

Full Disclosure Report of the LDBC Social Network Benchmark

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

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.

GraphScope Flex¹ 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, the 'db_hiactor_cppsp_mcsr' build of GraphScope Flex 0.23.0 was used to execute scale factors SF30, SF100, and SF300 in a single-instance setting (plus another instance to run the driver). The instances were deployed on the Amazon Web Services infrastructure.

The queries are implemented imperatively using stored procedures written in C++17, which are 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 nor precomputed properties are used. The system under test and the driver communicate 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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¹https://github.com/alibaba/GraphScope/tree/main/flex

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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 Amazon Web Services dashboard (Instance Details page). The operating system was obtained from running uname -a command.

Table 1.1: Machine Type and Location

Cloud provider	Amazon Web Services
Machine region	US East(N.Virginia) us-east-1 Zone: us-east-1c
Common name of the item	r5d.12xlarge
Operating system	Ubuntu 20.04.1 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" » etcsysctl.conf && sysctl -p etcsysctl.conf

This benchmark used two r5d.12xlarge 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.

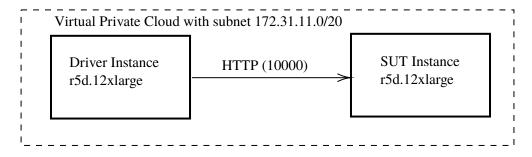


Figure 1.1: Overview of benchmark setup

1.1.2 CPU details

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

Table 1.2: CPU details summary

Туре	Intel(R) Xeon(R) Platinum 8175M
Total number	1
Cores per CPU	24
Threads per CPU core	2
CPU clock frequency	2.50 GHz
	L1 cache: 768KiB Data + 768KiB Instruction
Total cache size per CPU	L2 cache: 24MiB
	L3 cache: 33MiB

1.1.3 Memory details

The total size of the memory installed is 384GiB and the type of memory is DDR4 2666 Mhz. This information was obtained using the sudo 1shw -c memory command (Listing A.2) issued from the virtual machine instance.

1.1.4 Disk and storage details

The instance has multiple disks attached. Two 900GB NVMe SSD devices /dev/nvme1n1 and /dev/nvme1n2 (mounted at /disk1 and /disk2 respectively), used during the benchmarking: datasets (including update streams) were stored in /dev/nvme1n1 while /dev/nvme1n2 was used to run the driver and the database in their respective instances.

The file system type used for both drives was xfs. We tested the performance of /disk2 of the SUT, where the database workspace lies with the fio command, using 4KB blocks and a queue depth of 1 (Listing A.5), obtaining an average of 18050 IOPS.

1.1.5 Network details

The benchmark was run using two r5d.12xlarge instances, both deployed in the same availability zone behind a Virtual Private Cloud (VPC) configured with subnetwork 172.31.11.0/20. Only SUT had the following ports open:

• 10000: HTTP port used by SUT

The r5d.12x1arge instances use a common Ethernet adapter. This information was obtained using the lshw -class network command (Listing A.3). Network throughput between the two instances was measured using the iperf tool on port 10000 using 48 threads and the output (Listing A.4) showed an average of 11.5 Gbit/sec from client to server and 17.5 Gbit/sec from server to client.

1.1.6 Machine pricing

The system pricing summary is included in the table below. The pricing of the AWS machine 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 \$. The maintenance service fee guarantees 24-hour availability, 7 days a week with a 4-hour response time. The service is provided by the open-source project's major contributors and maintainers.

Table 1.3: Pricing summary

Item	Price
r5d.12xlarge reserved instance machine in Amazon Web Services (standard 3-year term)	39 236.04 USD
Permanent Graphscope Flex license	0.00 USD
Maintenance service fee (3 years)	60 000.00 USD
Total cost of ownership	99 236.04 USD

1.1.7 System availability

The latest software version of Graphscope Flex (version 0.23.0) was made available on May 27th, 2023. 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 GitHub¹.

 $^{^{1}}$ https://github.com/alibaba/GraphScope/releases/download/v0.23.0/graphscope_flex_db_hiactor_cppsp_mcsr_0.23.0_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	30, 100, and 300
Number of partitions	32

For validation, we used SF10. Validation parameters where downloaded from LDBC GitHub¹, which are generated using the Neo4j Implementation.

2.2 Datagen configurations

The Datagen configuration for SF10 is shown in Listing 2.1. The configurations for SF30, SF100 and SF300 are shown in Listings A.6–A.8.

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

- | ldbc.snb.datagen.generator.scaleFactor:snb.interactive.10
- 2 | 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

2.3 Data loading and data schema

The output produced by Datagen is loaded as-is into the system, without any kind of preprocessing. Two configuration files are used to specify what to load and the schema: bulk_load_XXX.yaml (see Listing 2.2) and graph.yaml (Listing A.9).

On the one hand, bulk_load_XXX.yaml is scale factor specific, and specifies the paths to the csv files with the data, along with the type of object being loaded (e.g. vertex or edge), the label (e.g. PERSON, KNOWS, etc.) and the format of the file. Properties are inferred from column names.

On the other hand, graph.yaml is shared between scale factors, and there we specify the schema (vertex and edge types, their properties, type of edge indexing, etc.) and the stored procedures paths.

 $^{^{\}mathrm{I}}$ https://pub-383410a98aef4cb686f0c7601eddd25f.r2.dev/interactive-v1/validation_params-sf0.1-sf10.tar.zst

Listing 2.2: Excerpt from bulk_load_sf100_32p.yaml, describing the data loading process

```
2
     graph:
3
     vertex:
4
      - label_name: PLACE
        files:
           - path: /disk1/sf100_32p/social_network/static/place_0_0.csv
             format: standard_csv
      - label_name: PERSON
8
9
10
           - path: /disk1/sf100_32p/social_network/dynamic/person_0_0.csv
             format: standard_csv
11
12
       - label_name: COMMENT
        files:
13
           - path: /disk1/sf100_32p/social_network/dynamic/comment_0_0.csv
14
             format: standard_csv
15
       - label_name: POST
16
17
         files:
           - path: /disk1/sf100_32p/social_network/dynamic/post_0_0.csv
18
             format: standard csv
19
       - label_name: FORUM
20
         files:
21
22
           - path: /disk1/sf100_32p/social_network/dynamic/forum_0_0.csv
23
             format: standard csv
24
       - label_name: ORGANISATION
25
26
           - path: /disk1/sf100_32p/social_network/static/organisation_0_0.csv
27
             format: standard_csv
28
       - label_name: TAGCLASS
29
           - path: /disk1/sf100_32p/social_network/static/tagclass_0_0.csv
30
31
             format: standard_csv
32
       - label_name: TAG
         files:
33
           - path: /disk1/sf100_32p/social_network/static/tag_0_0.csv
34
35
             format: standard_csv
36
37
      - src_label_name: COMMENT
        dst_label_name: PERSON
38
        edge_label_name: HASCREATOR
39
40
           - path: /disk1/sf100_32p/social_network/dynamic/comment_hasCreator_person_0_0.csv
41
             format: standard_csv
42
43
44
```

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 2.2: Data loading times and startup times

Scale factor	Loading time (s)	Startup time (s)
30	394.493	14.23
100	1 311.83	44.90
300	3 992.51	128.743

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/2001.02299v3.pdf
Driver read threads	48	
Driver write threads	64	

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

 $\verb|org.ldbcoucil.snb.impls.workloads.graphscope.interactive.GraphScopeInteractiveDb| \\$ 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=0.00112 for scale factor 30,
- TCR=0.0039 for scale factor 100 and
- TCR=0.014 for scale factor 300.

The complete configuration files for the different scale factors are shown in Listings A.10-A.12, and are also included in the attached supplementary materials.

4 Performance Metrics

The performance metrics reported here show benchmark runs with scale factors 30, 100 and 300. 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 30

Benchmark duration	Benchmark operations	Throughput	Query on-time compliance		
02h 03m 03.184s	244 980 478	$33\ 180.87 \frac{\text{operations}}{\text{second}}$	100.00%		

Table 4.2: Summary of results for scale factor 100

Benchmark duration	Benchmark operations	Throughput	Query on-time compliance
02h 01m 25.413s	244 974 654	33 625.36 operations second	100.00%

Table 4.3: Summary of results for scale factor 300

Benchmark duration	Benchmark operations	Throughput	Query on-time compliance	
02h 02m 44.435s	244 951 252	$33\ 261.38\ \frac{\text{operations}}{\text{second}}$	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 (μ s) precision. The notation $\mathbf{P_i}$ is used for the i^{th} percentile among all observed execution run times of a given query type.

¹The 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 30 in microseconds

Query	Total count	Min.	Max.	Mean	P_{50}	P_{90}	P_{95}	P_{99}
Query1	1 625 244	457	343 248	1 255.18	862	1 157	1 255	15 737
Query2	1 142 064	544	323 216	1 707.83	1 578	2 366	2 581	3 004
Query3	398 645	3 246	330 176	5 889.02	5 629	7 365	7 629	8 653
Query4	1 173 787	202	330 944	552.66	440	616	696	973
Query5	586 894	37 222	557 824	144 925.59	130 872	233 520	252 992	278 960
Query6	133 723	168	298 576	698.68	638	1 186	1 294	1 520
Query7	880 341	108	330 928	265.12	183	280	320	439
Query8	4 695 150	398	341 024	1 494.04	1 213	2 383	2 730	3 545
Query9	110 043	84 908	570 400	197 889.27	181 152	284 928	303 120	332 816
Query10	1 142 064	1 893	337 552	7 312.28	6 370	9 914	13 632	23 928
Query11	2 112 817	137	329 440	259.67	211	277	313	402
Query12	960 371	1 384	345 152	7 151.85	6 784	10 010	11 116	13 465
Query13	2 224 018	118	355 296	281.88	226	343	389	489
Query14	862 375	230	339 952	7 137.01	3 667	9 960	38 382	71 736
ShortQuery1PersonProfile	22 651 539	97	365 440	179.39	136	182	217	349
ShortQuery2PersonPosts	22 651 539	99	367 664	265.23	206	329	410	681
ShortQuery3PersonFriends	22 651 539	98	368 464	447.59	287	689	1 409	2 212
ShortQuery4MessageContent	22 653 918	96	365 216	186.46	137	188	227	352
ShortQuery5MessageCreator	22 653 918	95	391 392	170.14	131	172	205	306
ShortQuery6MessageForum	22 653 918	97	386 368	170.34	131	172	205	306
ShortQuery7MessageReplies	22 653 918	98	342 624	180.10	141	187	216	316
Update1AddPerson	12 946	178	215 648	390.59	311	560	631	885
Update2AddPostLike	9 844 761	139	383 328	315.54	203	283	332	557
Update3AddCommentLike	10 983 263	137	377 680	303.20	201	281	330	548
Update4AddForum	229 785	150	316 736	324.19	215	303	355	600
Update5AddForumMembership	34 908 158	136	375 776	317.98	203	284	332	559
Update6AddPost	2 967 525	149	344 192	328.69	224	334	396	647
Update7AddComment	8 503 041	150	369 776	335.55	223	330	391	657
Update8AddFriendship	913 174	142	337 584	308.38	203	283	331	557

Table 4.5: 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	1 496 789	156	486 768	2 847.58	1 065	1 452	22 577	36 210
Query2	1 051 798	110	456 624	2 062.93	1 941	2 884	3 157	3 712
Query3	316 394	9 251	450 096	16 027.79	15 307	19 823	20 618	23 273
Query4	1 081 014	155	477 088	504.38	445	633	706	894
Query5	498 930	2 900	577 760	142 587.03	136 712	202 584	217 984	241 120
Query6	89 670	171	331 984	1 145.18	453	2 399	2 637	3 032
Query7	1 024 119	113	438 992	226.33	180	271	310	418
Query8	7 783 303	107	513 456	230.18	188	257	290	372
Query9	73 845	126	577 888	282 994.38	265 936	390 336	417 664	459 024
Query10	972 912	124	472 336	7 828.94	7 134	9 886	12 780	22 106
Query11	1 768 933	128	457 424	268.55	227	295	329	417
Query12	884 466	112	476 224	8 320.30	7 987	11 434	12 571	15 175
Query13	2 048 238	135	442 528	393.11	346	511	545	658
Query14	794 214	322	426 304	20 344.01	4 582	67 296	78 092	92 976
ShortQuery1PersonProfile	24 956 031	98	491 776	172.14	136	181	217	331
ShortQuery2PersonPosts	24 956 031	99	496 560	268.87	212	353	450	752
ShortQuery3PersonFriends	24 956 031	99	518 912	497.06	317	815	1 651	2 561
ShortQuery4MessageContent	24 959 042	97	489 712	179.43	137	190	228	335
ShortQuery5MessageCreator	24 959 042	95	513 392	163.02	132	172	205	299
ShortQuery6MessageForum	24 959 042	96	493 568	163.52	132	173	206	301
ShortQuery7MessageReplies	24 959 042	99	483 536	176.78	146	193	222	317
Update1AddPerson	9 945	192	235 624	447.20	321	569	627	838
Update2AddPostLike	7 066 490	141	478 496	303.90	208	291	339	554
Update3AddCommentLike	10 925 360	139	523 792	302.28	207	291	339	553
Update4AddForum	170 420	151	424 656	329.79	220	310	364	588
Update5AddForumMembership	21 709 074	138	505 040	301.65	207	291	339	555
Update6AddPost	2 325 968	152	495 248	364.33	235	354	420	691
Update7AddComment	7 400 652	153	524 112	340.41	231	341	405	660
Update8AddFriendship	777 859	143	476 864	307.31	210	296	345	565

Table 4.6: 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	1 190 062	213	647 712	2 015.47	1 352	1 735	1 863	37 230
Query2	836 260	105	594 144	2 480.34	2 325	3 633	3 972	4 629
Query3	217 899	27 023	652 736	48 627.44	49 670	59 824	62 796	69 356
Query4	859 489	142	565 856	602.16	519	756	828	1 026
Query5	368 353	137	720 768	193 494.59	192 344	283 008	302 576	333 568
Query6	53 348	190	465 776	2 531.99	548	5 869	6 429	7 377
Query7	966 925	126	593 024	249.42	195	290	332	454
Query8	10 313 870	106	665 824	242.00	187	256	291	379
Query9	43 889	136	784 512	399 810.44	392 192	543 520	584 416	652 160
Query10	703 218	134	605 728	8 703.32	8 437	11 334	12 291	15 997
Query11	1 289 233	136	679 168	336.06	281	357	396	509
Query12	703 218	111	560 384	9 462.91	9 099	13 742	15 161	18 160
Query13	1 628 506	178	635 040	633.63	579	781	835	1 016
Query14	631 462	429	661 280	41 384.64	8 495	107 900	121 096	145 304
ShortQuery1PersonProfile	24 856 718	98	738 432	185.34	139	187	226	343
ShortQuery2PersonPosts	24 856 718	97	681 344	303.86	229	401	523	915
ShortQuery3PersonFriends	24 856 718	98	741 536	581.34	368	947	1 880	3 015
ShortQuery4MessageContent	24 854 797	95	712 096	197.08	140	198	240	348
ShortQuery5MessageCreator	24 854 797	95	752 384	175.56	134	177	213	316
ShortQuery6MessageForum	24 854 797	93	700 480	175.07	135	178	213	317
ShortQuery7MessageReplies	24 854 797	100	666 464	198.28	158	210	243	347
Update1AddPerson	6 980	192	376 976	605.42	361	607	692	946
Update2AddPostLike	6 967 271	140	746 688	345.45	214	304	356	640
Update3AddCommentLike	14 037 494	140	740 480	347.46	214	304	356	642
Update4AddForum	119 708	152	580 864	378.86	230	335	394	702
Update5AddForumMembership	16 380 979	137	771 968	346.38	214	304	356	641
Update6AddPost	2 172 529	153	673 088	630.40	255	410	500	1 904
Update7AddComment	10 848 212	150	709 408	367.55	238	359	425	760
Update8AddFriendship	623 005	143	608 768	355.58	224	332	385	682

5 Validation of the Results

The scale factor 10 data set was used for validating the correctness of the implementation over the SUT. The validation data set was created using the SNB Interactive reference implementation over Neo4j, which can be download from the LDBC GitHub repository¹. The system with the driver configuration shown in Listing A.13 successfully returned the expected result sets for the queries of the benchmark.

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:

- 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: SF30, SF100 and SF300. 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)
30	30.54
100	161.05
300	153.61

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 tool, the presence of the contents on each update query was checked.

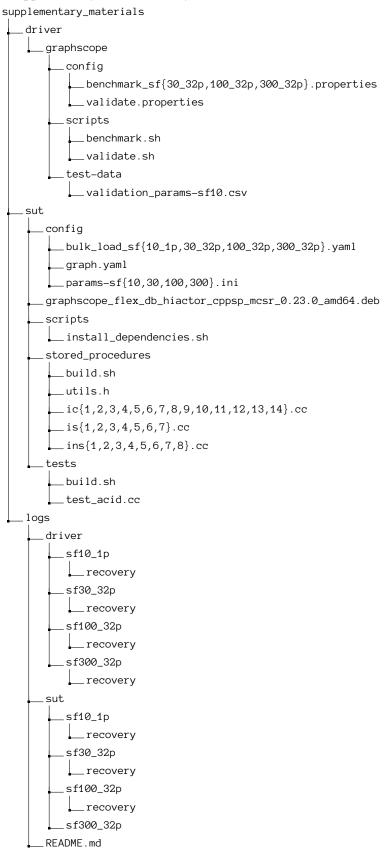
7 Supplementary Materials

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_sf{30_32p,100_32p,300_32p}.properties	Driver configuration properties per scale factor
validate.properties	Driver configuration properties used for validation
benchmark.sh	Script used to run the driver for sf30-300
validate.sh	Script used to run the driver for validation
validation_params-sf10.csv	CSV with sf10 validation params used
bulk_load_sf{10_1p,30_32p,100_32p,300_32p}.yaml	SUT loading process config file for different scale fac-
	tors
graph.yaml	SUT schema file
params-sf{10,30,100,300}.ini	Datagen config params for different scale factors
graphscope_flex_db_hiactor_cppsp_mcsr_0.23.0_amd64.deb	Binary package with the SUT database
install_dependencies.sh	Script that installs required dependencies and configures
	machine parameters
build.sh	Build script
ic{1,2,3,4,5,6,7,8,9,10,11,12,13,14}.cc	Stored procedures implementing the benchmark Com-
	plex 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.tgz	Compressed archive of the logs folder
logs/driver/sf{10_1p,30_32p,100_32p,300_32p}	folder with driver logs of normal runs
logs/driver/sf{10_1p,30_32p,100_32p,300_32p}/recovery	folder with driver logs of recovery runs
logs/sut/sf{10_1p,30_32p,100_32p,300_32p}	folder with SUT logs of normal runs
logs/sut/sf{10_1p,30_32p,100_32p,300_32p}/recovery	folder with SUT logs of recovery runs

The supplementary folder directory structure is as follows:



A Appendix

A.1 CPU details

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

```
1 Architecture:
                                     x86 64
  CPU op-mode(s):
                                     32-bit, 64-bit
  Byte Order:
                                    Little Endian
  Address sizes:
                                    46 bits physical, 48 bits virtual
  CPU(s):
                                    48
6 On-line CPU(s) list:
                                    0 - 47
7 Thread(s) per core:
8 Core(s) per socket:
                                    24
9 Socket(s):
                                     1
10 NUMA node(s):
  Vendor ID:
                                    GenuineIntel
11
12 CPU family:
13 Model:
                                     85
14 Model name:
                                     Intel(R) Xeon(R) Platinum 8175M CPU @ 2.50GHz
15 Stepping:
16 CPU MHz:
                                     2500.000
17 BogoMIPS:
                                     5000.00
18 Hypervisor vendor:
                                     KVM
19 Virtualization type:
                                     ful1
20 Idd cache:
                                     768 KiB
21 L1i cache:
                                    768 KiB
22 L2 cache:
                                     24 MiB
23 L3 cache:
                                     33 MiB
24 NUMA node0 CPU(s):
                                    0-47
25 Vulnerability Itlb multihit:
                                    KVM: Mitigation: VMX unsupported
  Vulnerability L1tf:
26
                                    Mitigation; PTE Inversion
  | Vulnerability Mds:
                                    Vulnerable: Clear CPU buffers attempted, no microcode; SMT Host state unknown
27
28 Vulnerability Meltdown:
                                    Mitigation; PTI
29 Vulnerability Mmio stale data:
                                    Vulnerable: Clear CPU buffers attempted, no microcode; SMT Host state unknown
30 Vulnerability Retbleed:
                                     Vulnerable
31 Vulnerability Spec store bypass: Vulnerable
32 Vulnerability Spectre v1:
                                    {\tt Mitigation; \ usercopy/swapgs \ barriers \ and \ \_user \ pointer \ sanitization}
  Vulnerability Spectre v2:
                                    Mitigation; Retpolines, STIBP disabled, RSB filling
34
  Vulnerability Srbds:
                                    Not affected
35 Vulnerability Tsx async abort:
                                    Not affected
36 Flags:
                                     fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 clflush
       mmx fxsr sse sse2 ss ht syscall nx pdpe1gb rdtscp lm constant_tsc arch_perfmon rep_good nopl xtopo
37
                                     logy nonstop_tsc cpuid aperfmperf tsc_known_freq pni pclmulqdq monitor ssse3 fma
        cx16 pcid sse4_1 sse4_2 x2apic movbe popcnt tsc_deadline_timer aes xsave avx f16c rdrand hypervis
38
                                     or lahf_lm abm 3dnowprefetch invpcid_single pti fsgsbase tsc_adjust bmi1 avx2
       smep bmi2 erms invpcid mpx avx512f avx512dq rdseed adx smap clflushopt clwb avx512cd avx512bw avx512
                                     vl xsaveopt xsavec xgetbv1 xsaves ida arat pku ospke
39
```

Appendix A.2. Memory details

A.2 Memory details

Listing A.2: Output of the 1shw -c memory command

```
*-firmware
2
          description: BIOS
3
          vendor: Amazon EC2
          physical id: 0
4
          version: 1.0
          date: 10/16/2017
          size: 64KiB
          capacity: 64KiB
8
9
          capabilities: pci edd acpi virtualmachine
10
     *-cache:0
          description: L1 cache
11
12
          physical id: 5
13
          slot: L1-Cache
          size: 1536KiB
14
          capacity: 1536KiB
15
16
          capabilities: synchronous internal write-back instruction
17
          configuration: level=1
     *-cache:1
18
          description: L2 cache
19
          physical id: 6
20
21
          slot: L2-Cache
22
         size: 24MiB
          capacity: 24MiB
23
24
          capabilities: synchronous internal varies unified
          configuration: level=2
25
     *-cache:2
26
27
          description: L3 cache
28
          physical id: 7
          slot: L3-Cache
29
          size: 33MiB
30
          capacity: 33MiB
31
32
          capabilities: synchronous internal varies unified
          configuration: level=3
33
34
     *-memory
          description: System Memory
35
36
          physical id: 8
          slot: System board or motherboard
37
          size: 384GiB
38
39
40
             description: DIMM DDR4 Static column Pseudo-static Synchronous Window DRAM 2666 MHz (0.4 ns)
             physical id: 0
41
             size: 384GiB
42
43
             width: 64 bits
             clock: 2666MHz (0.4ns)
```

Appendix A.3. Network details

A.3 Network details

Listing A.3: Output of the 1shw -class network command

```
*-network
2
          description: Ethernet interface
          product: Elastic Network Adapter (ENA)
3
4
         vendor: Amazon.com, Inc.
         physical id: 5
         bus info: pci@0000:00:05.0
         logical name: ens5
         version: 00
9
         serial: 02:74:02:41:3a:81
         width: 32 bits
10
11
         clock: 33MHz
12
         capabilities: pciexpress msix bus_master cap_list ethernet physical
13
         configuration: broadcast=yes driver=ena driverversion=5.15.0-1019-aws ip=172.31.11.250 latency=0 link=yes
       multicast=ves
         resources: irq:0 memory:febf4000-febf7fff memory:fe800000-fe8fffff memory:febe0000-febeffff
14
```

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.4: Output of the iperf command

```
# iperf -c 172.16.18.134 -r --parallel 48 -i 1 -t 2 -p 10000
  Server listening on TCP port 10000
  TCP window size: 128 KByte (default)
  Client connecting to 172.31.11.250, TCP port 10000
  TCP window size: 455 KByte (default)
10 [ 51] local 172.31.10.47 port 46782 connected with 172.31.11.250 port 10000
11 [ 50] local 172.31.10.47 port 46770 connected with 172.31.11.250 port 10000
12 | [ 49] local 172.31.10.47 port 46762 connected with 172.31.11.250 port 10000
13 [ 5] local 172.31.10.47 port 46332 connected with 172.31.11.250 port 10000
  [ 3] local 172.31.10.47 port 46346 connected with 172.31.11.250 port 10000
     4] local 172.31.10.47 port 46320 connected with 172.31.11.250 port 10000
     8] local 172.31.10.47 port 46360 connected with 172.31.11.250 port 10000
  [ 6] local 172.31.10.47 port 46356 connected with 172.31.11.250 port 10000
18 | [ 7] local 172.31.10.47 port 46374 connected with 172.31.11.250 port 10000
19 [ 10] local 172.31.10.47 port 46366 connected with 172.31.11.250 port 10000
20 [ 11] local 172.31.10.47 port 46400 connected with 172.31.11.250 port 10000
21 [ 13] local 172.31.10.47 port 46406 connected with 172.31.11.250 port 10000
22 [ 9] local 172.31.10.47 port 46388 connected with 172.31.11.250 port 10000
23 [ 14] local 172.31.10.47 port 46442 connected with 172.31.11.250 port 10000
24 | [ 18] local 172.31.10.47 port 46452 connected with 172.31.11.250 port 10000
25 [ 21] local 172.31.10.47 port 46462 connected with 172.31.11.250 port 10000
26 [ 16] local 172.31.10.47 port 46432 connected with 172.31.11.250 port 10000
27 [ 15] local 172.31.10.47 port 46418 connected with 172.31.11.250 port 10000
28 [ 17] local 172.31.10.47 port 46456 connected with 172.31.11.250 port 10000
29 [ 19] local 172.31.10.47 port 46464 connected with 172.31.11.250 port 10000
30 [ 24] local 172.31.10.47 port 46490 connected with 172.31.11.250 port 10000
```

```
31 [ 22] local 172.31.10.47 port 46498 connected with 172.31.11.250 port 10000
32 [ 12] local 172.31.10.47 port 46426 connected with 172.31.11.250 port 10000
33 [ 26] local 172.31.10.47 port 46530 connected with 172.31.11.250 port 10000
34 [ 23] local 172.31.10.47 port 46476 connected with 172.31.11.250 port 10000
35 [ 25] local 172.31.10.47 port 46514 connected with 172.31.11.250 port 10000
36 [ 27] local 172.31.10.47 port 46540 connected with 172.31.11.250 port 10000
  [ 29] local 172.31.10.47 port 46550 connected with 172.31.11.250 port 10000
  [ 30] local 172.31.10.47 port 46562 connected with 172.31.11.250 port 10000
  [ 34] local 172.31.10.47 port 46572 connected with 172.31.11.250 port 10000
40 [ 20] local 172.31.10.47 port 46588 connected with 172.31.11.250 port 10000
41 [ 37] local 172.31.10.47 port 46602 connected with 172.31.11.250 port 10000
42 [ 31] local 172.31.10.47 port 46580 connected with 172.31.11.250 port 10000
43 [ 36] local 172.31.10.47 port 46630 connected with 172.31.11.250 port 10000
44 [ 33] local 172.31.10.47 port 46612 connected with 172.31.11.250 port 10000
45
  [ 38] local 172.31.10.47 port 46626 connected with 172.31.11.250 port 10000
  [ 39] local 172.31.10.47 port 46644 connected with 172.31.11.250 port 10000
  [ 35] local 172.31.10.47 port 46656 connected with 172.31.11.250 port 10000
48 [ 43] local 172.31.10.47 port 46684 connected with 172.31.11.250 port 10000
49 [ 40] local 172.31.10.47 port 46706 connected with 172.31.11.250 port 10000
50 [ 41] local 172.31.10.47 port 46682 connected with 172.31.11.250 port 10000
51 [ 42] local 172.31.10.47 port 46668 connected with 172.31.11.250 port 10000
52 [ 45] local 172.31.10.47 port 46690 connected with 172.31.11.250 port 10000
53 [ 46] local 172.31.10.47 port 46712 connected with 172.31.11.250 port 10000
  [ 44] local 172.31.10.47 port 46716 connected with 172.31.11.250 port 10000
55 | [ 47] local 172.31.10.47 port 46746 connected with 172.31.11.250 port 10000
56 | [ 48] local 172.31.10.47 port 46732 connected with 172.31.11.250 port 10000
57 | [ 28] local 172.31.10.47 port 46534 connected with 172.31.11.250 port 10000
58 [ ID] Interval
                       Transfer
                                    Bandwidth
  [ 51] 0.0- 1.0 sec 40.5 MBytes
                                    340 Mbits/sec
59
  [ 49]
         0.0- 1.0 sec 48.1 MBytes
                                     404 Mbits/sec
                       36.9 MBytes
     5]
         0.0- 1.0 sec
                                     309 Mbits/sec
  [ 3]
         0.0- 1.0 sec 17.2 MBytes
62
                                     145 Mbits/sec
63 [ 4]
         0.0- 1.0 sec 24.4 MBytes
                                     204 Mbits/sec
64 [ 8] 0.0-1.0 sec 17.2 MBytes
                                     145 Mbits/sec
  [ 6] 0.0-1.0 sec 24.2 MBytes
                                     203 Mbits/sec
  [ 7] 0.0-1.0 sec 36.8 MBytes
                                     308 Mbits/sec
  [ 10] 0.0- 1.0 sec 24.0 MBytes
                                     201 Mbits/sec
67
  [ 11] 0.0- 1.0 sec 31.4 MBytes
                                     263 Mbits/sec
  [ 13] 0.0- 1.0 sec 41.1 MBytes
                                     345 Mbits/sec
70 [ 9] 0.0-1.0 sec 17.4 MBytes
                                     146 Mbits/sec
71 [ 14] 0.0- 1.0 sec 40.9 MBytes
                                     343 Mbits/sec
72 [ 21] 0.0- 1.0 sec 17.5 MBytes
                                     147 Mbits/sec
73 [ 16] 0.0- 1.0 sec 37.0 MBytes
                                     310 Mbits/sec
74 [ 15] 0.0- 1.0 sec 41.4 MBytes
                                     347 Mbits/sec
75 [ 17]
         0.0- 1.0 sec 40.0 MBytes
                                     336 Mbits/sec
  [ 19]
         0.0- 1.0 sec 24.4 MBytes
                                     204 Mbits/sec
76
77
  [ 24]
         0.0- 1.0 sec 25.2 MBytes
                                     212 Mbits/sec
  [ 22]
         0.0- 1.0 sec 25.4 MBytes
                                     213 Mbits/sec
78
  [ 12] 0.0- 1.0 sec 40.2 MBytes
                                     338 Mbits/sec
  [ 26] 0.0-1.0 sec 17.5 MBytes
                                     147 Mbits/sec
  [ 23] 0.0-1.0 sec 25.2 MBytes
                                     212 Mbits/sec
81
  [ 25] 0.0-1.0 sec 24.0 MBytes
                                     201 Mbits/sec
82
  [ 27] 0.0-1.0 sec 40.2 MBytes
83
                                     338 Mbits/sec
  [ 29] 0.0-1.0 sec 36.9 MBytes
                                     309 Mbits/sec
  [ 30] 0.0-1.0 sec 40.0 MBytes
                                     336 Mbits/sec
86 [ 34] 0.0-1.0 sec 24.2 MBytes
                                     203 Mbits/sec
87 [ 20] 0.0- 1.0 sec 24.5 MBytes
                                     206 Mbits/sec
88 [ 37] 0.0-1.0 sec 36.9 MBytes
                                     309 Mbits/sec
```

90 [36] 0.0- 1.0 sec 31.4 MBytes 263 Mt							
91 [33]	89	[31]	0.0- 1.0 s	sec 24.0	MBytes 2	201	Mbits/sec
92 [38]	90	[36]	0.0- 1.0 s	sec 31.4	MBytes 2	263	Mbits/sec
1 39 0.0 1.0 sec 17.2 MBytes 145 MB 1 35 0.0 1.0 sec 24.4 MBytes 204 MB 1 41 0.0 1.0 sec 24.1 MBytes 262 MB 2 41 0.0 1.0 sec 24.1 MBytes 202 MB 3 42 0.0 1.0 sec 40.9 MBytes 336 MB 4 30.0 1.0 sec 40.0 MBytes 336 MB 4 4 0.0 1.0 sec 40.0 MBytes 336 MB 4 4 0.0 1.0 sec 40.0 MBytes 336 MB 4 4 0.0 1.0 sec 40.0 MBytes 336 MB 4 4 0.0 1.0 sec 40.0 MBytes 336 MB 4 6 0.0 1.0 sec 40.0 MBytes 336 MB 5 6 0.0 1.0 sec 40.0 MBytes 336 MB 6 8 0.0 1.0 sec 40.0 MBytes 336 MB 7 8 0.0 1.0 sec 40.0 MBytes 345 MB 8 1.0 1.0 sec 29.9 MBytes 262 MB 9 1 8 0.0 1.0 sec 29.9 MBytes 245 MB 108 1 1.0 2.0 sec 29.9 MBytes 232 MB 109 1 1.0 2.0 sec 29.4 MBytes 246 MB 109 1 8 0.0 2.0 sec 31.4 MBytes 245 MB 110 1 8 0.0 2.0 sec 29.4 MBytes 246 MB 111 1 8 0.0 2.0 sec 29.4 MBytes 245 MB 112 1 6 0.0 2.0 sec 29.5 MBytes 245 MB 113 1 6 0.0 2.0 sec 29.5 MBytes 246 MB 114 1 23 1.0 2.0 sec 29.5 MBytes 247 MB 115 1 25 0.0 2.0 sec 53.5 MBytes 248 MB 116 1 25 0.0 2.0 sec 53.5 MBytes 248 MB 117 1 25 0.0 2.0 sec 53.5 MBytes 248 MB 118 1 38 0.0 2.0 sec 53.5 MBytes 248 MB 129 1 1.0 2.0 sec 29.4 MBytes 246 MB 120 1 35 0.0 2.0 sec 53.5 MBytes 248 MB 121 1 35 0.0 2.0 sec 53.5 MBytes 248 MB 122 1 40 0.0 2.0 sec 53.5 MBytes 248 MB 123 1 0.0 2.0 sec 34.1 MBytes 348 MB 124 1 0.0 2.0 sec 34.1 MBytes 348 MB 125 1 0.0 2.0 sec 34.1 MBytes 348 MB 126 1 1 0.0	91	[33]	0.0- 1.0 s	sec 23.9	MBytes 2	200	Mbits/sec
94 [35] 0.0- 1.0 sec	92		0.0- 1.0 s		•	211	Mbits/sec
95	93	[39]	0.0- 1.0 s	sec 17.2	MBytes :	145	Mbits/sec
96	94	[35]	0.0- 1.0 s	sec 24.4	MBytes 2	204	Mbits/sec
97	95		0.0- 1.0 s	sec 31.2	MBytes 2	262	Mbits/sec
98 [42] 0.0- 1.0 sec 40.0 MBytes 336 MB 99 [45] 0.0- 1.0 sec 17.4 MBytes 146 MB 100 [46] 0.0- 1.0 sec 17.2 MBytes 145 MB 101 [44] 0.0- 1.0 sec 31.2 MBytes 262 MB 102 [47] 0.0- 1.0 sec 31.4 MBytes 263 MB 103 [48] 0.0- 1.0 sec 29.9 MBytes 251 MB 106 [18] 0.0- 1.0 sec 29.9 MBytes 251 MB 107 [SUM] 0.0- 1.0 sec 27.6 MBytes 232 MB 107 [SUM] 0.0- 1.0 sec 29.4 MBytes 246 MB 109 [4] 0.0- 2.0 sec 53.8 MBytes 225 MB 110 [8] 1.0- 2.0 sec 31.4 MBytes 148 MB 111 [6] 1.0- 2.0 sec 29.4 MBytes 247 MB 112 [6] 1.0- 2.0 s	96				MBytes 2	202	Mbits/sec
99	97				•	343	Mbits/sec
100	98				MBytes 3	336	Mbits/sec
101	99				•		Mbits/sec
102	100				=		Mbits/sec
103					•		Mbits/sec
104					•		Mbits/sec
105					=		Mbits/sec
106					•		Mbits/sec
107 [SUM] 0.0- 1.0 sec 1.41 GBytes 12.1 GB					•		Mbits/sec
108					•		Mbits/sec
100					•		Gbits/sec
110					J		Mbits/sec
111					•		Mbits/sec
112 [6]					•		Mbits/sec
113					•		Mbits/sec
114					-		Mbits/sec
115					=		Mbits/sec
116					•		Mbits/sec
117							
118 [38]					-		Mbits/sec
119 [38] 0.0- 2.0 sec 50.9 MBytes 213 Mt 120 [35] 1.0- 2.0 sec 29.4 MBytes 246 Mt 121 [35] 0.0- 2.0 sec 53.8 MBytes 225 Mt 122 [40] 1.0- 2.0 sec 29.4 MBytes 246 Mt 123 [40] 0.0- 2.0 sec 34.1 MBytes 224 Mt 124 [42] 1.0- 2.0 sec 34.1 MBytes 286 Mt 125 [42] 0.0- 2.0 sec 74.1 MBytes 311 Mt 126 [45] 1.0- 2.0 sec 14.0 MBytes 117 Mt 127 [45] 0.0- 2.0 sec 31.4 MBytes 128 Mt 128 [47] 1.0- 2.0 sec 34.0 MBytes 285 Mt 129 [47] 0.0- 2.0 sec 34.0 MBytes 310 Mt 120 [48] 1.0- 2.0 sec 39.1 MBytes 328 Mt 131 [48] 0.0- 2.0 sec 70.5 MBytes 296 Mt 132 [51] 1.0- 2.0 sec 70.5 MBytes 329 Mt 131 [50] 1.0- 2.0 sec 79.8 MBytes 333 Mt 134 [50] 1.0- 2.0 sec 79.8 MBytes 329 Mt 135 [50] 0.0- 2.0 sec 59.5 MBytes 249 Mt 136 [49] 1.0- 2.0 sec 34.4 MBytes 288 Mt 137 [49] 0.0- 2.0 sec 34.4 MBytes 288 Mt 137 [49] 0.0- 2.0 sec 34.4 MBytes 288 Mt 137 [49] 0.0- 2.0 sec 34.4 MBytes 288 Mt 137 [49] 0.0- 2.0 sec 34.4 MBytes 288 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 288 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 247 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 248 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 249 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 248 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 248 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 254 Mt 140 [3] 1.0- 2.0 sec 31.6 MBytes 254 Mt 141 [3] 0.0- 2.0 sec 31.6 MBytes 254 Mt 142 [7] 1.0- 2.0 sec 60.8 MBytes 254 Mt 143 [7] 0.0- 2.0 sec 60.8 MBytes 254 Mt 144 [10] 1.0- 2.0 sec 53.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes					-		·
120 [35] 1.0- 2.0 sec 29.4 MBytes 246 Mt 121 [35] 0.0- 2.0 sec 53.8 MBytes 225 Mt 122 [40] 1.0- 2.0 sec 53.5 MBytes 224 Mt 123 [40] 0.0- 2.0 sec 34.1 MBytes 224 Mt 124 [42] 1.0- 2.0 sec 34.1 MBytes 286 Mt 125 [42] 0.0- 2.0 sec 14.0 MBytes 311 Mt 126 [45] 1.0- 2.0 sec 14.0 MBytes 117 Mt 127 [45] 0.0- 2.0 sec 31.4 MBytes 132 Mt 128 [47] 1.0- 2.0 sec 34.0 MBytes 285 Mt 129 [47] 0.0- 2.0 sec 34.0 MBytes 328 Mt 130 [48] 1.0- 2.0 sec 39.1 MBytes 328 Mt 131 [48] 0.0- 2.0 sec 74.0 MBytes 328 Mt 131 [48] 0.0- 2.0 sec 70.5 MBytes 329 Mt 132 [51] 1.0- 2.0 sec 39.2 MBytes 329 Mt 132 [50] 1.0- 2.0 sec 79.8 MBytes 333 Mt 134 [50] 1.0- 2.0 sec 59.5 MBytes 247 Mt 136 [49] 1.0- 2.0 sec 34.4 MBytes 248 Mt 137 [49] 0.0- 2.0 sec 34.4 MBytes 248 Mt 137 [49] 0.0- 2.0 sec 34.4 MBytes 248 Mt 138 [5] 1.0- 2.0 sec 34.4 MBytes 249 Mt 138 [5] 1.0- 2.0 sec 34.4 MBytes 248 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 249 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 249 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 249 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 249 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 249 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 249 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 249 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 249 Mt 139 [5] 1.0- 2.0 sec 34.4 MBytes 254 Mt 140 [3] 1.0- 2.0 sec 34.6 MBytes 254 Mt 141 [3] 0.0- 2.0 sec 31.6 MBytes 254 Mt 142 [7] 1.0- 2.0 sec 31.6 MBytes 254 Mt 141 [3] 0.0- 2.0 sec 31.6 MBytes 254 Mt 142 [7] 1.0- 2.0 sec 29.8 MBytes 254 Mt 144 [10] 1.0- 2.0 sec 29.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 254 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt 145					-		Mbits/sec
121					=		Mbits/sec
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138 [5] 1.0- 2.0 sec 24.1 MBytes 202 Mt 139 [5] 0.0- 2.0 sec 61.0 MBytes 254 Mt 140 [3] 1.0- 2.0 sec 14.4 MBytes 121 Mt 141 [3] 0.0- 2.0 sec 31.6 MBytes 132 Mt 142 [7] 1.0- 2.0 sec 24.0 MBytes 201 Mt 143 [7] 0.0- 2.0 sec 60.8 MBytes 254 Mt 144 [10] 1.0- 2.0 sec 29.8 MBytes 250 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt	136	[49]	1.0- 2.0 s	sec 34.4	MBytes 2	288	Mbits/sec
139 [5] 0.0- 2.0 sec 61.0 MBytes 254 Mt 140 [3] 1.0- 2.0 sec 14.4 MBytes 121 Mt 141 [3] 0.0- 2.0 sec 31.6 MBytes 132 Mt 142 [7] 1.0- 2.0 sec 24.0 MBytes 201 Mt 143 [7] 0.0- 2.0 sec 60.8 MBytes 254 Mt 144 [10] 1.0- 2.0 sec 29.8 MBytes 250 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt	137	[49]	0.0- 2.0 s	sec 82.5	MBytes 3	342	Mbits/sec
140 [3] 1.0- 2.0 sec 14.4 MBytes 121 Mt 141 [3] 0.0- 2.0 sec 31.6 MBytes 132 Mt 142 [7] 1.0- 2.0 sec 24.0 MBytes 201 Mt 143 [7] 0.0- 2.0 sec 60.8 MBytes 254 Mt 144 [10] 1.0- 2.0 sec 29.8 MBytes 250 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt	138	[5]	1.0- 2.0 9	sec 24.1	MBytes 2	202	Mbits/sec
141 [3] 0.0- 2.0 sec 31.6 MBytes 132 Mt 142 [7] 1.0- 2.0 sec 24.0 MBytes 201 Mt 143 [7] 0.0- 2.0 sec 60.8 MBytes 254 Mt 144 [10] 1.0- 2.0 sec 29.8 MBytes 250 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt	139	[5]	0.0- 2.0 s	sec 61.0	MBytes 2	254	Mbits/sec
142 [7] 1.0- 2.0 sec 24.0 MBytes 201 Mt 143 [7] 0.0- 2.0 sec 60.8 MBytes 254 Mt 144 [10] 1.0- 2.0 sec 29.8 MBytes 250 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt	140	[3]	1.0- 2.0 9	sec 14.4	MBytes 2	121	Mbits/sec
143 [7] 0.0- 2.0 sec 60.8 MBytes 254 Mt 144 [10] 1.0- 2.0 sec 29.8 MBytes 250 Mt 145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt	141	[3]	0.0- 2.0 s	sec 31.6	MBytes :	132	Mbits/sec
144 [10] 1.0-2.0 sec 29.8 MBytes 250 Mt 145 [10] 0.0-2.0 sec 53.8 MBytes 224 Mt	142	[7]	1.0- 2.0 \$	sec 24.0	MBytes 2	201	Mbits/sec
145 [10] 0.0- 2.0 sec 53.8 MBytes 224 Mt	143	[7]	0.0- 2.0 s	sec 60.8	MBytes 2	254	Mbits/sec
	144	[10]	1.0- 2.0 \$	sec 29.8	MBytes 2	250	Mbits/sec
146 [11] 1.0- 2.0 sec 39.6 MBytes 332 Mb	145	[10]			MBytes 2	224	Mbits/sec
l e e e e e e e e e e e e e e e e e e e	146	[11]	1.0- 2.0 5	sec 39.6	MBytes 3	332	Mbits/sec

147	[11]	0.0- 2.0 9	sec 71.0	MBytes 2	297	Mbits/sec
148	[13]	1.0- 2.0 9	sec 45.4	MBytes 3	381	Mbits/sec
149	[13]	0.0- 2.0 9	sec 86.5	MBytes 3	362	Mbits/sec
150	[9]	1.0- 2.0	sec 14.2	MBytes 1	120	Mbits/sec
151	[9]	0.0- 2.0 9	sec 31.6	MBytes 1	132	Mbits/sec
152	[14]	1.0- 2.0 9	sec 45.6	MBytes 3	383	Mbits/sec
153	[14]	0.0- 2.0 9	sec 86.5	MBytes 3	362	Mbits/sec
154	[18]	1.0- 2.0 9	sec 25.8	MBytes 2	216	Mbits/sec
155	[18]	0.0- 2.0 9	sec 53.4	MBytes 2	221	Mbits/sec
156	[21]	1.0- 2.0 9	sec 14.2	MBytes 1	120	Mbits/sec
157	[21]	0.0- 2.0 9	sec 31.8	MBytes 1	132	Mbits/sec
158	[16]	1.0- 2.0 9	sec 24.0	MBytes 2	201	Mbits/sec
159	[16]		sec 61.0	-		Mbits/sec
160	[15]		sec 45.4	•	381	Mbits/sec
161	[15]			-		Mbits/sec
162	[17]			-		Mbits/sec
163	[17]			•	311	Mbits/sec
164	[19]			,		Mbits/sec
165	[19]		sec 53.8	,		Mbits/sec
166	[24]		sec 25.8	-		Mbits/sec
167	[24]		sec 51.0	•		Mbits/sec
168	[22]		sec 25.8	J		Mbits/sec
169	[22]		sec 51.1			Mbits/sec
170	[12]		sec 34.0	-		Mbits/sec
171	[12]		sec 74.2	-		Mbits/sec
172	[26] [26]		sec 14.4 sec 31.9		121	Mbits/sec Mbits/sec
173 174	[26] [27]		sec 31.9 sec 34.0			Mbits/sec
175	[27]		sec 34.0	-		Mbits/sec
176	[29]		sec 24.1			Mbits/sec
177	[29]		sec 61.0	-		Mbits/sec
178	[30]		sec 34.4			Mbits/sec
179	[30]		sec 74.4	-		Mbits/sec
180	[34]		sec 29.8			Mbits/sec
181	[34]	0.0- 2.0 9	sec 54.0	MBytes 2	225	Mbits/sec
182	[20]	1.0- 2.0 9	sec 29.6	MBytes 2	249	Mbits/sec
183	[20]	0.0- 2.0 9	sec 54.1	MBytes 2	226	Mbits/sec
184	[37]	1.0- 2.0 9	sec 24.1	MBytes 2	202	Mbits/sec
185	[37]	0.0- 2.0 9	sec 61.0	MBytes 2	254	Mbits/sec
186	[31]	1.0- 2.0	sec 29.9	MBytes 2	251	Mbits/sec
187	[31]	0.0- 2.0 9	sec 53.9	MBytes 2	225	Mbits/sec
188	[36]	1.0- 2.0	sec 39.2	MBytes 3	329	Mbits/sec
189	[36]	0.0- 2.0 9	sec 70.6	MBytes 2	296	Mbits/sec
190	[33]	1.0- 2.0 9	sec 29.8	MBytes 2	250	Mbits/sec
191	[33]	0.0- 2.0 9		MBytes 2	224	Mbits/sec
192	[39]	1.0- 2.0 9		,	121	Mbits/sec
193	[39]	0.0- 2.0 9		,	132	Mbits/sec
194	[43]	1.0- 2.0 9		-		Mbits/sec
195	[43]	0.0- 2.0 s		-		Mbits/sec
196	[41]	1.0- 2.0 9		-		Mbits/sec
197	[41]	0.0- 2.0 9		•	361	Mbits/sec
198	[46]	1.0- 2.0 9		•	121	Mbits/sec
199	[46]	0.0- 2.0 9		-		Mbits/sec
200	[44]	1.0- 2.0 9		-		Mbits/sec
201	[44]	0.0- 2.0 9		-		Mbits/sec
202	[28] [SUM]	1.0- 2.0 9		-		Mbits/sec
203	1 1			-		Gbits/sec
204	[28]	0.0- 2.0 s	sec 86.8	MBytes 3	∠∪ر	Mbits/sec

```
205 [SUM] 0.0-2.0 sec 2.79 GBytes 11.9 Gbits/sec
   [ 3] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45152
207 [ 6] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45168
208 | 4 | local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45164
209 [ 7] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45176
210 [ 10] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45200
   [ 9] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45188
   [ 5] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45212
213 [ 8] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45216
214 [ 11] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45228
215 [ 12] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45222
216 [ 13] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45266
217 [ 16] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45236
218 [ 15] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45274
   [ 14] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45252
   [ 19] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45304
221 [ 17] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45290
222 [ 18] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45298
223 [ 21] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45308
224 [ 20] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45318
225 [ 22] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45328
226 [ 23] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45366
   [ 24] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45330
228 [ 27] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45360
229 [ 28] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45344
230 [ 25] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45338
231 [ 31] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45376
232 [ 26] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45374
233 [ 29] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45384
   [ 30] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45396
   [ 33] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45444
236 [ 34] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45428
237 [ 35] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45474
238 [ 37] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45468
239 [ 36] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45562
240 [ 38] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45478
241 [ 40] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45504
242 [ 39] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45558
   [ 41] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45490
244 [ 43] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45416
245 [ 42] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45540
246 [ 46] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45528
247 [ 44] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45402
248 [ 48] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45590
249 [ 45] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45512
   [ 47] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45578
   [ 50] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45552
251
   [ 51] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45456
253 [ 49] local 172.31.10.47 port 10000 connected with 172.31.11.250 port 45452
         0.0- 1.0 sec 37.0 MBytes
                                      310 Mbits/sec
      6] 0.0-1.0 sec 30.6 MBytes
                                      257 Mbits/sec
255
      4] 0.0-1.0 sec 54.5 MBytes
                                      457 Mbits/sec
256
      7] 0.0-1.0 sec 44.1 MBytes
257
                                      370 Mbits/sec
   [ 10]
          0.0- 1.0 sec 19.3 MBytes
                                      162 Mbits/sec
259
   [ 9]
          0.0- 1.0 sec 19.7 MBytes
                                      165 Mbits/sec
260 [ 5] 0.0-1.0 sec 36.9 MBytes
                                      310 Mbits/sec
261 [ 8] 0.0-1.0 sec 36.8 MBytes
                                      309 Mbits/sec
262 [ 11] 0.0- 1.0 sec 54.3 MBytes
                                      456 Mbits/sec
```

263] [12]	0.0-	- 1.0	sec	18.7	MBytes	157	Mbits/sec
264	[13]	0.0	- 1.0	sec	36.8	MBytes	309	Mbits/sec
265	[16]	0.0	- 1.0	sec	18.6	MBytes	156	Mbits/sec
266	[15]	0.0	- 1.0	sec	42.2	MBytes	354	Mbits/sec
267	[14]	0.0	- 1.0	sec	19.2	MBytes	161	Mbits/sec
268	[19]	0.0	- 1.0	sec	11.8	MBytes	99.3	Mbits/sec
269	[17]	0.0	- 1.0	sec	14.7	MBytes	124	Mbits/sec
270	[18]	0.0	- 1.0	sec	11.8	MBytes	98.9	Mbits/sec
271	[21]	0.0	- 1.0	sec	19.2	MBytes	161	Mbits/sec
272	[20]	0.0	- 1.0	sec	11.8	MBytes	99.0	Mbits/sec
273	[22]	0.0	- 1.0	sec	44.1	MBytes	370	Mbits/sec
274	[23]	0.0	- 1.0	sec	19.1	MBytes	160	Mbits/sec
275	[24]	0.0	- 1.0	sec	11.8	MBytes	99.0	Mbits/sec
276	[27]	0.0	- 1.0	sec	44.1	MBytes	370	Mbits/sec
277	[28]	0.0	- 1.0	sec	44.1	MBytes	370	Mbits/sec
278	[25]	0.0	- 1.0	sec	54.2	MBytes	454	Mbits/sec
279	[31]	0.0	- 1.0	sec	19.2	MBytes	161	Mbits/sec
280	[26]	0.0	- 1.0	sec	12.8	MBytes	108	Mbits/sec
281	[29]	0.0	- 1.0	sec	36.7	MBytes	308	Mbits/sec
282	[30]	0.0	- 1.0	sec	42.2	MBytes	354	Mbits/sec
283	[33]	0.0	- 1.0	sec	42.2	MBytes	354	Mbits/sec
284	[34]	0.0	- 1.0	sec	18.5	MBytes	156	Mbits/sec
285	[35]	0.0	- 1.0	sec	30.1	MBytes	252	Mbits/sec
286	[37]	0.0	- 1.0	sec	44.1	MBytes	370	Mbits/sec
287	[36]	0.0	- 1.0	sec	44.0	MBytes	369	Mbits/sec
288	[38]	0.0	- 1.0	sec	42.1	MBytes	353	Mbits/sec
289	[40]	0.0	- 1.0	sec	42.1	MBytes	353	Mbits/sec
290	[39]	0.0	- 1.0	sec	36.6	MBytes	307	Mbits/sec
291	[41]	0.0	- 1.0	sec	44.0	MBytes	369	Mbits/sec
292	[43]	0.0	- 1.0	sec	18.5	MBytes	156	Mbits/sec
293	[42]	0.0	- 1.0	sec	19.1	MBytes	160	Mbits/sec
294	[46]	0.0	- 1.0	sec	17.3	MBytes	145	Mbits/sec
295	[44]	0.0	- 1.0	sec	42.1	MBytes	353	Mbits/sec
296	[48]	0.0	- 1.0	sec	30.0	MBytes	252	Mbits/sec
297	[45]	0.0	- 1.0	sec	18.5	MBytes	156	Mbits/sec
298	[47]	0.0	- 1.0	sec	30.1	MBytes	252	Mbits/sec
299	[50]	0.0	- 1.0	sec	11.8	MBytes	98.6	Mbits/sec
300] [51]		- 1.0		11.8	MBytes	98.6	Mbits/sec
301] [49]	0.0	- 1.0	sec	11.8	MBytes	98.6	Mbits/sec
302] [3]	1.0-	- 2.0	sec	26.8	MBytes	225	Mbits/sec
303] [6]		- 2.0			MBytes		Mbits/sec
304	[4]		- 2.0		54.1	MBytes		Mbits/sec
305] [7]		- 2.0			MBytes		Mbits/sec
306] [10]		- 2.0			MBytes		Mbits/sec
307] [9]		- 2.0			MBytes		Mbits/sec
308	[5]		- 2.0			MBytes		Mbits/sec
309	[8]		- 2.0			MBytes		Mbits/sec
310] [11]		- 2.0		54.1	•		Mbits/sec
311] [12]		- 2.0			MBytes		Mbits/sec
312] [13]		- 2.0			MBytes		Mbits/sec
313] [16]		- 2.0			MBytes		Mbits/sec
314] [15]		- 2.0			MBytes		Mbits/sec
315] [14]		- 2.0			MBytes		Mbits/sec
316] [19]		- 2.0			MBytes		Mbits/sec
317] [17]		- 2.0			MBytes		Mbits/sec
318] [18]		- 2.0			MBytes		Mbits/sec
319] [21]		- 2.0			MBytes		Mbits/sec
320	[20]	1.0-	- 2.0	sec	16.7	MBytes	140	Mbits/sec

321	[22]	-	1.0-	2.0	sec	44.3	MBytes	371	Mbits/sec
322	[23]		1.0-	2.0	sec	23.7	MBytes	199	Mbits/sec
323	[24]		1.0-	2.0	sec	16.7	MBytes	140	Mbits/sec
324	[27]		1.0-	2.0	sec	44.3	MBytes	371	Mbits/sec
325	[28]	1	1.0-	2.0	sec	44.3	MBytes	371	Mbits/sec
326	[25]		1.0-	2.0	sec	54.1	MBytes	454	Mbits/sec
327	[31]	-	1.0-	2.0	sec	23.7	MBytes	199	Mbits/sec
328	[26]		1.0-	2.0	sec	13.0	MBytes	109	Mbits/sec
329	[29]	-	1.0-	2.0	sec	26.7	MBytes	224	Mbits/sec
330	[30]	-	1.0-	2.0	sec	33.8	MBytes	283	Mbits/sec
331	[33]	-	1.0-	2.0	sec	33.8	MBytes	284	Mbits/sec
332	[34]	-	1.0-	2.0	sec	23.5	MBytes	197	Mbits/sec
333	[35]	1	1.0-	2.0	sec	37.7	MBytes	316	Mbits/sec
334	[37]	1	1.0-	2.0	sec	44.3	MBytes	371	Mbits/sec
335	[36]		1.0-	2.0	sec	44.3	${\tt MBytes}$	371	Mbits/sec
336	[38]		1.0-	2.0	sec	33.8	${\tt MBytes}$	284	Mbits/sec
337	[40]		1.0-	2.0	sec	33.8	${\tt MBytes}$	284	Mbits/sec
338	[39]		1.0-	2.0	sec	26.8	${\tt MBytes}$	225	Mbits/sec
339	[41]		1.0-	2.0	sec	44.3	${\tt MBytes}$	371	Mbits/sec
340	[43]		1.0-	2.0	sec	23.5	${\tt MBytes}$	197	Mbits/sec
341	[42]	1	1.0-	2.0	sec	23.7	MBytes	199	Mbits/sec
342	[46]		1.0-	2.0	sec	24.7	${\tt MBytes}$	207	Mbits/sec
343	[44]	1	1.0-	2.0	sec	33.8	MBytes	283	Mbits/sec
344	[48]		1.0-	2.0	sec	37.7	MBytes	316	Mbits/sec
345	[45]		1.0-	2.0	sec	23.5	MBytes	197	Mbits/sec
346	[47]	1	1.0-	2.0	sec	37.7	MBytes	316	Mbits/sec
347	[50]	1	1.0-	2.0	sec	16.7	MBytes	140	Mbits/sec
348	[51]	1	1.0-	2.0	sec	16.7	MBytes	140	Mbits/sec
349	[49]	-	1.0-	2.0	sec	16.7	MBytes	140	Mbits/sec
350	[3]	(0.0-	2.0	sec	64.5	MBytes	267	Mbits/sec
351	[6]	(0.0-	2.0	sec	60.8	MBytes	252	Mbits/sec
352	[4]		0.0-			110	MBytes	456	Mbits/sec
353	[7]		0.0-				MBytes		Mbits/sec
354	[10]		0.0-				MBytes	182	
355	[9]		0.0-				MBytes		Mbits/sec
356	[5]		0.0-				MBytes	268	
357	[8]		0.0-				MBytes		Mbits/sec
358	ĺ	11]		0.0-				MBytes		Mbits/sec
359	[12]		0.0-				MBytes		Mbits/sec
360	[13]		0.0-				MBytes	266	·
361	[16]		0.0-				MBytes	178	
362	[15]		0.0-				MBytes	318	
363	[14]		0.0-				MBytes	181	Mbits/sec
364	[19]		0.0-				MBytes	121	Mbits/sec
365	[18]		0.0-				MBytes	121	Mbits/sec
366	[21]		0.0- 0.0-				MBytes	181	Mbits/sec
367]	20]						MBytes MBytes	121	Mbits/sec
368]	22]		0.0- 0.0-				MBytes	371	Mbits/sec Mbits/sec
369	-	23]						•	180	
370]	24]		0.0- 0.0-				MBytes MBytes	121 371	Mbits/sec Mbits/sec
371	_ [27]		0.0- 0.0-				MBytes	371	Mbits/sec
372 373	ſ	28] 25]		0.0-				MBytes	455	
374	ſ	31]		0.0-				MBytes	181	Mbits/sec
375	1	26]		0.0-				MBytes	109	
376	ſ	29]		0.0-				MBytes	267	
377	ſ	30]		0.0-				MBytes	318	
378]	33]		0.0-				MBytes		Mbits/sec
010	L	50]	,		2.0	500	0	. 15 y 0C3	010	.151 03/360

A.4. Network performance

Appendix

379	[34]	0.0- 2.0 sec	43.0 MBytes	178 Mbits/sec
380	[35]	0.0- 2.0 sec	68.9 MBytes	285 Mbits/sec
381	[37]	0.0- 2.0 sec	89.4 MBytes	371 Mbits/sec
382	[36]	0.0- 2.0 sec	89.2 MBytes	370 Mbits/sec
383	[40]	0.0- 2.0 sec	76.8 MBytes	318 Mbits/sec
384	[39]	0.0- 2.0 sec	64.1 MBytes	265 Mbits/sec
385	[41]	0.0- 2.0 sec	89.2 MBytes	370 Mbits/sec
386	[43]	0.0- 2.0 sec	42.8 MBytes	177 Mbits/sec
387	[42]	0.0- 2.0 sec	43.8 MBytes	181 Mbits/sec
388	[44]	0.0- 2.0 sec	76.9 MBytes	318 Mbits/sec
389	[48]	0.0- 2.0 sec	68.8 MBytes	285 Mbits/sec
390	[45]	0.0- 2.0 sec	42.5 MBytes	177 Mbits/sec
391	[47]	0.0- 2.0 sec	68.9 MBytes	285 Mbits/sec
392	[50]	0.0- 2.0 sec	29.2 MBytes	121 Mbits/sec
393	[51]	0.0- 2.0 sec	29.2 MBytes	121 Mbits/sec
394	[49]	0.0- 2.0 sec	29.2 MBytes	121 Mbits/sec
395	[17]	0.0- 2.0 sec	30.2 MBytes	124 Mbits/sec
396	[38]	0.0- 2.1 sec	77.0 MBytes	313 Mbits/sec
397	[46]	0.0- 2.1 sec	43.1 MBytes	175 Mbits/sec
398	[SUM]	0.0- 2.1 sec	4.21 GBytes	17.5 Gbits/sec

A.5. IO performance Appendix

A.5 IO performance

Listing A.5: Output of the fio command

```
1 | $ fio --rw=write --ioengine=sync --fdatasync=1 --direct=1 --directory=io-test-data --size=2g --bs=4k --name=
  iotest: (g=0): rw=write, bs=(R) 4096B-4096B, (W) 4096B-4096B, (T) 4096B-4096B, ioengine=sync, iodepth=1
3 fio-3.16
4 Starting 1 process
5 iotest: Laying out IO file (1 file / 2048MiB)
6 Jobs: 1 (f=1): [W(1)][100.0%][w=70.5MiB/s][w=18.1k IOPS][eta 00m:00s]
  iotest: (groupid=0, jobs=1): err= 0: pid=371625: Thu Jun 15 16:05:45 2023
    write: IOPS=18.1k, BW=70.5MiB/s (73.9MB/s)(2048MiB/29043msec); 0 zone resets
9
      clat (usec): min=21, max=614, avg=23.74, stdev= 2.60
       lat (usec): min=21, max=614, avg=23.81, stdev= 2.62
10
11
      clat percentiles (nsec):
12
       | 1.00th=[22144], 5.00th=[22400], 10.00th=[22400], 20.00th=[22656],
       30.00th=[22912], 40.00th=[23168], 50.00th=[23168], 60.00th=[23424],
13
       | 70.00th=[23680], 80.00th=[23936], 90.00th=[24448], 95.00th=[25728],
14
15
       99.00th=[35584], 99.50th=[39168], 99.90th=[46336], 99.95th=[50944],
16
       99.99th=[69120]
     bw ( KiB/s): min=67784, max=72968, per=99.99%, avg=72201.86, stdev=688.73, samples=58
17
                 : min=16946, max=18242, avg=18050.45, stdev=172.17, samples=58
18
19
    lat (usec) : 50=99.95%, 100=0.05%, 250=0.01%, 750=0.01%
20
    fsync/fdatasync/sync_file_range:
      sync (usec): min=27, max=3659, avg=30.78, stdev=12.40
21
22
       sync percentiles (nsec):
23
       | 1.00th=[28544], 5.00th=[28800], 10.00th=[29056], 20.00th=[29312],
       | 30.00th=[29568], 40.00th=[29568], 50.00th=[29824], 60.00th=[30336],
24
       | 70.00th=[30592], 80.00th=[30848], 90.00th=[31616], 95.00th=[35584],
25
26
       99.00th=[47872], 99.50th=[51456], 99.90th=[61184], 99.95th=[67072],
27
       | 99.99th=[90624]
                 : usr=4.24%, sys=21.50%, ctx=1572866, majf=0, minf=13
28
    cpu
                 : 1=200.0%, 2=0.0%, 4=0.0%, 8=0.0%, 16=0.0%, 32=0.0%, >=64=0.0%
    IO depths
29
                 : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
30
31
       \texttt{complete} \quad : \; 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
32
       latency : target=0, window=0, percentile=100.00%, depth=1
33
34
35 Run status group 0 (all jobs):
    WRITE: bw=70.5MiB/s (73.9MB/s), 70.5MiB/s-70.5MiB/s (73.9MB/s-73.9MB/s), io=2048MiB (2147MB), run=29043-29043
36
       msec
37
38 Disk stats (read/write):
    nvme2n1: ios=0/1047263, merge=0/4, ticks=0/19506, in_queue=19506, util=99.74%
```

A.6 Datagen configuration

Listing A.6: Contents of params-sf30.ini used for scale factor 30

```
ldbc.snb.datagen.generator.scaleFactor:snb.interactive.30
ldbc.snb.datagen.serializer.numUpdatePartitions:32

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.7: Contents of params-sf100.ini used for scale factor 100

```
ldbc.snb.datagen.generator.scaleFactor:snb.interactive.100
ldbc.snb.datagen.serializer.numUpdatePartitions:32

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.8: Contents of params-sf300.ini used for scale factor 300

A.7 Import configuration

Listing A.9: Content of import.conf describing the data schema

```
graph:
     graph_store: mutable_csr
3
     vertex:
       - label_name: PLACE
         properties:
           - name: _ID
             type: int64
8
           - name: name
9
             type: String
10
           - name: url
             type: String
11
12
           - name: type
             type: String
13
         max_vertex_num: 1460
14
```

```
- label_name: PERSON
15
16
         properties:
           - name: _ID
17
             type: int64
18
           - name: firstName
19
             type: String
20
21
           - name: lastName
22
             type: String
23
           - name: gender
             type: String
24
25
           - name: birthday
             type: Date
26
27
           - name: creationDate
             type: Date
28
29
           - name: locationIP
             type: String
30
           - name: browserUsed
31
32
             type: String
33
           - name: language
             type: String
34
           - name: email
35
             type: String
36
37
         max_vertex_num: 1254000
38
       - label_name: COMMENT
         properties:
39
           - name: _ID
40
41
             type: int64
42
           - name: creationDate
43
             type: Date
44
           - name: locationIP
45
             type: String
46
           - name: browserUsed
47
             type: String
48
           - name: content
49
             type: String
           - name: length
50
             type: int32
51
52
         max_vertex_num: 762949871
53
       - label_name: POST
54
         properties:
           - name: _ID
55
56
             type: int64
57
           - name: imageFile
             type: String
58
           - name: creationDate
59
60
             type: Date
           - name: locationIP
61
             type: String
62
63
           - name: browserUsed
             type: String
64
           - name: language
65
             type: String
66
           - name: content
67
68
             type: String
           - name: length
69
             type: int32
70
         max_vertex_num: 187893047
71
       - label_name: FORUM
```

```
73
          properties:
            - name: _ID
74
              type: int64
75
76
            - name: title
77
              type: String
            - name: creationDate
78
79
              type: Date
80
          max_vertex_num: 12549398
        - label_name: ORGANISATION
81
          properties:
82
83
            - name: _ID
              type: int64
84
            - name: type
85
              type: String
86
87
            - name: name
              type: String
88
            - name: url
89
90
              type: String
91
          max_vertex_num: 7955
        - label_name: TAGCLASS
92
          properties:
93
            - name: _ID
94
95
              type: int64
96
            - name: name
              type: String
97
98
            - name: url
99
              type: String
100
          max_vertex_num: 71
        - label_name: TAG
101
102
          properties:
            - name: _ID
103
              type: int64
104
105
            - name: name
106
              type: String
107
            - name: url
              type: String
108
          max_vertex_num: 16080
109
110
      edge:
111
        - src_label_name: COMMENT
          dst_label_name: PERSON
112
          \verb|edge_label_name: HASCREATOR|\\
113
          properties:
            - name: _SRC
115
              type: int64
116
            - name: _DST
117
118
              type: int64
119
          outgoing_edge_strategy: Single
        - src_label_name: POST
120
121
          dst_label_name: PERSON
122
          edge_label_name: HASCREATOR
          properties:
123
            - name: _SRC
124
              type: int64
125
126
            - name: _DST
              type: int64
127
          outgoing_edge_strategy: Single
128
        - src_label_name: POST
129
          dst_label_name: TAG
130
```

```
edge_label_name: HASTAG
131
132
          properties:
            - name: _SRC
133
              type: int64
134
135
            - name: _DST
              type: int64
136
137
        - src_label_name: COMMENT
138
          dst_label_name: COMMENT
          edge_label_name: REPLYOF
139
          properties:
140
141
            - name: _SRC
              type: int64
142
            - name: _DST
143
              type: int64
144
145
          outgoing_edge_strategy: Single
        - src_label_name: COMMENT
146
          dst_label_name: POST
147
          edge_label_name: REPLYOF
148
149
          properties:
            - name: _SRC
150
              type: int64
151
            - name: _DST
152
153
              type: int64
154
          outgoing_edge_strategy: Single
        - src_label_name: FORUM
155
          dst_label_name: POST
156
157
          edge_label_name: CONTAINEROF
158
          properties:
            - name: _SRC
159
160
              type: int64
            - name: _DST
161
              type: int64
162
163
          outgoing_edge_strategy: None
164
          incoming_edge_strategy: Single
165
        - src_label_name: FORUM
          dst_label_name: PERSON
166
          edge_label_name: HASMEMBER
167
168
          properties:
169
            - name: _SRC
170
              type: int64
            - name: _DST
171
172
              type: int64
            - name: joinDate
173
              type: Date
174
175
          outgoing_edge_strategy: None
176
        - src_label_name: FORUM
177
          dst_label_name: PERSON
          edge_label_name: HASMODERATOR
178
179
          properties:
            - name: _SRC
180
              type: int64
181
            - name: _DST
182
              type: int64
183
          outgoing_edge_strategy: Single
          incoming_edge_strategy: None
185
        - src_label_name: PERSON
186
187
          dst_label_name: TAG
          edge_label_name: HASINTEREST
188
```

```
189
          properties:
            - name: _SRC
190
191
               type: int64
192
             - name: _DST
193
               type: int64
          {\tt incoming\_edge\_strategy} \colon \: {\tt None}
194
195
        - src_label_name: COMMENT
196
          dst_label_name: PLACE
          edge_label_name: ISLOCATEDIN
197
          properties:
198
199
            - name: _SRC
               type: int64
200
            - name: _DST
201
               type: int64
202
203
          \verb"outgoing_edge_strategy: None"
        - src_label_name: PERSON
204
          dst_label_name: PLACE
205
          edge_label_name: ISLOCATEDIN
206
207
          properties:
            - name: _SRC
208
              type: int64
209
            - name: _DST
210
               type: int64
212
          outgoing_edge_strategy: Single
        - src_label_name: POST
213
          dst_label_name: PLACE
214
215
          edge_label_name: ISLOCATEDIN
216
          properties:
            - name: _SRC
217
218
               type: int64
             - name: _DST
219
              type: int64
220
221
          \verb"outgoing_edge_strategy: None"
222
        - src_label_name: ORGANISATION
223
          dst_label_name: PLACE
          edge_label_name: ISLOCATEDIN
224
          properties:
225
226
            - name: _SRC
227
               type: int64
228
            - name: _DST
               type: int64
229
230
          outgoing_edge_strategy: Single
        - src_label_name: PERSON
231
          dst_label_name: PERSON
232
          edge_label_name: KNOWS
233
234
          properties:
235
            - name: _SRC
              type: int64
236
237
            - name: _DST
238
               type: int64
            - name: creationDate
239
               type: Date
240
        - src_label_name: PERSON
241
242
          dst_label_name: COMMENT
          edge_label_name: LIKES
243
          properties:
244
245
            - name: _SRC
               type: int64
246
```

```
- name: _DST
247
              type: int64
248
249
            - name: creationDate
250
              type: Date
251
          outgoing_edge_strategy: None
        - src_label_name: PERSON
252
253
          dst_label_name: POST
254
          edge_label_name: LIKES
          properties:
255
            - name: _SRC
256
257
              type: int64
            - name: _DST
258
              type: int64
259
260
            - name: creationDate
261
              type: Date
          outgoing_edge_strategy: None
262
        - src_label_name: PERSON
263
264
          dst_label_name: ORGANISATION
265
          edge_label_name: WORKAT
          properties:
266
            - name: _SRC
267
              type: int64
268
269
            - name: _DST
270
              type: int64
            - name: workFrom
271
              type: int32
272
273
        - src_label_name: PLACE
274
          dst_label_name: PLACE
          edge_label_name: ISPARTOF
275
276
          properties:
            - name: _SRC
277
              type: int64
278
279
            - name: _DST
280
              type: int64
281
          outgoing_edge_strategy: Single
        - src_label_name: TAG
282
          dst_label_name: TAGCLASS
283
284
          edge_label_name: HASTYPE
285
          properties:
            - name: _SRC
286
              type: int64
287
288
            - name: _DST
              type: int64
289
290
          outgoing_edge_strategy: Single
        - src_label_name: TAGCLASS
291
292
          dst_label_name: TAGCLASS
          edge_label_name: ISSUBCLASSOF
293
          properties:
294
295
            - name: _SRC
              type: int64
296
            - name: _DST
297
              type: int64
298
299
          outgoing_edge_strategy: Single
300
        - src_label_name: PERSON
          dst_label_name: ORGANISATION
301
          edge_label_name: STUDYAT
302
          properties:
303
            - name: _SRC
304
```

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```
305
              type: int64
306
            - name: _DST
307
              type: int64
              name: studyFrom
308
              type: int32
309
310
          incoming_edge_strategy: None
311
312
    stored_procedures:
     - /disk2/ldbc_snb_audit/stored_procedures/libic1.so
313
     - /disk2/ldbc_snb_audit/stored_procedures/libic2.so
314
     - /disk2/ldbc_snb_audit/stored_procedures/libic3.so
315
316
     - /disk2/ldbc_snb_audit/stored_procedures/libic4.so
     - /disk2/ldbc_snb_audit/stored_procedures/libic5.so
317
     - /disk2/ldbc\_snb\_audit/stored\_procedures/libic6.so
318
319
      - /disk2/ldbc_snb_audit/stored_procedures/libic7.so
     - /disk2/ldbc_snb_audit/stored_procedures/libic8.so
320
     - /disk2/ldbc_snb_audit/stored_procedures/libic9.so
321
322
     - /disk2/ldbc\_snb\_audit/stored\_procedures/libic10.so
323
     - /disk2/ldbc_snb_audit/stored_procedures/libic11.so
324
     - /disk2/ldbc_snb_audit/stored_procedures/libic12.so
     - /disk2/ldbc_snb_audit/stored_procedures/libic13.so
325
326
      - /disk2/ldbc_snb_audit/stored_procedures/libic14.so
327
      - /disk2/ldbc_snb_audit/stored_procedures/libis1.so
328
      - /disk2/ldbc_snb_audit/stored_procedures/libis2.so
     - /disk2/ldbc_snb_audit/stored_procedures/libis3.so
329
330
     - /disk2/ldbc_snb_audit/stored_procedures/libis4.so
     - /disk2/ldbc_snb_audit/stored_procedures/libis5.so
331
     - /disk2/ldbc_snb_audit/stored_procedures/libis6.so
332
     - /disk2/ldbc\_snb\_audit/stored\_procedures/libis7.so
333
334
      - /disk2/ldbc_snb_audit/stored_procedures/libins1.so
335
     - /disk2/ldbc_snb_audit/stored_procedures/libins2.so
336
     - /disk2/ldbc_snb_audit/stored_procedures/libins3.so
337
     - /disk2/ldbc_snb_audit/stored_procedures/libins4.so
338
     - /disk2/ldbc_snb_audit/stored_procedures/libins5.so
     - /disk2/ldbc_snb_audit/stored_procedures/libins6.so
339
     - /disk2/ldbc_snb_audit/stored_procedures/libins7.so
340
     - /disk2/ldbc_snb_audit/stored_procedures/libins8.so
341
```

A.8 Benchmark configuration

Listing A.10: Contents of benchmark_sf30_32p.properties used for scale factor 30

```
url=http://172.31.11.250:10000
        printQueryNames=false
        printQueryStrings=false
        printQueryResults=false
        status=1
  8
        thread_count=48
        name=LDBC-SNB
        mode=execute_benchmark
10
11
       results_log=true
12
       status=1
        time_unit=MICROSECONDS
14 time_compression_ratio=0.00112
       peer_identifiers=
        workload_statistics=false
         spinner_wait_duration=1
        help=false
18
        ignore_scheduled_start_times=false
19
20
        workload = org.ldbcouncil.snb.driver.workloads.interactive.LdbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.in
        \verb|db=| org.ldb| coucil.snb.impls.workloads.graphscope.interactive.GraphScopeInteractiveDb| organization and the control of t
22
23
24
        ldbc.snb.interactive.updates_dir=/disk1/sf30_32p/social_network/
25
        ldbc.snb.interactive.parameters_dir=/disk1/sf30_32p/substitution_parameters/
26
27
        {\tt ldbc.snb.interactive.short\_read\_dissipation=0.2}
        # Supported scale factors are 0.1, 0.3, 1, 3, 10, 30, 100, 300, 1000
29
        ldbc.snb.interactive.scale_factor=30
30
31
        operation_count=245000000
32
         warmup=58000000
33
        ldbc.snb.interactive.LdbcQuery1_enable=true
34
35 | ldbc.snb.interactive.LdbcQuery2_enable=true
36 | ldbc.snb.interactive.LdbcQuery3_enable=true
37 | ldbc.snb.interactive.LdbcQuery4_enable=true
38 | ldbc.snb.interactive.LdbcQuery5_enable=true
39
        ldbc.snb.interactive.LdbcQuery6_enable=true
        ldbc.snb.interactive.LdbcQuery7_enable=true
        ldbc.snb.interactive.LdbcQuery8_enable=true
41
42 | ldbc.snb.interactive.LdbcQuery9_enable=true
43 | ldbc.snb.interactive.LdbcQuery10_enable=true
44 | ldbc.snb.interactive.LdbcQuery11_enable=true
45 | ldbc.snb.interactive.LdbcQuery12_enable=true
46 | ldbc.snb.interactive.LdbcQuery13_enable=true
47
        ldbc.snb.interactive.LdbcQuery14_enable=true
48
49 | ldbc.snb.interactive.LdbcShortQuery1PersonProfile_enable=true
50 | ldbc.snb.interactive.LdbcShortQuery2PersonPosts_enable=true
51 | ldbc.snb.interactive.LdbcShortQuery3PersonFriends_enable=true
52 | ldbc.snb.interactive.LdbcShortQuery4MessageContent_enable=true
13 ldbc.snb.interactive.LdbcShortQuery5MessageCreator_enable=true
54 | ldbc.snb.interactive.LdbcShortQuery6MessageForum_enable=true
```

Appendix

```
55 | ldbc.snb.interactive.LdbcShortQuery7MessageReplies_enable=true
56
57 | ldbc.snb.interactive.LdbcUpdate1AddPerson_enable=true
58 | ldbc.snb.interactive.LdbcUpdate2AddPostLike_enable=true
59 | ldbc.snb.interactive.LdbcUpdate3AddCommentLike_enable=true
60 ldbc.snb.interactive.LdbcUpdate4AddForum_enable=true
61 | ldbc.snb.interactive.LdbcUpdate5AddForumMembership_enable=true
   {\tt ldbc.snb.interactive.LdbcUpdate6AddPost\_enable=true}
  ldbc.snb.interactive.LdbcUpdate7AddComment_enable=true
63
   {\tt ldbc.snb.interactive.LdbcUpdate8AddFriendship\_enable=true}
```

Listing A.11: Contents of benchmark_sf100_32p.properties used for scale factor 100

```
url=http://172.31.11.250:10000
         printQueryNames=false
         printQueryStrings=false
         printQueryResults=false
         status=1
          thread_count=48
         name=L DBC-SNB
          mode=execute_benchmark
          results_log=true
11
         status=1
12
13 time_unit=MICROSECONDS
         time_compression_ratio=0.0039
15 peer_identifiers=
        workload_statistics=false
16
17
          spinner_wait_duration=1
18
          help=false
          ignore_scheduled_start_times=false
19
20
21
          workload = org.ldbcouncil.snb.driver.workloads.interactive.LdbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactive.ldbcSnbInteractiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWorkloads.interactiveWork
         \verb|db=| org.ldb| coucil.snb.impls.workloads.graphscope.interactive.GraphScopeInteractiveDb| organization and the control of t
23
24
25
          ldbc.snb.interactive.updates_dir=/disk1/sf100_32p/social_network/
26
          ldbc.snb.interactive.parameters_dir=/disk1/sf100_32p/substitution_parameters/
          ldbc.snb.interactive.short_read_dissipation=0.2
27
         # Supported scale factors are 0.1, 0.3, 1, 3, 10, 30, 100, 300, 1000
28
        ldbc.snb.interactive.scale_factor=100
29
30
31
        operation_count=245000000
         warmup=65000000
32
33
          ldbc.snb.interactive.LdbcQuery1_enable=true
34
35
        ldbc.snb.interactive.LdbcQuery2_enable=true
36 | ldbc.snb.interactive.LdbcQuery3_enable=true
37 | ldbc.snb.interactive.LdbcQuery4_enable=true
38 | ldbc.snb.interactive.LdbcQuery5_enable=true
39 | ldbc.snb.interactive.LdbcQuery6_enable=true
40 | ldbc.snb.interactive.LdbcQuery7_enable=true
41 | ldbc.snb.interactive.LdbcQuery8_enable=true
42
         ldbc.snb.interactive.LdbcQuery9_enable=true
43 | ldbc.snb.interactive.LdbcQuery10_enable=true
44 | ldbc.snb.interactive.LdbcQuery11_enable=true
45 | ldbc.snb.interactive.LdbcQuery12_enable=true
```

Appendix

```
46 ldbc.snb.interactive.LdbcQuery13_enable=true
   ldbc.snb.interactive.LdbcQuery14_enable=true
47
48
   ldbc.snb.interactive.LdbcShortQuery1PersonProfile_enable=true
50 | ldbc.snb.interactive.LdbcShortQuery2PersonPosts_enable=true
1dbc.snb.interactive.LdbcShortQuery3PersonFriends_enable=true
52
  {\tt ldbc.snb.interactive.LdbcShortQuery4MessageContent\_enable=true}
53
   {\tt ldbc.snb.interactive.LdbcShortQuery5MessageCreator\_enable=true}
   ldbc.snb.interactive.LdbcShortQuery6MessageForum_enable=true
54
  ldbc.snb.interactive.LdbcShortQuery7MessageReplies_enable=true
55
57 | ldbc.snb.interactive.LdbcUpdate1AddPerson_enable=true
58 | ldbc.snb.interactive.LdbcUpdate2AddPostLike_enable=true
59
  ldbc.snb.interactive.LdbcUpdate3AddCommentLike_enable=true
60
  ldbc.snb.interactive.LdbcUpdate4AddForum_enable=true
61
   {\tt ldbc.snb.interactive.LdbcUpdate5AddForumMembership\_enable=true}
62
  ldbc.snb.interactive.LdbcUpdate6AddPost enable=true
63 | ldbc.snb.interactive.LdbcUpdate7AddComment_enable=true
  ldbc.snb.interactive.LdbcUpdate8AddFriendship_enable=true
```

Listing A.12: Contents of benchmark_sf300_32p.properties used for scale factor 300

```
url=http://172.31.11.250:10000
 2
  3
       printQueryNames=false
       printQueryStrings=false
       printQueryResults=false
       status=1
  8
        thread_count=48
        name=LDBC-SNB
       mode=execute_benchmark
10
11 results_log=true
12 status=1
13 time_unit=MICROSECONDS
14 time_compression_ratio=0.014
15 peer_identifiers=
       workload_statistics=false
17
        spinner_wait_duration=1
18 help=false
19 ignore_scheduled_start_times=false
20
        workload=org.ldbcouncil.snb.driver.workloads.interactive.LdbcSnbInteractiveWorkload
21
       \verb|db=| org.ldb| coucil.snb.impls.workloads.graphscope.interactive.GraphScopeInteractiveDb| | organization | o
22
23
24
        ldbc.snb.interactive.updates_dir=/disk1/sf300_32p/social_network/
25
       ldbc.snb.interactive.parameters_dir=/disk1/sf300_32p/substitution_parameters/
26
27
       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
29
30
       operation_count=245000000
31
        warmup=57000000
32
33
34 | ldbc.snb.interactive.LdbcQuery1_enable=true
35 | ldbc.snb.interactive.LdbcQuery2_enable=true
36 | ldbc.snb.interactive.LdbcQuery3_enable=true
```

```
37 | ldbc.snb.interactive.LdbcQuery4_enable=true
38 | ldbc.snb.interactive.LdbcQuery5_enable=true
39 | ldbc.snb.interactive.LdbcQuery6_enable=true
40 ldbc.snb.interactive.LdbcQuery7_enable=true
41 | ldbc.snb.interactive.LdbcQuery8_enable=true
42 | ldbc.snb.interactive.LdbcQuery9_enable=true
  ldbc.snb.interactive.LdbcQuery10_enable=true
   ldbc.snb.interactive.LdbcQuery11_enable=true
  ldbc.snb.interactive.LdbcQuery12_enable=true
45
  ldbc.snb.interactive.LdbcQuery13_enable=true
47
  ldbc.snb.interactive.LdbcQuery14_enable=true
48
  ldbc.snb.interactive.LdbcShortQuery1PersonProfile_enable=true
49
  ldbc.snb.interactive.LdbcShortQuery2PersonPosts_enable=true
50
51
  {\tt ldbc.snb.interactive.LdbcShortQuery3PersonFriends\_enable=true}
  ldbc.snb.interactive.LdbcShortQuery4MessageContent_enable=true
52
  ldbc.snb.interactive.LdbcShortQuery5MessageCreator_enable=true
53
  {\tt ldbc.snb.interactive.LdbcShortQuery6MessageForum\_enable=true}
  {\tt ldbc.snb.interactive.LdbcShortQuery7MessageReplies\_enable=true}
56
  ldbc.snb.interactive.LdbcUpdate1AddPerson_enable=true
57
58 | ldbc.snb.interactive.LdbcUpdate2AddPostLike_enable=true
  ldbc.snb.interactive.LdbcUpdate3AddCommentLike_enable=true
  ldbc.snb.interactive.LdbcUpdate4AddForum_enable=true
60
  ldbc.snb.interactive.LdbcUpdate5AddForumMembership_enable=true
61
  ldbc.snb.interactive.LdbcUpdate6AddPost_enable=true
  {\tt ldbc.snb.interactive.LdbcUpdate7AddComment\_enable=true}
  ldbc.snb.interactive.LdbcUpdate8AddFriendship_enable=true
```

Validation configuration A.9

Listing A.13: The contents of validate properties

```
1 url=http://172.31.11.250:10000
  readTimeout=5000000
  connectTimeout=5000000
  connect.PoolMaxIdle=10
  keepAliveDuration=5000
  maxRequestsPerHost=180
  maxRequests=180
  printQueryNames=false
  printQueryStrings=false
  printQueryResults=false
11
12
  status=1
13
   thread_count=1
14
15
  mode=validate_database
  name=LDBC-SNB
  results_log=false
18 time_unit=MILLISECONDS
  time_compression_ratio=0.001
  peer identifiers=
  workload_statistics=false
  spinner_wait_duration=0
23 help=false
```

```
24 ignore_scheduled_start_times=true
25
26
  ldbc.snb.interactive.update_interleave=895969
  workload=org.ldbcouncil.snb.driver.workloads.interactive.LdbcSnbInteractiveWorkload
  db=org.ldbcoucil.snb.impls.workloads.graphscope.interactive.GraphScopeInteractiveDb
28
29
30
  operation_count=10000
31
  validate_database=/disk1/sf10_1p/validation_params.csv
32
  ldbc.snb.interactive.parameters_dir=/disk1/sf10_1p/substitution_parameters/
33
  ldbc.snb.interactive.short_read_dissipation=0.2
35 # Supported scale factors are 0.1, 0.3, 1, 3, 10, 30, 100, 300, 1000
  ldbc.snb.interactive.scale_factor=10
36
37
38
  ldbc.snb.interactive.LdbcQuery1_freq=1
39
  ldbc.snb.interactive.LdbcQuery2_freq=1
40
  ldbc.snb.interactive.LdbcQuery3_freq=1
41 | ldbc.snb.interactive.LdbcQuery4_freq=1
42 | ldbc.snb.interactive.LdbcQuery5_freq=1
43 | ldbc.snb.interactive.LdbcQuery6_freq=1
44 | ldbc.snb.interactive.LdbcQuery7_freq=1
45 | ldbc.snb.interactive.LdbcQuery8_freq=1
  ldbc.snb.interactive.LdbcQuery9_freq=1
47
  ldbc.snb.interactive.LdbcQuery10_freq=1
  ldbc.snb.interactive.LdbcQuery11_freq=1
48
49
  ldbc.snb.interactive.LdbcQuery12_freq=1
  ldbc.snb.interactive.LdbcQuery13_freg=1
  ldbc.snb.interactive.LdbcQuery14_freq=1
51
52
53
  ldbc.snb.interactive.LdbcQuery1_enable=true
54
   ldbc.snb.interactive.LdbcQuery2_enable=true
  ldbc.snb.interactive.LdbcQuery3_enable=true
55
56
  ldbc.snb.interactive.LdbcQuery4_enable=true
57 | ldbc.snb.interactive.LdbcQuery5_enable=true
58 | ldbc.snb.interactive.LdbcOuerv6 enable=true
59 | ldbc.snb.interactive.LdbcQuery7_enable=true
60 | ldbc.snb.interactive.LdbcQuery8_enable=true
  ldbc.snb.interactive.LdbcQuery9_enable=true
62
  ldbc.snb.interactive.LdbcQuery10_enable=true
  ldbc.snb.interactive.Ldbc0uerv11 enable=true
63
64 | ldbc.snb.interactive.LdbcQuery12_enable=true
65 | ldbc.snb.interactive.LdbcQuery13_enable=true
66 | ldbc.snb.interactive.LdbcQuery14_enable=true
67
68
  {\tt ldbc.snb.interactive.LdbcShortQuery1PersonProfile\_enable=true}
   ldbc.snb.interactive.LdbcShortQuery2PersonPosts_enable=true
  ldbc.snb.interactive.LdbcShortQuery3PersonFriends_enable=true
70
71
  {\tt ldbc.snb.interactive.LdbcShortQuery4MessageContent\_enable=true}
72
  {\tt ldbc.snb.interactive.LdbcShortQuery5MessageCreator\_enable=true}
  {\tt ldbc.snb.interactive.LdbcShortQuery6MessageForum\_enable=true}
  ldbc.snb.interactive.LdbcShortQuery7MessageReplies_enable=true
74
75
76
  {\tt ldbc.snb.interactive.LdbcUpdate1AddPerson\_enable=true}
  ldbc.snb.interactive.LdbcUpdate2AddPostLike_enable=true
77
78
  ldbc.snb.interactive.LdbcUpdate3AddCommentLike_enable=true
  ldbc.snb.interactive.LdbcUpdate4AddForum_enable=true
79
  {\tt ldbc.snb.interactive.LdbcUpdate5AddForumMembership\_enable=true}
81 | ldbc.snb.interactive.LdbcUpdate6AddPost_enable=true
```

A.9. Validation configuration

Appendix

82 | ldbc.snb.interactive.LdbcUpdate7AddComment_enable=true

83 | ldbc.snb.interactive.LdbcUpdate8AddFriendship_enable=true