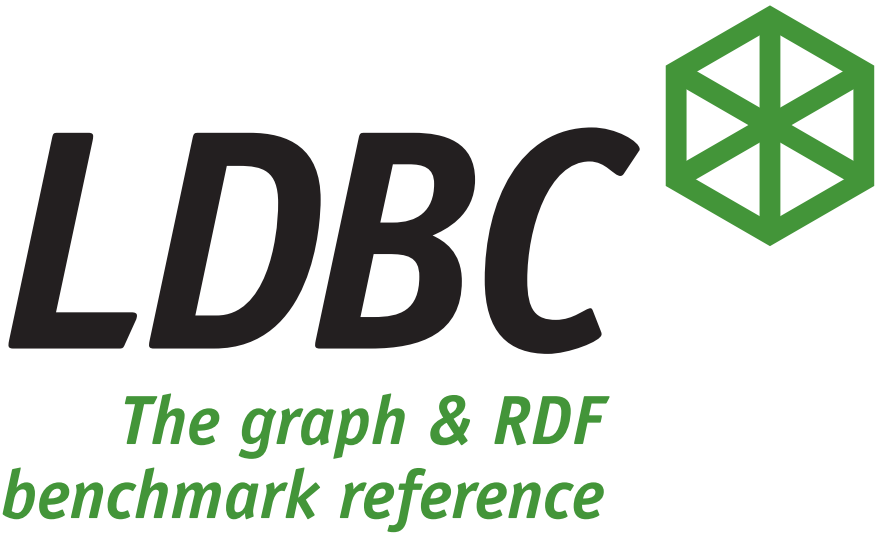

Full Disclosure Report of the LDBC Social Network Benchmark

An Implementation of the LDBC Social Network Benchmark's Interactive Workload over GraphScope Flex

May 14, 2024

General Terms

Executive Summary

This document describes an implementation of the LDBC Social Network Benchmark's Interactive workload on a graph database-like build of GraphScope Flex, a modular graph computing stack developed by Alibaba Cloud.

GraphScope Flex[1] is designed to accommodate the diverse and complex needs of real-world graph applications. These applications can involve a variety of graph workloads and can be deployed in different modes.

In the audited benchmark runs, GraphScope Flex 0.26.1 was used to execute scale factors SF100, SF300, and SF1000 in a single-instance setting (plus another instance to run the driver). The instances were deployed on the Alibaba Cloud infrastructure.

The queries were implemented imperatively using stored procedures written in C++17, which were then compiled and loaded into the database at runtime as shared libraries. The data schema follows the property graph model with indices only over vertex identifiers and neighbour sets. No additional indices or precomputed properties were used. The system under test and the driver communicated using remote http.

Declaration of Audit Success

This report contains an audited LDBC benchmark run. The results have been gathered by an independent and impartial auditor who has validated the implementation of the queries, successfully run the ACID tests associated with the claimed isolation level (serializable), and verified the overall system's configuration conformance to the description of the benchmark and its strict requirements.

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[1] https://github.com/alibaba/GraphScope/tree/main/flex

Table of Contents

1 System Description and Pricing Summary

1.1 Details of machines driving and running the workload

1.1.1 Machine overview

The details below were obtained from Alibaba Cloud dashboard (Instance Details page). The operating system was obtained from running `uname -a` and `lsb_release -a` commands.

Table 1.1: Machine Type and Location

Cloud provider	Alibaba Cloud
Machine region	China (Ulanqab)
Common name of the item	ecs.r8a.16xlarge
Operating system	Linux 5.4.0-171-generic #189-Ubuntu 20.04.6 LTS SMP

Note that the system is configured with the following additional command, to allow for the required amount of asynchronous requests:

```
echo "fs.aio-max-nr=1048576" » /etc/sysctl.conf && sysctl -p /etc/sysctl.conf
```

Also, for SF100 and SF300, hugepages[1] are enabled with:

```
echo "vm.nr_hugepages=123579" » /etc/sysctl.conf && sysctl -p /etc/sysctl.conf
```

This benchmark used two `ecs.r8a.16xlarge` instances, one for the driver and one for the system under test (SUT). Both machines were assigned to the same VPC with the same subnetwork. This is shown in Figure 1.1.

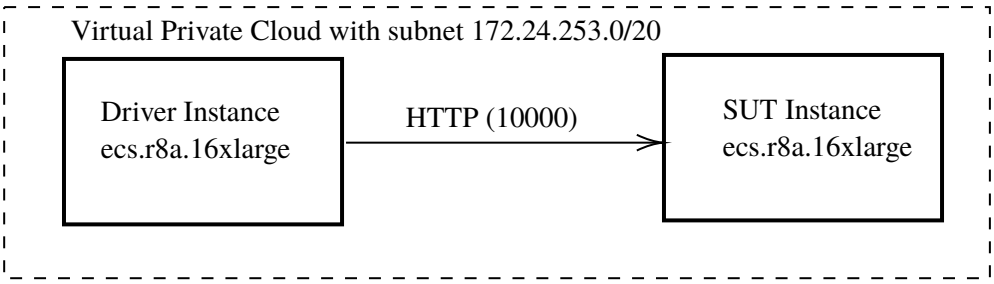

Figure 1.1: Overview of benchmark setup

1.1.2 CPU details

The details below were obtained using the command `lscpu` (Listing A.1) issued from the machine SUT and the datasheet of the used CPU type.

Table 1.2: CPU details summary

Type	AMD EPYC 9T24 96-Core Processor
Total number	1
Cores per Instance	32
Threads per CPU core	2
CPU clock frequency	3.70 GHz
Total cache size per CPU	L1 cache: 1MiB Data + 1MiB Instruction L2 cache: 32MiB L3 cache: 128MiB

[1] `https://www.kernel.org/doc/html/latest/admin-guide/mm/hugetlbpage.html`

1.1.3 Memory details

The total size of the memory installed is 512GB and the type of memory is DDR5 (according to CPU specs). We could not obtain the memory type nor the frequencies using the `sudo lshw -c memory` (Listing A.2) and other similar commands, as they were reported as 'Unknown'.

We measured the memory read and write bandwidth with the `sysbench` tool, obtaining a bandwidth of 643 GB/s (Listing A.3) and 195.5 GB/s (Listing A.4) respectively, using 64 threads and 1GB memory blocks.

1.1.4 Disk and storage details

The instance has multiple disks attached. Has one 40GB NVMe ESSD device `/dev/nvme0n1` with three partitions:

- `/dev/nvme0n1p1` bios boot, not mounted (1M)
- `/dev/nvme0n1p2` mounted at `/boot/efi` (vfat - 128MB)
- `/dev/nvme0n1p3` mounted at `/` (ext4 - 39.8GB)

and another 4TB NVMe ESSD device `/dev/nvme1n1` mounted at '/data'. The filesystem used for this disk is 'xfs' During all the audit, only the 4TB disk was used in both instances.

The file system type used for both drives was `xfs`. We tested the performance of `/dev/nvme1n1` of the SUT, both for Driver Listing A.7 and Server Listing A.8 instances with the `fio` command, using 4KB blocks and a queue depth of 1 obtaining an average of 11.1k and 10.0k IOPS respectively.

1.1.5 Network details

The benchmark was run using two `ecs.r8a.16xlarge` instances, both deployed in the same availability zone behind a Virtual Private Cloud (VPC) configured with subnetwork `172.24.253.0/20`. Only the SUT instance had the following ports open:

- `10000`: HTTP port used by SUT

The `ecs.r8a.16xlarge` instances use a common Ethernet adapter. This information was obtained using the `lshw -class network` command (Listing A.5). Network throughput between the two instances was measured using the `iperf` tool on port 10000 using 64 threads and the output (Listing A.6) showed an average of 24.3 Gbit/s from client to server and 35.9 Gbit/s from server to client.

1.1.6 Machine pricing

The system pricing summary is included in the table below. The pricing of the Alibaba Cloud instance is the price for a 3-year Standard Reserved Instance (without upfront payment). The GraphScope Flex database software is freely available under the Apache Software License v2.0, hence its permanent license cost is 0.00 RMB. The maintenance service fee guarantees 24-hour availability, 7 days a week with a 4-hour response time.

Table 1.3: Pricing summary

Item	**Price**
ecs.r8a.16xlarge reserved instance machine in Alibaba Cloud (standard 3-year term)	338 274.72 RMB
Permanent GraphScope Flex license	0.00 RMB
Maintenance service fee (3 years)	400 000.00 RMB
Total cost of ownership	738 274.72 RMB

1.1.7 System availability

The latest software version of GraphScope Flex (version 0.26.1) was made available on April 1st, 2024. This version was deployed to the machine described in this section. GraphScope Flex is an open-source software released under the Apache Software License 2.0, the used release is available online on GitHub[2].

[2] https://github.com/alibaba/GraphScope/releases/download/v0.26.0/graphscope_flex_0.26.1_amd64.deb

2 Dataset Generation

2.1 General information

The data generation settings of the LDBC Datagen are described below.

Table 2.1: Datagen settings summary

Datagen version	v0.3.8
Output format	CsvComposite serializer
Scale factors	100, 300, 1000
Number of update stream partitions	48

For validation, we used scale factors from SF0.1 to SF10. Validation parameters were downloaded from LDBC GitHub[1], which are generated using the Neo4j implementation. Such datasets are generated with the following settings:

Table 2.2: Datagen settings summary for Validation Datasets

Datagen version	v0.3.8
Output format	CsvComposite serializer
Scale factors	0.1, 0.3, 1, 3, 10
Number of update stream partitions	1

2.2 Datagen configurations

The Datagen configuration for scale factor SF10 is shown in Listing 2.1. The configurations for SF100, SF300 and SF1000 are shown in Listings A.9–A.11.

Listing 2.1: Contents of `params-sf10.ini` used for scale factor 10

```
1 ldbc.snb.datagen.generator.scaleFactor:snb.interactive.10
2 ldbc.snb.datagen.serializer.dynamicActivitySerializer:ldbc.snb.datagen.serializer.snb.csv.dynamicserializer.
      activity.CsvCompositeDynamicActivitySerializer
3 ldbc.snb.datagen.serializer.dynamicPersonSerializer:ldbc.snb.datagen.serializer.snb.csv.dynamicserializer.person.
      CsvCompositeDynamicPersonSerializer
4 ldbc.snb.datagen.serializer.staticSerializer:ldbc.snb.datagen.serializer.snb.csv.staticserializer.
      CsvCompositeStaticSerializer
```

2.3 Data loading and data schema

The output produced by Datagen is preprocessed with `add_column`, a tool provided (including source code in C++). Such tool joins the `creationDate` column is extracted from `post_0_0.csv` and `comment_0_0.csv` with the `post_hasCreator_person_0_0.csv` and `comment_hasCreator_person_0_0.csv` to create two new files, `post_hasCreator_person_0_0.csv.creation_date` and `comment_hasCreator_person_0_0.csv.creation_date`, with `Post.id/Comment.id`, `Person.id` and `creationDate`.

We utilize two configuration files to define the data loading process and the schema: `bulk_load.yaml` (Listing 2.2) and `graph.yaml` (Listing A.12).

The `bulk_load.yaml` file is defined for each dataset (of given scale factor). It is automatically configured using the UNIX `sed` tool. This file outlines the path to the CSV files containing the data, specifies whether the objects

[1] `https://pub-383410a98aef4cb686f0c7601eddd25f.r2.dev/interactive-v1/validation_params-sf0.1-sf10.tar.zst`

being loaded are vertices or edges, labels these objects with appropriate tags (such as PERSON, KNOWS, etc.), and defines the file format. The properties of these objects are inferred from the column names in the CSV files.

The `graph.yaml` is consistent across all datasets. This file details the schema, including the types of vertices and edges, their properties, the indexing type for edges, and the path to the stored procedures. The configuration of stored procedure paths is also handled using the UNIX `sed` tool.

Listing 2.2: Excerpt from `bulk_load.yaml`, describing the data loading process

```
{
graph: ldbc_snb
loading_config:
  data_source:
    scheme: file
    location: {PATH_TO_DATASET}
  import_option: init # append, overwrite, only init is supported now
  format:
    type: csv
    metadata:
      delimiter: "|"  # other loading configuration places here
vertex_mappings:
  - type_name: PLACE
    inputs:
      - static/place_0_0.csv
  - type_name: PERSON
    inputs:
      - dynamic/person_0_0.csv
   ...
edge_mappings:
  - type_triplet:
      edge: HASCREATOR
      source_vertex: COMMENT
      destination_vertex: PERSON
    inputs:
      - dynamic/comment_hasCreator_person_0_0.csv.creation_date
    source_vertex_mappings:
      - column:
          index: 0
          name: id
    destination_vertex_mappings:
      - column:
          index: 1
          name: id
    column_mappings:
      - column:
          index: 2
          name: creationDate
        property: creationDate
    ...
}
```

Data loading times are shown for each scale factor in the table below (second column). Loading times are reported by the SUT, and source code was inspected to audit its correctness. After loading, the database was shut down and started again. The third column shows the times to startup from an already loaded database.

Table 2.3: Data loading times and startup times

Scale factor	Loading time (s)	Startup time (s)
100	351.83	16.46
300	1 129.28	492.94
1000	5 451.27	153.681

Varying startup times for scale factors SF100, SF300, and SF1000 were observed, which initially seemed counterintuitive as one might expect startup times to increase linearly with scale factor size. Several factors contribute to these variations:

- SF100 Benefits from Page Caching: SF100 benefits significantly from that fact that its data can fit entirely within the OS page cache. Clearing the page cache using the command `echo 1 > /proc/sys/vm/drop_caches`[2] raises SF100's startup time to 180 seconds, approximately one-third that of SF300.
- Impact of Hugepages: While SF100 and SF300 use hugepages, which optimize memory handling but require more time for startup due to their data loading processes, the absence of hugepage allows SF1000 to benefit from alternative memory handling techniques that enable faster construction of file-to-memory mappings without the need to preload the entire data into memory upon startup.

[2] https://www.kernel.org/doc/html/latest/admin-guide/sysctl/vm.html

3 Test Driver Details

The driver and implementations version used are described below as well as the amount of read and write threads used by the driver.

Table 3.1: Summary of test artifacts and main configuration parameters

Driver version	v1.2.0	https://github.com/ldbc/ldbc_snb_interactive_driver/releases/tag/v1.2.0
Implementations version	v1.0.0	https://github.com/ldbc/ldbc_snb_interactive_impls/releases/tag/1.0.0
LDBC SNB specification version	v0.3.6	https://arxiv.org/pdf/2001.02299.pdf
Driver read threads	64	
Driver write threads	96	

3.1 Driver implementation

A test driver adaptation for the SUT was provided by the test sponsor and is available as part of the attachment package. The SUT-specific test driver class `org.ldbcouncil.snb.impls.workloads.graphscope.interactive.GraphScopeInteractiveDb` extends the class `com.ldbc.driver.Db` provided in the LDBC SNB Interactive driver package. Internally, the `GraphScopeInteractiveDb` relies on an http connection to communicate with the SUT.

3.2 Benchmark configuration of driver

The driver applied time compression ratio values of

- TCR=0.001 for scale factor 100,
- TCR=0.00335 for scale factor 300 and
- TCR=0.0227 for scale factor 1000.

The complete configuration files for the different scale factors are shown in Listings A.13–A.15, and are also included in the attached supplementary materials.

4 Performance Metrics

The performance metrics reported here show benchmark runs with scale factors 100, 300 and 1000. In each case, the query on-time compliance is higher than the minimum required 95% [1]. The performance summary tables below highlight key performance characteristics.

Table 4.1: Summary of results for scale factor 100

Benchmark duration	Benchmark operations	Throughput	Query on-time compliance
02h 00m 23.388s	939 750 919	130 098.36 $\frac{\text{operations}}{\text{second}}$	99.97%

Table 4.2: Summary of results for scale factor 300

Benchmark duration	Benchmark operations	Throughput	Query on-time compliance
02h 01m 03.734s	953 465 825	131 263.87 $\frac{\text{operations}}{\text{second}}$	99.98%

Table 4.3: Summary of results for scale factor 1000

Benchmark duration	Benchmark operations	Throughput	Query on-time compliance
02h 01m 33.277s	931 967 792	127 784.51 $\frac{\text{operations}}{\text{second}}$	100.00%

During the benchmark run, the query execution times shown in the tables below were observed using the different scale factors. Columns (except for Query and Total count) are showing duration values in microseconds (μs) precision. The notation $\mathbf{P_i}$ is used for the i^{th} percentile among all observed execution run times of a given query type.

[1] The total number of late operations for each run in the results in the attachment is referred to as `excessive_delay_count`.

Table 4.4: Detailed performance benchmark results for scale factor 100 in microseconds

Query	Total count	Min.	Max.	Mean	P_{50}	P_{90}	P_{95}	P_{99}
Query1	5 441 126	221	202 624	2 028.30	717	962	16 724	26 430
Query2	3 823 494	78	169 456	223.83	155	190	214	577
Query3	1 150 157	4 836	179 616	9 206.01	9 324	10 451	10 831	12 215
Query4	3 929 702	100	174 992	498.95	388	656	738	1 004
Query5	1 813 708	800	316 912	88 978.86	86 608	137 072	147 656	162 248
Query6	325 966	106	163 824	717.44	483	1 301	1 414	1 689
Query7	3 722 876	62	182 112	177.86	108	156	189	530
Query8	28 293 855	60	184 336	186.47	115	149	174	552
Query9	268 442	2 037	176 104	9 040.06	8 832	12 387	13 463	15 897
Query10	3 536 731	934	180 112	4 827.04	4 752	5 971	6 329	7 219
Query11	6 430 422	79	178 256	204.82	135	165	189	568
Query12	3 215 211	916	174 776	5 837.70	5 585	7 843	8 640	11 266
Query13	7 445 751	73	182 272	254.13	175	281	318	621
Query14	2 887 128	132	190 064	8 505.72	2 017	29 177	32 351	37 622
ShortQuery1PersonProfile	90 724 074	54	192 880	148.56	89	113	137	506
ShortQuery2PersonPosts	90 724 074	58	186 560	158.70	103	128	151	497
ShortQuery3PersonFriends	90 724 074	58	191 104	303.37	168	454	836	1 299
ShortQuery4MessageContent	90 730 561	54	197 384	159.38	90	114	139	530
ShortQuery5MessageCreator	90 730 561	54	186 848	143.29	88	111	134	484
ShortQuery6MessageForum	90 730 561	54	185 688	143.73	89	112	134	483
ShortQuery7MessageReplies	90 730 561	57	193 560	150.51	95	120	142	484
Update1AddPerson	36 137	185	156 640	577.60	265	681	779	1 595
Update2AddPostLike	32 830 666	151	192 120	355.36	202	290	463	1 200
Update3AddCommentLike	38 680 212	148	185 712	341.89	201	282	449	1 172
Update4AddForum	647 321	159	167 224	360.40	208	305	530	1 209
Update5AddForumMembership	120 792 916	149	198 648	361.87	202	293	471	1 214
Update6AddPost	8 717 783	153	185 352	366.32	212	405	619	1 193
Update7AddComment	27 592 691	155	189 736	367.69	210	361	604	1 229
Update8AddFriendship	3 074 158	152	168 336	348.85	203	286	457	1 187

Table 4.5: Detailed performance benchmark results for scale factor 300 in microseconds

Query	Total count	Min.	Max.	Mean	P_{50}	P_{90}	P_{95}	P_{99}
Query1	4 808 404	66	178 952	1 341.59	830	1 053	1 141	32 478
Query2	3 378 879	73	161 464	212.99	152	186	202	408
Query3	880 412	1 702	182 032	23 936.04	24 164	27 026	28 102	30 246
Query4	3 472 736	90	162 072	597.82	489	831	914	1 133
Query5	1 488 316	262	306 720	92 837.33	94 112	124 076	131 368	144 160
Query6	215 549	104	137 832	1 399.16	505	2 958	3 222	3 761
Query7	3 906 828	66	151 008	174.33	110	152	178	373
Query8	41 672 830	61	171 832	171.13	109	139	155	365
Query9	177 332	88	147 712	8 518.77	8 237	11 949	12 903	14 572
Query10	2 841 329	77	165 120	5 842.69	5 779	7 449	7 939	9 017
Query11	5 209 104	82	157 136	219.18	154	186	206	420
Query12	2 841 329	71	167 192	6 490.52	6 239	9 315	10 265	12 414
Query13	6 579 921	90	157 776	417.13	344	539	583	755
Query14	2 551 397	195	208 672	17 892.15	3 702	45 164	49 654	58 248
ShortQuery1PersonProfile	100 441 034	55	166 888	138.35	89	111	125	320
ShortQuery2PersonPosts	100 441 034	57	166 496	148.78	104	127	141	318
ShortQuery3PersonFriends	100 441 034	59	162 352	321.48	188	477	917	1 446
ShortQuery4MessageContent	100 443 877	54	170 448	151.35	90	112	127	354
ShortQuery5MessageCreator	100 443 877	54	161 696	133.11	88	109	123	301
ShortQuery6MessageForum	100 443 877	54	173 280	133.19	89	110	124	300
ShortQuery7MessageReplies	100 443 877	57	170 336	143.26	99	123	138	308
Update1AddPerson	28 331	186	128 904	572.45	271	730	863	1 879
Update2AddPostLike	23 661 434	155	170 248	369.92	210	308	564	1 293
Update3AddCommentLike	38 298 299	153	175 464	370.93	209	308	562	1 295
Update4AddForum	491 387	161	145 064	379.42	215	333	617	1 326
Update5AddForumMembership	72 795 145	154	167 504	367.17	209	306	562	1 289
Update6AddPost	7 098 921	160	163 264	465.18	222	520	712	1 523
Update7AddComment	25 498 083	158	166 736	404.61	218	437	681	1 404
Update8AddFriendship	2 471 249	154	160 112	366.86	210	306	562	1 289

Table 4.6: Detailed performance benchmark results for scale factor 1000 in microseconds

Query	Total count	Min.	Max.	Mean	P_{50}	P_{90}	P_{95}	P_{99}
Query1	2 471 452	64	139 120	2 071.30	930	1 335	1 507	58 062
Query2	1 736 696	63	118 916	169.22	154	194	209	308
Query3	389 440	85	156 744	7 489.44	5 467	11 899	15 742	63 054
Query4	1 784 937	75	184 728	133.62	118	157	176	307
Query5	706 129	73	184 568	9 217.77	10 461	14 264	15 525	17 844
Query6	80 726	111	23 438	3 550.40	928	8 085	9 226	11 190
Query7	2 570 310	69	104 660	123.66	108	147	166	273
Query8	64 257 749	59	325 184	111.20	98	126	139	238
Query9	66 451	81	341 312	12 236.87	11 512	18 249	20 336	25 613
Query10	1 367 186	76	114 584	7 090.43	6 852	10 182	11 447	13 950
Query11	2 471 451	76	125 356	208.25	192	251	277	381
Query12	1 460 404	68	147 936	10 194.39	9 675	15 342	17 448	21 841
Query13	3 381 987	112	194 744	287.44	247	389	470	802
Query14	1 311 383	202	532 768	22 411.31	6 666	58 362	72 344	103 328
ShortQuery1PersonProfile	105 505 304	54	377 088	93.52	82	104	116	216
ShortQuery2PersonPosts	105 505 304	56	203 144	114.90	100	127	140	389
ShortQuery3PersonFriends	105 505 304	56	218 568	276.30	187	462	830	1 352
ShortQuery4MessageContent	105 502 956	54	376 800	96.61	82	105	118	368
ShortQuery5MessageCreator	105 502 956	54	256 016	91.44	80	101	113	230
ShortQuery6MessageForum	105 502 956	54	275 248	92.89	82	103	115	230
ShortQuery7MessageReplies	105 502 956	61	226 616	108.68	95	123	139	357
Update1AddPerson	12 137	187	14 757	380.01	259	682	789	1 290
Update2AddPostLike	14 200 744	151	242 216	267.26	197	436	539	1 229
Update3AddCommentLike	26 885 165	149	182 928	259.83	195	409	534	1 229
Update4AddForum	209 377	159	59 204	255.00	205	272	529	1 201
Update5AddForumMembership	32 238 778	150	199 304	242.92	194	250	452	1 180
Update6AddPost	5 003 262	158	334 912	350.61	228	581	819	1 415
Update7AddComment	29 652 949	153	419 904	272.38	206	367	626	1 255
Update8AddFriendship	1 181 343	151	116 660	247.55	200	258	449	1 184

5 Validation of the Results

Scale factors from SF0.1 to SF10 were used to validate the correctness of the implementation over the SUT. The validation data sets were created using the SNB Interactive reference implementation over Neo4j, which can be download from the LDBC Cloudflare R2 bucket[1]. The system with the driver configuration shown in Listing A.16 successfully returned the expected result sets for the queries of the benchmark.

[1] https://pub-383410a98aef4cb686f0c7601eddd25f.r2.dev/interactive-v1/validation_params-sf0.1-sf10.tar.zst

6 ACID Compliance

6.1 Transaction isolation level

The SUT supports the *serializable* isolation level, which is more strict than the *read committed* isolation level minimally required by the SNB Interactive specification.

6.2 SNB Interactive ACID test results

The ACID test implementation was reviewed to conform to the ACID test specifications, with all specified test cases implemented. The test was executed 200 times with a 100% rate of success: no atomicity or isolation tests failed. In particular, the following anomaly tests tested successfully:

- Atomicity-C and Atomicity-RB
- Dirty Writes (G0)
- Aborted Reads (G1A)
- Intermediate Reads (G1B)
- Circular Information Flow (G1C)
- Item-Many-Preceders (IMP)
- Predicate-Many-Preceders (PMP)
- Observed Transaction Vanishes (OTV)
- Fractured Reads (FR)
- Lost Updates (LU)
- Write Skews (WS)

6.3 Recovery and durability

Durability tests were conducted on all three audited scale factors: SF100, SF300 and SF1000. After around two hours of execution time, the database process was killed with the `sudo pkill -9 rt_server` command. The following table shows the database restart times after the database server was killed.

Scale factor	Recovery startup time (s)
100	36.32
300	551.98
1000	595.576

After killing and recovering from the crash, the driver log was inspected and, for each scale factor, the last 10 update operations were matched with their corresponding update queries from the dataset. Then, using the provided `rt_admin` command line tool, which allows quering the vertices and edges of the graph with specific ids, we checked the update queries were committed. Also, we used a provided test script, that checked the last committed occurrence of each update operation type was present in the database.

7 Supplementary Materials

The table below shows the list of supplementary materials. These materials are made available with this full disclosure report to allow reproducibility of results.

Table 7.1: Supplementary materials

File	Purpose
benchmark_sf100.properties	Driver configuration properties for scale factor 100
benchmark_sf300.properties	Driver configuration properties for scale factor 300
benchmark_sf1000.properties	Driver configuration properties for scale factor 1000
validate.properties	Driver configuration properties used for validation
run_driver.sh	Script used to run the driver
run_driver_validate.sh	Script used to run the driver for validation
download_ldbc_socialnetwork.sh	Script used to download official LDBC datasets (social network)
download_ldbc_substitution_parameters.sh	Script used to download official LDBC datasets (substitution parameters)
download_ldbc_updatestreams.sh	Script used to download official LDBC datasets (update streams)
load_dataset.sh	Script used to load a given dataset
run_server.sh	Script used to start the SUT server
run_server_recovery.sh	Script used to start the SUT server (during recovery after a crash. It only differs in the log file name)
sysctl_hugepages_off.conf	File used to config the SUT (hugepages off)
sysctl_hugepages_on.conf	File used to config the SUT (hugepages on)
bulk_load.yaml	SUT loading process config file for different scale factors
graph.yaml	SUT schema file
params-sf{10,100,300,1000}.ini	Datagen config params for different scale factors
graphscope_flex_0.26.1_amd64.deb	Binary package with the SUT database
aocc-compiler-4.1.0_1_amd64.deb	Binary package with the AMD optimizing C++ compiler. Used to build the stored procedures. See README.txt in supplementary material
install_dependencies.sh	Script that installs required dependencies and configures machine parameters
ic{1,2,3,4,5,6,7,8,9,10,11,12,13,14}.cc	Stored procedures implementing the benchmark Complex Reads
is{1,2,3,4,5,6,7}.cc	Stored procedures implementing the benchmark Short Reads
ins{1,2,3,4,5,6,7,8}.cc	Stored procedures implementing the benchmark Inserts
logs_driver.tgz	Compressed archive of the driver logs folder
logs_server.tgz	Compressed archive of the server logs folder

The supplementary folder directory structure is as follows:

```
supplementary_materials
├── README.txt
├── graphscope_flex_0.26.1_amd64.deb
├── aocc-compiler-4.1.0_1_amd64.deb
├── flex_ldbc_snb
│   ├── driver
│   │   └── graphscope
│   ├── scripts
│   │   └── install_dependencies.sh
│   ├── stored_procedures
│   │   ├── allocator.h .4 bitset.h .4 utils.h
│   │   ├── ic{1,2,3,4,5,6,7,8,9,10,11,12,13,14}.cc
│   │   ├── is{1,2,3,4,5,6,7}.cc
│   │   └── ins{1,2,3,4,5,6,7,8}.cc
│   └── tests
│       └── test_acid.cc
├── logs_driver.tgz
├── logs_server.tgz
└── graphscope_audit_2024
    ├── benchmark-sf{10,100,300,1000}.properties
    ├── bulk_load.yaml
    ├── download_ldbc_socialnetwork.sh
    ├── download_ldbc_substitution_parameters.sh
    ├── download_ldbc_updatestreams.sh
    ├── graph.yaml
    ├── load_dataset.sh
    ├── run_driver.sh
    ├── run_driver_validate.sh
    ├── run_server.sh
    ├── run_server_recovery.sh
    ├── sysctl_hugepages_off.conf
    ├── sysctl_hugepages_on.conf
    └── validate.properties
```

A Appendix

A.1 CPU details

Listing A.1: Output of the `lscpu` command for one core

```
Architecture:                       x86_64
CPU op-mode(s):                     32-bit, 64-bit
Byte Order:                         Little Endian
Address sizes:                      52 bits physical, 57 bits virtual
CPU(s):                             64
On-line CPU(s) list:                0-63
Thread(s) per core:                 2
Core(s) per socket:                 32
Socket(s):                          1
NUMA node(s):                       1
Vendor ID:                          AuthenticAMD
CPU family:                         25
Model:                              17
Model name:                         AMD EPYC 9T24 96-Core Processor
Stepping:                           1
CPU MHz:                            3696.500
BogoMIPS:                           5399.99
Hypervisor vendor:                  KVM
Virtualization type:                full
L1d cache:                          1 MiB
L1i cache:                          1 MiB
L2 cache:                           32 MiB
L3 cache:                           128 MiB
NUMA node0 CPU(s):                  0-63
Vulnerability Gather data sampling: Not affected
Vulnerability Itlb multihit:        Not affected
Vulnerability L1tf:                 Not affected
Vulnerability Mds:                  Not affected
Vulnerability Meltdown:             Not affected
Vulnerability Mmio stale data:      Not affected
Vulnerability Retbleed:             Not affected
Vulnerability Spec store bypass:    Vulnerable
Vulnerability Spectre v1:           Mitigation; usercopy/swapgs barriers and __user pointer sanitization
Vulnerability Spectre v2:           Mitigation; Retpolines, STIBP disabled, RSB filling, PBRSB-eIBRS Not affected
Vulnerability Srbds:                Not affected
Vulnerability Tsx async abort:      Not affected
Flags:                              fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36
    clflush mmx fxsr sse sse2 ht syscall nx mmxext fxsr_opt pdpe1gb rdtscp lm constant_tsc rep_good nopl no
                                    nstop_tsc cpuid extd_apicid aperfmperf tsc_known_freq pni pclmulqdq monitor
    ssse3 fma cx16 pcid sse4_1 sse4_2 x2apic movbe popcnt aes xsave avx f16c rdrand hypervisor lahf_lm
                                    cmp_legacy cr8_legacy abm sse4a misalignsse 3dnowprefetch osvw topoext
    invpcid_single vmmcall fsgsbase tsc_adjust bmi1 avx2 smep bmi2 erms invpcid avx512f avx512dq rdseed adx
                                    smap avx512ifma clflushopt clwb avx512cd sha_ni avx512bw avx512vl xsaveopt
    xsavec xgetbv1 xsaves avx512_bf16 clzero xsaveerptr wbnoinvd arat avx512vbmi umip pku ospke avx512_v
                                    bmi2 gfni vaes vpclmulqdq avx512_vnni avx512_bitalg avx512_vpopcntdq rdpid
    arch_capabilities
```

A.2 Memory details

Listing A.2: Output of the `lshw -c memory` command

```
sudo lshw -c memory
  *-firmware
       description: BIOS
       vendor: SeaBIOS
       physical id: 0
       version: 449e491
       date: 04/01/2014
       size: 96KiB
  *-memory
       description: System Memory
       physical id: 1000
       size: 512GiB
       capabilities: ecc
       configuration: errordetection=multi-bit-ecc
     *-bank:0
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: 0
          slot: DIMM 0
          size: 16GiB
     *-bank:1
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: 1
          slot: DIMM 1
          size: 16GiB
     *-bank:2
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: 2
          slot: DIMM 2
          size: 16GiB
     *-bank:3
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: 3
          slot: DIMM 3
          size: 16GiB
     *-bank:4
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: 4
          slot: DIMM 4
          size: 16GiB
     *-bank:5
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: 5
          slot: DIMM 5
          size: 16GiB
     *-bank:6
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: 6
```

```
          slot: DIMM 6
          size: 16GiB
     *-bank:7
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: 7
          slot: DIMM 7
          size: 16GiB
     *-bank:8
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: 8
          slot: DIMM 8
          size: 16GiB
     *-bank:9
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: 9
          slot: DIMM 9
          size: 16GiB
     *-bank:10
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: a
          slot: DIMM 10
          size: 16GiB
     *-bank:11
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: b
          slot: DIMM 11
          size: 16GiB
     *-bank:12
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: c
          slot: DIMM 12
          size: 16GiB
     *-bank:13
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: d
          slot: DIMM 13
          size: 16GiB
     *-bank:14
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: e
          slot: DIMM 14
          size: 16GiB
     *-bank:15
          description: DIMM RAM
          vendor: Alibaba Cloud
          physical id: f
          slot: DIMM 15
          size: 16GiB
     *-bank:16
          description: DIMM RAM
```

```
113          vendor: Alibaba Cloud
114          physical id: 10
115          slot: DIMM 16
116          size: 16GiB
117       *-bank:17
118          description: DIMM RAM
119          vendor: Alibaba Cloud
120          physical id: 11
121          slot: DIMM 17
122          size: 16GiB
123       *-bank:18
124          description: DIMM RAM
125          vendor: Alibaba Cloud
126          physical id: 12
127          slot: DIMM 18
128          size: 16GiB
129       *-bank:19
130          description: DIMM RAM
131          vendor: Alibaba Cloud
132          physical id: 13
133          slot: DIMM 19
134          size: 16GiB
135       *-bank:20
136          description: DIMM RAM
137          vendor: Alibaba Cloud
138          physical id: 14
139          slot: DIMM 20
140          size: 16GiB
141       *-bank:21
142          description: DIMM RAM
143          vendor: Alibaba Cloud
144          physical id: 15
145          slot: DIMM 21
146          size: 16GiB
147       *-bank:22
148          description: DIMM RAM
149          vendor: Alibaba Cloud
150          physical id: 16
151          slot: DIMM 22
152          size: 16GiB
153       *-bank:23
154          description: DIMM RAM
155          vendor: Alibaba Cloud
156          physical id: 17
157          slot: DIMM 23
158          size: 16GiB
159       *-bank:24
160          description: DIMM RAM
161          vendor: Alibaba Cloud
162          physical id: 18
163          slot: DIMM 24
164          size: 16GiB
165       *-bank:25
166          description: DIMM RAM
167          vendor: Alibaba Cloud
168          physical id: 19
169          slot: DIMM 25
170          size: 16GiB
```

```
171      *-bank:26
172           description: DIMM RAM
173           vendor: Alibaba Cloud
174           physical id: 1a
175           slot: DIMM 26
176           size: 16GiB
177      *-bank:27
178           description: DIMM RAM
179           vendor: Alibaba Cloud
180           physical id: 1b
181           slot: DIMM 27
182           size: 16GiB
183      *-bank:28
184           description: DIMM RAM
185           vendor: Alibaba Cloud
186           physical id: 1c
187           slot: DIMM 28
188           size: 16GiB
189      *-bank:29
190           description: DIMM RAM
191           vendor: Alibaba Cloud
192           physical id: 1d
193           slot: DIMM 29
194           size: 16GiB
195      *-bank:30
196           description: DIMM RAM
197           vendor: Alibaba Cloud
198           physical id: 1e
199           slot: DIMM 30
200           size: 16GiB
201      *-bank:31
202           description: DIMM RAM
203           vendor: Alibaba Cloud
204           physical id: 1f
205           slot: DIMM 31
206           size: 16GiB
```

Listing A.3: Output of the `sysbench memory` read command

```
sysbench memory --memory-block-size=1G --memory-total-size=16384G --memory-oper=read --threads=64 run
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 64
Initializing random number generator from current time


Running memory speed test with the following options:
  block size: 1048576KiB
  total size: 16777216MiB
  operation: read
  scope: global

Initializing worker threads...

Threads started!

Total operations: 6553 (  643.08 per second)

6710272.00 MiB transferred (658511.46 MiB/sec)


General statistics:
    total time:                          10.1895s
    total number of events:              6553

Latency (ms):
         min:                                    58.06
         avg:                                    98.13
         max:                                   296.68
         95th percentile:                       137.35
         sum:                                643019.99

Threads fairness:
    events (avg/stddev):           102.3906/8.72
    execution time (avg/stddev):   10.0472/0.05
```

Listing A.4: Output of the `sysbench memory` write command

```
sysbench memory --memory-block-size=1G --memory-total-size=16384G --memory-oper=write --threads=64 run
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 64
Initializing random number generator from current time


Running memory speed test with the following options:
  block size: 1048576KiB
  total size: 16777216MiB
  operation: write
  scope: global

Initializing worker threads...

Threads started!

Total operations: 2013 (  195.50 per second)

2061312.00 MiB transferred (200192.33 MiB/sec)


General statistics:
    total time:                          10.2961s
    total number of events:              2013

Latency (ms):
         min:                                  108.83
         avg:                                  323.17
         max:                                  451.12
         95th percentile:                      383.33
         sum:                                650548.27

Threads fairness:
    events (avg/stddev):           31.4531/0.50
    execution time (avg/stddev):   10.1648/0.10
```

A.3 Network details

Listing A.5: Output of the `lshw -class network` command

```
1
2  ## DRIVER
3   *-network
4         description: Ethernet controller
5         product: Virtio network device
6         vendor: Red Hat, Inc.
7         physical id: 5
8         bus info: pci@0000:00:05.0
9         version: 00
10        width: 64 bits
11        clock: 33MHz
12        capabilities: msix bus_master cap_list
13        configuration: driver=virtio-pci latency=0
14        resources: irq:0 memory:fa208000-fa208fff memory:fa204000-fa207fff
15      *-virtio1
16           description: Ethernet interface
17           physical id: 0
18           bus info: virtio@1
19           logical name: eth0
20           serial: 00:16:3e:04:97:fa
21           capabilities: ethernet physical
22           configuration: autonegotiation=off broadcast=yes driver=virtio_net driverversion=1.0.0 ip=172.24.253.88
       link=yes multicast=yes
23 ## SERVER
24    *-network
25         description: Ethernet controller
26         product: Virtio network device
27         vendor: Red Hat, Inc.
28         physical id: 5
29         bus info: pci@0000:00:05.0
30         version: 00
31         width: 64 bits
32         clock: 33MHz
33         capabilities: msix bus_master cap_list
34         configuration: driver=virtio-pci latency=0
35         resources: irq:0 memory:fa20c000-fa20cfff memory:fa204000-fa207fff
36       *-virtio1
37           description: Ethernet interface
38           physical id: 0
39           bus info: virtio@1
40           logical name: eth0
41           serial: 00:16:3e:04:a1:d7
42           capabilities: ethernet physical
43           configuration: autonegotiation=off broadcast=yes driver=virtio_net driverversion=1.0.0 ip=172.24.253.89
       link=yes multicast=yes
```

A.4 Network performance

Some of the output has been omitted for briefness. First sum is from client to server, second sum from server to client.

Listing A.6: Output of the `iperf` command

```
iperf -c 172.24.253.89 -p 10000 -r --parallel 64 -i 1 -t 2
------------------------------------------------------------
Server listening on TCP port 10000
TCP window size:  128 KByte (default)
------------------------------------------------------------
------------------------------------------------------------
Client connecting to 172.24.253.89, TCP port 10000
TCP window size:  357 KByte (default)
------------------------------------------------------------
[ 62] local 172.24.253.88 port 47858 connected with 172.24.253.89 port 10000
[ 67] local 172.24.253.88 port 47900 connected with 172.24.253.89 port 10000
[ 68] local 172.24.253.88 port 47894 connected with 172.24.253.89 port 10000
[ 60] local 172.24.253.88 port 47870 connected with 172.24.253.89 port 10000
[ 64] local 172.24.253.88 port 47892 connected with 172.24.253.89 port 10000
[  3] local 172.24.253.88 port 47320 connected with 172.24.253.89 port 10000
[ 63] local 172.24.253.88 port 47880 connected with 172.24.253.89 port 10000
[  5] local 172.24.253.88 port 47326 connected with 172.24.253.89 port 10000
[  4] local 172.24.253.88 port 47338 connected with 172.24.253.89 port 10000
[ 11] local 172.24.253.88 port 47386 connected with 172.24.253.89 port 10000
[  6] local 172.24.253.88 port 47358 connected with 172.24.253.89 port 10000
[ 10] local 172.24.253.88 port 47370 connected with 172.24.253.89 port 10000
[  7] local 172.24.253.88 port 47354 connected with 172.24.253.89 port 10000
[  9] local 172.24.253.88 port 47376 connected with 172.24.253.89 port 10000
[ 14] local 172.24.253.88 port 47406 connected with 172.24.253.89 port 10000
[ 12] local 172.24.253.88 port 47396 connected with 172.24.253.89 port 10000
[ 16] local 172.24.253.88 port 47410 connected with 172.24.253.89 port 10000
[ 17] local 172.24.253.88 port 47422 connected with 172.24.253.89 port 10000
[ 13] local 172.24.253.88 port 47390 connected with 172.24.253.89 port 10000
[ 18] local 172.24.253.88 port 47430 connected with 172.24.253.89 port 10000
[ 21] local 172.24.253.88 port 47476 connected with 172.24.253.89 port 10000
[ 20] local 172.24.253.88 port 47446 connected with 172.24.253.89 port 10000
[ 22] local 172.24.253.88 port 47494 connected with 172.24.253.89 port 10000
[ 24] local 172.24.253.88 port 47524 connected with 172.24.253.89 port 10000
[ 25] local 172.24.253.88 port 47500 connected with 172.24.253.89 port 10000
[ 26] local 172.24.253.88 port 47540 connected with 172.24.253.89 port 10000
[ 15] local 172.24.253.88 port 47420 connected with 172.24.253.89 port 10000
[ 29] local 172.24.253.88 port 47510 connected with 172.24.253.89 port 10000
[ 33] local 172.24.253.88 port 47612 connected with 172.24.253.89 port 10000
[ 23] local 172.24.253.88 port 47478 connected with 172.24.253.89 port 10000
[ 30] local 172.24.253.88 port 47556 connected with 172.24.253.89 port 10000
[ 28] local 172.24.253.88 port 47572 connected with 172.24.253.89 port 10000
[ 31] local 172.24.253.88 port 47590 connected with 172.24.253.89 port 10000
[ 41] local 172.24.253.88 port 47700 connected with 172.24.253.89 port 10000
[ 34] local 172.24.253.88 port 47624 connected with 172.24.253.89 port 10000
[ 35] local 172.24.253.88 port 47644 connected with 172.24.253.89 port 10000
[ 43] local 172.24.253.88 port 47690 connected with 172.24.253.89 port 10000
[ 37] local 172.24.253.88 port 47636 connected with 172.24.253.89 port 10000
[ 42] local 172.24.253.88 port 47710 connected with 172.24.253.89 port 10000
[ 40] local 172.24.253.88 port 47672 connected with 172.24.253.89 port 10000
[ 48] local 172.24.253.88 port 47742 connected with 172.24.253.89 port 10000
[ 32] local 172.24.253.88 port 47600 connected with 172.24.253.89 port 10000
[ 47] local 172.24.253.88 port 47760 connected with 172.24.253.89 port 10000
[ 27] local 172.24.253.88 port 47580 connected with 172.24.253.89 port 10000
[ 36] local 172.24.253.88 port 47628 connected with 172.24.253.89 port 10000
[ 49] local 172.24.253.88 port 47752 connected with 172.24.253.89 port 10000
[ 56] local 172.24.253.88 port 47778 connected with 172.24.253.89 port 10000
[ 50] local 172.24.253.88 port 47770 connected with 172.24.253.89 port 10000
[ 45] local 172.24.253.88 port 47720 connected with 172.24.253.89 port 10000
```

```
[ 52] local 172.24.253.88 port 47800 connected with 172.24.253.89 port 10000
[ 54] local 172.24.253.88 port 47764 connected with 172.24.253.89 port 10000
[ 55] local 172.24.253.88 port 47790 connected with 172.24.253.89 port 10000
[ 51] local 172.24.253.88 port 47776 connected with 172.24.253.89 port 10000
[ 58] local 172.24.253.88 port 47818 connected with 172.24.253.89 port 10000
[ 57] local 172.24.253.88 port 47816 connected with 172.24.253.89 port 10000
[ 61] local 172.24.253.88 port 47844 connected with 172.24.253.89 port 10000
[ 59] local 172.24.253.88 port 47830 connected with 172.24.253.89 port 10000
[ 65] local 172.24.253.88 port 47884 connected with 172.24.253.89 port 10000
[ 44] local 172.24.253.88 port 47732 connected with 172.24.253.89 port 10000
[ 53] local 172.24.253.88 port 47804 connected with 172.24.253.89 port 10000
[ 38] local 172.24.253.88 port 47656 connected with 172.24.253.89 port 10000
[ 19] local 172.24.253.88 port 47460 connected with 172.24.253.89 port 10000
[ 39] local 172.24.253.88 port 47684 connected with 172.24.253.89 port 10000
[  8] local 172.24.253.88 port 47368 connected with 172.24.253.89 port 10000
[ ID] Interval       Transfer     Bandwidth
[ 67]  0.0- 1.0 sec  68.9 MBytes   578 Mbits/sec
[ 60]  0.0- 1.0 sec  79.2 MBytes   665 Mbits/sec
[ 64]  0.0- 1.0 sec  93.1 MBytes   781 Mbits/sec
[ 63]  0.0- 1.0 sec  6.65 MBytes  55.8 Mbits/sec
[ 10]  0.0- 1.0 sec  55.4 MBytes   465 Mbits/sec
[  7]  0.0- 1.0 sec  96.2 MBytes   807 Mbits/sec
[ 14]  0.0- 1.0 sec  87.1 MBytes   731 Mbits/sec
[ 12]  0.0- 1.0 sec  23.8 MBytes   199 Mbits/sec
[ 17]  0.0- 1.0 sec  69.4 MBytes   582 Mbits/sec
[ 18]  0.0- 1.0 sec  80.9 MBytes   678 Mbits/sec
[ 21]  0.0- 1.0 sec  24.0 MBytes   201 Mbits/sec
[ 20]  0.0- 1.0 sec  19.1 MBytes   160 Mbits/sec
[ 22]  0.0- 1.0 sec  46.9 MBytes   393 Mbits/sec
[ 24]  0.0- 1.0 sec  40.6 MBytes   341 Mbits/sec
[ 25]  0.0- 1.0 sec  46.2 MBytes   388 Mbits/sec
[ 26]  0.0- 1.0 sec  74.6 MBytes   626 Mbits/sec
[ 15]  0.0- 1.0 sec  38.9 MBytes   326 Mbits/sec
[ 33]  0.0- 1.0 sec   130 MBytes  1.09 Gbits/sec
[ 23]  0.0- 1.0 sec  25.8 MBytes   216 Mbits/sec
[ 30]  0.0- 1.0 sec  37.1 MBytes   311 Mbits/sec
[ 28]  0.0- 1.0 sec  15.2 MBytes   128 Mbits/sec
[ 41]  0.0- 1.0 sec   167 MBytes  1.40 Gbits/sec
[ 35]  0.0- 1.0 sec  94.6 MBytes   794 Mbits/sec
[ 43]  0.0- 1.0 sec  30.9 MBytes   259 Mbits/sec
[ 37]  0.0- 1.0 sec  31.0 MBytes   260 Mbits/sec
[ 42]  0.0- 1.0 sec  27.4 MBytes   230 Mbits/sec
[ 40]  0.0- 1.0 sec   132 MBytes  1.11 Gbits/sec
[ 48]  0.0- 1.0 sec  45.9 MBytes   385 Mbits/sec
[ 32]  0.0- 1.0 sec  46.1 MBytes   387 Mbits/sec
[ 47]  0.0- 1.0 sec  55.4 MBytes   465 Mbits/sec
[ 27]  0.0- 1.0 sec  92.8 MBytes   778 Mbits/sec
[ 36]  0.0- 1.0 sec  14.2 MBytes   120 Mbits/sec
[ 49]  0.0- 1.0 sec  26.0 MBytes   218 Mbits/sec
[ 50]  0.0- 1.0 sec  31.8 MBytes   266 Mbits/sec
[ 45]  0.0- 1.0 sec  44.9 MBytes   376 Mbits/sec
[ 52]  0.0- 1.0 sec  62.9 MBytes   527 Mbits/sec
[ 54]  0.0- 1.0 sec  46.9 MBytes   393 Mbits/sec
[ 51]  0.0- 1.0 sec  26.9 MBytes   225 Mbits/sec
[ 58]  0.0- 1.0 sec  47.2 MBytes   396 Mbits/sec
[ 57]  0.0- 1.0 sec  46.2 MBytes   388 Mbits/sec
[ 61]  0.0- 1.0 sec  31.1 MBytes   261 Mbits/sec
[ 65]  0.0- 1.0 sec  29.0 MBytes   243 Mbits/sec
```

```
[ 44]  0.0- 1.0 sec  24.8 MBytes   208 Mbits/sec
[ 53]  0.0- 1.0 sec  49.2 MBytes   413 Mbits/sec
[ 38]  0.0- 1.0 sec  26.4 MBytes   221 Mbits/sec
[ 19]  0.0- 1.0 sec  22.2 MBytes   187 Mbits/sec
[ 39]  0.0- 1.0 sec  32.0 MBytes   268 Mbits/sec
[  8]  0.0- 1.0 sec  65.5 MBytes   549 Mbits/sec
[  4]  0.0- 1.0 sec  61.6 MBytes   517 Mbits/sec
[ 13]  0.0- 1.0 sec  36.6 MBytes   307 Mbits/sec
[ 34]  0.0- 1.0 sec  24.0 MBytes   201 Mbits/sec
[ 62]  0.0- 1.0 sec  59.0 MBytes   495 Mbits/sec
[  3]  0.0- 1.0 sec  74.4 MBytes   624 Mbits/sec
[  5]  0.0- 1.0 sec  38.4 MBytes   322 Mbits/sec
[ 11]  0.0- 1.0 sec  62.1 MBytes   521 Mbits/sec
[ 56]  0.0- 1.0 sec  29.4 MBytes   246 Mbits/sec
[ 68]  0.0- 1.0 sec   132 MBytes  1.11 Gbits/sec
[ 16]  0.0- 1.0 sec  17.0 MBytes   143 Mbits/sec
[ 29]  0.0- 1.0 sec  87.5 MBytes   734 Mbits/sec
[ 59]  0.0- 1.0 sec  24.2 MBytes   203 Mbits/sec
[  6]  0.0- 1.0 sec  64.5 MBytes   541 Mbits/sec
[ 31]  0.0- 1.0 sec  46.1 MBytes   387 Mbits/sec
[ 55]  0.0- 1.0 sec  55.6 MBytes   467 Mbits/sec
[  9]  0.0- 1.0 sec  37.6 MBytes   316 Mbits/sec
[SUM]  0.0- 1.0 sec  3.28 GBytes  28.2 Gbits/sec
[ 67]  1.0- 2.0 sec   104 MBytes   868 Mbits/sec
[ 67]  0.0- 2.0 sec   172 MBytes   723 Mbits/sec
[ 68]  1.0- 2.0 sec  30.1 MBytes   253 Mbits/sec
[ 68]  0.0- 2.0 sec   163 MBytes   682 Mbits/sec
[ 60]  1.0- 2.0 sec  34.0 MBytes   285 Mbits/sec
[ 60]  0.0- 2.0 sec   113 MBytes   475 Mbits/sec
[ 64]  1.0- 2.0 sec   126 MBytes  1.05 Gbits/sec
[ 64]  0.0- 2.0 sec   219 MBytes   917 Mbits/sec
[ 12]  1.0- 2.0 sec  42.8 MBytes   359 Mbits/sec
[ 12]  0.0- 2.0 sec  66.5 MBytes   279 Mbits/sec
[ 16]  1.0- 2.0 sec  49.2 MBytes   413 Mbits/sec
[ 16]  0.0- 2.0 sec  66.2 MBytes   278 Mbits/sec
[ 17]  1.0- 2.0 sec  58.6 MBytes   492 Mbits/sec
[ 17]  0.0- 2.0 sec   128 MBytes   537 Mbits/sec
[ 21]  1.0- 2.0 sec  48.5 MBytes   407 Mbits/sec
[ 21]  0.0- 2.0 sec  72.5 MBytes   304 Mbits/sec
[ 22]  1.0- 2.0 sec  34.1 MBytes   286 Mbits/sec
[ 22]  0.0- 2.0 sec  81.0 MBytes   339 Mbits/sec
[ 29]  1.0- 2.0 sec  84.4 MBytes   708 Mbits/sec
[ 29]  0.0- 2.0 sec   172 MBytes   720 Mbits/sec
[ 33]  1.0- 2.0 sec  70.6 MBytes   592 Mbits/sec
[ 33]  0.0- 2.0 sec   201 MBytes   843 Mbits/sec
[ 34]  1.0- 2.0 sec  25.8 MBytes   216 Mbits/sec
[ 34]  0.0- 2.0 sec  49.8 MBytes   209 Mbits/sec
[ 35]  1.0- 2.0 sec  14.0 MBytes   117 Mbits/sec
[ 35]  0.0- 2.0 sec   109 MBytes   455 Mbits/sec
[ 37]  1.0- 2.0 sec  47.5 MBytes   398 Mbits/sec
[ 37]  0.0- 2.0 sec  78.6 MBytes   330 Mbits/sec
[ 48]  1.0- 2.0 sec  27.5 MBytes   231 Mbits/sec
[ 48]  0.0- 2.0 sec  73.4 MBytes   308 Mbits/sec
[ 47]  1.0- 2.0 sec  37.9 MBytes   318 Mbits/sec
[ 47]  0.0- 2.0 sec  93.2 MBytes   391 Mbits/sec
[ 36]  1.0- 2.0 sec  64.0 MBytes   537 Mbits/sec
[ 36]  0.0- 2.0 sec  78.2 MBytes   328 Mbits/sec
[ 56]  1.0- 2.0 sec  67.5 MBytes   566 Mbits/sec
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[ 56]  0.0- 2.0 sec  96.9 MBytes   406 Mbits/sec
[ 52]  1.0- 2.0 sec  68.6 MBytes   576 Mbits/sec
[ 52]  0.0- 2.0 sec   132 MBytes   551 Mbits/sec
[ 54]  1.0- 2.0 sec  31.4 MBytes   263 Mbits/sec
[ 54]  0.0- 2.0 sec  78.2 MBytes   328 Mbits/sec
[ 55]  1.0- 2.0 sec  41.1 MBytes   345 Mbits/sec
[ 55]  0.0- 2.0 sec  96.8 MBytes   405 Mbits/sec
[ 58]  1.0- 2.0 sec  36.5 MBytes   306 Mbits/sec
[ 58]  0.0- 2.0 sec  83.8 MBytes   351 Mbits/sec
[ 38]  1.0- 2.0 sec  36.2 MBytes   304 Mbits/sec
[ 38]  0.0- 2.0 sec  62.6 MBytes   262 Mbits/sec
[ 19]  1.0- 2.0 sec  53.5 MBytes   449 Mbits/sec
[ 19]  0.0- 2.0 sec  75.8 MBytes   318 Mbits/sec
[ 39]  1.0- 2.0 sec  55.6 MBytes   467 Mbits/sec
[ 39]  0.0- 2.0 sec  87.6 MBytes   367 Mbits/sec
[  8]  1.0- 2.0 sec  78.4 MBytes   657 Mbits/sec
[  8]  0.0- 2.0 sec   144 MBytes   603 Mbits/sec
[  3]  1.0- 2.0 sec  19.1 MBytes   160 Mbits/sec
[  3]  0.0- 2.0 sec  93.5 MBytes   390 Mbits/sec
[ 63]  1.0- 2.0 sec  30.8 MBytes   258 Mbits/sec
[ 63]  0.0- 2.0 sec  37.4 MBytes   157 Mbits/sec
[  5]  1.0- 2.0 sec  24.6 MBytes   207 Mbits/sec
[  5]  0.0- 2.0 sec  63.0 MBytes   262 Mbits/sec
[  4]  1.0- 2.0 sec  34.2 MBytes   287 Mbits/sec
[  4]  0.0- 2.0 sec  95.9 MBytes   400 Mbits/sec
[  6]  1.0- 2.0 sec  34.2 MBytes   287 Mbits/sec
[  6]  0.0- 2.0 sec  98.8 MBytes   413 Mbits/sec
[  7]  1.0- 2.0 sec   106 MBytes   885 Mbits/sec
[  7]  0.0- 2.0 sec   202 MBytes   841 Mbits/sec
[  9]  1.0- 2.0 sec  27.0 MBytes   226 Mbits/sec
[  9]  0.0- 2.0 sec  64.6 MBytes   270 Mbits/sec
[ 20]  1.0- 2.0 sec  53.9 MBytes   452 Mbits/sec
[ 20]  0.0- 2.0 sec  73.0 MBytes   305 Mbits/sec
[ 24]  1.0- 2.0 sec  52.6 MBytes   441 Mbits/sec
[ 24]  0.0- 2.0 sec  93.2 MBytes   390 Mbits/sec
[ 25]  1.0- 2.0 sec  57.8 MBytes   484 Mbits/sec
[ 25]  0.0- 2.0 sec   104 MBytes   435 Mbits/sec
[ 26]  1.0- 2.0 sec  91.5 MBytes   768 Mbits/sec
[ 26]  0.0- 2.0 sec   166 MBytes   694 Mbits/sec
[ 30]  1.0- 2.0 sec  68.4 MBytes   574 Mbits/sec
[ 30]  0.0- 2.0 sec   106 MBytes   438 Mbits/sec
[ 28]  1.0- 2.0 sec  36.2 MBytes   304 Mbits/sec
[ 28]  0.0- 2.0 sec  51.5 MBytes   216 Mbits/sec
[ 41]  1.0- 2.0 sec  30.0 MBytes   252 Mbits/sec
[ 41]  0.0- 2.0 sec   197 MBytes   821 Mbits/sec
[ 43]  1.0- 2.0 sec  20.9 MBytes   175 Mbits/sec
[ 43]  0.0- 2.0 sec  51.8 MBytes   216 Mbits/sec
[ 42]  1.0- 2.0 sec  45.5 MBytes   382 Mbits/sec
[ 42]  0.0- 2.0 sec  72.9 MBytes   304 Mbits/sec
[ 32]  1.0- 2.0 sec  13.4 MBytes   112 Mbits/sec
[ 32]  0.0- 2.0 sec  59.5 MBytes   247 Mbits/sec
[ 49]  1.0- 2.0 sec  42.9 MBytes   360 Mbits/sec
[ 49]  0.0- 2.0 sec  68.9 MBytes   288 Mbits/sec
[ 50]  1.0- 2.0 sec  39.1 MBytes   328 Mbits/sec
[ 50]  0.0- 2.0 sec  70.9 MBytes   296 Mbits/sec
[ 45]  1.0- 2.0 sec  34.5 MBytes   289 Mbits/sec
[ 45]  0.0- 2.0 sec  79.4 MBytes   332 Mbits/sec
[ 61]  1.0- 2.0 sec  32.5 MBytes   273 Mbits/sec
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[ 61]  0.0- 2.0 sec  63.6 MBytes   265 Mbits/sec
[ 59]  1.0- 2.0 sec  60.6 MBytes   509 Mbits/sec
[ 59]  0.0- 2.0 sec  84.9 MBytes   355 Mbits/sec
[  8] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 33886
[ 17] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 33874
[ 12] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 33864
[ 21] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 33890
[ 16] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 33900
[ 19] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 33902
[ 34] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 33926
[ 29] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 33910
[ 22] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 33928
[ 33] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 33942
[ 35] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 33956
[ 38] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 33958
[ 47] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 33972
[ 37] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 33988
[ 48] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34012
[ 36] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 33996
[ 52] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34024
[ 55] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34040
[ 58] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34054
[ 39] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34060
[ 54] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34064
[ 11]  1.0- 2.0 sec  23.2 MBytes   195 Mbits/sec
[ 11]  0.0- 2.0 sec  85.4 MBytes   353 Mbits/sec
[ 10]  1.0- 2.0 sec  12.2 MBytes   103 Mbits/sec
[ 10]  0.0- 2.0 sec  67.6 MBytes   278 Mbits/sec
[ 13]  1.0- 2.0 sec  30.1 MBytes   253 Mbits/sec
[ 13]  0.0- 2.0 sec  66.8 MBytes   275 Mbits/sec
[ 44]  1.0- 2.0 sec  36.5 MBytes   306 Mbits/sec
[ 44]  0.0- 2.0 sec  61.2 MBytes   253 Mbits/sec
[  3] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34124
[  5] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34208
[  4] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34108
[ 20] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34126
[  7] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34280
[ 25] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34084
[ 26] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34222
[  9] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34136
[  6] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34246
[ 24] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34070
[ 28] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34154
[ 32] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34150
[ 30] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34178
[ 45] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34200
[ 42] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34234
[ 41] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34190
[ 43] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34278
[ 49] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34168
[ 63] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34076
[ 68] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34266
[ 61] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34112
[ 50] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34092
[ 56] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34216
[ 66] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34250
[ 62]  1.0- 2.0 sec  66.4 MBytes   557 Mbits/sec
[ 62]  0.0- 2.0 sec   125 MBytes   514 Mbits/sec
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[ 14]  1.0- 2.0 sec  34.4 MBytes   288 Mbits/sec
[ 14]  0.0- 2.1 sec   122 MBytes   494 Mbits/sec
[ 31]  1.0- 2.0 sec  44.6 MBytes   374 Mbits/sec
[ 31]  0.0- 2.0 sec  90.8 MBytes   372 Mbits/sec
[ 53]  1.0- 2.0 sec  41.8 MBytes   350 Mbits/sec
[ 53]  0.0- 2.1 sec  91.0 MBytes   372 Mbits/sec
[ 11] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34294
[ 10] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34310
[ 13] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34324
[ 44] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34314
[ 31] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34330
[ 14] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34344
[ 59] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34354
[ 62] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34368
[ 15]  1.0- 2.0 sec  3.75 MBytes  31.5 Mbits/sec
[ 15]  0.0- 2.1 sec  42.6 MBytes   170 Mbits/sec
[ 23]  1.0- 2.0 sec  36.6 MBytes   307 Mbits/sec
[ 23]  0.0- 2.1 sec  62.4 MBytes   248 Mbits/sec
[ 51]  1.0- 2.0 sec  57.4 MBytes   481 Mbits/sec
[ 51]  0.0- 2.1 sec  84.2 MBytes   332 Mbits/sec
[ 40]  1.0- 2.0 sec  65.6 MBytes   551 Mbits/sec
[ 40]  0.0- 2.2 sec   198 MBytes   772 Mbits/sec
[ 65]  1.0- 2.0 sec  33.2 MBytes   279 Mbits/sec
[ 65]  0.0- 2.1 sec  62.2 MBytes   244 Mbits/sec
[ 15] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34380
[ 18]  1.0- 2.0 sec  57.5 MBytes   482 Mbits/sec
[ 18]  0.0- 2.2 sec   138 MBytes   538 Mbits/sec
[ 27]  1.0- 2.0 sec  79.1 MBytes   664 Mbits/sec
[ 27]  0.0- 2.2 sec   172 MBytes   666 Mbits/sec
[ 23] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34388
[ 40] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34394
[ 51] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34398
[ 57]  1.0- 2.0 sec  43.5 MBytes   365 Mbits/sec
[SUM]  1.0- 2.0 sec  2.92 GBytes  25.1 Gbits/sec
[ 57]  0.0- 2.2 sec  89.8 MBytes   344 Mbits/sec
[SUM]  0.0- 2.2 sec  6.20 GBytes  24.3 Gbits/sec
[ 18] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34422
[ 27] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34414
[ 57] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34426
[ 53] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34424
[ 64] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34432
[ 60] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34446
[  8]  0.0- 1.0 sec  44.5 MBytes   373 Mbits/sec
[ 12]  0.0- 1.0 sec  35.5 MBytes   298 Mbits/sec
[ 21]  0.0- 1.0 sec  85.5 MBytes   717 Mbits/sec
[ 16]  0.0- 1.0 sec  46.5 MBytes   390 Mbits/sec
[ 19]  0.0- 1.0 sec  83.9 MBytes   704 Mbits/sec
[ 34]  0.0- 1.0 sec  46.7 MBytes   392 Mbits/sec
[ 29]  0.0- 1.0 sec  34.3 MBytes   288 Mbits/sec
[ 22]  0.0- 1.0 sec  54.3 MBytes   456 Mbits/sec
[ 33]  0.0- 1.0 sec  54.4 MBytes   457 Mbits/sec
[ 35]  0.0- 1.0 sec  28.5 MBytes   239 Mbits/sec
[ 38]  0.0- 1.0 sec  30.5 MBytes   256 Mbits/sec
[ 47]  0.0- 1.0 sec  33.2 MBytes   279 Mbits/sec
[ 37]  0.0- 1.0 sec  17.1 MBytes   143 Mbits/sec
[ 48]  0.0- 1.0 sec  58.8 MBytes   493 Mbits/sec
[ 36]  0.0- 1.0 sec  28.7 MBytes   240 Mbits/sec
[ 52]  0.0- 1.0 sec  28.7 MBytes   240 Mbits/sec
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[ 58]  0.0- 1.0 sec  36.9 MBytes   309 Mbits/sec
[ 54]  0.0- 1.0 sec   125 MBytes  1.05 Gbits/sec
[  3]  0.0- 1.0 sec  45.5 MBytes   382 Mbits/sec
[  5]  0.0- 1.0 sec  17.7 MBytes   149 Mbits/sec
[  4]  0.0- 1.0 sec  33.8 MBytes   284 Mbits/sec
[ 20]  0.0- 1.0 sec  28.2 MBytes   236 Mbits/sec
[  7]  0.0- 1.0 sec  46.6 MBytes   391 Mbits/sec
[ 25]  0.0- 1.0 sec  91.6 MBytes   768 Mbits/sec
[  9]  0.0- 1.0 sec  54.4 MBytes   457 Mbits/sec
[  6]  0.0- 1.0 sec  32.1 MBytes   269 Mbits/sec
[ 28]  0.0- 1.0 sec  65.2 MBytes   547 Mbits/sec
[ 32]  0.0- 1.0 sec  91.2 MBytes   765 Mbits/sec
[ 30]  0.0- 1.0 sec  58.5 MBytes   491 Mbits/sec
[ 45]  0.0- 1.0 sec  27.0 MBytes   227 Mbits/sec
[ 42]  0.0- 1.0 sec  43.8 MBytes   367 Mbits/sec
[ 41]  0.0- 1.0 sec  30.8 MBytes   259 Mbits/sec
[ 43]  0.0- 1.0 sec  62.7 MBytes   526 Mbits/sec
[ 49]  0.0- 1.0 sec  32.8 MBytes   275 Mbits/sec
[ 63]  0.0- 1.0 sec  51.4 MBytes   431 Mbits/sec
[ 68]  0.0- 1.0 sec  99.6 MBytes   836 Mbits/sec
[ 61]  0.0- 1.0 sec  33.0 MBytes   277 Mbits/sec
[ 50]  0.0- 1.0 sec  26.6 MBytes   223 Mbits/sec
[ 66]  0.0- 1.0 sec  27.1 MBytes   227 Mbits/sec
[ 11]  0.0- 1.0 sec  61.3 MBytes   514 Mbits/sec
[ 10]  0.0- 1.0 sec  27.4 MBytes   230 Mbits/sec
[ 13]  0.0- 1.0 sec  87.6 MBytes   735 Mbits/sec
[ 31]  0.0- 1.0 sec  85.2 MBytes   715 Mbits/sec
[ 14]  0.0- 1.0 sec  20.7 MBytes   174 Mbits/sec
[ 62]  0.0- 1.0 sec  23.5 MBytes   197 Mbits/sec
[ 15]  0.0- 1.0 sec  25.0 MBytes   210 Mbits/sec
[ 23]  0.0- 1.0 sec  21.8 MBytes   183 Mbits/sec
[ 40]  0.0- 1.0 sec   109 MBytes   918 Mbits/sec
[ 18]  0.0- 1.0 sec  43.7 MBytes   367 Mbits/sec
[ 27]  0.0- 1.0 sec  62.0 MBytes   520 Mbits/sec
[ 57]  0.0- 1.0 sec  43.7 MBytes   367 Mbits/sec
[ 53]  0.0- 1.0 sec  39.1 MBytes   328 Mbits/sec
[ 64]  0.0- 1.0 sec  55.6 MBytes   466 Mbits/sec
[ 60]  0.0- 1.0 sec  63.3 MBytes   531 Mbits/sec
[ 55]  0.0- 1.0 sec  41.1 MBytes   345 Mbits/sec
[ 51]  0.0- 1.0 sec  62.7 MBytes   526 Mbits/sec
[ 17]  0.0- 1.0 sec  98.6 MBytes   827 Mbits/sec
[ 56]  0.0- 1.0 sec  90.0 MBytes   755 Mbits/sec
[ 39]  0.0- 1.0 sec  80.4 MBytes   674 Mbits/sec
[ 26]  0.0- 1.0 sec  36.6 MBytes   307 Mbits/sec
[ 44]  0.0- 1.0 sec   111 MBytes   929 Mbits/sec
[ 59]  0.0- 1.0 sec  72.9 MBytes   612 Mbits/sec
[ 65] local 172.24.253.88 port 10000 connected with 172.24.253.89 port 34402
[ 65]  0.0- 1.0 sec  1.44 KBytes  11.8 Kbits/sec
[ 24]  0.0- 1.0 sec  29.2 MBytes   245 Mbits/sec
[ 17]  1.0- 2.0 sec  28.1 MBytes   236 Mbits/sec
[ 12]  1.0- 2.0 sec  46.9 MBytes   394 Mbits/sec
[ 21]  1.0- 2.0 sec  64.7 MBytes   543 Mbits/sec
[ 19]  1.0- 2.0 sec  48.6 MBytes   407 Mbits/sec
[ 34]  1.0- 2.0 sec  29.9 MBytes   251 Mbits/sec
[ 29]  1.0- 2.0 sec  17.2 MBytes   144 Mbits/sec
[ 33]  1.0- 2.0 sec  60.8 MBytes   510 Mbits/sec
[ 38]  1.0- 2.0 sec  41.9 MBytes   351 Mbits/sec
[ 47]  1.0- 2.0 sec  21.1 MBytes   177 Mbits/sec
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[ 37]  1.0- 2.0 sec  31.1 MBytes   261 Mbits/sec
[ 48]  1.0- 2.0 sec  52.0 MBytes   436 Mbits/sec
[ 36]  1.0- 2.0 sec  29.8 MBytes   250 Mbits/sec
[ 52]  1.0- 2.0 sec  38.6 MBytes   324 Mbits/sec
[ 55]  1.0- 2.0 sec  43.5 MBytes   365 Mbits/sec
[ 58]  1.0- 2.0 sec  30.1 MBytes   252 Mbits/sec
[ 39]  1.0- 2.0 sec   103 MBytes   863 Mbits/sec
[  3]  1.0- 2.0 sec  24.2 MBytes   203 Mbits/sec
[  5]  1.0- 2.0 sec  25.7 MBytes   215 Mbits/sec
[  4]  1.0- 2.0 sec  16.6 MBytes   139 Mbits/sec
[ 20]  1.0- 2.0 sec  21.3 MBytes   179 Mbits/sec
[  7]  1.0- 2.0 sec  36.1 MBytes   303 Mbits/sec
[ 25]  1.0- 2.0 sec  72.4 MBytes   607 Mbits/sec
[ 26]  1.0- 2.0 sec  44.1 MBytes   370 Mbits/sec
[  9]  1.0- 2.0 sec  54.6 MBytes   458 Mbits/sec
[  6]  1.0- 2.0 sec  30.0 MBytes   252 Mbits/sec
[ 24]  1.0- 2.0 sec  33.0 MBytes   277 Mbits/sec
[ 28]  1.0- 2.0 sec  66.2 MBytes   555 Mbits/sec
[ 30]  1.0- 2.0 sec  63.4 MBytes   532 Mbits/sec
[ 45]  1.0- 2.0 sec  30.9 MBytes   259 Mbits/sec
[ 42]  1.0- 2.0 sec  59.0 MBytes   495 Mbits/sec
[ 41]  1.0- 2.0 sec  41.7 MBytes   350 Mbits/sec
[ 43]  1.0- 2.0 sec  32.6 MBytes   273 Mbits/sec
[ 49]  1.0- 2.0 sec  31.5 MBytes   264 Mbits/sec
[ 63]  1.0- 2.0 sec  60.1 MBytes   504 Mbits/sec
[ 68]  1.0- 2.0 sec   126 MBytes  1.06 Gbits/sec
[ 61]  1.0- 2.0 sec  28.7 MBytes   241 Mbits/sec
[ 56]  1.0- 2.0 sec  19.2 MBytes   161 Mbits/sec
[ 66]  1.0- 2.0 sec  21.2 MBytes   178 Mbits/sec
[ 11]  1.0- 2.0 sec  58.5 MBytes   491 Mbits/sec
[ 10]  1.0- 2.0 sec  35.9 MBytes   301 Mbits/sec
[ 13]  1.0- 2.0 sec   123 MBytes  1.03 Gbits/sec
[ 44]  1.0- 2.0 sec  83.7 MBytes   702 Mbits/sec
[ 31]  1.0- 2.0 sec  94.8 MBytes   795 Mbits/sec
[ 14]  1.0- 2.0 sec  24.4 MBytes   205 Mbits/sec
[ 15]  1.0- 2.0 sec  34.8 MBytes   292 Mbits/sec
[ 23]  1.0- 2.0 sec  23.5 MBytes   197 Mbits/sec
[ 40]  1.0- 2.0 sec  91.0 MBytes   763 Mbits/sec
[ 51]  1.0- 2.0 sec  95.6 MBytes   802 Mbits/sec
[ 18]  1.0- 2.0 sec  27.5 MBytes   231 Mbits/sec
[ 27]  1.0- 2.0 sec  93.5 MBytes   784 Mbits/sec
[ 57]  1.0- 2.0 sec  21.8 MBytes   183 Mbits/sec
[ 53]  1.0- 2.0 sec  39.3 MBytes   330 Mbits/sec
[ 64]  1.0- 2.0 sec  56.2 MBytes   471 Mbits/sec
[ 60]  1.0- 2.0 sec  67.8 MBytes   569 Mbits/sec
[ 65]  1.0- 2.0 sec  25.3 MBytes   212 Mbits/sec
[ 39]  0.0- 2.0 sec   186 MBytes   771 Mbits/sec
[ 21]  0.0- 2.0 sec   155 MBytes   635 Mbits/sec
[ 19]  0.0- 2.0 sec   136 MBytes   555 Mbits/sec
[ 47]  0.0- 2.1 sec  56.4 MBytes   230 Mbits/sec
[ 36]  0.0- 2.0 sec  60.6 MBytes   248 Mbits/sec
[ 55]  0.0- 2.1 sec  87.2 MBytes   356 Mbits/sec
[ 25]  0.0- 2.0 sec   169 MBytes   695 Mbits/sec
[ 30]  0.0- 2.0 sec   128 MBytes   524 Mbits/sec
[ 68]  0.0- 2.0 sec   232 MBytes   949 Mbits/sec
[ 17]  0.0- 2.1 sec   129 MBytes   526 Mbits/sec
[ 29]  0.0- 2.1 sec  54.5 MBytes   221 Mbits/sec
[ 38]  0.0- 2.1 sec  75.9 MBytes   309 Mbits/sec
```

```
[ 48]  0.0- 2.1 sec   114 MBytes   462 Mbits/sec
[ 52]  0.0- 2.1 sec  69.8 MBytes   283 Mbits/sec
[  7]  0.0- 2.1 sec  86.4 MBytes   352 Mbits/sec
[ 26]  0.0- 2.1 sec  85.5 MBytes   348 Mbits/sec
[  9]  0.0- 2.1 sec   113 MBytes   460 Mbits/sec
[ 24]  0.0- 2.1 sec  66.1 MBytes   269 Mbits/sec
[ 28]  0.0- 2.1 sec   135 MBytes   545 Mbits/sec
[ 32]  1.0- 2.0 sec  76.8 MBytes   644 Mbits/sec
[ 49]  0.0- 2.1 sec  67.2 MBytes   272 Mbits/sec
[ 50]  1.0- 2.0 sec  19.6 MBytes   164 Mbits/sec
[  8]  1.0- 2.0 sec  34.4 MBytes   289 Mbits/sec
[ 34]  0.0- 2.1 sec  80.2 MBytes   322 Mbits/sec
[ 37]  0.0- 2.1 sec  51.2 MBytes   206 Mbits/sec
[  4]  0.0- 2.1 sec  53.0 MBytes   213 Mbits/sec
[ 20]  0.0- 2.1 sec  52.1 MBytes   210 Mbits/sec
[  6]  0.0- 2.1 sec  65.2 MBytes   262 Mbits/sec
[ 32]  0.0- 2.1 sec   170 MBytes   683 Mbits/sec
[ 45]  0.0- 2.1 sec  60.9 MBytes   245 Mbits/sec
[ 42]  0.0- 2.1 sec   107 MBytes   429 Mbits/sec
[ 41]  0.0- 2.1 sec  76.6 MBytes   307 Mbits/sec
[ 50]  0.0- 2.1 sec  48.6 MBytes   195 Mbits/sec
[ 66]  0.0- 2.1 sec  50.8 MBytes   204 Mbits/sec
[ 11]  0.0- 2.1 sec   124 MBytes   497 Mbits/sec
[ 10]  0.0- 2.1 sec  66.2 MBytes   266 Mbits/sec
[ 13]  0.0- 2.1 sec   218 MBytes   874 Mbits/sec
[ 44]  0.0- 2.1 sec   202 MBytes   810 Mbits/sec
[ 31]  0.0- 2.1 sec   189 MBytes   758 Mbits/sec
[ 14]  0.0- 2.1 sec  49.6 MBytes   199 Mbits/sec
[  8]  0.0- 2.1 sec  82.9 MBytes   329 Mbits/sec
[ 16]  1.0- 2.0 sec  26.6 MBytes   223 Mbits/sec
[ 54]  1.0- 2.0 sec  59.3 MBytes   498 Mbits/sec
[ 54]  0.0- 2.1 sec   186 MBytes   739 Mbits/sec
[ 16]  0.0- 2.1 sec  75.8 MBytes   299 Mbits/sec
[ 22]  1.0- 2.0 sec  35.7 MBytes   300 Mbits/sec
[ 22]  0.0- 2.2 sec  93.6 MBytes   365 Mbits/sec
[ 23]  0.0- 2.2 sec  68.1 MBytes   265 Mbits/sec
[ 51]  0.0- 2.2 sec   182 MBytes   708 Mbits/sec
[ 59]  1.0- 2.0 sec  61.7 MBytes   518 Mbits/sec
[ 62]  1.0- 2.0 sec  24.7 MBytes   207 Mbits/sec
[ 40]  0.0- 2.2 sec   234 MBytes   907 Mbits/sec
[ 18]  0.0- 2.2 sec   110 MBytes   423 Mbits/sec
[ 27]  0.0- 2.2 sec   194 MBytes   749 Mbits/sec
[ 62]  0.0- 2.2 sec  50.5 MBytes   193 Mbits/sec
[ 35]  1.0- 2.0 sec  26.4 MBytes   221 Mbits/sec
[ 35]  0.0- 2.2 sec  57.4 MBytes   217 Mbits/sec
[ 57]  0.0- 2.2 sec   118 MBytes   448 Mbits/sec
[ 53]  0.0- 2.2 sec   135 MBytes   512 Mbits/sec
[ 58]  0.0- 2.2 sec  69.4 MBytes   260 Mbits/sec
[  5]  0.0- 2.2 sec  46.1 MBytes   173 Mbits/sec
[ 64]  0.0- 2.2 sec   172 MBytes   644 Mbits/sec
[ 12]  0.0- 2.3 sec  85.4 MBytes   317 Mbits/sec
[ 33]  0.0- 2.3 sec   118 MBytes   440 Mbits/sec
[  3]  0.0- 2.3 sec  74.0 MBytes   275 Mbits/sec
[ 61]  0.0- 2.3 sec  65.2 MBytes   242 Mbits/sec
[ 60]  0.0- 2.3 sec   209 MBytes   777 Mbits/sec
[ 43]  0.0- 2.3 sec  98.6 MBytes   364 Mbits/sec
[ 63]  0.0- 2.3 sec   115 MBytes   420 Mbits/sec
[ 56]  0.0- 2.3 sec   112 MBytes   408 Mbits/sec
```

```
[ 15]  0.0- 2.3 sec  67.8 MBytes   245 Mbits/sec
[SUM]  0.0- 2.3 sec  9.72 GBytes  35.9 Gbits/sec
[ 59]  0.0- 2.4 sec   136 MBytes   480 Mbits/sec
[ 65]  2.0- 3.0 sec   580 MBytes  4.87 Gbits/sec
[ 65]  0.0- 3.2 sec   712 MBytes  1.88 Gbits/sec
```

A.5 IO performance

Listing A.7: Output of the `fio` command in Driver instance

```
$ fio --rw=write --ioengine=sync --fdatasync=1 --direct=1 --directory=io-test-data --size=2g --bs=4k --name=iotest
iotest: (g=0): rw=write, bs=(R) 4096B-4096B, (W) 4096B-4096B, (T) 4096B-4096B, ioengine=sync, iodepth=1
fio-3.16
Starting 1 process
Jobs: 1 (f=1): [W(1)][100.0%][w=43.2MiB/s][w=11.1k IOPS][eta 00m:00s]
iotest: (groupid=0, jobs=1): err= 0: pid=125123: Sun Apr 14 18:29:57 2024
  write: IOPS=11.2k, BW=43.6MiB/s (45.7MB/s)(2048MiB/46972msec); 0 zone resets
    clat (usec): min=80, max=3857, avg=88.74, stdev=18.06
     lat (usec): min=80, max=3857, avg=88.77, stdev=18.06
    clat percentiles (usec):
     |  1.00th=[   84],  5.00th=[   85], 10.00th=[   85], 20.00th=[   86],
     | 30.00th=[   86], 40.00th=[   87], 50.00th=[   87], 60.00th=[   88],
     | 70.00th=[   89], 80.00th=[   90], 90.00th=[   92], 95.00th=[   95],
     | 99.00th=[  115], 99.50th=[  141], 99.90th=[  433], 99.95th=[  469],
     | 99.99th=[  570]
   bw (  KiB/s): min=43920, max=45120, per=100.00%, avg=44651.00, stdev=216.78, samples=93
   iops        : min=10980, max=11280, avg=11162.74, stdev=54.21, samples=93
  lat (usec)   : 100=97.22%, 250=2.61%, 500=0.15%, 750=0.01%, 1000=0.01%
  lat (msec)   : 2=0.01%, 4=0.01%
  fsync/fdatasync/sync_file_range:
    sync (nsec): min=320, max=23080, avg=485.91, stdev=112.59
    sync percentiles (nsec):
     |  1.00th=[  410],  5.00th=[  422], 10.00th=[  442], 20.00th=[  450],
     | 30.00th=[  462], 40.00th=[  462], 50.00th=[  470], 60.00th=[  470],
     | 70.00th=[  482], 80.00th=[  502], 90.00th=[  564], 95.00th=[  588],
     | 99.00th=[  700], 99.50th=[  748], 99.90th=[  964], 99.95th=[ 2672],
     | 99.99th=[ 5984]
  cpu          : usr=0.91%, sys=2.86%, ctx=524290, majf=0, minf=13
  IO depths    : 1=200.0%, 2=0.0%, 4=0.0%, 8=0.0%, 16=0.0%, 32=0.0%, >=64=0.0%
     submit    : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
     complete  : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
     issued rwts: total=0,524288,0,0 short=524287,0,0,0 dropped=0,0,0,0
     latency   : target=0, window=0, percentile=100.00%, depth=1

Run status group 0 (all jobs):
  WRITE: bw=43.6MiB/s (45.7MB/s), 43.6MiB/s-43.6MiB/s (45.7MB/s-45.7MB/s), io=2048MiB (2147MB), run=46972-46972msec

Disk stats (read/write):
  nvme1n1: ios=0/523435, merge=0/0, ticks=0/45670, in_queue=0, util=99.83%
```

Listing A.8: Output of the `fio` command in Server instance

```
$ fio --rw=write --ioengine=sync --fdatasync=1 --direct=1 --directory=io-test-data --size=2g --bs=4k --name=
    iotest
iotest: (g=0): rw=write, bs=(R) 4096B-4096B, (W) 4096B-4096B, (T) 4096B-4096B, ioengine=sync, iodepth=1
fio-3.16
Starting 1 process
Jobs: 1 (f=1): [W(1)][100.0%][w=42.0MiB/s][w=10.0k IOPS][eta 00m:00s]
iotest: (groupid=0, jobs=1): err= 0: pid=3435806: Sun Apr 14 18:32:24 2024
  write: IOPS=10.0k, BW=42.9MiB/s (45.0MB/s)(2048MiB/47688msec); 0 zone resets
    clat (usec): min=81, max=2706, avg=90.14, stdev=19.74
     lat (usec): min=81, max=2706, avg=90.17, stdev=19.74
    clat percentiles (usec):
     |  1.00th=[   85],  5.00th=[   86], 10.00th=[   86], 20.00th=[   87],
     | 30.00th=[   88], 40.00th=[   88], 50.00th=[   88], 60.00th=[   89],
     | 70.00th=[   90], 80.00th=[   90], 90.00th=[   92], 95.00th=[   96],
     | 99.00th=[  123], 99.50th=[  178], 99.90th=[  404], 99.95th=[  469],
     | 99.99th=[  701]
   bw (  KiB/s): min=42664, max=44640, per=100.00%, avg=43976.41, stdev=390.28, samples=95
   iops        : min=10666, max=11160, avg=10994.08, stdev=97.58, samples=95
  lat (usec)   : 100=96.61%, 250=3.15%, 500=0.22%, 750=0.02%, 1000=0.01%
  lat (msec)   : 2=0.01%, 4=0.01%
  fsync/fdatasync/sync_file_range:
    sync (nsec): min=310, max=19340, avg=450.55, stdev=109.86
    sync percentiles (nsec):
     |  1.00th=[  410],  5.00th=[  422], 10.00th=[  422], 20.00th=[  422],
     | 30.00th=[  422], 40.00th=[  430], 50.00th=[  430], 60.00th=[  430],
     | 70.00th=[  442], 80.00th=[  462], 90.00th=[  524], 95.00th=[  572],
     | 99.00th=[  668], 99.50th=[  732], 99.90th=[  892], 99.95th=[ 2768],
     | 99.99th=[ 5344]
  cpu          : usr=0.84%, sys=2.65%, ctx=524290, majf=0, minf=14
  IO depths    : 1=200.0%, 2=0.0%, 4=0.0%, 8=0.0%, 16=0.0%, 32=0.0%, >=64=0.0%
     submit    : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
     complete  : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
     issued rwts: total=0,524288,0,0 short=524287,0,0,0 dropped=0,0,0,0
     latency   : target=0, window=0, percentile=100.00%, depth=1

Run status group 0 (all jobs):
  WRITE: bw=42.9MiB/s (45.0MB/s), 42.9MiB/s-42.9MiB/s (45.0MB/s-45.0MB/s), io=2048MiB (2147MB), run=47688-47688
    msec

Disk stats (read/write):
  nvme1n1: ios=0/523825, merge=0/0, ticks=0/46410, in_queue=0, util=99.84%
```

A.6 Datagen configuration

Listing A.9: Contents of `params-sf100.ini` used for scale factor 100

```
ldbc.snb.datagen.generator.scaleFactor:snb.interactive.100
ldbc.snb.datagen.serializer.numUpdatePartitions:48

ldbc.snb.datagen.serializer.dynamicActivitySerializer:ldbc.snb.datagen.serializer.snb.csv.dynamicserializer.activity.CsvCompositeDynamicActivitySerializer
ldbc.snb.datagen.serializer.dynamicPersonSerializer:ldbc.snb.datagen.serializer.snb.csv.dynamicserializer.person.CsvCompositeDynamicPersonSerializer
ldbc.snb.datagen.serializer.staticSerializer:ldbc.snb.datagen.serializer.snb.csv.staticserializer.CsvCompositeStaticSerializer
```

Listing A.10: Contents of `params-sf300.ini` used for scale factor 300

```
ldbc.snb.datagen.generator.scaleFactor:snb.interactive.300
ldbc.snb.datagen.serializer.numUpdatePartitions:48

ldbc.snb.datagen.serializer.dynamicActivitySerializer:ldbc.snb.datagen.serializer.snb.csv.dynamicserializer.activity.CsvCompositeDynamicActivitySerializer
ldbc.snb.datagen.serializer.dynamicPersonSerializer:ldbc.snb.datagen.serializer.snb.csv.dynamicserializer.person.CsvCompositeDynamicPersonSerializer
ldbc.snb.datagen.serializer.staticSerializer:ldbc.snb.datagen.serializer.snb.csv.staticserializer.CsvCompositeStaticSerializer
```

Listing A.11: Contents of `params-sf1000.ini` used for scale factor 1000

```
ldbc.snb.datagen.generator.scaleFactor:snb.interactive.1000
ldbc.snb.datagen.serializer.numUpdatePartitions:48

ldbc.snb.datagen.serializer.dynamicActivitySerializer:ldbc.snb.datagen.serializer.snb.csv.dynamicserializer.activity.CsvCompositeDynamicActivitySerializer
ldbc.snb.datagen.serializer.dynamicPersonSerializer:ldbc.snb.datagen.serializer.snb.csv.dynamicserializer.person.CsvCompositeDynamicPersonSerializer
ldbc.snb.datagen.serializer.staticSerializer:ldbc.snb.datagen.serializer.snb.csv.staticserializer.CsvCompositeStaticSerializer
```

A.7 Import configuration

Listing A.12: Content of `import.conf` describing the data schema

```
name: ldbc_snb
store_type: mutable_csr
stored_procedures:
  directory: {PATH_TO_STORED_PROCEDURES}
  enable_lists:
    - libic1.so
    - libic2.so
    - libic3.so
    - libic4.so
    - libic5.so
    - libic6.so
    - libic7.so
    - libic8.so
    - libic9.so
```

```
    - libic10.so
    - libic11.so
    - libic12.so
    - libic13.so
    - libic14.so
    - libis1.so
    - libis2.so
    - libis3.so
    - libis4.so
    - libis5.so
    - libis6.so
    - libis7.so
    - libins1.so
    - libins2.so
    - libins3.so
    - libins4.so
    - libins5.so
    - libins6.so
    - libins7.so
    - libins8.so
schema:
  vertex_types:
    - type_id: 0
      type_name: PLACE
      properties:
        - property_id: 0
          property_name: id
          property_type:
            primitive_type: DT_SIGNED_INT64
        - property_id: 1
          property_name: name
          property_type:
            varchar:
              max_length: 256
        - property_id: 2
          property_name: url
          property_type:
            varchar:
              max_length: 256
        - property_id: 3
          property_name: type
          property_type:
            varchar:
              max_length: 64
      primary_keys:
        - id
    - type_id: 1
      type_name: PERSON
      properties:
        - property_id: 0
          property_name: id
          property_type:
            primitive_type: DT_SIGNED_INT64
        - property_id: 1
          property_name: firstName
          property_type:
            varchar:
              max_length: 40
```

```
        - property_id: 2
          property_name: lastName
          property_type:
            varchar:
              max_length: 40
        - property_id: 3
          property_name: gender
          property_type:
            varchar:
              max_length: 40
        - property_id: 4
          property_name: birthday
          property_type:
            day: "day"
        - property_id: 5
          property_name: creationDate
          property_type:
            date: "date"
        - property_id: 6
          property_name: locationIP
          property_type:
            varchar:
              max_length: 40
        - property_id: 7
          property_name: browserUsed
          property_type:
            varchar:
              max_length: 40
        - property_id: 8
          property_name: language
          property_type:
            varchar:
              max_length: 2048
        - property_id: 9
          property_name: email
          property_type:
            varchar:
              max_length: 2048
      primary_keys:
        - id
    - type_id: 2
      type_name: COMMENT
      properties:
        - property_id: 0
          property_name: id
          property_type:
            primitive_type: DT_SIGNED_INT64
        - property_id: 1
          property_name: creationDate
          property_type:
            date: "date"
        - property_id: 2
          property_name: locationIP
          property_type:
            varchar:
              max_length: 40
        - property_id: 3
          property_name: browserUsed
```

```
        property_type:
          varchar:
            max_length: 40
      - property_id: 4
        property_name: content
        property_type:
          varchar:
            max_length: 2000
      - property_id: 5
        property_name: length
        property_type:
          primitive_type: DT_SIGNED_INT32
    primary_keys:
      - id
  - type_id: 3
    type_name: POST
    properties:
      - property_id: 0
        property_name: id
        property_type:
          primitive_type: DT_SIGNED_INT64
      - property_id: 1
        property_name: imageFile
        property_type:
          varchar:
            max_length: 40
      - property_id: 2
        property_name: creationDate
        property_type:
          date: "date"
      - property_id: 3
        property_name: locationIP
        property_type:
          varchar:
            max_length: 40
      - property_id: 4
        property_name: browserUsed
        property_type:
         varchar:
            max_length: 40
      - property_id: 5
        property_name: language
        property_type:
          varchar:
            max_length: 40
      - property_id: 6
        property_name: content
        property_type:
          varchar:
            max_length: 2000
      - property_id: 7
        property_name: length
        property_type:
          primitive_type: DT_SIGNED_INT32
    primary_keys:
      - id
  - type_id: 4
    type_name: FORUM
```

```
    properties:
      - property_id: 0
        property_name: id
        property_type:
          primitive_type: DT_SIGNED_INT64
      - property_id: 1
        property_name: title
        property_type:
          varchar:
            max_length: 256
      - property_id: 2
        property_name: creationDate
        property_type:
          date: "date"
    primary_keys:
      - id
  - type_id: 5
    type_name: ORGANISATION
    properties:
      - property_id: 0
        property_name: id
        property_type:
          primitive_type: DT_SIGNED_INT64
      - property_id: 1
        property_name: type
        property_type:
          varchar:
            max_length: 64
      - property_id: 2
        property_name: name
        property_type:
          varchar:
            max_length: 256
      - property_id: 3
        property_name: url
        property_type:
          varchar:
            max_length: 256
    primary_keys:
      - id
  - type_id: 6
    type_name: TAGCLASS
    properties:
      - property_id: 0
        property_name: id
        property_type:
          primitive_type: DT_SIGNED_INT64
      - property_id: 1
        property_name: name
        property_type:
          varchar:
            max_length: 256
      - property_id: 2
        property_name: url
        property_type:
          varchar:
            max_length: 256
    primary_keys:
```

```
      - id
  - type_id: 7
    type_name: TAG
    properties:
      - property_id: 0
        property_name: id
        property_type:
          primitive_type: DT_SIGNED_INT64
      - property_id: 1
        property_name: name
        property_type:
          varchar:
            max_length: 256
      - property_id: 2
        property_name: url
        property_type:
          varchar:
            max_length: 256
    primary_keys:
      - id
edge_types:
  - type_id: 0
    type_name: HASCREATOR
    vertex_type_pair_relations:
      - source_vertex: COMMENT
        destination_vertex: PERSON
        relation: MANY_TO_ONE
        x_csr_params:
          oe_mutability: IMMUTABLE
          sort_on_compaction: TRUE
      - source_vertex: POST
        destination_vertex: PERSON
        relation: MANY_TO_ONE
        x_csr_params:
          oe_mutability: IMMUTABLE
          sort_on_compaction: TRUE
    properties:
      - property_id: 0
        property_name: creationDate
        property_type:
          date: "date"
  - type_id: 1
    type_name: HASTAG
    vertex_type_pair_relations:
      - source_vertex: POST
        destination_vertex: TAG
        relation: MANY_TO_MANY
  - type_id: 2
    type_name: REPLYOF
    vertex_type_pair_relations:
      - source_vertex: COMMENT
        destination_vertex: COMMENT
        relation: MANY_TO_ONE
        x_csr_params:
          oe_mutability: IMMUTABLE
      - source_vertex: COMMENT
        destination_vertex: POST
        relation: MANY_TO_ONE
```

```
        x_csr_params:
          oe_mutability: IMMUTABLE
  - type_id: 3
    type_name: CONTAINEROF
    vertex_type_pair_relations:
      - source_vertex: FORUM
        destination_vertex: POST
        relation: ONE_TO_MANY
        x_csr_params:
          ie_mutability: IMMUTABLE
          edge_storage_strategy: ONLY_IN
  - type_id: 4
    type_name: HASMEMBER
    vertex_type_pair_relations:
      - source_vertex: FORUM
        destination_vertex: PERSON
        relation: MANY_TO_MANY
        x_csr_params:
          edge_storage_strategy: ONLY_IN
          sort_on_compaction: TRUE
    properties:
      - property_id: 0
        property_name: joinDate
        property_type:
          date: "date"
  - type_id: 5
    type_name: HASMODERATOR
    vertex_type_pair_relations:
      - source_vertex: FORUM
        destination_vertex: PERSON
        relation: MANY_TO_ONE
        x_csr_params:
          oe_mutability: IMMUTABLE
          edge_storage_strategy: ONLY_OUT
  - type_id: 6
    type_name: HASINTEREST
    vertex_type_pair_relations:
      - source_vertex: PERSON
        destination_vertex: TAG
        relation: MANY_TO_MANY
        x_csr_params:
          edge_storage_strategy: ONLY_OUT
  - type_id: 7
    type_name: ISLOCATEDIN
    vertex_type_pair_relations:
      - source_vertex: COMMENT
        destination_vertex: PLACE
        relation: MANY_TO_ONE
        x_csr_params:
          oe_mutability: IMMUTABLE
      - source_vertex: PERSON
        destination_vertex: PLACE
        relation: MANY_TO_ONE
        x_csr_params:
          oe_mutability: IMMUTABLE
      - source_vertex: POST
        destination_vertex: PLACE
        relation: MANY_TO_ONE
```

```
        x_csr_params:
          oe_mutability: IMMUTABLE
      - source_vertex: ORGANISATION
        destination_vertex: PLACE
        relation: MANY_TO_ONE
        x_csr_params:
          oe_mutability: IMMUTABLE
  - type_id: 8
    type_name: KNOWS
    vertex_type_pair_relations:
      - source_vertex: PERSON
        destination_vertex: PERSON
        relation: MANY_TO_MANY
    properties:
      - property_id: 0
        property_name: creationDate
        property_type:
          date: "date"
  - type_id: 9
    type_name: LIKES
    vertex_type_pair_relations:
      - source_vertex: PERSON
        destination_vertex: COMMENT
        relation: MANY_TO_MANY
        x_csr_params:
          edge_storage_strategy: ONLY_IN
      - source_vertex: PERSON
        destination_vertex: POST
        relation: MANY_TO_MANY
        x_csr_params:
          edge_storage_strategy: ONLY_IN
    properties:
      - property_id: 0
        property_name: creationDate
        property_type:
          date: "date"
  - type_id: 10
    type_name: WORKAT
    vertex_type_pair_relations:
      - source_vertex: PERSON
        destination_vertex: ORGANISATION
        relation: MANY_TO_MANY
    properties:
      - property_id: 0
        property_name: workFrom
        property_type:
          primitive_type: DT_SIGNED_INT32
  - type_id: 11
    type_name: ISPARTOF
    vertex_type_pair_relations:
      - source_vertex: PLACE
        destination_vertex: PLACE
        relation: MANY_TO_ONE
        x_csr_params:
          oe_mutability: IMMUTABLE
  - type_id: 12
    type_name: HASTYPE
    vertex_type_pair_relations:
```

```
      - source_vertex: TAG
        destination_vertex: TAGCLASS
        relation: MANY_TO_ONE
        x_csr_params:
          oe_mutability: IMMUTABLE
  - type_id: 13
    type_name: ISSUBCLASSOF
    vertex_type_pair_relations:
      - source_vertex: TAGCLASS
        destination_vertex: TAGCLASS
        relation: MANY_TO_ONE
        x_csr_params:
          oe_mutability: IMMUTABLE
  - type_id: 14
    type_name: STUDYAT
    vertex_type_pair_relations:
      - source_vertex: PERSON
        destination_vertex: ORGANISATION
        relation: MANY_TO_MANY
        x_csr_params:
          edge_storage_strategy: ONLY_OUT
    properties:
      - property_id: 0
        property_name: classYear
        property_type:
          primitive_type: DT_SIGNED_INT32
```

A.8 Benchmark configuration

Listing A.13: Contents of `benchmark_sf100.properties` used for scale factor 100

```
url={SERVER}

printQueryNames=false
printQueryStrings=false
printQueryResults=false

status=1
thread_count=64
name=LDBC-SNB
mode=execute_benchmark
results_log=true
time_unit=MICROSECONDS
time_compression_ratio=0.001
peer_identifiers=
workload_statistics=false
spinner_wait_duration=1
help=false
ignore_scheduled_start_times=false

workload=org.ldbcouncil.snb.driver.workloads.interactive.LdbcSnbInteractiveWorkload
db=org.ldbcouncil.snb.impls.workloads.graphscope.interactive.GraphScopeInteractiveDb


ldbc.snb.interactive.updates_dir={UPDATE_STREAMS}
ldbc.snb.interactive.parameters_dir={SUBSTITUTION_PARAMS}
ldbc.snb.interactive.short_read_dissipation=0.2
# Supported scale factors are 0.1, 0.3, 1, 3, 10, 30, 100, 300, 1000
ldbc.snb.interactive.scale_factor=100
operation_count=939800000
warmup=238000000

ldbc.snb.interactive.LdbcQuery1_enable=true
ldbc.snb.interactive.LdbcQuery2_enable=true
ldbc.snb.interactive.LdbcQuery3_enable=true
ldbc.snb.interactive.LdbcQuery4_enable=true
ldbc.snb.interactive.LdbcQuery5_enable=true
ldbc.snb.interactive.LdbcQuery6_enable=true
ldbc.snb.interactive.LdbcQuery7_enable=true
ldbc.snb.interactive.LdbcQuery8_enable=true
ldbc.snb.interactive.LdbcQuery9_enable=true
ldbc.snb.interactive.LdbcQuery10_enable=true
ldbc.snb.interactive.LdbcQuery11_enable=true
ldbc.snb.interactive.LdbcQuery12_enable=true
ldbc.snb.interactive.LdbcQuery13_enable=true
ldbc.snb.interactive.LdbcQuery14_enable=true

ldbc.snb.interactive.LdbcShortQuery1PersonProfile_enable=true
ldbc.snb.interactive.LdbcShortQuery2PersonPosts_enable=true
ldbc.snb.interactive.LdbcShortQuery3PersonFriends_enable=true
ldbc.snb.interactive.LdbcShortQuery4MessageContent_enable=true
ldbc.snb.interactive.LdbcShortQuery5MessageCreator_enable=true
ldbc.snb.interactive.LdbcShortQuery6MessageForum_enable=true
ldbc.snb.interactive.LdbcShortQuery7MessageReplies_enable=true

```

```
ldbc.snb.interactive.LdbcUpdate1AddPerson_enable=true
ldbc.snb.interactive.LdbcUpdate2AddPostLike_enable=true
ldbc.snb.interactive.LdbcUpdate3AddCommentLike_enable=true
ldbc.snb.interactive.LdbcUpdate4AddForum_enable=true
ldbc.snb.interactive.LdbcUpdate5AddForumMembership_enable=true
ldbc.snb.interactive.LdbcUpdate6AddPost_enable=true
ldbc.snb.interactive.LdbcUpdate7AddComment_enable=true
ldbc.snb.interactive.LdbcUpdate8AddFriendship_enable=true
```

Listing A.14: Contents of `benchmark_sf300.properties` used for scale factor 300

```
url={SERVER}

printQueryNames=false
printQueryStrings=false
printQueryResults=false

status=1
thread_count=64
name=LDBC-SNB
mode=execute_benchmark
results_log=true
time_unit=MICROSECONDS
time_compression_ratio=0.00335

peer_identifiers=
workload_statistics=false
spinner_wait_duration=1
help=false
ignore_scheduled_start_times=false


workload=org.ldbcouncil.snb.driver.workloads.interactive.LdbcSnbInteractiveWorkload
db=org.ldbcouncil.snb.impls.workloads.graphscope.interactive.GraphScopeInteractiveDb

ldbc.snb.interactive.updates_dir={UPDATE_STREAMS}
ldbc.snb.interactive.parameters_dir={SUBSTITUTION_PARAMS}
ldbc.snb.interactive.short_read_dissipation=0.2
# Supported scale factors are 0.1, 0.3, 1, 3, 10, 30, 100, 300, 1000
ldbc.snb.interactive.scale_factor=300
operation_count=953500000
warmup=251000000

ldbc.snb.interactive.LdbcQuery1_enable=true
ldbc.snb.interactive.LdbcQuery2_enable=true
ldbc.snb.interactive.LdbcQuery3_enable=true
ldbc.snb.interactive.LdbcQuery4_enable=true
ldbc.snb.interactive.LdbcQuery5_enable=true
ldbc.snb.interactive.LdbcQuery6_enable=true
ldbc.snb.interactive.LdbcQuery7_enable=true
ldbc.snb.interactive.LdbcQuery8_enable=true
ldbc.snb.interactive.LdbcQuery9_enable=true
ldbc.snb.interactive.LdbcQuery10_enable=true
ldbc.snb.interactive.LdbcQuery11_enable=true
ldbc.snb.interactive.LdbcQuery12_enable=true
ldbc.snb.interactive.LdbcQuery13_enable=true
ldbc.snb.interactive.LdbcQuery14_enable=true

```

```
ldbc.snb.interactive.LdbcShortQuery1PersonProfile_enable=true
ldbc.snb.interactive.LdbcShortQuery2PersonPosts_enable=true
ldbc.snb.interactive.LdbcShortQuery3PersonFriends_enable=true
ldbc.snb.interactive.LdbcShortQuery4MessageContent_enable=true
ldbc.snb.interactive.LdbcShortQuery5MessageCreator_enable=true
ldbc.snb.interactive.LdbcShortQuery6MessageForum_enable=true
ldbc.snb.interactive.LdbcShortQuery7MessageReplies_enable=true


ldbc.snb.interactive.LdbcUpdate1AddPerson_enable=true
ldbc.snb.interactive.LdbcUpdate2AddPostLike_enable=true
ldbc.snb.interactive.LdbcUpdate3AddCommentLike_enable=true
ldbc.snb.interactive.LdbcUpdate4AddForum_enable=true
ldbc.snb.interactive.LdbcUpdate5AddForumMembership_enable=true
ldbc.snb.interactive.LdbcUpdate6AddPost_enable=true
ldbc.snb.interactive.LdbcUpdate7AddComment_enable=true
ldbc.snb.interactive.LdbcUpdate8AddFriendship_enable=true
```

Listing A.15: Contents of `benchmark_sf1000.properties` used for scale factor 1000

```
url={SERVER}

printQueryNames=false
printQueryStrings=false
printQueryResults=false

status=1
thread_count=64
name=LDBC-SNB
mode=execute_benchmark
results_log=true
status=1
time_unit=MICROSECONDS
time_compression_ratio=0.0227
peer_identifiers=
workload_statistics=false
spinner_wait_duration=1
help=false
ignore_scheduled_start_times=false

workload=org.ldbcouncil.snb.driver.workloads.interactive.LdbcSnbInteractiveWorkload
db=org.ldbcouncil.snb.impls.workloads.graphscope.interactive.GraphScopeInteractiveDb


ldbc.snb.interactive.updates_dir={UPDATE_STREAMS}
ldbc.snb.interactive.parameters_dir={SUBSTITUTION_PARAMS}
ldbc.snb.interactive.short_read_dissipation=0.2
# Supported scale factors are 0.1, 0.3, 1, 3, 10, 30, 100, 300, 1000
ldbc.snb.interactive.scale_factor=1000
operation_count=932000000
warmup=143000000

ldbc.snb.interactive.LdbcQuery1_enable=true
ldbc.snb.interactive.LdbcQuery2_enable=true
ldbc.snb.interactive.LdbcQuery3_enable=true
ldbc.snb.interactive.LdbcQuery4_enable=true
ldbc.snb.interactive.LdbcQuery5_enable=true
ldbc.snb.interactive.LdbcQuery6_enable=true
```

```
ldbc.snb.interactive.LdbcQuery7_enable=true
ldbc.snb.interactive.LdbcQuery8_enable=true
ldbc.snb.interactive.LdbcQuery9_enable=true
ldbc.snb.interactive.LdbcQuery10_enable=true
ldbc.snb.interactive.LdbcQuery11_enable=true
ldbc.snb.interactive.LdbcQuery12_enable=true
ldbc.snb.interactive.LdbcQuery13_enable=true
ldbc.snb.interactive.LdbcQuery14_enable=true

ldbc.snb.interactive.LdbcShortQuery1PersonProfile_enable=true
ldbc.snb.interactive.LdbcShortQuery2PersonPosts_enable=true
ldbc.snb.interactive.LdbcShortQuery3PersonFriends_enable=true
ldbc.snb.interactive.LdbcShortQuery4MessageContent_enable=true
ldbc.snb.interactive.LdbcShortQuery5MessageCreator_enable=true
ldbc.snb.interactive.LdbcShortQuery6MessageForum_enable=true
ldbc.snb.interactive.LdbcShortQuery7MessageReplies_enable=true

ldbc.snb.interactive.LdbcUpdate1AddPerson_enable=true
ldbc.snb.interactive.LdbcUpdate2AddPostLike_enable=true
ldbc.snb.interactive.LdbcUpdate3AddCommentLike_enable=true
ldbc.snb.interactive.LdbcUpdate4AddForum_enable=true
ldbc.snb.interactive.LdbcUpdate5AddForumMembership_enable=true
ldbc.snb.interactive.LdbcUpdate6AddPost_enable=true
ldbc.snb.interactive.LdbcUpdate7AddComment_enable=true
ldbc.snb.interactive.LdbcUpdate8AddFriendship_enable=true
```

A.9 Validation configuration

Listing A.16: The contents of `validate.properties`

```
url=http://172.31.11.250:10000
readTimeout=5000000
connectTimeout=5000000
connectPoolMaxIdle=10
keepAliveDuration=5000
maxRequestsPerHost=180
maxRequests=180

printQueryNames=false
printQueryStrings=false
printQueryResults=false

status=1
thread_count=1
mode=validate_database
name=LDBC-SNB
results_log=false
time_unit=MILLISECONDS
time_compression_ratio=0.001
peer_identifiers=
workload_statistics=false
spinner_wait_duration=0
help=false
ignore_scheduled_start_times=true

ldbc.snb.interactive.update_interleave=895969
```

```
workload=org.ldbcouncil.snb.driver.workloads.interactive.LdbcSnbInteractiveWorkload
db=org.ldbcoucil.snb.impls.workloads.graphscope.interactive.GraphScopeInteractiveDb

operation_count=10000

validate_database=/disk1/sf10_1p/validation_params.csv
ldbc.snb.interactive.parameters_dir=/disk1/sf10_1p/substitution_parameters/
ldbc.snb.interactive.short_read_dissipation=0.2
# Supported scale factors are 0.1, 0.3, 1, 3, 10, 30, 100, 300, 1000
ldbc.snb.interactive.scale_factor=10

ldbc.snb.interactive.LdbcQuery1_freq=1
ldbc.snb.interactive.LdbcQuery2_freq=1
ldbc.snb.interactive.LdbcQuery3_freq=1
ldbc.snb.interactive.LdbcQuery4_freq=1
ldbc.snb.interactive.LdbcQuery5_freq=1
ldbc.snb.interactive.LdbcQuery6_freq=1
ldbc.snb.interactive.LdbcQuery7_freq=1
ldbc.snb.interactive.LdbcQuery8_freq=1
ldbc.snb.interactive.LdbcQuery9_freq=1
ldbc.snb.interactive.LdbcQuery10_freq=1
ldbc.snb.interactive.LdbcQuery11_freq=1
ldbc.snb.interactive.LdbcQuery12_freq=1
ldbc.snb.interactive.LdbcQuery13_freq=1
ldbc.snb.interactive.LdbcQuery14_freq=1

ldbc.snb.interactive.LdbcQuery1_enable=true
ldbc.snb.interactive.LdbcQuery2_enable=true
ldbc.snb.interactive.LdbcQuery3_enable=true
ldbc.snb.interactive.LdbcQuery4_enable=true
ldbc.snb.interactive.LdbcQuery5_enable=true
ldbc.snb.interactive.LdbcQuery6_enable=true
ldbc.snb.interactive.LdbcQuery7_enable=true
ldbc.snb.interactive.LdbcQuery8_enable=true
ldbc.snb.interactive.LdbcQuery9_enable=true
ldbc.snb.interactive.LdbcQuery10_enable=true
ldbc.snb.interactive.LdbcQuery11_enable=true
ldbc.snb.interactive.LdbcQuery12_enable=true
ldbc.snb.interactive.LdbcQuery13_enable=true
ldbc.snb.interactive.LdbcQuery14_enable=true

ldbc.snb.interactive.LdbcShortQuery1PersonProfile_enable=true
ldbc.snb.interactive.LdbcShortQuery2PersonPosts_enable=true
ldbc.snb.interactive.LdbcShortQuery3PersonFriends_enable=true
ldbc.snb.interactive.LdbcShortQuery4MessageContent_enable=true
ldbc.snb.interactive.LdbcShortQuery5MessageCreator_enable=true
ldbc.snb.interactive.LdbcShortQuery6MessageForum_enable=true
ldbc.snb.interactive.LdbcShortQuery7MessageReplies_enable=true

ldbc.snb.interactive.LdbcUpdate1AddPerson_enable=true
ldbc.snb.interactive.LdbcUpdate2AddPostLike_enable=true
ldbc.snb.interactive.LdbcUpdate3AddCommentLike_enable=true
ldbc.snb.interactive.LdbcUpdate4AddForum_enable=true
ldbc.snb.interactive.LdbcUpdate5AddForumMembership_enable=true
ldbc.snb.interactive.LdbcUpdate6AddPost_enable=true
ldbc.snb.interactive.LdbcUpdate7AddComment_enable=true
ldbc.snb.interactive.LdbcUpdate8AddFriendship_enable=true
```