ivy dedupe / compression support

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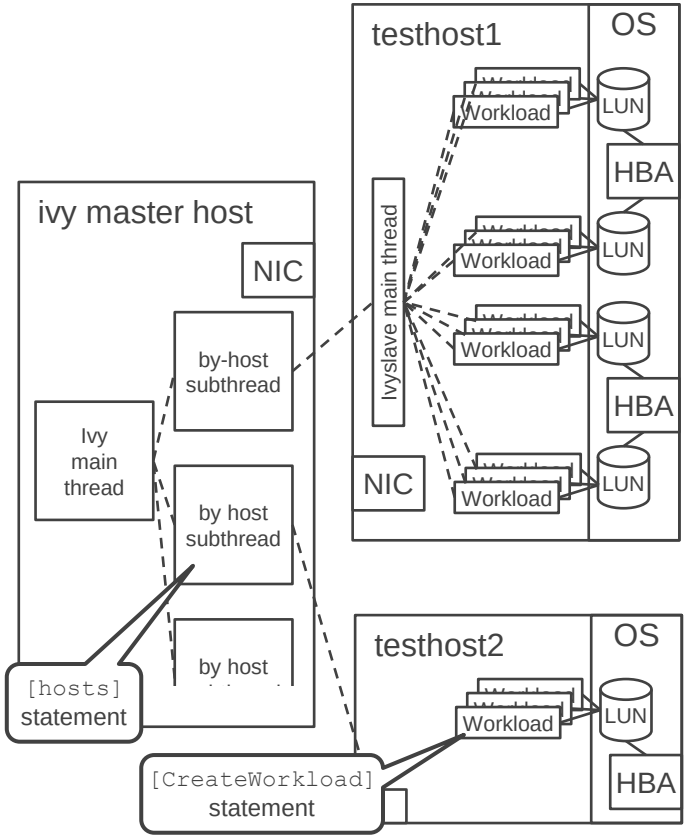
Review



- In ivy, you can layer multiple named “workload” I/O generator threads on LUNs
- A "workload name" is unique on each host LUN.
- ```
  [CreateWorkload]     "owl"
        [select]       "port" is { "1A", "2A" }
        [iogenerator]  "random_steady"
        [parameters]   "IOPS=max,
                        fraction_read=\"50%\",
                        blocksize = \"4KiB\" ";
  ```
  - This creates a workload thread called "owl" on each host LUN that is mapped to port 1A or port 2A.
- Each workload thread uses an I/O sequencer plug-in that generates I/Os in scheduled I/O start time sequence.
  ```

.ivyscript dedupe syntax

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```
[CreateWorkload]  "owl"
     [select]      "port" is "1A"
     [iogenerator] "random_steady"
     [parameters]  "IOPS=max,fraction_read=\"50%\",
                    blocksize = \"4KiB\"
                    dedupe = 1.5 ";
```

- The dedupe parameter (default `dedupe = 1.0`) controls the average number of copies of a generated pattern that is written across the set of workload threads each mapped to a LUN on a test host with the same workload name (e.g. "`owl`")
  - `dedupe` must set to a value greater than or equal to 1.0
  - It is an error if some workload threads are set to a different `dedupe` value than other workload threads with the same name.
  - The `dedupe` parameter is ignored for `fraction_read = 100%`.

.ivyscript compressibility syntax

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```
[CreateWorkload]  "owl"
     [select]      "port" is "1A"
     [iogenerator] "random_steady"
     [parameters]  "IOPS=max,fraction_read=\"50%\",
                    blocksize = \"4KiB\"
                    pattern = random ";
```

- The `pattern` parameter selects a pattern generator to fill the contents of a block before it is written to the LUN.
- The default is `pattern = random`.

.ivyscript pattern parameter

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- `pattern = random`
  - Random binary noise. Not compressible. This is the ivy default
- `pattern = trailing_zeros, compressibility = 50%`
  - Each block has an incompressible section and a section with repeated zeros.
  - `compressibility` specifies the % of the block that is repeating zeros.
- `pattern = ascii`
  - Random ascii characters. Fixed degree of compressibility
- `pattern = gobbledegook`
  - Pseudo-English text generated by randomly selecting words from a dictionary.
  - Fixed degree of compressibility.

Using the first 32 Ki Words appearing in the 1913 public domain edition of Webster's dictionary.

pattern=random

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```
offset 0x0000     0 "..G.n....:%.~wuH/...f.cM......6." (ffd44709 6ecaf4c6 fb3a25be 7e777548 2fa3c79b 66a2634d 9b04101f 1dab36ef)
offset 0x0020    32 "......N.\QL..I......?.....~.j.U4" (e816f69a 7f0a4e1b 5c514ce4 e549c1a4 90dd0cc5 3f13ba91 [illegible]
offset 0x0040    64 "~.p...!<.Z.=..#;P....7...|>*..Q." (7e89701e bf84213c 1d5ae83d e184233b 50e6aeff 0f370bec [illegible]
offset 0x0060    96 "..}..Z/.;}q.../.$..2...p.....JE." (b81d7d87 135a2fc7 3b7d71fc 10e62fce 24b60532 96d58370 [illegible]
offset 0x0080   128 ".4.I3.M....h].....I0...;..V$".l" (8434e949 33d64d02 dbed9d68 5df512ee 97a51949 3098881e [illegible]
offset 0x00a0   160 ".......h.#l[..G.n....<....be.:.e" (d7e40db2 9b0fc868 1a236c5b e29147d5 6e9ba8c3 ef3c10aa [illegible]
offset 0x00c0   192 ".../......w.....y~W%;Ao..[x..Y.A" (d2c9a32f 17c099c2 b092779a e9c2f8af 797e5725 3b416f15 [illegible]
offset 0x00e0   224 "...?\..{.H/mw.}F.....G.P.Y.v+.\." (f4e1913f 5cd1147b c1482f6d 77b27d46 8d97a484 ba478d50 [illegible]
offset 0x0100   256 "..+M..Q.+..n~.t...v..i...s.^=k.G" (92152b4d 95d251dc 2b10b76e 7ea87409 ede576ed 0869cfa9 [illegible]
offset 0x0120   288 "...b.8r`P{9....a.\]@@.*P%....$.=" (94aff162 9a387260 507b390c ee80e961 1e5c5d40 408c2a50 [illegible]
offset 0x0140   320 "..||>.........MV.J.&..S._7..f._." (ad1d7c7c 3eeb14ef f6aae09b 0f1c4d56 e84ae126 1ed65319 [illegible] 66c45ff1)
offset 0x0160   352 "..H..z.AB...,...$......=.CZ....|" (890948a3 d07aee41 42b91aed 2c9de494 2497ccc2 1da2e[illegible] 82435aa2 cdd08f7c)
offset 0x0180   384 ".\.\.......& ...O.&#....+s.?..0'" (125c925c e59fe31c f60fc926 20f0be09 4f932623 [illegible] 48687d6 2b73113f b4e43027)
offset 0x01a0   416 "....^.R..|......stq$....|......." (a9a6d3d3 5e8c527f 817cc7e8 d88c92be 73747124 c19ae1b3 7ce3d6fe f00d98a5)
offset 0x01c0   448 ".1t...I.A[S[.c.....\........l_.x" (8a3174a6 0ddd49e6 415b535b 9b638f05 d1f08d5c 8d97a9db 85181698 6c5fae78)
offset 0x01e0   480 ".Y.P.<...w.hb>.n&..d.IE}e.w..g.b" (f0590f50 cc3ceffe bb77e368 623eb26e 2612f664 db49457d 65ae77a2 9467f462)
offset 0x0200   512 "W..g...L&V#....+.q}..,3........." (57e49d67 b18cd74c 26562304 8094ba2b 06717dea d72c33cc ddf5b4c1 098f0b1e)
offset 0x0220   544 "..[.m....dN..lw...5o....f..C...." (d0c85ba9 6de71307 9c644ead fe6c7704 c8ac356f ba12d7d3 66b6c543 84e717e7)
offset 0x0240   576 "....*u../4.0.q..4.....w...x...m." (c1d71713 2a75c5b6 2f34fa4f 1271e980 34cf9b00 18d377c0 dc1a78be 1ba16dea)
offset 0x0260   608 "#..6.>...i......P..l.giv...|.5.." (23bc1f36 ec3efe10 a169f489 ae0fd68c 50eaad6c b3676976 b310fd7c 8a35e1e3)
offset 0x0280   640 ".....N..Bs......J^{<.k.cp..b..SU" (e6861bf1 a54ee8a1 4273c0c8 d3dffef7 4a5e7b3c fb6be163 70afb362 de955355)
offset 0x02a0   672 ".-B}.}..a<9.....k......y.8.<.7.a" (a32d427d 907d0ca5 613c39f7 a98b90d3 6b17c2f6 19088c79 9e380a3c a237c861)
offset 0x02c0   704 ".........}.&);d...'ki......X...." (f20ed0c9 ee0dacc0 1c7d1a26 293b64da 8b7f276b 69f01aee d68cab58 9fade706)
offset 0x02e0   736 "...p.......u6...5}..U....~._.b.." (d10770ca 0c86f111 b0fe7536 ca99bc35 7db9ee55 8fc7db8b 7ef8065f 8e62c6a5)
offset 0x0300   768 "...3.MsP.4N.u.Y..*..@...C#....g." (0fed0433 d34d7350 bc344e0f 75be5918 e12afdd5 40dd99f8 4323a5fc a6086717)
offset 0x0320   800 ".e..jbd..E.........q..>K..%.9.`." (8f65f999 6a6264e7 e845f916 97dbceea 9ea58371 cdab3e4b e4e725da 390a60b9)
offset 0x0340   832 "o..cM........c...s..5.E.ro..71Z." (6fb2ac63 4dc3b00c eb1713b5 e36397dd 0973cdfc 350645b6 726f0587 37315ac2)
offset 0x0360   864 "c..."...B.r.x,.e.o..No.K...L..[." (63939ac6 22c5b295 42e672b9 782cb865 986feef2 4e6ff34b bde6e04c 11c45bd0)
offset 0x0380   896 ".(h..8\.Vw..\.Tc.?_`.Q.........." (062868d4 fc385c19 5677e9c6 5ca75463 ab3f5f60 95517fe4 dd8ae4e5 f884d519)
offset 0x03a0   928 ".$........Q,-.......C,..&........" (b1249cfa 88a1cbbf 07fc512c 2d93a7e1 09ebe643 2cdcb026 960bc381 c6d19b04)
offset 0x03c0   960 "....7hF.9.l.O8.... .._.`....3j5." (ccdb8f07 3768461e 39ed6cf2 4f38e3ec f4e0209d a15fe560 a8fe1cdd 336a359c)
offset 0x03e0   992 "..6...P7.[.;.....)..K......oi..." (edd6367f e1e45037 ae5b923b d78ef3b2 e729b1fe 4b1fa79f 05e7f96f 69dcef9a)
```

Random binary data (incompressible)

pattern=trailing_zeros,compressibility=50%

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```
offset 0x0000     0 "6.8.`Qe..n,x...v....'.-.;......." (360738cd 605165ed a06e2c78 bcdbd676 0b8cac94 27db2dd3 3be90396 1a120e9b)
offset 0x0020    32 ".S..3.........I.....Z.t..`~....H" (aa53d8bf 33c79f05 89ffd187 14bf49c5 0989acaf 5a9974f9 be607e8e 8790b
offset 0x0040    64 ".E..f..<...I`....B..~...<0.-...." (a645ac8d 6610993c 7ff51749 6083fbfc b342d9c6 7eade19f 3c30c02d 1498
offset 0x0060    96 "......-B. .......d.A.=.....yT..-3" (118cbca3 ae2d42cd 20111afe 05d5e216 64dd4106 3d9fb48e f5de7954 c3b1
offset 0x0080   128 "..Nr.vu....L..r......3.S^.^R...n" (afe14e72 be767584 aab4084c 8e87721d 1397022e ef33b553 5e145e52 cb10
offset 0x00a0   160 ".Dxb..q<......a..]c..3.7..n..R.." (8f447862 f99a713c 90b2ec06 0e1c611e 815d63b2 1133b337 05c36e9a ac52
offset 0x00c0   192 "._...3.D...y...Wq.Z..\.*,_....." (b1ba5ffa d51933b6 44faaf02 79dbb481 5771ec5a be865c13 2a2c5fd0 c5
offset 0x00e0   224 "..H.....K=":.Q.w.-d............." (9bef4812 89baabf6 4b3d223a cd519b77 9e2d649b 188188b1 928ba59
offset 0x0100   256 "...f...\Pw.U. wI1....c.0.?U..8.." (1bb49566 1c06955c 50778f55 a9207749 31b80bfe b563a030 903
offset 0x0120   288 ".([.._...{.K.*P"R>1G.....LsA.V.." (84285b90 bf5fe9ad 1e7bae4b 092a5022 523e3147 9b10c58b 4c7341 b856d9
offset 0x0140   320 "rKbp{.....|..n...~...p.e......D\" (724b6270 7bd5cf07 8b177cb5 e26e8694 e77e8fef ca70bd65 8880e1d2 80ea445c)
offset 0x0160   352 "o7.......dR9...m...Sl.S.Fq......" (6f371d12 e2bc9b1d 88645239 b4f2bb6d ebb90353 6ca853cd 4671f813 a7a3cbbb)
offset 0x0180   384 "....B.......&./.Q...h...6.B&Ly.." (04e2d180 4299dc8b 86acb4f4 26922fbe 51b8ceb2 68d61008 36044226 4c79eb17)
offset 0x01a0   416 "q.m..0Bq...uW..\.m..Q.2.......1." (71876ddc f7304271 15dede75 57dc065c 106dc40d 51ee3288 c60caf95 c5af31ac)
offset 0x01c0   448 ".?....P)^....?..9..@............" (be3fa2ba bbfd5029 5ef9dfdb c93fe41c 39e41640 c685d6bc ddf7aa83 b4cbd0e4)
offset 0x01e0   480 "...~rJ.q.y7#....i.Xme...{;.i...." (a58e897e 724a1671 e5793723 b3f71cf2 6999586d 65011ecd 7b3b8069 c2c9bde9)
offset 0x0200   512 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
offset 0x0220   544 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
offset 0x0240   576 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
offset 0x0260   608 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
offset 0x0280   640 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
offset 0x02a0   672 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
offset 0x02c0   704 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
offset 0x02e0   736 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
offset 0x0300   768 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
offset 0x0320   800 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
offset 0x0340   832 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
offset 0x0360   864 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
offset 0x0380   896 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
offset 0x03a0   928 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
offset 0x03c0   960 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
offset 0x03e0   992 "................................" (00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000)
```

Leading part of block is random binary data (incompressible)

compressibility = 50% means 50% trailing binary zeros

pattern=ascii

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```
offset 0x0000     0 "aPJYuQcQ4yaW>Oa}LGc7;z[[9PFOj{\4" (61504a59 75516351 34796157 3e4f617d 4c476337 3b7a5b5b 3950464f 6a7b5c34)
offset 0x0020    32 "b|n=Vp%]iWLB^JIYRkXiH-$b%qBjz(b!" (627c6e3d 5670255d 69574c42 5e4a4959 526b5869 482d2462 2571426a 7a286221)
offset 0x0040    64 "A+>/bf.%nu^GV(t_ZFT7 AlZ76Y)Ran " (412b3e2f 62662e25 6e755e47 5628745f 5a465437 20416c5a 37365929 52616e20)
offset 0x0060    96 "ngxq??<Clv?'?M&w !po=ouj3fI/cnR=" (6e677871 3f3f3c43 6c763f27 3f4d2677 2021706f 3d6f756a 3366492f 636e523d)
offset 0x0080   128 "DI<:l?*([:Znm %5i*olN<'%!4"EQjVt" (44493c3a 6c3f2a28 5b3a5a6e 6d202535 692
offset 0x00a0   160 "UE]pNzawt<![XfUaB$`;~yQ/t8,O)*HE" (55455d70 4e7a6177 743c215b 58665561 422
offset 0x00c0   192 ",/~IB|VO2w ym`XZ`xRIn{S#mpe_RQ_)" (2c2f7e49 427c564f 32772079 6d60585a 607
offset 0x00e0   224 "U/>LPMdpl>FzJZY(3K=FYo}DD+eM:wU/" (552f3e4c 504d6470 6c3e467a 4a5a5928 334
offset 0x0100   256 "NQjVxX{YQ50]NMQ`SYG7t|3k<u@H1hsR" (4e516a56 78587b59 5135305d 4e4d5160 535
offset 0x0120   288 "AKphT_Y?pq+_xs#xo8)-ExmlwSrw:%]H" (414b7068 545f593f 70712b5f 78732378 65
offset 0x0140   320 "8D,f`,9/FE%HV7#$[. `1^MB[7_m!nZ(" (38442c66 602c392f 46452548 562
offset 0x0160   352 "O\7afoGRP/iX_;8?<{)E a:[L|?4_K{)" (4f5c3761 666f4752 503
offset 0x0180   384 "zKqHz8%+W/oca,%J*(C%`Z+]o9Is7qO$" (7a4b7148 7a30                  612c254a 2a2
offset 0x01a0   416 "CVz/Z%cqy3|@"R.<Tsc7=/!SEyD:(2lq" (4356                  79337c40 22522e3c 54736537 5d2f2155 4579445a 28526c71)
offset 0x01c0   448 " OevIIX31`1?wP}n]WOK['T}YbU@S8h"  (204f6576 49495833 3160313f 77507d6e 5d574f4b 5b27547d 59625540 5338683f)
offset 0x01e0   480 "7XVR9[sD"k^Xt%u/B>(wAwZv91[Qsk~S" (37585652 395b7344 226b5e58 7425752f 423e2877 41775a76 39315b51 736b7e53)
offset 0x0200   512 "q{m*=uU8WD6xXHvBzO9hKgBHTCib+]Sf" (717b6d2a 3d755538 57443678 58487642 7a4f3968 4b674248 54436962 2b5d5366)
offset 0x0220   544 "E`.z}^!6I-LX)X9kDW}%VT(1ixGC6`)K" (45602e7a 7d5e2136 492d4c58 2958396b 44577d25 56542831 69784743 3660294b)
offset 0x0240   576 "JkN^pNd@/}e+,3,HNA9W*-k\mzD~4i*V" (4a6b4e5e 704e6440 2f7d652b 2c332c48 4e413957 2a2d6b5c 6d7a447e 34692a56)
offset 0x0260   608 "FFb+sEQW&JE`kLL))9S1J\Y^-fV3":)}" (4646622b 73455157 264a4560 6b4c4c29 29395331 4a5c595e 2d665633 223a297d)
offset 0x0280   640 "{uIM9 >\9XUHp&UoOJH~.iT9H}{f'<io" (7b75494d 39203e5c 39585548 7026556f 4f4a487e 2e695439 487d7b66 273c696f)
offset 0x02a0   672 "1Ubl)&\RcmQ~,%2"XB!tOds#=+s%VGlm" (3155626c 29265c52 636d517e 2c253222 58422174 4f647323 3d2b7325 56476c6d)
offset 0x02c0   704 "v{=S\\hEJ7}&'qJqK{1)>BF,HW`/C(?P" (767b3d53 5c5c6845 4a377d26 27714a71 4b7b3129 3e42462c 4857602f 43283f50)
offset 0x02e0   736 "*(Bp.p">t=5XQBdU48@'\+._Z8$!1cv?" (2a284270 2e70223e 743d3558 51426455 34384027 5c2b2e5f 5a382421 3163763f)
offset 0x0300   768 "|n}SR;^->+n5f}taf5U=$f=po|FBG/L%" (7c6e7d53 523b5e2d 3e2b6e35 667d7461 6635553d 24663d70 6f7c4642 472f4c25)
offset 0x0320   800 ""<8*"7/yNR |DW|Sgamv\k]3i1bVO-Zl" (223c382a 22372f79 4e52207c 44577c53 67616d76 5c6b5d33 69316256 4f2d5a6c)
offset 0x0340   832 "dBogZ&1 7L6f6s.F"VNCO8..mD1*?4OV" (64426f67 5a263120 374c3666 36732e46 22564e43 4f382e2e 6d44312a 3f344f56)
offset 0x0360   864 "w%?ODQ&imX}W:e}c(9\]tN+`p+66Wi!l" (77253f4f 44512669 6d587d57 3a657d63 28395c5d 744e2b60 702b3636 5769216c)
offset 0x0380   896 "Su, cHdCRXx>.O/QQK$mFgy6~b#.}?B2" (53752c20 63486443 5258783e 2e4f2f51 514b246d 46677936 7e62232e 7d3f4232)
offset 0x03a0   928 "QnYH&:.l&xvoho58(I`h*U~`;|rt`+W}" (516e5948 263a2e6c 2678766f 686f3538 28496068 2a557e60 3b7c7274 602b577d)
offset 0x03c0   960 "6J**<hVYXQ0(]wa<bV7JwP[-U{yd F<A" (364a2a2a 3c685659 58513028 5d77613c 6256374a 77505b2d 557b7964 20463c41)
offset 0x03e0   992 "I=FaNDTK7FP-P{qJMjYfkbnnVH-_J3qn" (493d4661 4e44544b 3746502d 507b714a 4d6a5966 6b626e6e 56482d5f 4a33716e)
```

Randomly selected printable ASCII characters (fixed degree of compressibility)

pattern=gobbledegook

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```
offset 0x0000     0 "agens fever APPLICATORY indignan" (6167656e 73206665 76657220 4150504c 49434154 4f525920 696e6469 676e616e)
offset 0x0020    32 "t bacoro anamnestic ADVERTENCE W" (74206261 636f726f 20616e61 6d6e6573 74696320 41445645 5254454e 43452057)
offset 0x0040    64 "EBSTER weighed DELEGATE ail radi" (45425354 45522077 65696768 65642044 454c4547 41544520 61696c20 72616469)
offset 0x0060    96 "ant ANGLOMANIAC publicity fixus " (616e7420 414e474c 4f4d414e 49414320 [illegible])
offset 0x0080   128 "alouer reality arma satiety aumo" (616c6f75 65722072 65616c69 74792[illegible])
offset 0x00a0   160 "snier isotropic Seeley actinism " (736e6965 72206973 6f74726f 70696[illegible])
offset 0x00c0   192 "hatched addicere extrinsically p" (68617463 68656420 61646469 63657[illegible])
offset 0x00e0   224 "arlance fell aquiline passed ant" (61726c61 6e636520 66656c6c 20617[illegible])
offset 0x0100   256 "iquarian rot AGGRANDIZER AFTERBI" (69717561 7269616e 20726f74 204[illegible])
offset 0x0120   288 "RTH ANALYTICS yearly occultation" (52544820 414e414c 595449[illegible])
offset 0x0140   320 " nathra Notwithstanding discrimi" (206e6174 68726120 [illegible])
offset 0x0160   352 "nate CHAMBER mongst tacitly prom" (6e617465 204[illegible] 4424552 206d6f6e 67737420 74616369 746c7920 70726f6d)
offset 0x0180   384 "inences ambulacral designs avail" (696e656[illegible] 7320 616d6275 6c616372 616c2064 65736967 6e732061 7661696c)
offset 0x01a0   416 " aberrating Argillaceous making " (20[illegible] 72726174 696e6720 41726769 6c6c6163 656f7573 206d616b 696e6720)
offset 0x01c0   448 "prose apostele tro ALLODIARY ho" (70726f73 65206170 6f737465 6c652074 726f2041 4c4c4f44 49415259 20626f77)
offset 0x01e0   480 "lines malonyl exists Per bases a" (6c696e65 73206d61 6c6f6e79 6c206578 69737473 20506572 20626173 65732061)
offset 0x0200   512 "cuminate ciere legumes necessary" (63756d69 6e617465 20636965 7265206c 6567756d 6573206e 65636573 73617279)
offset 0x0220   544 " onward Bombax APPLY exploit sym" (206f6e77 61726420 426f6d62 61782041 50504c59 20657870 6c6f6974 2073796d)
offset 0x0240   576 "pathy ANGELICALNESS ALGAROBA gai" (70617468 7920414e 47454c49 43414c4e 45535320 414c4741 524f4241 20676169)
offset 0x0260   608 "ning Alpes ACTIVITY buoyancy wit" (6e696e67 20416c70 65732041 43544956 49545920 62756f79 616e6379 20776974)
offset 0x0280   640 "her filaments Blackfeet opponent" (68657220 66696c61 6d656e74 7320426c 61636b66 65657420 6f70706f 6e656e74)
offset 0x02a0   672 "s footing cannon anai APTLY arge" (7320666f 6f74696e 67206361 6e6e6f6e 20616e61 69204150 544c5920 61726765)
offset 0x02c0   704 "ntic ALLUSION appropinquatus apo" (6e746963 20414c4c 5553494f 4e206170 70726f70 696e7175 61747573 2061706f)
offset 0x02e0   736 "stel ARCHIEPISCOPATE AGGLOMERATE" (7374656c 20415243 48494550 4953434f 50415445 20414747 4c4f4d45 52415445)
offset 0x0300   768 "D nightingale aphol ACCUSTOMABLE" (44206e69 67687469 6e67616c 65206170 686f6c20 41434355 53544f4d 41424c45)
offset 0x0320   800 " law centripetal AMIABLE rin AMN" (206c6177 2063656e 74726970 6574616c 20414d49 41424c45 2072696e 20414d4e)
offset 0x0340   832 "ESIA yardarm deserving jure argu" (45534941 20796172 6461726d 20646573 65727669 6e67206a 75726520 61726775)
offset 0x0360   864 "mentatio Num flushed Abas APRICA" (6d656e74 6174696f 204e756d 20666c75 73686564 20416261 73204150 52494341)
offset 0x0380   896 "TION AFFLUENTLY old affected Hud" (54494f4e 20414646 4c55454e 544c5920 6f6c6420 61666665 63746564 20487564)
offset 0x03a0   928 "ibras ACROTISM ARAEOSYSTYLE Gall" (69627261 73204143 524f5449 534d2041 5241454f 53595354 594c4520 47616c6c)
offset 0x03c0   960 "icism PEAR ACHIEVEMENT reclining" (69636973 6d205045 41522041 43484945 56454d45 4e542072 65636c69 6e696e67)
offset 0x03e0   992 " mechanism Amalgamating cooperat" (206d6563 68616e69 736d2041 6d616c67 616d6174 696e6720 636f6f70 65726174)
```

Randomly selected words from Webster's 1913 dictionary.
(fixed degree of compressibility)

dedupe mechanism

Goal for ivy dedupe design

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1. Enable selection of dedupe "scope" to one LUN, across multiple LUNs, across test hosts, or across an entire subsystem.
   - The "scope" means the extent across which multiple copies of the same pattern are written.
2. Use a method which is "self-contained" within a workload thread
   - No interlock, no communication between workload threads / test hosts.
3. Enable layering of multiple workloads, each with different characteristics including dedupe blocksize and/or compressibility characteristics.

Method

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- A deterministic method is used to generate a sequence of I/O patterns
  - Deterministic means that given the same initial parameters, the same sequence of patterns is generated.
  - "pattern" means the data written in a block.
  - Even though a deterministic method, given the same input parameters, will produce the same sequence of data patterns written, by using "pseudo-random" number generators we can generate unique and apparently random patterns.
- The scope of dedupe pattern generation is across the group of workload thread instances of the same "workload name".

Scope of dedupe is across a "workload name"

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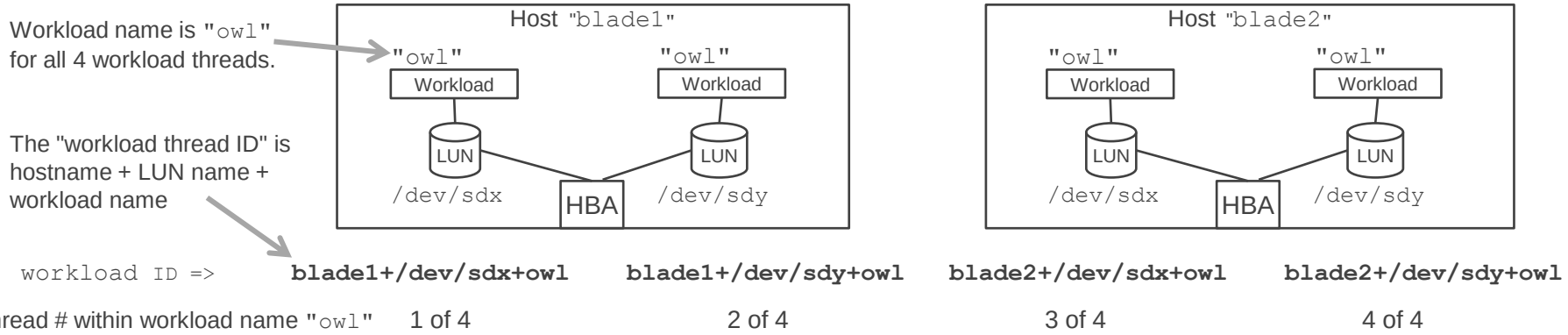
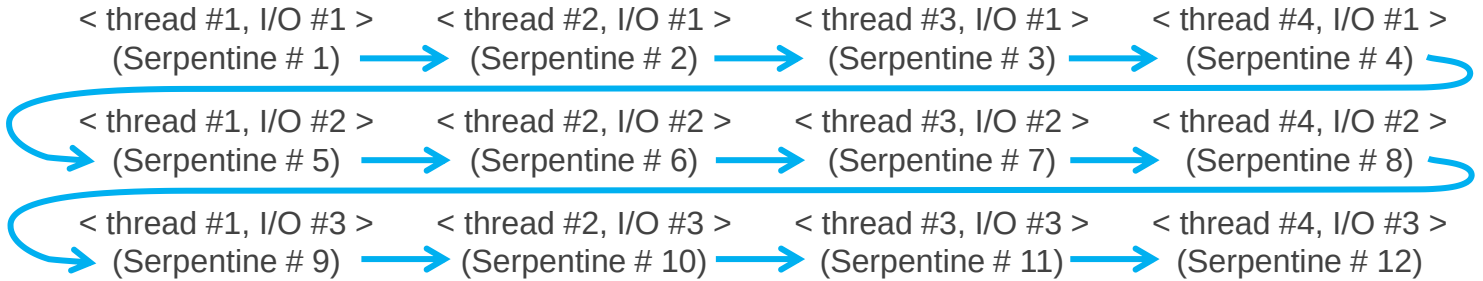


- A "serpentine sequence" is the key to the ivy dedupe pattern generation concept



Example for 100% writes, dedupe_factor = 1.5

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- Formula for data pattern number:
  - round up to next higher integer (serpentine number * write ratio / dedupe ratio)
  - round up to next higher integer (serpentine number * 100% / 1.5)

	A	B	C	D	E
1	Dedupe ratio	1.5			
2	Write ratio	100%			
3					
4		Thread #1	Thread #2	Thread #3	Thread #4
5	I/O number	1	1	1	1
6	Serpentine number	1	2	3	4
7	Data pattern number	1	2	2	3
8					
9	I/O number	2	2	2	2
10	Serpentine number	5	6	7	8
11	Data pattern number	4	4	5	6
12					
13	I/O number	3	3	3	3
14	Serpentine number	9	10	11	12
15	Data pattern number	6	7	8	8
16					
17	I/O number	4	4	4	4
18	Serpentine number	13	14	15	16
19	Data pattern number	9	10	10	11
20					
21	I/O number	5	5	5	5
22	Serpentine number	17	18	19	20
23	Data pattern number	12	12	13	14

Note that each data pattern is written on average 1.5 times

Example for 50% writes, dedupe_factor = 1.5

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- Formula for data pattern number:
  - round up to next higher integer (serpentine number * write ratio / dedupe ratio)
  - round up to next higher integer (serpentine number * 50% / 1.5)

	A	B	C	D	E
1	Dedupe ratio	1.5			
2	Write ratio	50%			
3					
4		Thread #1	Thread #2	Thread #3	Thread #4
5	I/O number	1	1	1	1
6	Serpentine number	1	2	3	4
7	Data pattern number	1	1	1	2
8					
9	I/O number	2	2	2	2
10	Serpentine number	5	6	7	8
11	Data pattern number	2	2	3	3
12					
13	I/O number	3	3	3	3
14	Serpentine number	9	10	11	12
15	Data pattern number	3	4	4	4
16					
17	I/O number	4	4	4	4
18	Serpentine number	13	14	15	16
19	Data pattern number	5	5	5	6
20					
21	I/O number	5	5	5	5
22	Serpentine number	17	18	19	20
23	Data pattern number	6	6	7	7

- With 50% writes, we still compute a pattern number for each I/O, whether it is a read or whether it is a write.
- Note that for 50% writes, each data pattern now occurs 3 times.
  - This is deterministic
- (For 50% writes, a random number between 0.0 and 1.0 is selected for each I/O, and if the number is below 0.5, the I/O will be a write.)
- On average, 50% of the patterns shown on the left will be written, so we will write on average 1.5 copies of each pattern

Simple arithmetic to calculate pattern number

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- For the first I/O, the **serpentine number** for a workload thread is the number of the thread within the group of threads with the same workload name
  - Thread #2 of 4 threads starts with serpentine number 2.
- For each successive I/O, the serpentine number is incremented by the number of threads with the same name.
- For each I/O, the I/O **pattern number** is calculated from the serpentine number
  - round up to next higher integer (serpentine number * write ratio / dedupe ratio)

Starting "pattern seed" sent by ivy master

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- For each workload name with a `dedupe` setting greater than 1.0
  - The ivy master thread comes up with a 64-bit unsigned starting "pattern seed" value that gets sent out to all threads with the same workload name.
  - Along with sending out the pattern seed value that is common to all threads with the same workload name, each thread individually is told you are workload "x" of total "y" threads in a dedupe group.
  - This lets each thread calculate the pattern number for each of that thread's I/Os according to the serpentine method.
- If `dedupe` = 1.0, each individual workload thread is given a unique starting "pattern seed" and is told it is "1" of "1" in the dedupe group

"pattern seed" sequence

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- The I/O sequencer calculates the pattern number from the serpentine number.
  - The pattern number may increment multiple times from one I/O to the next, or the pattern number may stay the same from one I/O to the next, depending on the `dedupe` parameter value and the number of threads with the same workload name.
- Each time the pattern number increments, the next 64-bit "pattern seed" is generated using a simple non-cryptographic quality pseudo-random generator
  - "xorshift64star" - see https://en.wikipedia.org/wiki/Xorshift.

"block seed" derived from "pattern seed"

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- In order that a unique but deterministic sequence of pseudo-random numbers is used to generate the contents of each block, a "block seed" is derived from the "pattern seed" by XORing the "pattern seed" with the 64-bit pattern number.
  - This derived value is the seed for the sequence of numbers used to generate the contents of a block.
- This makes sure that the contents of any one block are not just shifted by one pseudo-random number compared to the contents of the block for the previous pattern number.

Implications of selecting this design

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- Works for either random or sequential I/O generators
  - Sequential I/O sequences are either all reads, or all writes
- Multiple instances of a particular data pattern are written at roughly the same time.
- With `dedupe=3` and writes to random locations, there will be 3 copies of the most recently-written data.
  - Over time, like the math for radioactive decay, any one older block will have an increasing probability of having been over-written with a newer value.
  - The older the data, the fewer the copies that will remain.
  - A long-term "steady state" random dedupe will stabilize on fewer copies than the `dedupe` parameter value. (Haven't done the math on a long term correction factor.)

Compressibility of data patterns

Compressibility is a "difficult" subject

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- ivy offers several simplistic workload patterns to exercise storage compression features.
  - It is relatively easy to generate a pattern that compresses a pre-defined amount
- Real life workloads may be more complex
- Longer term, some advanced methods may be needed to not only to generate patterns that compress to a specified amount, but to also required the same amount of CPU resource to perform the compression.

Questions and Discussion

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