Alibaba Cloud

# Alibaba Cloud Computing Ltd.

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TPC Benchmark™ DS

Full Disclosure Report

for

Alibaba Cloud E-MapReduce

(with 19 Alibaba Cloud Elastic Compute Service Servers)

using

E-MapReduce 3.16.1

and

CentOS Linux Release 7.4

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**First Edition**

**March 19, 2019**

# First Edition – March, 2019

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# Abstract

This document contains the methodology and results of the TPC Benchmark™ DS (TPC-DS) test conducted in conformance with the requirements of the TPC-DS Standard Specification, Revision 2.10.1.

The test was conducted at a Scale Factor of 10000GB with 19 Alibaba Cloud Elastic Compute Service Servers running E-MapReduce 3.16.1 on CentOS Linux Release 7.4.

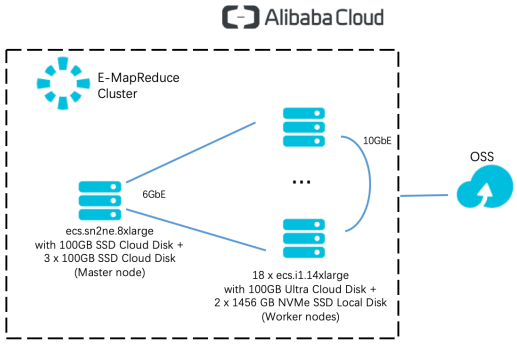
**Measured Configuration**

| Company Name | Cluster Node | Database Software | Operation System |
|---|---|---|---|
| Alibaba Cloud Computing Ltd. | Alibaba Cloud Elastic Compute Service Server | Alibaba Cloud E-MapReduce 3.16.1 | CentOS Linux Release 7.4 |

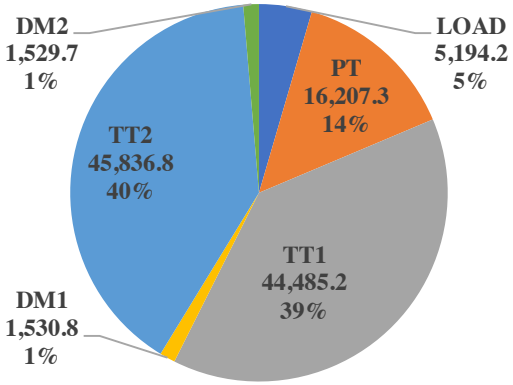
**TPC Benchmark™ DS Metrics**

| Total System Cost (USD) | TPC-DS Throughput (QphDS@10000GB) | Price/Performance (USD / QphDS@10000GB) | Availability Date |
|---|---|---|---|
| **$559,536.60** | **1,824,283** | **$0.31** | **As of Publication** |

| Alibaba Cloud | Alibaba Cloud E-MapReduce | | TPC-DS: 2.10.1<br>TPC-Pricing: 2.4.0<br>Report Date: Mar. 19, 2019 | |
|---|---|---|---|---|
| Total System Cost | TPC-DS Throughput | Price / Performance | System Availability Date | |
| **$559,536.60**<br>USD | **1,824,283**<br>QphDS@10000GB | **$0.31**<br>USD/QphDS@10000GB | **As of Publication** | |
| Dataset Size[1] | Database Manager | Operation System | Other Software | Cluster |
| 10,000 GB | E-MapReduce 3.16.1 | CentOS Linux Release 7.4 | N/A | Yes |




**Benchmarked Configuration**




**Elapsed Time**

| Load includes backup = No | RAID = RAID-1 for metadata; SmartFS with 3-way replication for table data |
|---|---|

| | |
|---|---|
| **System Configuration:** | **Alibaba Cloud E-MapReduce Cluster** |
| Servers: | 1 x ecs.sn2ne.8xlarge + 18 x ecs.i1.14xlarge |
| Total Processors/Cores/Threads: | 19/520/1,040 |
| Total Memory: | 4,160 GB |
| Total Storage[2]: | 64,856 GB |
| Storage Ratio[3]: | 6.49 |
| **Server Configuration:** | **Per node (ecs.sn2ne.8xlarge)** |
| Processors: | Intel(R)Xeon(R) Platinum 8163 CPU @ 2.50GHz, 33 MB L3 |
| Memory: | 128 GB |
| Network: | Bandwidth: 6.0 Gbps, Packet forwarding rate: 2,500,000 |
| Storage Device: | 3 x 100 GB SSD Cloud Disk (data disk)<br>1 x 100 GB SSD Cloud Disk (boot disk) |
| **Server Configuration:** | **Per node (ecs.i1.14xlarge)** |
| Processors: | Intel(R)Xeon(R) CPU E5-2682 v4 @ 2.50GHz, 40 MB L3 |
| Memory: | 224 GB |
| Network: | Bandwidth: 10.0 Gbps, Packet forwarding rate: 1,200,000 |
| Storage Device: | 2 x 1456 GB NVMe SSD Local Disk (data disk)<br>1 x 100 GB Ultra Cloud Disk (boot disk) |
| **Object Storage Service Configuration:** | **OSS Standard Storage** |
| Storage Capacity: | 10 TB |
| API Requests Read: | 1,000,000 / Day |
| API Requests Write: | 1,000,000 / Day |

1. Dataset Size includes only raw data (i.e., no temp, index, redundant storage space, etc.).
2. Total Storage = (100 + 100 * 3) (Master node) + (100 + 1,456 * 2) * 18 (Worker nodes) + 10 * 1,024 (OSS) = 64,856 GB
3. Storage Ratio = Total Storage / SF = 64,856 GB / 10,000 GB

| Alibaba Cloud | **Alibaba Cloud E-MapReduce** | TPC-DS: 2.10.1<br>TPC-Pricing: 2.4.0<br>Report Date: Mar. 19, 2019 |
|---|---|---|

| Description | Part Number | Src | Unit Price (USD) | Qty | Ext. Price (USD) | 3-Year Maint. (USD) |
|---|---|---|---|---|---|---|
| **Licensed Compute Services** | | | | | | |
| Virtual cloud server (China North 2) | | | | | | |
| ECS Instance ecs.sn2ne.8xlarge | ecs.sn2ne.8xlarge | 1 | 7132.04 | 3 | 21,396.12 | included |
| ECS System Disk (SSD Cloud Disk 100GB) | Option | 1 | 156.06 | 3 | 468.18 | included |
| ECS Data Disk (SSD Cloud Disk 100GB) x 3 | Option | 1 | 156.06 | 9 | 1,404.54 | included |
| Virtual cloud server (China North 2) | | | | | | |
| ECS Instance ecs.i1.14xlarge | ecs.i1.14xlarge | 1 | 8,400.11 | 54 | 453,605.94 | included |
| - NVMe SSD Local Disk (2 x 1456 GB) | | | | | | |
| ECS System Disk (Ultra Cloud Disk 100GB) | Option | 1 | 78.54 | 54 | 4,241.16 | included |
| | **Licensed Compute Services Sub-Total** | | | | **481,115.94** | **0.00** |
| **Licensed Software Services** | | | | | | |
| E-MapReduce for emr.sn2ne.8xlarge | | 1 | 1,069.81 | 3 | 3,209.43 | included |
| E-MapReduce for emr.i1.14xlarge | | 1 | 1,260.01 | 54 | 68,040.54 | included |
| | **Licensed Software Services Sub-Total** | | | | **71,249.97** | **0.00** |
| **Licensed Storage Services** | | | | | | |
| OSS Standard Storage (China North 2)<br>- Storage 10TB<br>- API Requests Read: 1,000,000 / day<br>- API Requests Write: 1,000,000 / day | | 1 | 2240.24 | 3 | 6,720.72 | included |
| | **Licensed Storage Services Sub-Total** | | | | **6,720.72** | **0.00** |
| **Other Components** | | | | | | |
| Lenovo 120S-14IAP Laptop (Includes spares) | 81A5001UUS | 2 | 149.99 | 3 | 449.97 | |
| | **Other Components Sub-Total** | | | | **449.97** | **0.00** |

| | | |
|---|---|---|
| 1 = Alibaba Cloud, 2 = BestBuy.com | **3-Year Cost of Ownership:** | **559,536.60** |
| All Licensed Services prices are based on 1-year pre-paid subscriptions. | **QphDS@10000GB:** | **1,824,283** |
| **Audited by Francois Raab, InfoSizing** | **$/QphDS@10000GB:** | **0.31** |

Prices used in TPC benchmarks reflect the actual prices a customer would pay for a one-time purchase of the stated components. Individually negotiated discounts are not permitted. Special prices based on assumptions about past or future purchases are not permitted. All discounts reflect standard pricing policies for the listed components. For complete details, see the pricing sections of the TPC benchmark specifications. If you find that the stated prices are not available according to these terms, please inform at pricing@tpc.org. Thank you.

| Alibaba Cloud | Alibaba Cloud<br>E-MapReduce | TPC-DS: 2.10.1<br>TPC-Pricing: 2.4.0<br>Report Date: Mar. 19, 2019 |
|---|---|---|

**Metrics Details:**

| Name | Value | Unit |
|---|---|---|
| Scale Factor (SF) | 10,000 | GB |
| Streams | 4 | Stream |
| Queries (Q) | 396 | Queries |
| T_load | 5,194.2 | Second |
| T_ld | 0.0578 | Hour |
| T_pt | 18.0082 | Hour |
| T_tt1 | 44,485.2 | Second |
| T_tt2 | 45,836.8 | Second |
| T_dm1 | 1,530.8 | Second |
| T_dm2 | 1,529.7 | Second |
| T_tt | 25.0895 | Hour |
| T_dm | 0.8502 | Hour |

| Load Step | Start | End | (sec.) | (hh:mm:ss) |
|---|---|---|---|---|
| Build | 03/09/19 17:52:53.34 | 03/09/19 19:19:27.48 | 5,194.14 | 1:26:34 |
| Audit | 03/09/19 19:19:27.48 | 03/09/19 20:01:08.05 | 2,500.57 | 0:41:41 |
| Finish | 03/09/19 20:01:08.05 | 03/09/19 20:01:08.06 | 0.01 | 0:00:00 |
| Reported | 03/09/19 17:52:53.34 | 03/09/19 20:01:08.05 | 5,194.15 | 1:26:34 |

| Test | Start | End | (sec.) | (hh:mm:ss) |
|---|---|---|---|---|
| Power | 03/09/19 20:17:46.11 | 03/10/19 00:47:53.40 | 16,207.29 | 4:30:07 |
| Thruput-1 | 03/10/19 00:47:53.42 | 03/10/19 13:09:18.53 | 44,485.11 | 12:21:25 |
| Thruput-2 | 03/10/19 13:34:49.32 | 03/11/19 02:18:46.04 | 45,836.72 | 12:43:57 |
| DM-1 | 03/10/19 13:09:18.55 | 03/10/19 13:34:49.31 | 1,530.76 | 0:25:31 |
| DM-2 | 03/11/19 02:18:46.05 | 03/11/19 02:44:15.68 | 1,529.63 | 0:25:30 |

| Stream | Start | End | (sec.) | (hh:mm:ss) |
|---|---|---|---|---|
| Pt - 0 | 03/09/19 20:17:46.11 | 03/10/19 00:47:53.40 | 16,207.29 | 4:30:07 |
| Tt1 - 1 | 03/10/19 00:47:53.42 | 03/10/19 13:06:49.69 | 44,336.27 | 12:18:56 |
| Tt1 - 2 | 03/10/19 00:47:53.42 | 03/10/19 13:09:18.53 | 44,485.11 | 12:21:25 |
| Tt1 - 3 | 03/10/19 00:47:53.42 | 03/10/19 12:27:00.19 | 41,946.77 | 11:39:07 |
| Tt1 - 4 | 03/10/19 00:47:53.42 | 03/10/19 13:00:49.31 | 43,975.89 | 12:12:56 |
| Tt2 - 5 | 03/10/19 13:34:49.32 | 03/11/19 02:18:46.04 | 45,836.72 | 12:43:57 |
| Tt2 - 6 | 03/10/19 13:34:49.32 | 03/11/19 02:15:31.14 | 45,641.82 | 12:40:42 |
| Tt2 - 7 | 03/10/19 13:34:49.32 | 03/11/19 02:07:35.14 | 45,165.82 | 12:32:46 |
| Tt2 - 8 | 03/10/19 13:34:49.32 | 03/11/19 01:34:59.68 | 43,210.36 | 12:00:10 |
| DMt1 - 1 | 03/10/19 13:09:18.55 | 03/10/19 13:22:22.44 | 783.90 | 0:13:04 |
| DMt1 - 2 | 03/10/19 13:22:22.45 | 03/10/19 13:34:49.31 | 746.85 | 0:12:27 |
| DMt2 - 3 | 03/11/19 02:18:46.05 | 03/11/19 02:31:12.23 | 746.18 | 0:12:26 |
| DMt2 - 4 | 03/11/19 02:31:12.24 | 03/11/19 02:44:15.68 | 783.44 | 0:13:03 |

**Timing Intervals for Each Query (In Seconds)**

| Query | Stream 0 | Stream 1 | Stream 2 | Stream 3 | Stream 4 | Min | 25%tile | Median | 75%tile | Max | Stream 5 | Stream 6 | Stream 7 | Stream 8 | Min | 25%tile | Median | 75%tile | Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 41.7 | 218.4 | 341.8 | 97.0 | 494.7 | 97.0 | 188.1 | 280.1 | 380.0 | 494.7 | 155.0 | 154.1 | 406.3 | 122.0 | 122.0 | 146.1 | 154.6 | 217.8 | 406.3 |
| 2 | 72.6 | 161.1 | 208.0 | 85.5 | 203.8 | 85.5 | 142.2 | 182.5 | 204.9 | 208.0 | 222.5 | 183.6 | 307.0 | 560.1 | 183.6 | 212.8 | 264.8 | 370.3 | 560.1 |
| 3 | 29.3 | 318.5 | 102.5 | 115.7 | 121.0 | 102.5 | 112.4 | 118.4 | 170.4 | 318.5 | 273.6 | 129.6 | 108.5 | 275.8 | 108.5 | 124.3 | 201.6 | 274.2 | 275.8 |
| 4 | 514.0 | 960.5 | 650.8 | 678.1 | 853.3 | 650.8 | 671.3 | 765.7 | 880.1 | 960.5 | 780.5 | 661.6 | 580.7 | 1,384.4 | 580.7 | 641.4 | 721.1 | 931.5 | 1,384.4 |
| 5 | 166.3 | 370.9 | 762.1 | 291.5 | 423.3 | 291.5 | 351.1 | 397.1 | 508.0 | 762.1 | 381.6 | 247.5 | 326.2 | 278.7 | 247.5 | 270.9 | 302.5 | 340.1 | 381.6 |
| 6 | 36.4 | 310.2 | 324.0 | 74.4 | 589.2 | 74.4 | 251.3 | 317.1 | 390.3 | 589.2 | 484.3 | 193.9 | 118.7 | 170.1 | 118.7 | 157.3 | 182.0 | 266.5 | 484.3 |
| 7 | 63.3 | 153.9 | 118.1 | 180.3 | 167.2 | 118.1 | 145.0 | 160.6 | 170.5 | 180.3 | 164.9 | 284.8 | 225.1 | 390.4 | 164.9 | 210.1 | 255.0 | 311.2 | 390.4 |
| 8 | 68.0 | 667.2 | 425.7 | 323.8 | 220.3 | 220.3 | 297.9 | 374.8 | 486.1 | 667.2 | 397.6 | 311.9 | 208.8 | 474.6 | 208.8 | 286.1 | 354.8 | 416.9 | 474.6 |
| 9 | 540.1 | 2,194.6 | 2,556.7 | 2,037.8 | 2,140.7 | 2,037.8 | 2,115.0 | 2,167.7 | 2,285.1 | 2,556.7 | 2,294.8 | 2,764.7 | 1,254.0 | 2,160.2 | 1,254.0 | 1,933.7 | 2,227.5 | 2,412.3 | 2,764.7 |
| 10 | 85.2 | 133.3 | 393.5 | 934.9 | 181.1 | 133.3 | 169.2 | 287.3 | 528.9 | 934.9 | 144.2 | 297.0 | 325.9 | 295.7 | 144.2 | 257.8 | 296.4 | 304.2 | 325.9 |
| 11 | 182.7 | 359.2 | 412.5 | 316.8 | 619.3 | 316.8 | 348.6 | 385.9 | 464.2 | 619.3 | 358.6 | 303.0 | 448.7 | 445.7 | 303.0 | 344.7 | 402.2 | 446.5 | 448.7 |
| 12 | 20.4 | 338.6 | 344.2 | 238.1 | 537.6 | 238.1 | 313.5 | 341.4 | 392.6 | 537.6 | 264.1 | 48.7 | 375.1 | 47.0 | 47.0 | 48.3 | 156.4 | 291.9 | 375.1 |
| 13 | 85.6 | 137.7 | 422.9 | 444.7 | 122.6 | 122.6 | 133.9 | 280.3 | 428.4 | 444.7 | 309.0 | 174.4 | 253.8 | 339.6 | 174.4 | 234.0 | 281.4 | 316.7 | 339.6 |
| 14 | 932.8 | 2,917.5 | 2,595.7 | 2,916.6 | 2,553.9 | 2,553.9 | 2,585.3 | 2,756.2 | 2,916.8 | 2,917.5 | 1,853.1 | 2,623.0 | 3,023.5 | 3,237.1 | 1,853.1 | 2,430.5 | 2,823.3 | 3,076.9 | 3,237.1 |
| 15 | 41.0 | 89.1 | 470.0 | 581.9 | 107.2 | 89.1 | 102.7 | 288.6 | 498.0 | 581.9 | 165.0 | 203.2 | 116.3 | 145.6 | 116.3 | 138.3 | 155.3 | 174.6 | 203.2 |
| 16 | 162.8 | 228.0 | 789.1 | 360.9 | 244.4 | 228.0 | 240.3 | 302.7 | 468.0 | 789.1 | 346.1 | 285.2 | 320.2 | 376.3 | 285.2 | 311.5 | 333.2 | 353.7 | 376.3 |
| 17 | 112.0 | 248.4 | 595.0 | 208.7 | 249.7 | 208.7 | 238.5 | 249.1 | 336.0 | 595.0 | 377.0 | 358.6 | 342.0 | 288.4 | 288.4 | 328.6 | 350.3 | 363.2 | 377.0 |
| 18 | 84.1 | 344.6 | 355.0 | 390.1 | 360.8 | 344.6 | 352.4 | 357.9 | 368.1 | 390.1 | 214.9 | 269.9 | 184.1 | 361.4 | 184.1 | 207.2 | 242.4 | 292.8 | 361.4 |
| 19 | 51.4 | 179.6 | 100.5 | 252.6 | 211.7 | 100.5 | 159.8 | 195.7 | 221.9 | 252.6 | 115.4 | 211.6 | 57.4 | 266.6 | 57.4 | 100.9 | 163.5 | 225.4 | 266.6 |
| 20 | 33.9 | 584.9 | 74.9 | 237.2 | 575.9 | 74.9 | 196.6 | 406.6 | 578.2 | 584.9 | 117.0 | 109.5 | 127.8 | 72.2 | 72.2 | 100.2 | 113.3 | 119.7 | 127.8 |
| 21 | 3.5 | 112.5 | 4.7 | 82.5 | 5.5 | 4.7 | 5.3 | 44.0 | 90.0 | 112.5 | 285.7 | 8.4 | 5.3 | 51.5 | 5.3 | 7.6 | 30.0 | 110.1 | 285.7 |
| 22 | 12.8 | 12.8 | 20.6 | 221.0 | 53.1 | 12.8 | 18.7 | 36.9 | 95.1 | 221.0 | 20.5 | 16.0 | 15.9 | 127.3 | 15.9 | 16.0 | 18.3 | 47.2 | 127.3 |
| 23 | 1,491.5 | 2,087.0 | 2,325.9 | 2,655.7 | 2,188.3 | 2,087.0 | 2,163.0 | 2,257.1 | 2,408.4 | 2,655.7 | 2,171.0 | 1,883.5 | 2,098.5 | 2,503.9 | 1,883.5 | 2,044.8 | 2,134.8 | 2,254.2 | 2,503.9 |
| 24 | 469.9 | 1,568.2 | 2,001.3 | 1,009.8 | 954.6 | 954.6 | 996.0 | 1,289.0 | 1,676.5 | 2,001.3 | 1,399.4 | 1,723.7 | 1,450.5 | 2,709.5 | 1,399.4 | 1,437.7 | 1,587.1 | 1,970.2 | 2,709.5 |
| 25 | 223.4 | 1,188.8 | 686.0 | 781.9 | 1,157.7 | 686.0 | 757.9 | 969.8 | 1,165.5 | 1,188.8 | 126.5 | 178.3 | 449.1 | 467.7 | 126.5 | 165.4 | 313.7 | 453.8 | 467.7 |
| 26 | 45.5 | 378.3 | 241.9 | 93.5 | 146.6 | 93.5 | 133.3 | 194.3 | 276.0 | 378.3 | 150.5 | 87.2 | 110.7 | 243.2 | 87.2 | 104.8 | 130.6 | 173.7 | 243.2 |
| 27 | 62.0 | 202.6 | 131.8 | 277.7 | 200.1 | 131.8 | 183.0 | 201.4 | 221.4 | 277.7 | 158.6 | 123.9 | 96.4 | 263.3 | 96.4 | 117.0 | 141.3 | 184.8 | 263.3 |
| 28 | 225.0 | 374.6 | 670.6 | 262.7 | 616.4 | 262.7 | 346.6 | 495.5 | 630.0 | 670.6 | 312.1 | 319.0 | 427.2 | 396.6 | 312.1 | 317.3 | 357.8 | 404.3 | 427.2 |
| 29 | 141.1 | 263.3 | 294.4 | 261.2 | 332.6 | 261.2 | 262.8 | 278.9 | 304.0 | 332.6 | 147.2 | 188.3 | 468.6 | 424.3 | 147.2 | 178.0 | 306.3 | 435.4 | 468.6 |
| 30 | 41.9 | 339.0 | 533.6 | 461.1 | 162.5 | 162.5 | 294.9 | 400.1 | 479.2 | 533.6 | 320.2 | 351.1 | 672.0 | 91.5 | 91.5 | 263.0 | 335.7 | 431.3 | 672.0 |
| 31 | 157.2 | 692.3 | 536.7 | 236.0 | 638.3 | 236.0 | 461.5 | 587.5 | 651.8 | 692.3 | 217.2 | 320.5 | 264.8 | 217.7 | 217.2 | 217.6 | 241.3 | 278.7 | 320.5 |
| 32 | 58.4 | 103.8 | 61.5 | 75.4 | 147.2 | 61.5 | 71.9 | 89.6 | 114.7 | 147.2 | 94.7 | 606.3 | 216.1 | 101.0 | 94.7 | 99.4 | 158.6 | 313.7 | 606.3 |
| 33 | 97.4 | 193.6 | 140.7 | 557.4 | 577.1 | 140.7 | 180.4 | 375.5 | 562.3 | 577.1 | 588.1 | 393.4 | 122.2 | 258.1 | 122.2 | 224.1 | 325.8 | 442.1 | 588.1 |
| 34 | 47.4 | 68.8 | 130.7 | 65.4 | 197.5 | 65.4 | 68.0 | 99.8 | 147.4 | 197.5 | 123.2 | 150.2 | 85.2 | 219.4 | 85.2 | 113.7 | 136.7 | 167.5 | 219.4 |
| 35 | 113.6 | 517.5 | 317.2 | 285.0 | 889.7 | 285.0 | 309.2 | 417.4 | 610.6 | 889.7 | 310.9 | 362.3 | 646.9 | 335.2 | 310.9 | 329.1 | 348.8 | 433.5 | 646.9 |
| 36 | 93.6 | 292.5 | 362.2 | 302.7 | 390.1 | 292.5 | 300.2 | 332.5 | 369.2 | 390.1 | 197.6 | 430.4 | 519.8 | 402.9 | 197.6 | 351.6 | 416.7 | 452.8 | 519.8 |
| 37 | 47.6 | 161.6 | 126.7 | 146.0 | 99.1 | 99.1 | 119.8 | 136.4 | 149.9 | 161.6 | 167.0 | 103.0 | 175.7 | 168.2 | 103.0 | 151.0 | 167.6 | 170.1 | 175.7 |
| 38 | 127.9 | 361.2 | 436.4 | 464.2 | 441.8 | 361.2 | 417.6 | 439.1 | 447.4 | 464.2 | 645.4 | 396.6 | 741.1 | 296.7 | 296.7 | 371.6 | 521.0 | 669.3 | 741.1 |
| 39 | 36.8 | 104.6 | 577.4 | 241.4 | 283.7 | 104.6 | 207.2 | 262.6 | 357.1 | 577.4 | 169.0 | 154.1 | 1,100.0 | 85.9 | 85.9 | 137.1 | 161.6 | 401.8 | 1,100.0 |
| 40 | 102.4 | 208.8 | 952.3 | 343.0 | 240.8 | 208.8 | 232.8 | 291.9 | 495.3 | 952.3 | 219.1 | 875.3 | 235.2 | 272.9 | 219.1 | 231.2 | 254.1 | 423.5 | 875.3 |
| 41 | 1.4 | 51.3 | 2.2 | 40.4 | 1.7 | 1.7 | 2.1 | 21.3 | 43.1 | 51.3 | 15.0 | 30.9 | 1.7 | 1.7 | 1.7 | 1.7 | 8.4 | 19.0 | 30.9 |
| 42 | 34.9 | 38.7 | 53.4 | 55.6 | 63.5 | 38.7 | 49.7 | 54.5 | 57.6 | 63.5 | 186.3 | 39.9 | 417.4 | 95.4 | 39.9 | 81.5 | 140.9 | 244.1 | 417.4 |
| 43 | 67.8 | 258.7 | 113.7 | 161.7 | 192.8 | 113.7 | 149.7 | 177.3 | 209.3 | 258.7 | 52.4 | 132.4 | 130.4 | 89.0 | 52.4 | 79.9 | 109.7 | 130.9 | 132.4 |
| 44 | 137.2 | 301.0 | 282.4 | 158.8 | 286.1 | 158.8 | 251.5 | 284.3 | 289.8 | 301.0 | 156.7 | 751.6 | 422.1 | 237.0 | 156.7 | 216.9 | 329.6 | 504.5 | 751.6 |
| 45 | 33.4 | 173.7 | 142.1 | 77.6 | 323.8 | 77.6 | 126.0 | 157.9 | 211.2 | 323.8 | 198.6 | 464.2 | 161.2 | 107.2 | 107.2 | 147.7 | 179.9 | 265.0 | 464.2 |
| 46 | 61.5 | 277.4 | 64.4 | 115.4 | 178.8 | 64.4 | 102.7 | 147.1 | 203.5 | 277.4 | 121.6 | 158.6 | 332.6 | 523.1 | 121.6 | 149.4 | 245.6 | 380.2 | 523.1 |
| 47 | 79.7 | 249.7 | 184.1 | 344.9 | 95.0 | 95.0 | 161.8 | 216.9 | 273.5 | 344.9 | 102.8 | 472.1 | 386.7 | 352.9 | 102.8 | 290.4 | 369.8 | 408.1 | 472.1 |
| 48 | 90.3 | 270.8 | 92.0 | 200.9 | 256.3 | 92.0 | 173.7 | 228.6 | 259.9 | 270.8 | 294.7 | 459.1 | 879.8 | 174.8 | 174.8 | 264.7 | 376.9 | 564.3 | 879.8 |
| 49 | 149.8 | 375.5 | 200.1 | 308.3 | 585.9 | 200.1 | 281.3 | 341.9 | 428.1 | 585.9 | 781.9 | 432.7 | 215.7 | 272.4 | 215.7 | 258.2 | 352.6 | 520.0 | 781.9 |
| 50 | 705.8 | 1,149.7 | 897.3 | 944.0 | 1,297.0 | 897.3 | 932.3 | 1,046.9 | 1,186.5 | 1,297.0 | 824.0 | 883.8 | 924.6 | 1,049.2 | 824.0 | 868.9 | 904.2 | 955.8 | 1,049.2 |
| 51 | 61.0 | 683.9 | 123.4 | 160.7 | 188.2 | 123.4 | 151.4 | 174.5 | 312.1 | 683.9 | 180.8 | 609.8 | 111.2 | 257.9 | 111.2 | 163.4 | 219.4 | 345.9 | 609.8 |
| 52 | 34.9 | 39.7 | 115.8 | 114.3 | 220.5 | 39.7 | 95.7 | 115.1 | 142.0 | 220.5 | 136.1 | 179.0 | 149.1 | 165.3 | 136.1 | 145.9 | 157.2 | 168.7 | 179.0 |
| 53 | 39.9 | 90.3 | 245.7 | 104.1 | 431.0 | 90.3 | 100.7 | 174.9 | 292.0 | 431.0 | 223.3 | 173.9 | 64.6 | 85.4 | 64.6 | 80.2 | 129.7 | 186.3 | 223.3 |
| 54 | 77.6 | 200.7 | 201.7 | 162.8 | 408.3 | 162.8 | 191.2 | 201.2 | 253.4 | 408.3 | 137.4 | 185.9 | 213.5 | 264.9 | 137.4 | 173.8 | 199.7 | 226.4 | 264.9 |
| 55 | 35.6 | 117.5 | 213.3 | 93.9 | 211.3 | 93.9 | 111.6 | 164.4 | 211.8 | 213.3 | 75.0 | 37.0 | 314.4 | 215.6 | 37.0 | 65.5 | 145.3 | 240.3 | 314.4 |
| 56 | 100.8 | 236.9 | 202.1 | 143.6 | 194.1 | 143.6 | 181.5 | 198.1 | 210.8 | 236.9 | 712.8 | 368.5 | 150.4 | 219.1 | 150.4 | 201.9 | 293.8 | 454.6 | 712.8 |
| 57 | 60.4 | 199.2 | 176.2 | 283.7 | 148.6 | 148.6 | 169.3 | 187.7 | 220.3 | 283.7 | 762.1 | 168.8 | 159.9 | 140.6 | 140.6 | 155.1 | 164.4 | 317.1 | 762.1 |
| 58 | 81.8 | 595.7 | 141.2 | 381.1 | 679.4 | 141.2 | 321.1 | 488.4 | 616.6 | 679.4 | 160.1 | 279.3 | 419.7 | 229.2 | 160.1 | 211.9 | 254.3 | 314.4 | 419.7 |
| 59 | 133.4 | 74.2 | 277.1 | 152.3 | 785.7 | 74.2 | 132.8 | 214.7 | 404.3 | 785.7 | 294.9 | 341.9 | 268.0 | 289.6 | 268.0 | 284.2 | 292.3 | 306.7 | 341.9 |
| 60 | 100.6 | 279.4 | 412.0 | 584.2 | 516.5 | 279.4 | 378.9 | 464.3 | 533.4 | 584.2 | 886.7 | 117.9 | 218.9 | 279.6 | 117.9 | 193.7 | 249.3 | 431.4 | 886.7 |
| 61 | 93.2 | 667.6 | 293.4 | 692.9 | 175.3 | 175.3 | 263.9 | 480.5 | 673.9 | 692.9 | 275.2 | 116.3 | 195.1 | 182.4 | 116.3 | 165.9 | 188.8 | 215.1 | 275.2 |
| 62 | 26.6 | 55.4 | 140.5 | 232.6 | 71.1 | 55.4 | 67.2 | 105.8 | 163.5 | 232.6 | 150.3 | 110.3 | 255.5 | 143.0 | 110.3 | 134.8 | 146.7 | 176.6 | 255.5 |
| 63 | 40.8 | 323.5 | 922.6 | 108.4 | 149.5 | 108.4 | 139.2 | 236.5 | 473.3 | 922.6 | 206.1 | 279.7 | 98.6 | 163.3 | 98.6 | 147.1 | 184.7 | 224.5 | 279.7 |
| 64 | 421.9 | 712.0 | 925.7 | 1,375.3 | 494.6 | 494.6 | 657.7 | 818.9 | 1,038.1 | 1,375.3 | 891.2 | 584.6 | 861.2 | 861.5 | 584.6 | 792.1 | 861.4 | 868.9 | 891.2 |
| 65 | 76.0 | 217.6 | 479.1 | 182.1 | 252.3 | 182.1 | 208.7 | 235.0 | 309.0 | 479.1 | 431.9 | 205.5 | 1,357.5 | 296.1 | 205.5 | 273.5 | 364.0 | 663.3 | 1,357.5 |
| 66 | 64.1 | 233.0 | 68.7 | 145.3 | 317.2 | 68.7 | 126.2 | 189.2 | 254.1 | 317.2 | 420.0 | 155.1 | 213.3 | 370.2 | 155.1 | 198.8 | 291.8 | 382.7 | 420.0 |
| 67 | 2,385.4 | 3,485.3 | 3,313.8 | 3,345.3 | 3,255.5 | 3,255.5 | 3,299.2 | 3,329.6 | 3,380.3 | 3,485.3 | 7,069.7 | 6,829.8 | 5,734.6 | 3,870.8 | 3,870.8 | 5,268.7 | 6,282.2 | 6,889.8 | 7,069.7 |
| 68 | 71.3 | 354.8 | 140.5 | 104.0 | 260.8 | 104.0 | 131.4 | 200.7 | 284.3 | 354.8 | 320.1 | 485.2 | 235.7 | 261.5 | 235.7 | 255.1 | 290.8 | 361.4 | 485.2 |
| 69 | 69.9 | 334.1 | 561.3 | 314.2 | 943.2 | 314.2 | 329.1 | 447.7 | 656.8 | 943.2 | 746.1 | 433.6 | 200.7 | 182.4 | 182.4 | 196.1 | 317.2 | 511.7 | 746.1 |
| 70 | 117.7 | 274.0 | 375.3 | 199.7 | 117.6 | 117.6 | 179.2 | 236.9 | 299.3 | 375.3 | 456.2 | 179.2 | 494.2 | 937.7 | 179.2 | 387.0 | 475.2 | 605.1 | 937.7 |
| 71 | 83.8 | 175.6 | 165.8 | 237.9 | 208.4 | 165.8 | 173.2 | 192.0 | 215.8 | 237.9 | 204.0 | 273.3 | 243.3 | 106.4 | 106.4 | 179.6 | 223.7 | 250.8 | 273.3 |
| 72 | 85.1 | 1,016.8 | 291.3 | 407.5 | 671.9 | 291.3 | 378.5 | 539.7 | 758.1 | 1,016.8 | 386.5 | 163.5 | 402.0 | 732.1 | 163.5 | 330.8 | 394.3 | 484.5 | 732.1 |
| 73 | 40.6 | 98.2 | 531.8 | 146.8 | 195.4 | 98.2 | 134.7 | 171.1 | 279.5 | 531.8 | 139.0 | 146.9 | 49.3 | 154.9 | 49.3 | 116.6 | 143.0 | 148.9 | 154.9 |
| 74 | 158.7 | 202.4 | 281.5 | 795.3 | 503.9 | 202.4 | 261.7 | 392.7 | 576.8 | 795.3 | 301.3 | 247.4 | 247.6 | 672.6 | 247.4 | 247.6 | 274.5 | 394.1 | 672.6 |
| 75 | 282.3 | 440.5 | 459.0 | 459.0 | 371.8 | 371.8 | 423.3 | 449.8 | 459.0 | 459.0 | 1,374.6 | 651.4 | 380.9 | 483.3 | 380.9 | 457.7 | 567.4 | 832.2 | 1,374.6 |
| 76 | 103.1 | 795.3 | 500.6 | 235.6 | 147.1 | 147.1 | 213.5 | 368.1 | 574.3 | 795.3 | 314.7 | 142.3 | 150.7 | 230.5 | 142.3 | 148.6 | 190.6 | 251.6 | 314.7 |
| 77 | 119.2 | 222.5 | 245.3 | 364.3 | 203.9 | 203.9 | 217.9 | 233.9 | 275.1 | 364.3 | 185.6 | 806.9 | 214.6 | 167.0 | 167.0 | 181.0 | 200.1 | 362.7 | 806.9 |
| 78 | 732.8 | 995.2 | 1,101.9 | 1,162.6 | 1,382.6 | 995.2 | 1,075.2 | 1,132.3 | 1,217.6 | 1,382.6 | 1,054.7 | 1,669.2 | 860.7 | 885.6 | 860.7 | 879.4 | 970.2 | 1,208.3 | 1,669.2 |
| 79 | 65.3 | 235.3 | 105.9 | 165.2 | 181.2 | 105.9 | 150.4 | 173.2 | 194.7 | 235.3 | 136.0 | 184.7 | 289.5 | 406.7 | 136.0 | 172.5 | 237.1 | 318.8 | 406.7 |
| 80 | 515.4 | 1,011.6 | 1,187.1 | 750.2 | 591.9 | 591.9 | 710.6 | 880.9 | 1,055.5 | 1,187.1 | 1,121.0 | 751.8 | 934.0 | 684.8 | 684.8 | 735.1 | 842.9 | 980.8 | 1,121.0 |
| 81 | 54.8 | 377.7 | 308.7 | 101.2 | 339.4 | 101.2 | 256.8 | 324.1 | 349.0 | 377.7 | 282.7 | 404.5 | 1,006.9 | 458.9 | 282.7 | 374.1 | 431.7 | 595.9 | 1,006.9 |
| 82 | 83.4 | 247.5 | 160.8 | 163.1 | 189.1 | 160.8 | 162.5 | 176.1 | 203.7 | 247.5 | 207.5 | 310.9 | 392.3 | 141.8 | 141.8 | 191.1 | 259.2 | 331.3 | 392.3 |
| 83 | 25.3 | 198.4 | 403.3 | 181.8 | 269.2 | 181.8 | 194.3 | 233.8 | 302.7 | 403.3 | 170.9 | 299.2 | 173.4 | 290.5 | 170.9 | 172.8 | 232.0 | 292.7 | 299.2 |
| 84 | 16.9 | 101.1 | 158.8 | 18.9 | 505.7 | 18.9 | 80.6 | 130.0 | 245.5 | 505.7 | 100.5 | 330.4 | 27.4 | 34.7 | 27.4 | 32.9 | 67.6 | 158.0 | 330.4 |
| 85 | 45.8 | 184.4 | 247.8 | 116.4 | 163.3 | 116.4 | 151.6 | 173.9 | 200.3 | 247.8 | 164.6 | 324.3 | 209.3 | 153.4 | 153.4 | 161.8 | 187.0 | 238.1 | 324.3 |
| 86 | 56.3 | 308.2 | 175.8 | 253.0 | 312.9 | 175.8 | 233.7 | 280.6 | 309.4 | 312.9 | 111.3 | 166.0 | 556.4 | 208.5 | 111.3 | 152.3 | 187.3 | 295.5 | 556.4 |
| 87 | 151.9 | 554.5 | 622.3 | 624.4 | 398.0 | 398.0 | 515.4 | 588.4 | 622.8 | 624.4 | 431.7 | 541.9 | 840.5 | 504.6 | 431.7 | 486.4 | 523.3 | 616.6 | 840.5 |
| 88 | 211.3 | 224.7 | 334.6 | 949.9 | 454.5 | 224.7 | 307.1 | 394.6 | 578.4 | 949.9 | 456.5 | 409.3 | 292.4 | 284.3 | 284.3 | 290.4 | 350.9 | 421.1 | 456.5 |
| 89 | 40.7 | 157.0 | 41.0 | 173.7 | 72.7 | 41.0 | 64.8 | 114.9 | 161.2 | 173.7 | 372.6 | 262.9 | 135.3 | 171.7 | 135.3 | 162.6 | 217.3 | 290.3 | 372.6 |
| 90 | 23.1 | 55.1 | 318.6 | 28.3 | 137.7 | 28.3 | 48.4 | 96.4 | 182.9 | 318.6 | 193.9 | 306.8 | 51.8 | 92.9 | 51.8 | 82.6 | 143.4 | 222.1 | 306.8 |
| 91 | 19.0 | 107.3 | 175.5 | 63.7 | 149.5 | 63.7 | 96.4 | 128.4 | 156.0 | 175.5 | 323.4 | 299.2 | 77.5 | 71.7 | 71.7 | 76.1 | 188.4 | 305.3 | 323.4 |
| 92 | 32.5 | 215.6 | 168.4 | 35.4 | 136.1 | 35.4 | 110.9 | 152.3 | 180.2 | 215.6 | 303.4 | 84.6 | 623.3 | 80.6 | 80.6 | 83.6 | 194.0 | 383.4 | 623.3 |
| 93 | 121.2 | 735.9 | 496.6 | 862.8 | 390.7 | 390.7 | 470.1 | 616.3 | 767.6 | 862.8 | 479.2 | 873.2 | 524.5 | 404.2 | 404.2 | 460.5 | 501.9 | 611.7 | 873.2 |
| 94 | 87.9 | 1,071.8 | 188.2 | 246.1 | 363.5 | 188.2 | 231.6 | 304.8 | 540.6 | 1,071.8 | 411.5 | 377.1 | 298.4 | 223.3 | 223.3 | 279.6 | 337.8 | 385.7 | 411.5 |
| 95 | 421.4 | 611.4 | 1,473.2 | 1,049.7 | 699.2 | 611.4 | 677.3 | 874.5 | 1,155.6 | 1,473.2 | 1,170.5 | 551.7 | 649.2 | 653.1 | 551.7 | 624.8 | 651.2 | 782.5 | 1,170.5 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 96 | 35.2 | 257.5 | 46.8 | 389.3 | 94.3 | 46.8 | 82.4 | 175.9 | 290.5 | 389.3 | 36.5 | 235.2 | 146.2 | 118.8 | 36.5 | 98.2 | 132.5 | 168.5 | 235.2 |
| 97 | 116.0 | 995.2 | 135.6 | 493.3 | 289.4 | 135.6 | 251.0 | 391.4 | 618.8 | 995.2 | 256.4 | 208.6 | 290.5 | 909.5 | 208.6 | 244.5 | 273.5 | 445.3 | 909.5 |
| 98 | 44.5 | 144.2 | 103.4 | 131.3 | 208.0 | 103.4 | 124.3 | 137.8 | 160.2 | 208.0 | 215.4 | 337.6 | 235.6 | 141.9 | 141.9 | 197.0 | 225.5 | 261.1 | 337.6 |
| 99 | 59.2 | 130.1 | 102.1 | 464.6 | 545.6 | 102.1 | 123.1 | 297.4 | 484.9 | 545.6 | 421.3 | 130.2 | 265.8 | 97.6 | 97.6 | 122.1 | 198.0 | 304.7 | 421.3 |

**Timing Intervals for Each Refresh Function (In Seconds)**

| DM Fx | R-Run 1 | R-Run 2 | R-Run 3 | R-Run 4 | Min | 25%tile | Median | 75%tile | Max |
|---|---|---|---|---|---|---|---|---|---|
| LF_CR | 46.3 | 38.5 | 42.9 | 41.1 | 38.5 | 40.5 | 42.0 | 43.8 | 46.3 |
| LF_CS | 265.2 | 261.0 | 279.5 | 267.2 | 261.0 | 264.2 | 266.2 | 270.3 | 279.5 |
| LF_I | 84.0 | 90.3 | 49.0 | 80.2 | 49.0 | 72.4 | 82.1 | 85.6 | 90.3 |
| LF_SR | 46.7 | 39.4 | 39.4 | 40.5 | 39.4 | 39.4 | 40.0 | 42.1 | 46.7 |
| LF_SS | 375.2 | 345.9 | 346.4 | 363.0 | 345.9 | 346.3 | 354.7 | 366.1 | 375.2 |
| LF_WR | 31.5 | 36.0 | 36.1 | 36.3 | 31.5 | 34.9 | 36.1 | 36.2 | 36.3 |
| LF_WS | 166.1 | 171.4 | 182.7 | 175.6 | 166.1 | 170.1 | 173.5 | 177.4 | 182.7 |
| DF_CS | 330.2 | 344.3 | 368.4 | 355.2 | 330.2 | 340.8 | 349.8 | 358.5 | 368.4 |
| DF_SS | 358.7 | 358.4 | 357.1 | 376.6 | 357.1 | 358.1 | 358.6 | 363.2 | 376.6 |
| DF_WS | 329.2 | 325.5 | 335.1 | 364.6 | 325.5 | 328.3 | 332.2 | 342.5 | 364.6 |
| DF_I | 121.2 | 137.7 | 113.2 | 139.6 | 113.2 | 119.2 | 129.5 | 138.2 | 139.6 |

# Preface

## TPC Benchmark™ DS Overview

The TPC Benchmark™ DS (TPC-DS) is a decision support benchmark that models several generally applicable aspects of a decision support system, including queries and data maintenance. The benchmark provides are presentative evaluation of performance as a general purpose decision support system.

This benchmark illustrates decision support systems that:

- Examine large volumes of data;
- Give answers to real-world business questions;
- Execute queries of various operational requirements and complexities (e.g., ad-hoc, reporting, iterative OLAP, data mining);
- Are characterized by high CPU and IO load;
- Are periodically synchronized with source OLTP databases through database maintenance functions.
- Run on “Big Data” solutions, such as RDBMS as well as Hadoop/Spark based systems.

A benchmark result measures query response time in single user mode, query throughput in multi user mode and data maintenance performance for a given hardware, operating system, and data processing system configuration under a controlled, complex, multi-user decision support workload.

The purpose of TPC benchmarks is to provide relevant, objective performance data to industry users. To achieve that purpose, TPC benchmark specifications require benchmark tests be implemented with systems, products, technologies and pricing that:

a) Are generally available to users;
b) Are relevant to the market segment that the individual TPC benchmark models or represents (e.g., TPC-DS models and represents complex, high data volume, decision support environments);
c) Would plausibly be implemented by a significant number of users in the market segment modeled or represented by the benchmark.

In keeping with these requirements, the TPC-DS database must be implemented using commercially available data processing software, and its queries must be executed via SQL interface. The use of new systems, products, technologies (hardware or software) and pricing is encouraged so long as they meet the requirements above. Specifically prohibited are benchmark systems, products, technologies or pricing (hereafter referred to as "implementations") whose primary purpose is performance optimization of TPC benchmark results without any corresponding applicability to real-world applications and environments. In other words, all "benchmark special" implementations, which improve benchmark results but not real-world performance or pricing, are prohibited.

TPC benchmark results are expected to be accurate representations of system performance. Therefore, there are specific guidelines that are expected to be followed when measuring those results. The approach or methodology to be used in the measurements are either explicitly described in the specification or left to the discretion of the test sponsor.

When not described in the specification, the methodologies and approaches used must meet the following requirements:

- The approach is an accepted engineering practice or standard;
- The approach does not enhance the result;
- Equipment used in measuring the results is calibrated according to established quality standards;
- Fidelity and candor is maintained in reporting any anomalies in the results, even if not specified in the benchmark requirements.

Further information is available at http://www.tpc.org/

# General Items

## 0.1 Test Sponsor

*A statement identifying the benchmark sponsor(s) and other participating companies must be provided.*

This benchmark was sponsored by Alibaba Cloud Computing Ltd.

## 0.2 Parameter Settings

*Settings must be provided for all customer-tunable parameters and options which have been changed from the defaults found in actual products, including by not limited to:*

- *Database Tuning Options*
- *Optimizer/Query execution options*
- *Query processing tool/language configuration parameters*
- *Recovery/commit options*
- *Consistency/locking options*
- *Operating system and configuration parameters*
- *Configuration parameters and options for any other software component incorporated into the pricing structure*
- *Compiler optimization options*

*This requirement can be satisfied by providing a full list of all parameters and options, as long as all those which have been modified from their default values have been clearly identified and these parameters and options are only set once.*

The Supporting File Archive (Clause 8) contains the Operating System and DBMS parameters used in this benchmark.

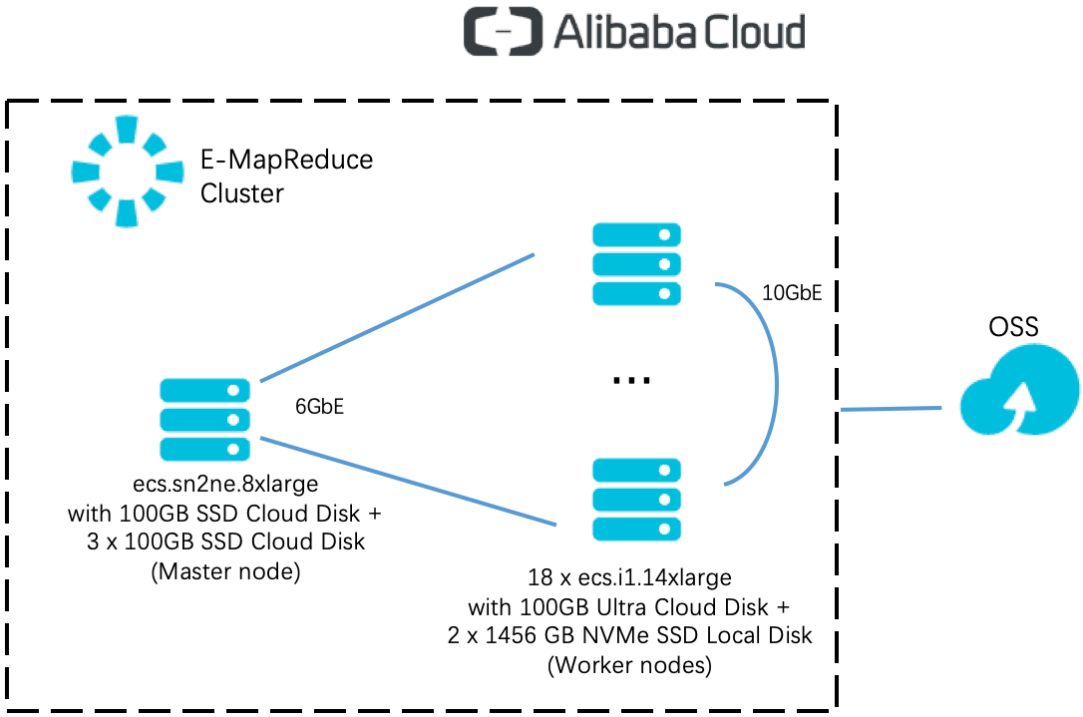
## 0.3 Configuration Diagrams

*Diagrams of both measured and priced configurations must be provided, accompanied by a description of the differences. This includes, but is not limited to:*

- *Number and type of processors*
- *Size of allocated memory, and any specific mapping/partitioning of memory unique to the test. Number and type of disk units (and controllers, if applicable).*
- *Number of channels or bus connections to disk units, including their protocol type.*
- *Number of LAN (e.g. Ethernet) Connections, including routers, workstations, terminals, etc., that were physically used in the test or are incorporated into the pricing structure.*
- *Type and the run-time execution location of software components (e.g., DBMS, query processing tools/languages, middle-ware components, software drivers, etc.).*

### Measured Configuration

**Figure 0.3: Measured Configuration**




The measured configuration consisted of 19 Nodes:

Master node details (1 node):

- ECS Instance Type: ecs.sn2ne.8xlarge
- Processors/Cores/Threads: 1/16/32
- Processor Model: Intel(R)Xeon(R) Platinum 8163 CPU @ 2.50GHz, 33 MB L3
- Memory: 128 GB
- Storage:
  - 3 x 100 GB SSD Cloud Disk (data disk)
  - 1 x 100 GB SSD Cloud Disk (boot disk)
- Network:
  - Bandwidth (Gbit/s): 6.0
  - Packet forwarding rate (Thousand pps): 2,500
  - NIC queues: 8
  - ENIs: 8

Worker nodes details (18 nodes):

- ECS Instance Type: ecs.i1.14xlarge
- Processors/Cores/Threads: 1/28/56
- Processor Model: Intel(R)Xeon(R) CPU E5-2682 v4 @ 2.50GHz, 40 MB L3
- Memory: 224 GB
- Storage:
  - 2 x 1456 GB NVMe SSD Local Disk (data disk)
  - 1 x 100 GB Ultra Cloud Disk (boot disk)
- Network:
  - Bandwidth (Gbit/s): 10.0
  - Packet forwarding rate (Thousand pps): 1,200
  - NIC queues: 4

- ENIs: 8

OSS Storage details:

- Storage Class: Standard Storage
- Storage Capacity: 10TB
- API Requests Read: 1,000,000 / Day
- API Requests Write: 1,000,000 / Day

**EMR System Components Configuration**

| | HDFS | | YARN | | Smartdata | | Spark | |
|---|---|---|---|---|---|---|---|---|
| | NameNode | DataNode | Resource Manager | Node Manager | Server | Worker | Thrift Server | Executor |
| Master | x | | x | | x | | x | |
| Worker 1-18 | | x | | x | | x | | x |

## Priced Configuration

There are no differences between the priced and measured configurations.

# Clause 2: Logical Database Design Related Items

## 2.1 Database Definition Statements

*Listings must be provided for the DDL scripts and must include all table definition statements and all other statements used to set up the test and qualification databases.*

The Supporting File Archive contains the table definitions and all other statements used to set up the test and qualification databases.

## 2.2 Physical Organization

*The physical organization of tables and indices within the test and qualification databases must be disclosed. If the column ordering of any table is different from that specified in Clause2.3 or 2.4, it must be noted.*

The store_sales, store_returns, catalog_sales, catalog_returns, web_sales, web_returns and inventory are partitioned. The partition columns for these tables respectively are ss_sold_date_sk, sr_returned_date_sk, cs_sold_date_sk, cr_returned_date_sk, ws_sold_date_sk, wr_returned_date_sk and inv_date_sk.

## 2.3 Horizontal Partitioning

*If any directives to DDLs are used to horizontally partition tables and rows in the test and qualification databases, these directives, DDLs, and other details necessary to replicate the partitioning behavior must be disclosed.*

Horizontal partitioning is used on store_sales, store_returns, catalog_sales, catalog_returns, web_sales, web_returns and inventory tables and the partitioning columns are ss_sold_date_sk, sr_returned_date_sk, cs_sold_date_sk, cr_returned_date_sk, ws_sold_date_sk, wr_returned_date_sk and inv_date_sk. The partition granularity is by day.

## 2.4 Replication

*Any replication of physical objects must be disclosed and must conform to the requirements of Clause 2.5.3.*

All the data are stored in three replicas, one on OSS for high reliability and two on local drives for redundancy of access with excellent performance. The OSS replica has a guaranteed reliability of 99.999999999%.

# Clause 3: Scaling and Database Population

## 3.1 Initial Cardinality of Tables

*The cardinality (e.g., the number of rows) of each table of the test database, as it existed at the completion of the database load (see Clause 7.1.2) must be disclosed.*

Table 3.1 lists the cardinality of each table as they existed upon completion of the build.

**Table 3.1 Initial Number of Rows**

| Table Name | Row Count |
|---|---|
| call_center | 54 |
| catalog_page | 40,000 |
| catalog_returns | 1,440,033,112 |
| catalog_sales | 14,399,964,710 |
| customer | 65,000,000 |
| customer_address | 32,500,000 |
| customer_demographics | 1,920,800 |
| date_dim | 73,049 |
| household_demographics | 7,200 |
| income_band | 20 |
| inventory | 1,311,525,000 |
| item | 402,000 |
| promotion | 2,000 |
| reason | 70 |
| ship_mode | 20 |
| store | 1,500 |
| store_returns | 2,879,544,876 |
| store_sales | 28,799,901,788 |
| time_dim | 86,400 |
| warehouse | 25 |
| web_page | 4,002 |
| web_returns | 720,020,485 |
| web_sales | 7,199,963,324 |
| web_site | 78 |

## 3.2 Distribution of Tables and Logs Across Media

*The distribution of tables and logs across all media must be explicitly described using a format similar to that shown in the following example for both the tested and priced systems.*

**Table 3.2 Distribution of Tables and Logs**

| Server Node | Disk Type | Disk drive | Description of Content |
|---|---|---|---|
| emr-header-1 | SSD Cloud Disk | /dev/vdb (/mnt/disk1) | logs |
| emr-header-1 | SSD Cloud Disk | /dev/vd{c,d} (/mnt/disk2 RAID-1) | Hive metadata, HDFS metadata and SmartFs metadata |
| emr-worker-{1 - 18} | Local SSD Disk | /dev/vd{b,c} (/mnt/disk[1-2]) | logs, temp files, cache, replica of table data (See Section 3.4) |
| emr-header-1 | SSD Cloud Disk | /dev/vda | Operating system, root directory, EMR software |
| emr-worker-{1 - 18} | Ultra Cloud Disk | /dev/vda | Operating system, root directory, EMR software |
| Remote Web Service | OSS | N/A | Replica of table data (See Section 3.4) |

All the Table contents were on SmartFS. Table size on SmartFS:

155.2 K smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/call_center
2.5 M smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/catalog_page
114.2 G smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/catalog_returns
1.0 T smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/catalog_sales
3.8 G smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/customer
835.4 M smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/customer_address
20.2 M smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/customer_demographics
2.1 M smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/date_dim
98.6 K smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/household_demographics
27.3 K smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/income_band
11.3 G smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/inventory
39.0 M smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/item
215.4 K smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/promotion
31.5 K smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/reason
41.0 K smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/ship_mode
329.4 K smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/store
152.5 G smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/store_returns
1.4 T smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/store_sales
1.5 M smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/time_dim
73.0 K smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/warehouse
172.6 K smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/web_page
56.4 G smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/web_returns
483.9 G smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/web_sales
143.7 K smartfs://emr-cluster/user/hive/warehouse/tpcds_smartfs_parquet_10000.db/web_site

## 3.3 Mapping of Database Partitions/Replications

*The mapping of database partitions/replications must be explicitly described.*

Neither database partitions nor replications are mapped to specific devices.

## 3.4 Implementation of RAID

*Implementations may use some form of RAID. The RAID level used must be disclosed for each device. If RAID is used in an implementation, the logical intent of its use must be disclosed*

The database tables were on top of SmartData Filesystem (SmartFS). SmartFS maintains 3 copies of table data. The master copy and 1 replica are stored on local worker node devices and 1 replica is stored onto Alibaba Cloud Object Storage Service (OSS). Note for better performance, more than 1 local replicas can be configured, and the use of OSS provides additional high data reliability, guaranteed to be 99.999999999%.

For the database and file system metadata, they are stored on a RAID-1 device, which is built on top of 2 local drives of the master node.

## 3.5 DBGEN Modifications

*The version number (i.e., the major revision number, the minor revision number, and third tier number) of dsdgen must be disclosed. Any modifications to the dsdgen source code (see Appendix B:) must be disclosed. In the event that a program other than dsdgen was used to populate the database, it must be disclosed in its entirety.*

Dsdgen version 2.10.1 was used. Two minor changes are made to the dsdgen tool. To reduce the dsdgen execution time, the dsdgen code is wrapped as a Map/Reduce job. The wrapper does not change any of the TPC-provided code. Patches for dsdgen tool and the wrapper with source codes were included in the Supporting Files.

## 3.6 Database Load time

*The database load time for the test database (see Clause 7.4.3.7) must be disclosed.*

The database load time was 5,194.2 seconds.

## 3.7 Data Storage Ratio

*The data storage ratio must be disclosed. It is computed by dividing the total data storage of the priced configuration (expressed in GB) by SF corresponding to the scale factor chosen for the test database as defined in Clause 3.1. The ratio must be reported to the nearest 1/100th, rounded up. For example, a system configured with 96 disks of 2.1 GB capacity for a 100GB test database has a data storage ratio of 2.02.*

The data storage ratio is (54,616 + 10,240) / 10,000 = 6.49.

Total Storage Capacity (Disk) = (100 + 100 * 3) (Master node) + (100 + 1,456 * 2) * 18 (Worker nodes) = 54,616 GB

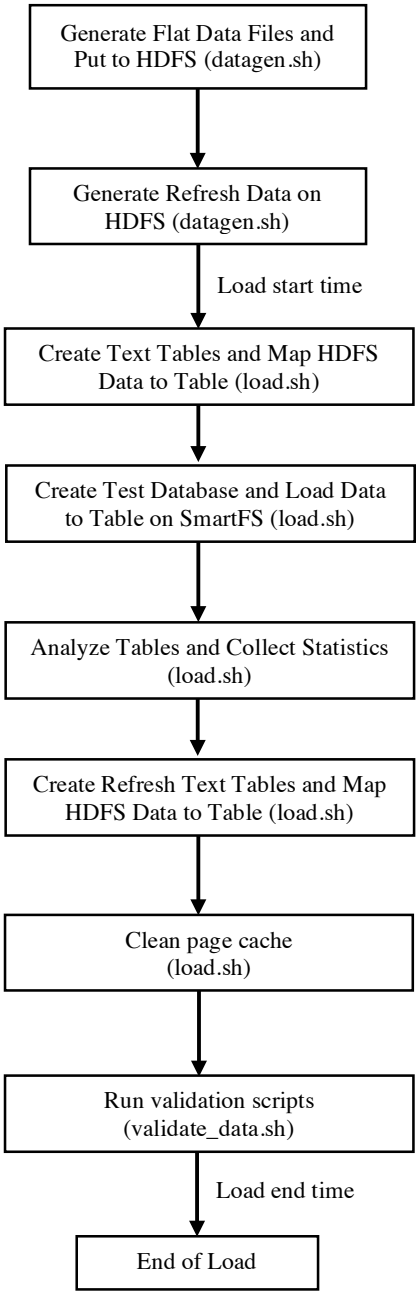
Total Storage Capacity (OSS) = 10 * 1,024 = 10,240 GB

## 3.8 Database Load Mechanism Details and Illustration

*The details of the database load must be disclosed, including a block diagram illustrating the overall process. Disclosure of the load procedure includes all steps, scripts, input and configuration files required to completely reproduce the test and qualification databases.*

The tables were loaded as shown in Figure 3.8. All of the related source code and scripts are included in the Supporting Files.

**Figure 3.8: Block Diagram of Database Load Process**




The final database load time is (load end time – load start time – duration of validation scripts).

## 3.9 Qualification Database Configuration

*Any differences between the configuration of the qualification database and the test database must be disclosed.*

The qualification database is created using the same scripts as the test database with the following exceptions:

- The Scale factor is adjusted to 1GB
- The script create_qual_text_tables.sql is used instead of create_text_tables.sql to build the database on the local node.

All of the related source code and scripts are included in the Supporting Files.

# Clause 4 and 5: Query and Data Maintenance Related Items

## 4.1 Query Language

*The query language used to implement the queries must be identified.*

SQL was the query language used to implement the queries.

## 4.2 Verifying Method of Random Number Generation

*The method of verification for the random number generation must be described unless the supplied dsdgen and dsqgen were used.*

A map/reduce wrapper based on TPC-supplied dsdgen version 2.10.1 and dsqgen version 2.10.1 were used.

## 4.3 Generating Values for Substitution Parameters

*The method used to generate values for substitution parameters must be disclosed. The version number (i.e., the major revision number, the minor revision number, and third tier number) of dsqgen must be disclosed.*

TPC supplied dsqgen version 2.10.1 was used to generate the substitution parameters:

```
./dsqgen -directory ../query_templates -input ../query_templates/templates.lst -scale 10000 -streams 9 -output_dir ../../queries -dialect sparksql -rngseed $SEED
```

## 4.4 Query Text and Output Data from Qualification Database

*The executable query text used for query validation must be disclosed along with the corresponding output data generated during the execution of the query text against the qualification database. If minor modifications have been applied to any functional query definitions or approved variants in order to obtain executable query text, these modifications must be disclosed and justified. The justification for a particular minor query modification can apply collectively to all queries for which it has been used. The output data for the power and Throughput Tests must be made available electronically upon request.*

Supporting Files Archive contains the actual query text and query output. Following are the modifications to the query.

The following MQM are used:

- Use vendor specific string concatenation operator. (MQM c.3)
  - Q5
  - Q66
  - Q80
  - Q84
- Use vendor-specific syntax of date expressions. (MQM f.1)
  - Q5
  - Q12
  - Q16
  - Q20
  - Q21
  - Q32
  - Q37
  - Q40
  - Q77

  - Q80
  - Q82
  - Q94
  - Q95
  - Q98
- Use back quotes instead of double quotes to delimit column names. (MQM e.1)
  - Q16
  - Q32
  - Q50
  - Q62
  - Q94
  - Q95
  - Q99

Query results are inserted in a file (Clause 4.2.5) using an external table with column delimiter

  - Q64 with an external table named q64_result_[s](stream[s])

The Supporting Files Archive contains the full set of executable query text template used in the test.

## 4.5 Query Substitution Parameters and Seeds Used

*All the query substitution parameters used during the performance test must be disclosed in tabular format, along with the seeds used to generate these parameters.*

The Supporting Files Archive contains the query substitution parameters and seed used in the test.

## 4.6 Refresh Setting

*All query and refresh session initialization parameters, settings and commands must be disclosed.*

The Supporting Files Archive contains the query and scripts, along with initialization parameters and settings.

## 4.7 Source Code of Refresh Functions

*The details of how the data maintenance functions were implemented must be disclosed (including source code of any non-commercial program used).*

The Supporting Files Archive contains the source code implementing the refresh functions.

## 4.8 Staging Area

*Any object created in the staging area (see Clause 5.1.8 for definition and usage restrictions) used to implement the data maintenance functions must be disclosed. Also, any disk storage used for the staging area must be priced, and any mapping or virtualization of disk storage must be disclosed.*

No staging area was used.

# Clause 6: Data Persistence Properties Related Items

*The results of the data accessibility tests must be disclosed along with a description of how the data accessibility requirements were met.*

The data accessibility test was performed by failing a disk drive on one worker node, failing the network access to OSS on another worker node and failing one disk in the RAID-1 volume on the master node. These failures were included during the execution of the first data maintenance test.

The worker disk failure was simulated by removing and invalidating the corresponding data directory on the disk, the OSS network access failure was simulated by corrupting the endpoint configuration, and the master disk failure was simulated via the Linux utility mdadm. After the failures, the test continued to run until completion.

The Supporting Files Archive contains the logs of status before and after the disk and OSS network access failures.

# Clause 7: Performance Metrics and Execution Rules Related Items

## 7.1 System Activity

*Any system activity on the SUT that takes place between the conclusion of the load test and the beginning of the performance test must be fully disclosed including listings of scripts or command logs.*

There only activity between the end of the load test and the beginning of the performance test was the generation of the executable query text.

## 7.2 Test Steps

*The details of the steps followed to implement the performance test must be disclosed.*

The Supporting Files Archive contains the scripts and logs.

## 7.3 Timing Intervals for Each Query and Refresh Function

*The timing intervals defined in Clause 7 must be disclosed.*

See the Executive Summary at the beginning of this report.

## 7.4 Throughput Test Result

*For each Throughput Test, the minimum, the 25th percentile, the median, the 75th percentile, and the maximum times for each query shall be reported.*

See the Executive Summary at the beginning of this report.

## 7.5 Time for Each Stream

*The start time and finish time for each query stream must be reported.*

See the Executive Summary at the beginning of this report.

## 7.6 Time for Each Refresh Function

*The start time and finish time for each data maintenance function in the refresh run must be reported for the Throughput Tests*

See the Executive Summary at the beginning of this report.

## 7.7 Performance Metrics

*The computed performance metric, related numerical quantities and the price/performance metric must be reported.*

QphDS@10000GB = 1,824,283

See the Executive Summary at the beginning of this report for more detail.

# Clause 8: SUT and Driver Implementation Related Items

## 8.1 Driver

*A detailed textual description of how the driver performs its functions, how its various components interact and any product functionalities or environmental settings on which it relies must be provided. All related source code, scripts and configuration files must be disclosed. The information provided should be sufficient for an independent reconstruction of the driver.*

beeline is the client of EMR Spark. It connects to the Spark Thrift Server by JDBC. The command is:

```
beeline -u jdbc:hive2://localhost:10001 -f sqlfile
```

The Spark Thrift Server accepts SQL queries from the beeline clients and processes the queries. The Thrift Server manages multiple executor nodes. All queries are compiled on the Thrift Server and then submitted to the Spark Executors as a job. When the job finishes, the Thrift Server takes the result from the Executors and sends it to beeline.

In the test, emr-header-1 is configured as the Spark Thrift Server, and all the EMR workers are configured as Spark Executors.

The Supporting Files Archive contains all the command, scripts and logs.

## 8.2 Implementation Specific Layer (ISL)

*If an implementation specific layer is used, then a detailed description of how it performs its functions, how its various components interact and any product functionalities or environmental setting on which it relies must be provided. All related source code, scripts and configuration files must be disclosed. The information provided should be sufficient for an independent reconstruction of the implementation specific layer.*

No Implementation Specific Layer was used.

## 8.3 Profile-Directed Optimization

*If profile-directed optimization as described in Clause 7.2.10 is used, such use must be disclosed. In particular, the procedure and any scripts used to perform the optimization must be disclosed.*

Profile-directed optimization was not used.

# Clause 9: Pricing Related Items

## 9.1 Hardware and Software Used

*A detailed list of hardware and software used in the priced system must be reported. The rules for pricing are included in the current revision of the TPC Pricing Specification located on the TPC website (http://www.tpc.org)*

A detailed list of all licensed services, hardware and software, is provided in the Executive Summary of this report.

## 9.2 Availability Date

*The System Availability Date (see Clause 7.6.5) must be the single availability date reported on the first page of the executive summary. The full disclosure report must report Availability Dates individually for at least each of the categories for which a pricing subtotal must be. All Availability Dates required to be reported must be disclosed to a precision of 1 day, but the precise format is left to the test sponsor.*

The total system is available as of the date of this report.

## 9.3 Country-Specific Pricing

*Additional Clause 7 related items may be included in the full disclosure report for each country specific priced configuration.*

The configuration is priced for the US market.

# Clause 11: Audit Related Items

## Auditor's Information and Attestation Letter

*The auditor's agency name, address, phone number, and attestation letter with a brief audit summary report indicating compliance must be included in the full disclosure report. A statement should be included specifying whom to contact in order to obtain further information regarding the audit process.*

This benchmark was audited by: Francois Raab, of InfoSizing.

InfoSizing

TPC Certified Auditor

Benchmark sponsor:

Wu Wei
Alibaba Cloud Computing Ltd.
969 West Wen Yi Road
Yu Hang District, Hangzhou,
Zhejiang
China

March 15, 2019

I verified the TPC Benchmark™ DS (TPC-DS™ v2.10.1) performance of the following configuration:

| | |
|---|---|
| Platform: | Alibaba Cloud E-MapReduce |
| Operating System: | CentOS Linux Release 7.4 |
| Database Manager: | Alibaba Cloud E-MapReduce 3.16.1 |

The results were:

| | |
|---|---|
| **Performance Metric** | **1,824,283 QphDS@10000GB** |
| Database Load Time | 1h 26m 34s |

**Servers** — **Alibaba Cloud Elastic Compute Service Server**

**1 Master Node, with:**

| | | | |
|---|---|---|---|
| CPUs | 1 x Intel Xeon Platinum 8163 (2.50GHz, 33MB L3) | | |
| Memory | 128 GB | | |
| Disks | ***Qty*** | ***Size*** | ***Type*** |
| | 1 | 100 GB | SSD Cloud Disk (boot) |
| | 3 | 100 GB | SSD Cloud Disk (data) |

**18 Worker Nodes, with:**

| | | | |
|---|---|---|---|
| CPUs | 1 x Intel Xeon E5-2682 v4 (2.5GHz, 40MB L3) | | |
| Memory | 224 GB | | |
| Disks | ***Qty*** | ***Size*** | ***Type*** |
| | 1 | 100 GB | SSD Ultra Cloud Disk (boot) |
| | 2 | 1,456 GB | NVMe SSD Local Disk (data) |

In my opinion, these performance results were produced in compliance with the TPC requirements for the benchmark.

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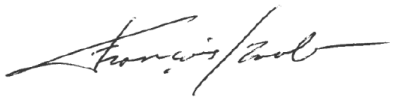
The following verification items were given special attention:

- The database records were defined with the proper layout and size
- The database population was generated using Dsdgen
- The database was properly scaled to 10,000GB and populated accordingly
- The database load time was correctly measured and reported
- The query templates were produced using approved minor query modifications and query variants
- The query input variables were generated by Dsqgen
- The execution of the queries against the qualification database produced compliant output
- The tests were driven and sequenced according to the requirements
- The throughput tests involved 4 query streams
- The execution times for queries and data maintenance functions were correctly measured and reported
- The data accessibility test was performed and verified
- The system pricing was verified for major components and maintenance
- The major pages from the FDR were verified for accuracy

Additional Audit Notes:

In the course of the benchmark execution and the independent audit process, a number of issues were raised with the benchmark maintenance subcommittee. These issues were resolved, sometimes resulting in changes to the benchmark specification. While this result was audited against version 2.10.1 of the benchmark, it also takes advantage of some pending changes that are intended for release in the next version of the benchmark.

Respectfully Yours,



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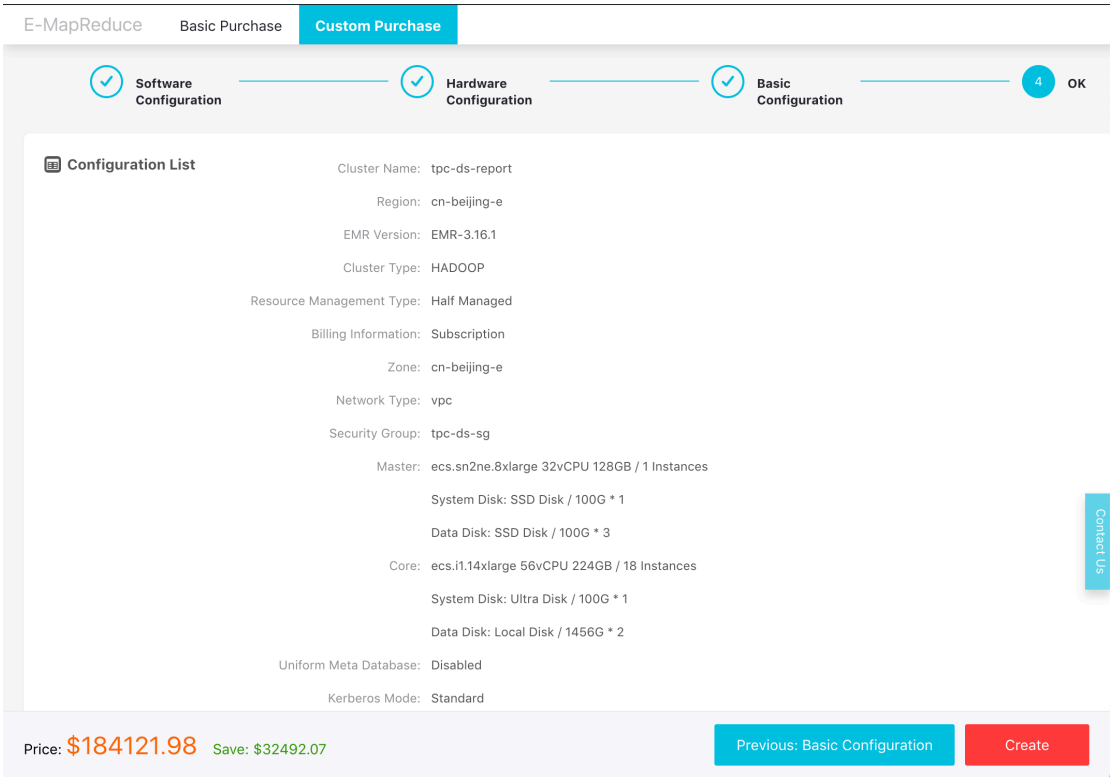
# Supporting Files Index

| Clause | Description | Archive File Pathname |
|---|---|---|
| Clause 3 | Database create and load scripts, SQL scripts for table creation and validation | SupportingFiles/Clause_3/ |
| | The code for the Map/Reducer wrapper of dsdgen | SupportingFiles/Clause_3/datagen |
| | Patches for data generation tools | SupportingFiles/Clause_3/patches/tools/ |
| Clause 4 | The script to execute qualification test | SupportingFiles/Clause_4/ |
| | Patches for query templates | SupportingFiles/Clause_4/patches/query_templates/ |
| | SQL for qualification queries | SupportingFiles/Clause_4/queries/ |
| | Output from executing qualification queries | SupportingFiles/Clause_4/output/ |
| Clause 5 | Data maintenance execution scripts and logs files | SupportingFiles/Clause_5/ |
| | SQL scripts for DM functions for stream [s] | SupportingFiles/Clause_5/mtsqls_[s]/ |
| | Data file with delete dates | SupportingFiles/Clause_5/delete/ |
| | | SupportingFiles/Clause_5/inventory_delete/ |
| Clause 6 | Data accessibility test scripts and logs | SupportingFiles/Clause_6/ |
| Clause 7 | Performance test scripts and logs | SupportingFiles/Clause_7/ |
| | Query text for query [q] in stream [s] | SupportingFiles/Clause_7/stream_[s]_queries/query_[q].sql |
| | Output of query [q] in stream [s] (top 500) | SupportingFiles/Clause_7/stream_[s]_results/query_[q].out |
| Clause 8 | EMR Configuration Inventory | SupportingFiles/Clause_8/ |

# Appendix A: Purchase Page of Creating Alibaba Cloud E-MapReduce Cluster with 1-Year Subscription



## Appendix B: Alibaba Cloud Object Storage Service Price Quotes

Wei Wu,

Here is the information you requested regarding pricing for Alibaba Cloud Object Store Service.

All pricing shown is in US Dollars ($) and can be pre-paid.

| Product Name | Region | Resource Quota | 1 Year Price ($) |
|---|---|---|---|
| Alibaba Cloud Object Storage Service | China North 2 (Beijing) | 1. Standard Storage: 10TB<br>2. API Requests:<br>Read 1,000,000/Day<br>Write 1,000,000/Day | 2240.24 |

If you have any questions about this price quote, please contact our sales via the link: https://www.alibabacloud.com/contact-sales.

Huajian Wu (Alibaba Cloud OSS Product Manager)
(huajian.whj@alibaba-inc.com)

# Appendix C: Third Party Price Quotes

Lenovo 120S-14IAP Laptop