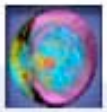
SciDAC

Scientific Discovery through Advanced Computing





- PETASCALE DATA STORAGE INSTITUTE
  - 3 universities, 5 labs, G. Gibson, CMU, PI
- SciDAC @ Petascale storage issues
  - www.pdsi-scidac.org
  - Community building: ie. PDSW-SC07 (Sun 11th)
  - APIs & standards: ie., Parallel NFS, POSIX
  - Failure data collection, analysis: ie., CFDR
  - Performance trace collection & benchmark publication
  - IT automation applied to HEC systems & problems
  - Novel mechanisms for core (esp. metadata, wide area)

Carnegie Mellon

center for information technology integration

UNIVERSITY OF MICHIGAN

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Sandia National Laboratories

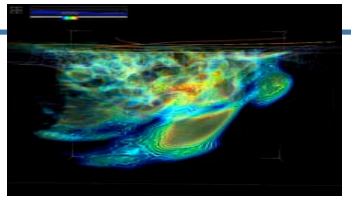
Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

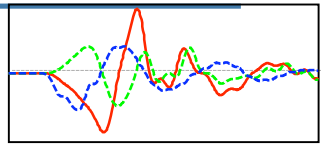
Carnegie Mellon
Parallel Data Laboratory

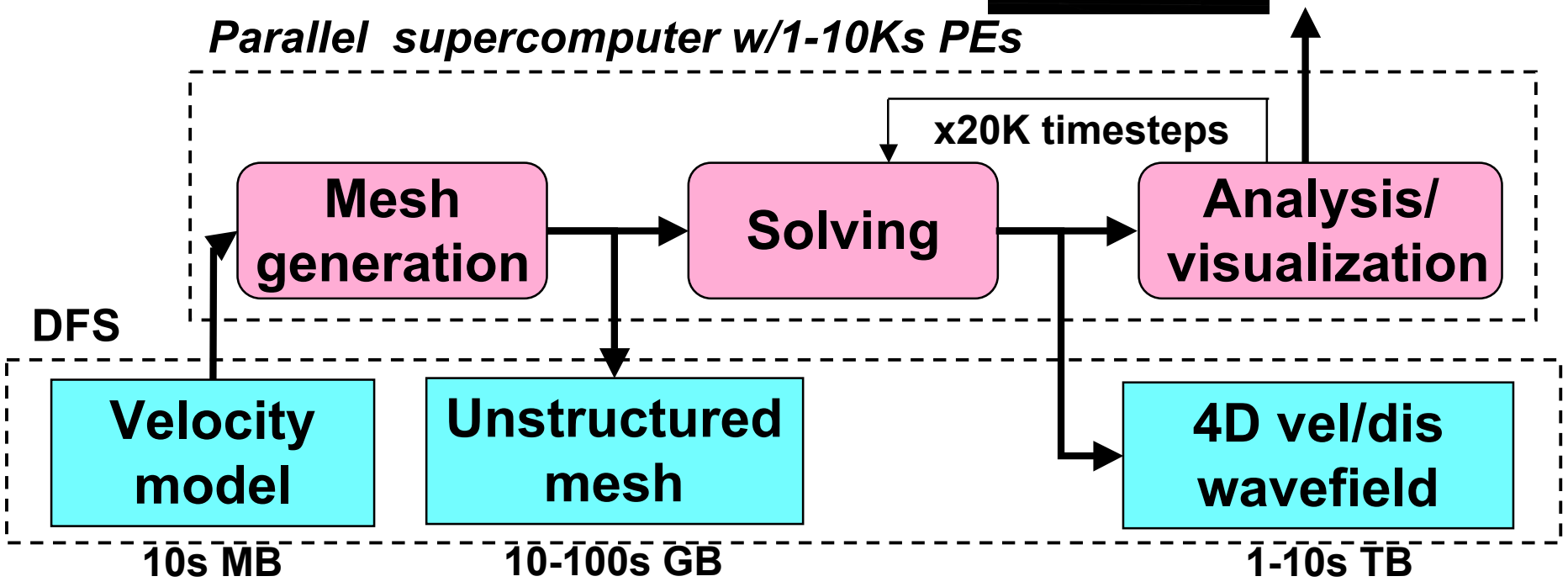
pdsi

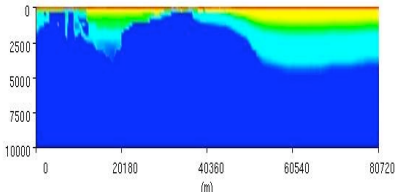
Earthquake simulation

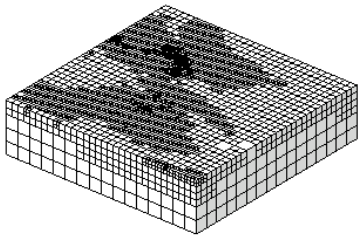
- c/o Dave O'Hallaron, www.cs.cmu.edu/~quake











Motivation: Earthquake analysis

- Serialization of model, mesh and wavefield into one database file
  - Total is generally much too large to be entirely loaded into memory
  - Multiple regions of the file contain data of different types
  - Different types of data see different access patterns
    - B-tree on mesh gets random tiny accesses
    - Mesh descriptors get random medium fetches
    - Wavefields get larger accesses, but concurrency makes it look random
- Basic problem: file system sees no internal structure information
  - Prefetching, allocation, caching strategies assume all data is of same type
  - Mixed access patterns strongly confuse file system policies
  - Fall back on safe, probably slower policies: no prefetching, serial locking
- What if file system knew more about “compound, out-of-core” files?
  - Hints? Tradition is too few codes issue them, too few systems use them, too hard to debug performance implications of hints
  - What alternatives?
    - Partial schema definitions: regions that have different types of access
    - Access Methods: embedded some structures in FS (B-trees, arrays …)

Motivation: file count scales w/ FLOPS?

- Understanding File Systems at Rest (www.pdsi-scidac.org/fsstats/)
  - Just getting started with data collection, but already see lots of tiny files
  - Manipulation of small files, and attributes of small files is a growing problem
  - Small things cost mechanical positioning -- orders of magnitude slower
  - Large files may in fact be collections of small things (HDF, netCDF, etc)
    - If sequentially loaded into memory and written from memory, cool
    - But if accessed “out-of-core”, really much the same problem
    - Gets worse as numbers of things gets larger, if not sequential access

```
file size:
count=12338926 average=18958.589506
min=0 max=757630040
  [         0-         2 KB):  3303866 (26.78%) ( 26.78% cumulative)      1996763.67 KB ( 0.00%) (  0.00% cumulative)
  [         2-         4 KB):   883060 ( 7.16%) ( 33.93% cumulative)      2534585.51 KB ( 0.00%) (  0.00% cumulative)
  [         4-         8 KB):   917461 ( 7.44%) ( 41.37% cumulative)      5182409.88 KB ( 0.00%) (  0.00% cumulative)
  [         8-        16 KB):   744358 ( 6.03%) ( 47.40% cumulative)      8591734.47 KB ( 0.00%) (  0.01% cumulative)
  [        16-        32 KB):   731235 ( 5.93%) ( 53.33% cumulative)     16534655.55 KB ( 0.01%) (  0.01% cumulative)
  [        32-        64 KB):   669568 ( 5.43%) ( 58.75% cumulative)     30855148.03 KB ( 0.01%) (  0.03% cumulative)
  [        64-       128 KB):   757320 ( 6.14%) ( 64.89% cumulative)     70214295.14 KB ( 0.03%) (  0.06% cumulative)
  [       128-       256 KB):   631071 ( 5.11%) ( 70.01% cumulative)    114050978.13 KB ( 0.05%) (  0.11% cumulative)
  [       256-       512 KB):   558914 ( 4.53%) ( 74.54% cumulative)    189985048.43 KB ( 0.08%) (  0.19% cumulative)
  [       512-      1024 KB):   597161 ( 4.84%) ( 79.37% cumulative)    443400973.63 KB ( 0.19%) (  0.38% cumulative)
  [      1024-      2048 KB):   479472 ( 3.89%) ( 83.26% cumulative)    676898557.71 KB ( 0.29%) (  0.67% cumulative)
  [      2048-      4096 KB):   363371 ( 2.94%) ( 86.21% cumulative)   1019631931.23 KB ( 0.44%) (  1.10% cumulative)
  [      4096-      8192 KB):   255781 ( 2.07%) ( 88.28% cumulative)   1534778534.48 KB ( 0.66%) (  1.76% cumulative)
  [      8192-     16384 KB):   256358 ( 2.08%) ( 90.36% cumulative)   2894041905.64 KB ( 1.24%) (  3.00% cumulative)
  [     16384-     32768 KB):   230819 ( 1.87%) ( 92.23% cumulative)   5245575759.34 KB ( 2.24%) (  5.24% cumulative)
  [     32768-     65536 KB):   223892 ( 1.81%) ( 94.04% cumulative)  10337335940.35 KB ( 4.42%) (  9.66% cumulative)
  [     65536-    131072 KB):   584808 ( 4.74%) ( 98.78% cumulative)  52004123186.77 KB (22.23%) ( 31.89% cumulative)
  [    131072-    262144 KB):    42167 ( 0.34%) ( 99.12% cumulative)   7784126469.45 KB ( 3.33%) ( 35.22% cumulative)
  [    262144-    524288 KB):    31868 ( 0.26%) ( 99.38% cumulative)  11411821832.03 KB ( 4.88%) ( 40.09% cumulative)
  [    524288-   1048576 KB):    39972 ( 0.32%) ( 99.70% cumulative)  27336893196.49 KB (11.69%) ( 51.78% cumulative)
  [   1048576-   2097152 KB):    17726 ( 0.14%) ( 99.85% cumulative)  25773260950.03 KB (11.02%) ( 62.80% cumulative)
  [   2097152-   4194304 KB):    13237 ( 0.11%) ( 99.96% cumulative)  37985398325.45 KB (16.24%) ( 79.04% cumulative)
  [   4194304-   8388608 KB):     4336 ( 0.04%) ( 99.99% cumulative)  23511276177.30 KB (10.05%) ( 89.09% cumulative)
  [   8388608-  16777216 KB):      783 ( 0.01%) (100.00% cumulative)   8739054420.16 KB ( 3.74%) ( 92.82% cumulative)
  [  16777216-  33554432 KB):      168 ( 0.00%) (100.00% cumulative)   3598648498.69 KB ( 1.54%) ( 94.36% cumulative)
  [  33554432-  67108864 KB):      111 ( 0.00%) (100.00% cumulative)   5587776404.47 KB ( 2.39%) ( 96.75% cumulative)
  [  67108864- 134217728 KB):       25 ( 0.00%) (100.00% cumulative)   2318337024.21 KB ( 0.99%) ( 97.74% cumulative)
  [ 134217728- 268435456 KB):        9 ( 0.00%) (100.00% cumulative)   1559281156.26 KB ( 0.67%) ( 98.41% cumulative)
  [ 268435456- 536870912 KB):        8 ( 0.00%) (100.00% cumulative)   2969396082.00 KB ( 1.27%) ( 99.68% cumulative)
  [ 536870912-1073741824 KB):        1 ( 0.00%) (100.00% cumulative)    757630040.00 KB ( 0.32%) (100.00% cumulative)
```

```
"# The data contained herein was collected from Systems in the Environmental Molecular Sciences Laboratory", a
national scientific user facility sponsored by the Department of Energy's Office of Biological and Environmental
Research and located at Pacific Northwest National Laboratory."
"# Release Number: PNNL-17013"
"# Contact: Evan Felix <evan.felix@pnl.gov>"
```

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Parallel Data Laborat

pdsi

Motivation: HugeDirs -> AttributeDB

- CMU adding directories of 1B to 1T small files to PVFS
  - Partitioning entries into buckets distributed over all storage servers
  - Building index structure for insert(), delete(), lookup()
    - no range query, but unordered complete scan must be fast (readdir)
  - Making highly parallel, minimal bottlenecks, minimal coherency
  - Believe this is extensible to range queries (concurrent B-trees)
    - More challenging to fully load balance if key access patterns arbitrary
    - Probable next steps to do this however
- Simple extension to not create actual files, just manipulate records
  - Special directory is “key, opaque data” tuples
  - Use for extended attributes of small files to optimize to access patterns
    - Ie., type: mp3, code, pdf, checkpoint, …. Find all by type
    - Ie., timestamp of last modification, find N oldest
    - Ie,. Size, find N largest
  - Apply powerful aggregation structures as well as indices: ie., fastbits
- Could this be used for variable stores?

Motivation: ChangeLog Representation

- Fastest checkpoint might be a sequential series of “variable=value”
  - Instead of seeking to serialized location, just append operation to log
  - Each thread writes strictly sequential log of operations
  - “Meaning” of set of logs is applying log to (possibly null) initial database
- Decouple writing logs from applying logs to serialized database
  - Optimize each separately; pipeline from compute to IO nodes
  - Defer serializing by just storing changelogs for later application
  - Some checkpoints never read, so never serialized
  - If read before serialized, trigger serialization (or something smarter)
  - Represent logs as attributes of database; that is, hide in FS (directory?)
  - Important tricks: “block logs” so each can be applied in parallel later; type logs so “no overwrite” can be known and any order allowed
- Not always best representation
  - If data sequential anyway, operation encoding probably larger
  - If read intermingled with write, might force inefficient serialization

Issues: Library vs File System

- Library is user code bound into application
  - File has structure if the right library is bound into app touching it
  - Rapid development of new “ease of programming” APIs
  - Optimization for actual file system is best guess of library writers
    - Especially a problem if ease of programming was big goal
- File system is system code independent of application
  - File structure known to file system, facilitating optimization
  - Slower development and proliferation as file system is a broad service
  - FS is always-there service; easy delayed processing, rebalancing, recovery
  - FS is inherently distributed, aware of actual servers, changes in servers
- Deployment of new file system APIs?
  - Changes in parallel file systems in progress: pNFS, HEC Posix extensions
- Mitigation for deployment issues: canoncial representations
  - Any file system offering a specialized API also offers:
    - Canonicalization (tar, untar) routines and library implementation written to canonical representation, which does not have to be (as) fast
    - [special case of the backup problem & NDMP solution]

Next steps?

- Select and work through a few examples