Software Researches for Big Data and Extreme-Scale Computing

System Software for Post Petascale Data Intensive Science
System Software for Extreme Big Data

JST CREST Core Research for Evolutional Science and Technology Japan Science and Technology Agency

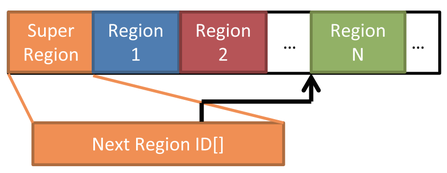
http://www.hpcs.cs.tsukuba.ac.jp/project/crest-ppfs/en/
http://www.extreme-bigdata.jp/

Distributed File System / Object store

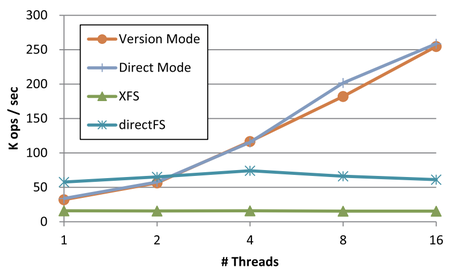
Object Storage for OpenNVM Flash Primitives

Object storage design for high bandwidth and high IOPS in OpenNVM

- OpenNVM flash primitives: **sparse address space and atomic batch write**
- Simple design based on fixed-size **Regions**
  - 》One region for one object
  - 》Enough region size to store one object
  - 》Object ID = region number
- Simple region number management in super region
  - 》Sequential assignment
  - 》Free' ed by persistent trim and no reuse
  - 》Blocked assignment to mitigate access conflict to the super block



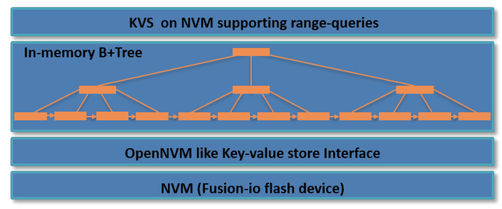
Initial Performance result for object creation

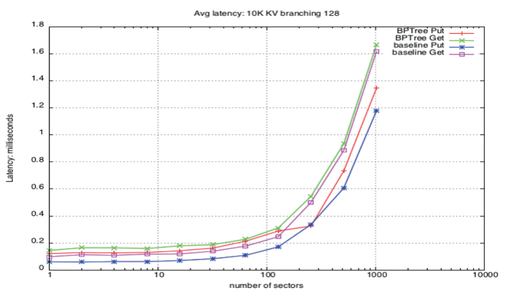


NVM-BPTree

NVM-BPTree is a Key-Value Stores (KVS) running natively over Non-Volatile-Memory (NVM) like flash supporting range-queries.

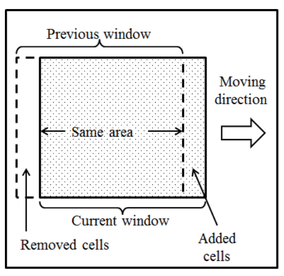
- Take advantage of enterprise class NVM new capabilities: atomic writes, direct access to NVM device natively as a KVS,...
  - 》*Leverage NVMKV an Open source KVS interface for NVM like flash.*
- Enable range-queries support for KVS running natively on NVM
  - 》*Keys stored in a in-memory B+Tree with negligible overhead for KV pair insertion and retrieval.*
- Support lock-free concurrent operation
  - 》*Search queries are not delayed by the tree' s dynamic rebalancing*





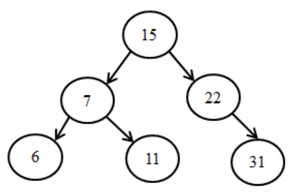
Runtime System

Accelerating percentile with incremental computation scheme over multi-dimensional arrays on SciDB



Basic window

15	7	31	18	2
6	11	22	27	11
31	6	15	9	8
2	9	7	21	13
8	22	7	13	20

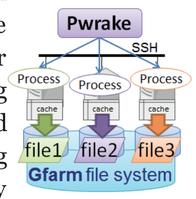


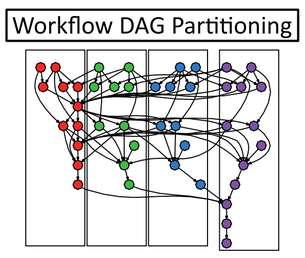
- Keeping values with binary BST
- SciDB implementation shows speed up by a factor of 13

Jiang Li, Hideyuki Kawashima, Osamu Tatebe, "Incremental Aggregates over Array Database" , IEEE BigData' 14. Codes: https://github.com/ljiangjl/Percentile-in-SciDB.git

Pwrake: Scalable Workflow System

Pwrake : Workflow engine for data-intensive sciences. For scalable I/O performance, Pwrake depends on ***Gfarm*** distributed file system which federates local storage of compute nodes. We proposed the following **Task Scheduling** for **Pwrake**; (1) **Locality-aware Scheduling** using **Multi-Constraint Graph Partitioning** (CCGrid 2012), (2) **Disk Cache-aware Scheduling** using LIFO-based task queue with dynamic priority (Cluster 2014).



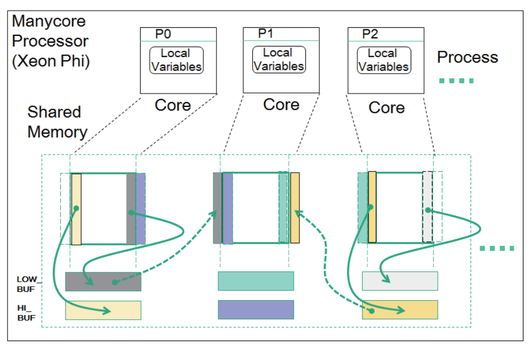


XcalableMP PGAS programing model for Manycore Cluster

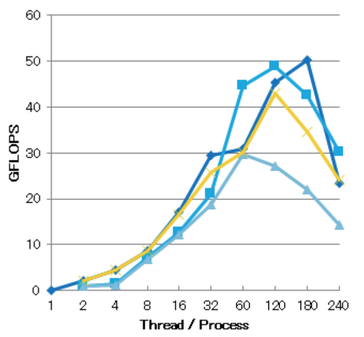
XcalableMP (XMP) is a PGAS language for distributed memory system, which is a directive-based language extension of C and Fortran. Currently, we are carrying out a design & implementation of XcalableMP runtime for Xeon Phi.

- Advantage of XcalableMP PGAS model for Manycore
  - 》MPI+OpenMP hybrid is a must in manycore, but its programming cost is high.
  - 》XcalableMP provides a unified programming model for both inter-node and intra-node parallelism. The runtime can be designed to make use of message passing for inter-node and shared memory for intra-node for efficient communication.
  - 》PGAS model allows the programmers to exploit locality in each core while providing a global address space.
- Design alternatives of XcalableMP for Manycore
  - (1)Using MPI even for intra-node (as same as for inter-node)
  - (2)Using shared memory allocated by mmap, shared by thread for intra-communication. (← the result shown in this poster)
  - (3)Program transformation from PGAS model (based on process) to thread model .
  - (4)Using a new thread model, PVAS (Partitioned Virtual Address Space) supported by Riken AICS, system software team.

Ghost region update on SHM in XMP runtime



Results of Himeno benchmark



HME_OMP_COL: OpenMP with collaps
HME_SHM: XMP with shared memory runtime
HME_MPI: MPI
HME_OMP: OpenMP

Reference: Mitsuru Ikei, Mitsuhisa Sato, "A PGAS Execution Model for Efficient Stencil Computation on Many-Core Processors." CCGRID 2014: 305-314

Results: Our overall performance advantage against OpenMP is 16.8 % for Lap1D and 13.8 % for Hime2D.

① **Blocking Effect of Global Arrays**: By dividing global arrays into sub-arrays detached each others, we could reduce 22.2 % and 27.3 % of CPU calculation time on Laplace and Himeno respectively.

② **Efficient Ghost Region Exchange**: By changing MPI sendrecvs to direct memory copy on SHM, we could reduce memory traffics about 32.3% to 44.6% and get the maximum performance gain 62.9 %.