Bad I/O and approaches to fixing it

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Overview

- T3E is a shared and highly contested resource
- Standard styles of I/O can give poor or even disastrous performance
- Some case studies based on our experiences

Cray FFIO library

- FFIO is a set of I/O layers tuned for different I/O characteristics
- Buffering of data (configurable size)
- Caching of data (configurable size)
- Available to regular Fortran I/O without reprogramming
- Available for C through POSIX-like calls, e.g. `ffopen`, `ffwrite`

The assign command

- The assign command controls
  - controls which FFIO layer is active
  - striping across multiple partitions
  - lots more
- Scope of assign
  - File name
  - Fortran unit number
  - File type (e.g. all sequential unformatted files)

bufa FFIO layer

- bufa is an asynchronous buffering layer
- Performs read-ahead, write-behind
- Specify buffer size with `-F bufa:`*`bs`*`:`*`nbufs`* where *`bs`* is the buffer size in units of 4Kbyte blocks, and *`nbufs`* is the number of buffers
- Buffer space increases your application's memory requirements

global FFIO layer

- global is a caching and buffering layer which enables multiple PEs to read and write to the same file
- If one PE has already read the data, an additional read request from another PE will result in a remote memory copy
- File open is a synchronizing event
- By default, all PEs must open a global file, this can be changed by calling GLIO_GROUP_MPI(comm)
- Specify buffer size with `-F global:`*`bs`*`:`*`nbufs`* where *`bs`* is the buffer size in units of 4Kbyte blocks, and *`nbufs`* is the number of buffers per PE

Case I

- Application is Computational Chemistry, Relativistic Self-Consistent Field Theory
- The SCF step involves reading in N^4 quantities from files and assembling an N^2 matrix
- Each PE reads a separate file using Fortran sequential unformatted I/O
- Default buffer size is 48 blocks, file is blocked
- Obvious tuning is to go to FFIO layer bufa with a larger buffer. Less I/O requests, read ahead, and no blocking

Case I (cont.)

- Results from calculation on UO_2^{2+} (333 Gb total I/O)

FFIO	*LOGIOReqs*	*IO WAIT (secs)*	*MPP (secs)*
cos:48	1736736	43539	222231
bufa:256:2	333400	2779	142892
new cray libs	330960	3513	156565

Case II

- Astrophysics application
- All PEs read overlapping sections from one file via POSIX I/O
- POSIX I/O can be efficient provided that requests are large, are not buffered at the system level, and are well-formed
  - start on sector boundaries
  - multiple of sector size
  - open with O_RAW and data cache line aligned
- Ill-formed I/O will all go through the system buffer cache

Case II (cont.)

- Replace POSIX I/O with FFIO calls
- FFIO global layer merges application level requests ensuring well-formed requests to system
- Results from test calculation (17Gb total I/O)

FFIO Spec	*LOGIOReqs.*	*IOWAIT (secs)*	*MPP (secs)*
none	299632	49327	58626
global:128:2	44497	992	18103

Case III

- Climate application
- All PEs use netCDF to read same data file
- By default, netCDF uses FFIO bufa:336:2 for each file
- bufa does not do well-formed I/O if application seeks to non-sector boundaries
- Pathological slowdown

Case III (cont.)

- netCDF reworked by R.K. Owen and Steve Luzmoor
- Obeys FFIO specification on a per file basis
- Added support for 'unlimited dimension' on parallel write
- Added API for subset of PEs to open a netCDF files which uses FFIO global layer

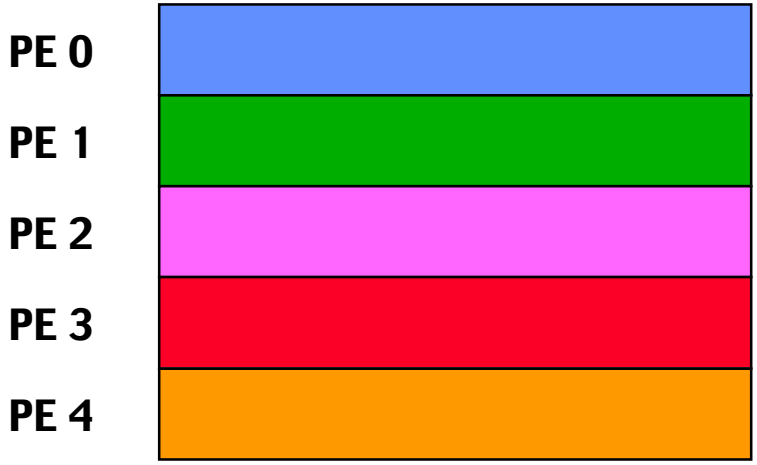
Case III (cont.)

- **Results from example netCDF dataset (64Mb array)**

#PEs	Total I/O (Mb)	LOGIO Reqs.	IOWAIT (secs)	MPP (secs)
bufa:336:2				
4	259	214	16	21
16	1023	850	252	290
32	2042	1698	974	1042
64	4079	3394	3835	4023
global:512:2				
4	65	45	3	17
16	65	81	2	69
32	65	129	5	177
64	65	225	5	702

Case IV

- Linear Algebra (Geology) application
- Write out a large distributed matrix using MPI I/O



MPI I/O

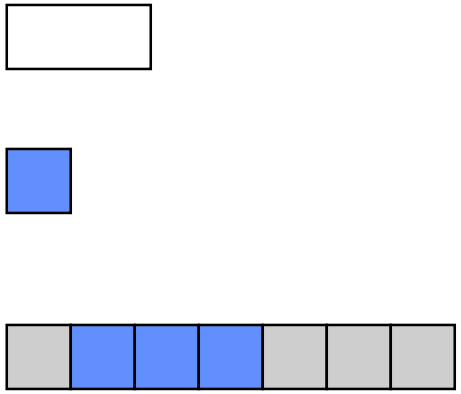
- Data partitioning
- Collective I/O
- Asynchronous I/O
- Portability and interoperability
- T3E implementation
  - Based on ROMIO 1.0.1
  - No shared file pointers
  - No non-blocking collective (split collective)

MPI I/O

- Simplest approach is to use individual and non-contiguous access. Poor performance
- Can use collective I/O to merge requests for non-contiguous data. Better performance
- Use MPI "fileview" to define the non-contiguous access pattern. Best performance

MPI I/O Fileviews

- A fileview is composed of three pieces:
  - a displacement (in bytes) form the beginning of the file
  - an elementary datatype (etype), which is the unit of data access and positioning within the file
  - a filetype, which defines a template for accessing the file. A filetype can contain etypes or holes of the same extent as etypes.



MPI I/O Fileviews (cont.)

- The filetype pattern is repeated, “tiling” the file
- Only the non-empty slots are available to read or write

Fileview (cont.)

- Each process can have a different filetype

Process 0

Process 1

Process 2

Case IV (cont.)

- **Write out a 70400 by 2000 matrix, distributed over 32 PEs**

I/O	*LOGIOReqs.*	*IOWAIT (secs)*	*MPP (secs)*
MPI I/O no fileview	64066	30251	39634
MPI I/O fileview	386	3651	6308
global:512:2	668	340	4076