS bandwidth	Up to 4,750	Up to 4,750
	Volume Type	General Purpose SSD (gp2) IOPS: 1200	General Purpose SSD (gp2) IOPS: 1200
	Key Software	Quorum v 21.7.1	Caliper v 4.0.0

System Configuration Points:

- Quorum should consist of a minimum of four units
- One Caliper.
  (Don't use Docker)
- Subnets are prepared in units of AZ, but communication between subnets is allowed unconditionally.

2. About Caliper

Caliper performs sample processing of balance setting, balance reference, and remittance to measure performance.
The following process (smart contract) was used for each verification.

Open: Set (write) balances
Query: Browse (read) balances
Transfer: send (write + read) balance

The main configuration items of Caliper set in this verification are:

Items	Caliper Configuration Name	Description
Target TPS	tps	The target TPS value for each process. (Example) If 50 is used, load is set to 50 tps.
Transaction Send Count	txNumber	The number of transactions that Caliper sends during the round. The number of times to send a transaction before reaching the target TPS. (Example) Assuming 1000, the test ends after 1000 transactions are sent.
Walker number	workersNumber	Number of processes to load.

Reference: Official Caliper Documentation https://hyperledger.github.io/caliper/v0.4.2/ethereum-config/

3. Measurement Conditions – Measurement items

Run Caliper and specify the items to be retrieved as follows:.
This measurement item is equivalent to the white paper.

Category	Items	Description
Information About Blockchains	Read Latency	Total time to send a read request and receive its response. Get from the result of the execution function Query.
	Read Throughput	Reads per second. Retrieve from the query result of the execution function.
	Transaction Latency	The time it takes for the entire network to validate the transaction. Obtain from the result of Open and Transfer of the execution function.
	Transaction Throughput	Percentage of time that valid transactions are committed by the blockchain during the defined time period. It is obtained from Throughput of Read and Write for each execution function.
Information about system resource utilization	CPU Load (Max, Min, Avg)	The load on the CPU. Obtain with the dstat command.
	disk capacity load (Max, Min, Avg)	Load on disk capacity. Obtain with the dstat command. The command to get Dstat is as follows. $dstat -tcd -o < outputfilename > 5 *Record time, CPU usage, and disk usage in 5-second intervals

3. Measurement Conditions – Validation Items

Policy: Target TPS is 50 (fixed) and number of walkers is 1 (fixed).
Repeat the verification while increasing the number of transactions sent by + 1000.

In this verification, measurement is carried out in the following pattern.

Verification No	Category	execution function	mining interval	Walker number	Target TPS	Transaction Send Count
1-1	fixed-rate	open	10 s	1	50	1,000
1-2	fixed-rate	query				
1-3	fixed-rate	transfer				
2-1	fixed-rate	open				2,000
2-2	fixed-rate	query				
2-3	fixed-rate	transfer				
Repeat after ・・・ (Target TPS 50 Fixed, Transactional Transmissions + 1000)						

*The above settings are defined in benchmarks/config.json.

4-1. measurement result

Measurement Results (Summary):

Verification No.	execution function	Read Latency			Transaction Latency			Transaction Throughput *(Total Read, Write)	Maximum resource utilization	
		Max [s]	Min [s]	Average [s]	Max [s]	Min [s]	Average [s]		CPU average value [%]	Average Disk Write I/O byte
1-1	Open	-	-	-	12.18	1.94	7.05	94.5	21.33335	0
1-2	Query	0	0	0	-	-	-	50.1	0.333333333	0
1-3	Transfer	-	-	-	12.03	1.22	6.42	50	6.000142857	0
2-1	Open	-	-	-	16.53	1.21	6.7	66.9	22.83191667	800.6414167
2-2	Query	0.01	0	0	-	-	-	50	1.222222222	376.539
2-3	Transfer	-	-	-	12.03	1.22	6.42	50	11.54527273	30.18190909
3-1	Open	-	-	-	34.92	1.99	17.37	60.3	29.94282353	2.823117647
3-2	Query	0.01	0	0	-	-	-	50	1.038384615	115.1046923
3-3	Transfer	-	-	-	12.23	1.21	6.58	50	10.53433333	5.868266667

4-2. measurement result

Measurement Results (Summary):

Verification No.	execution function	Read Latency			Transaction Latency			Transaction Throughput *(Total Read, Write)	Maximum resource utilization	
		Max [s]	Min [s]	Average [s]	Max [s]	Min [s]	Average [s]		CPU average value [%]	Average Disk Write I/O byte
4-1	Open	-	-	-	14.1	0.64	6.9	49.8	20.99794737	0
4-2	Query	0.01	0	0	-	-	-	50	0.027777778	54.22455556
4-3	Transfer	-	-	-	12.24	0.64	6.46	49.9	2.789473684	0
5-1	Open	-	-	-	12.25	0.96	6.63	49.9	57.85386957	169.5736522
5-2	Query	0.01	0	0	-	-	-	50	3.272727273	704.006
5-3	Transfer	-	-	-	12.23	1.16	6.67	49.9	48.34991304	3.304173913
6-1	Open	-	-	-	36.59	2.23	14.83	54.1	64.44280769	413.0867308
6-2	Query	0.01	0	0	-	-	-	50	0.942538462	0
6-3	Transfer	-	-	-	12.23	1.03	6.69	49.9	7.574074074	367.4096667

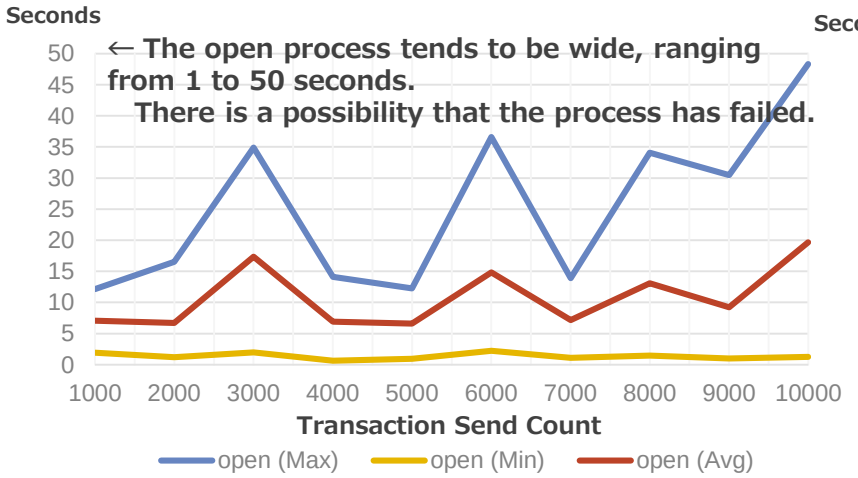
Measurement up to Verification No. 10 (Number of transactions sent: 10,000)

4-3. measurement result

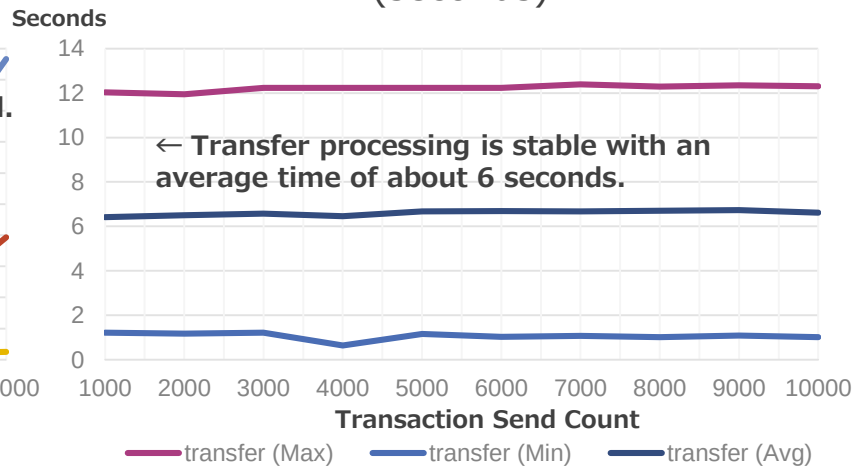
■About Latency Trends

As shown in the graph below, on average, latency tends to be low regardless of the number of transactions sent.
Also, while the read latency in query processing is always fast, the latency of the transaction in open and transfer processing tends to be high.

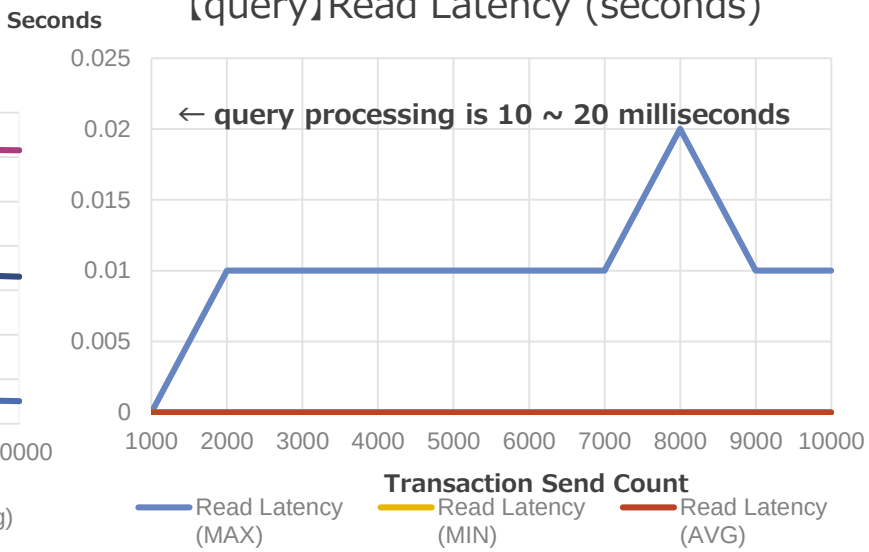
【open】Transaction Latency (seconds)



【transfer】Transaction Latency (seconds)



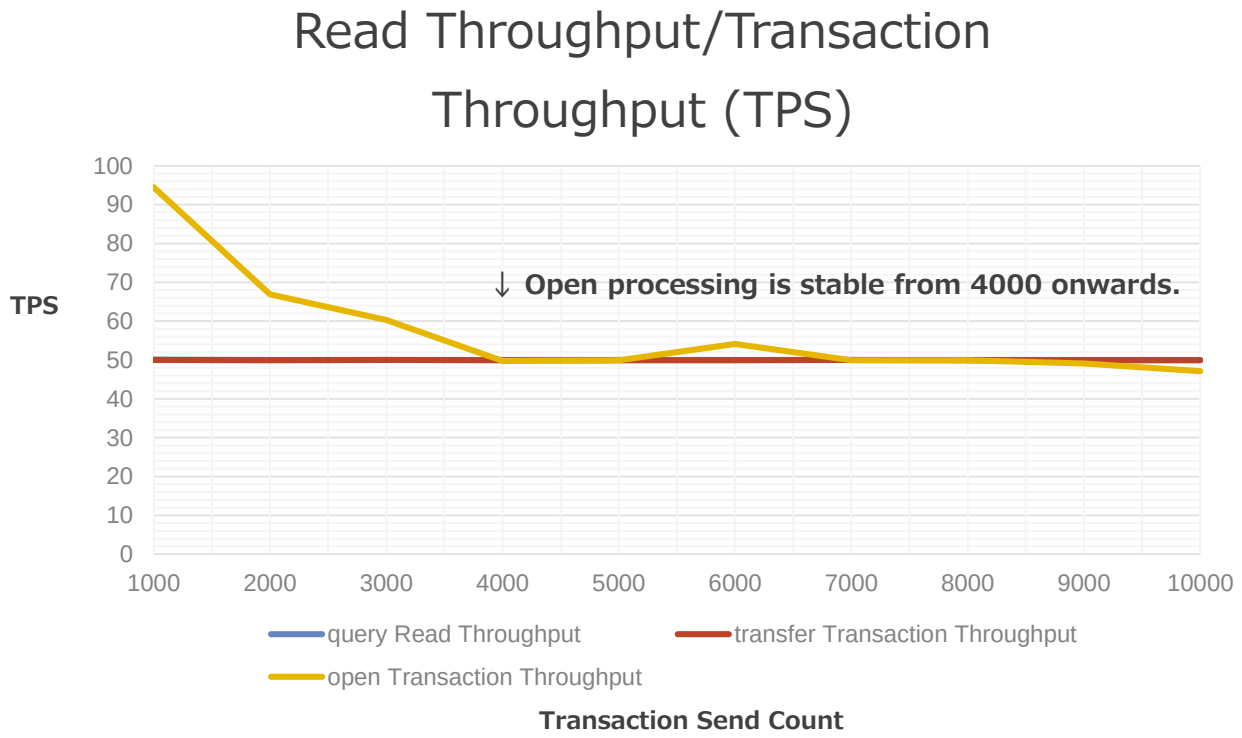
【query】Read Latency (seconds)



4-4. measurement result

■About Throughput Trends

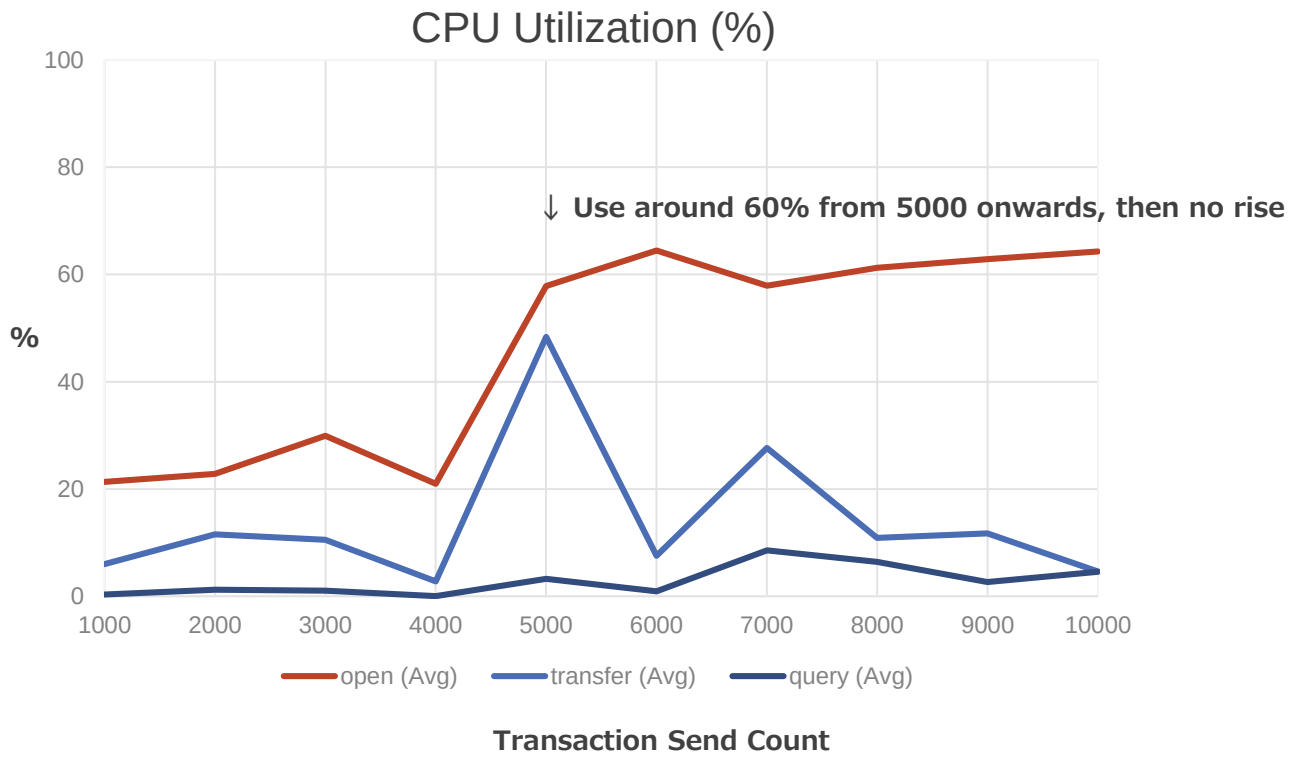
As shown in the graph below, as the number of transaction transmissions increases, Throughput moves toward the target TPS (50 tps), and the number of transaction transmissions tends to stabilize at 4000 or more.



4-5. measurement result

■About CPU Usage Trends

In the graph below, the value of the average value every 5 seconds is obtained by dstat, and the average value is calculated from the value for each transaction transmission number (each verification), and is graphed.
When the Open process reaches 60% and does not exceed 70%, the CPU usage is still high. Also, it can be seen that the Open process is the process using the CPU most.



4-6. measurement result

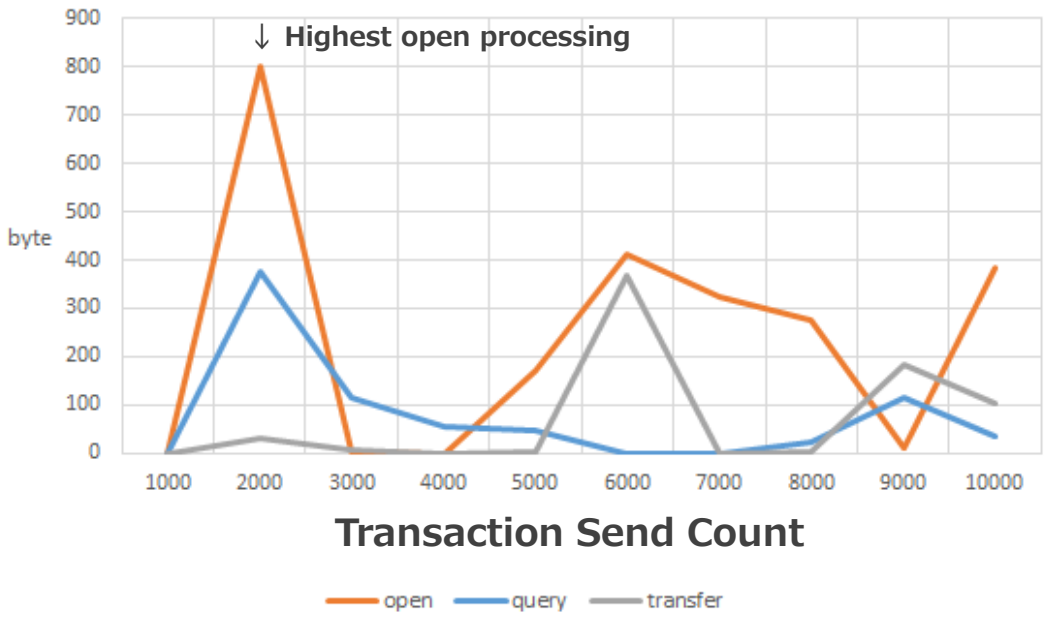
■Understanding Disk Load Trends

In the graph below, the value of the average value every 5 seconds is obtained by dstat, and the average value is calculated from the value for each transaction transmission number (for each verification), and is graphed (divided by Read and Write).

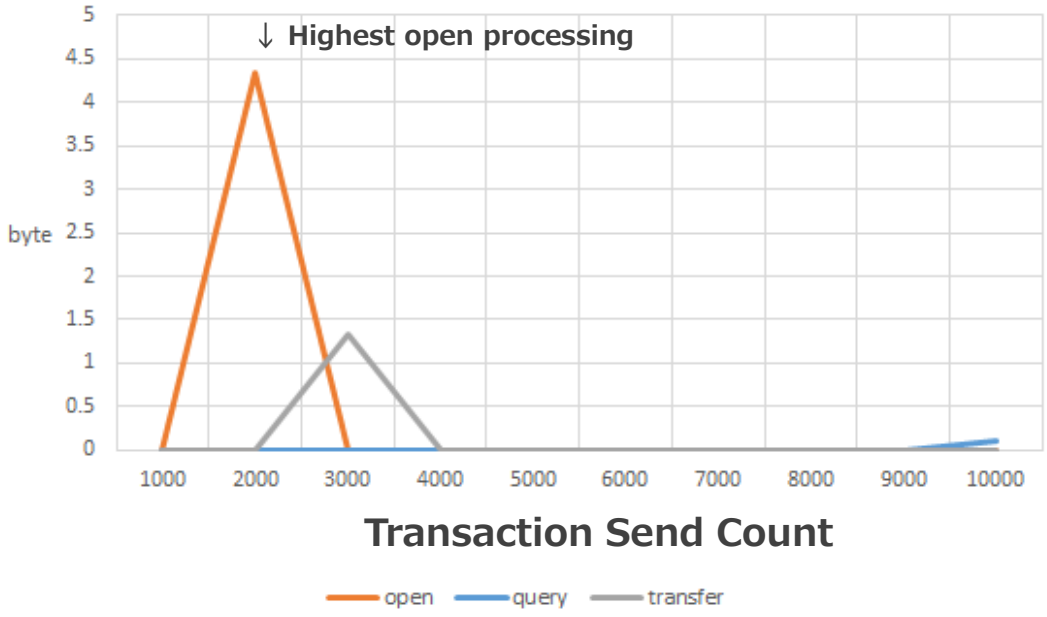
It can be seen that the Open process is the most burdensome process for both writing and reading.

However, since the disk capacity load by processes other than this measurement is included, it is necessary to prepare a disk to be loaded for more accurate measurement.

Disk Capacity load (Write)



Disk Capacity load (Read)

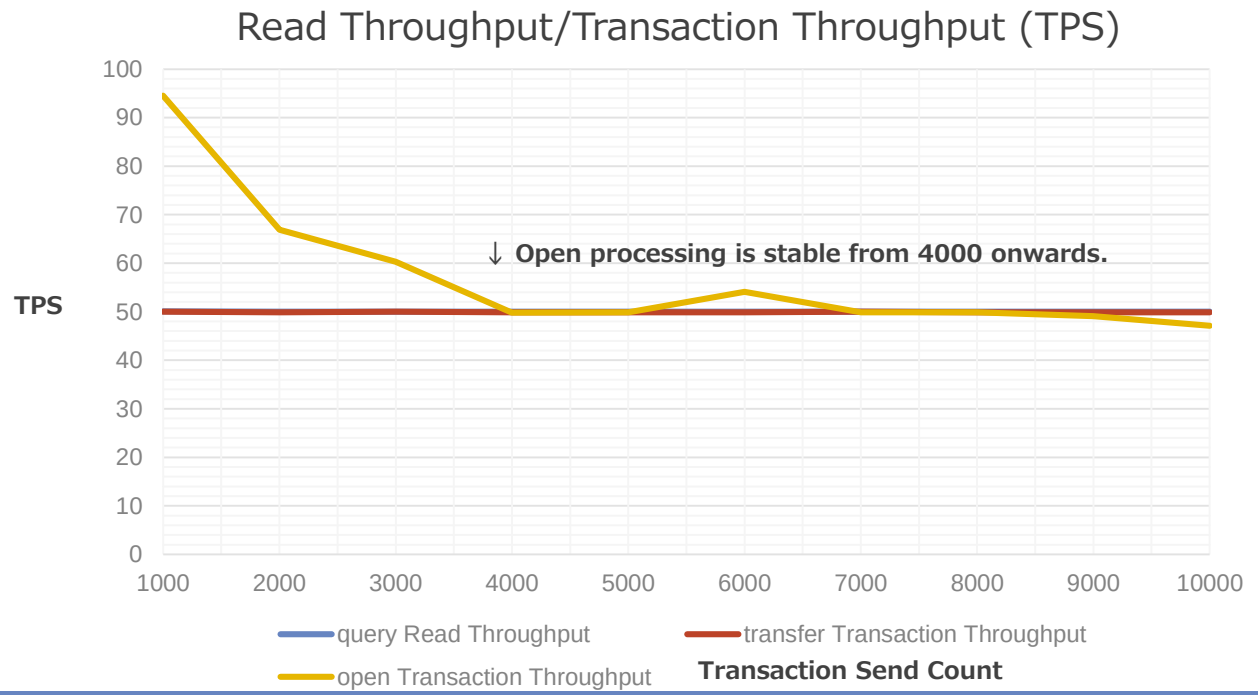


5. Discussion

■Relevance of Target TPS × Transaction Transmissions

Although verification was performed to increase the number of transaction transmissions from 1000 to 18000, the target TPS and CPU utilization tended to stabilize at transaction transmissions of 4000 or more. In this verification of the target TPS 50, it was found that the number of transaction transmissions should be set to 4000 or more in order to stably apply the appropriate load.

In this verification, the target TPS is fixed, but it is necessary to set the target TPS and the number of transaction transmissions appropriately when performing performance verification of high load.



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