Fault Tolerant Runtime Research @ ANL

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Joint Lab for Petascale Computing Workshop

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Brief History of FT

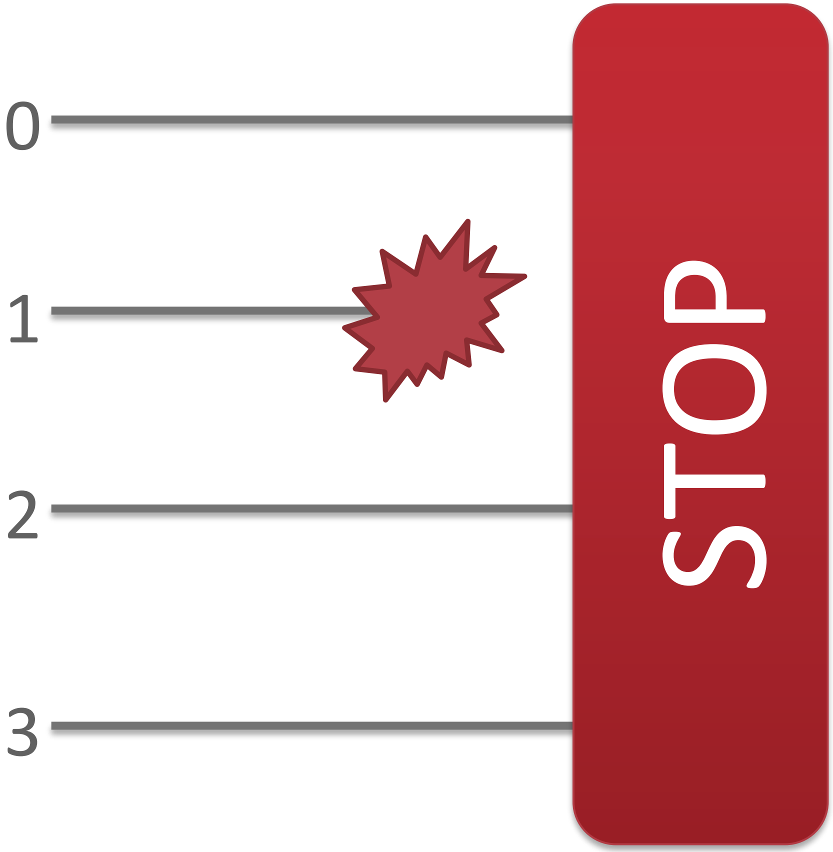
- Checkpoint/Restart (C/R) has been around for quite a while
  - Guards against process failure
  - Won't talk too much about this
- Algorithm Based Fault Tolerance (ABFT)
  - Spawned a new class of "naturally fault-tolerant" applications (linear algebra, Monte Carlo, etc.)
  - Requires libraries to be fault tolerant as well
    - FT-MPI
    - MPI/RT
- Soft Errors cause silent incorrect answers (cosmic rays, overheating, etc.)
  - Sometimes they're caught by ECC checking, other times not.
  - Don't cause process failures, but may require handling anyway
- Some FT methods are trying to handle everything at once
  - Containment domains

Overview

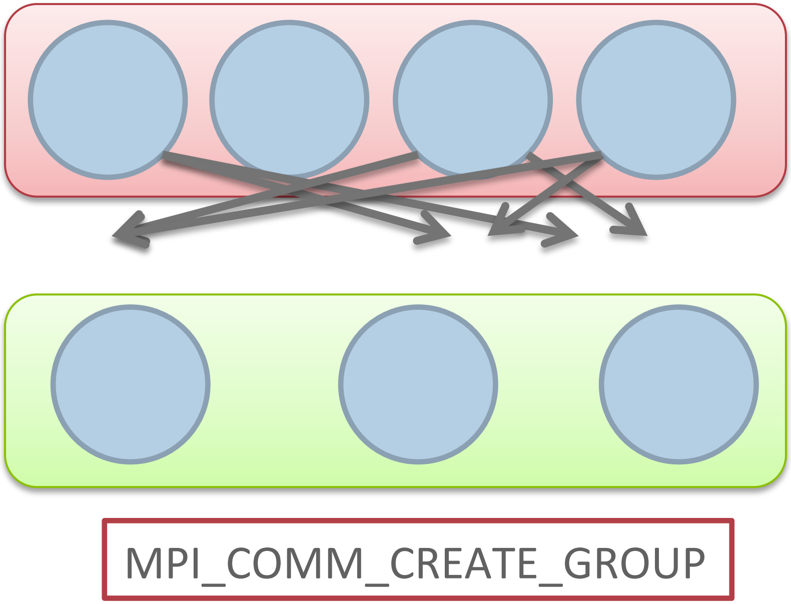
- Process Fault Tolerance Work
  - MPI-3
  - MPI-<next>
- Soft Errors
  - GVR / LRDS
  - VOCL-FT
- Future Work

Process Fault Tolerance Pre-MPI-3

- Process failure -> Application Failure
- Few implementations support MPI_Errhandlers
  - Previous Work: Checkpoint-on-Failure



Process Fault Tolerance
MPI-3

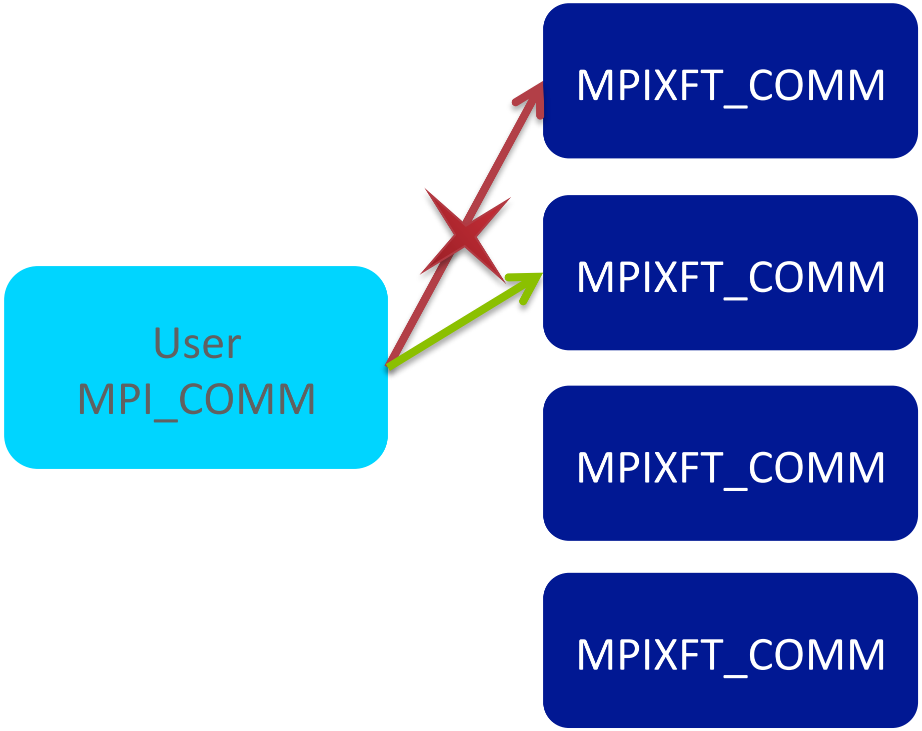


MPI_COMM_CREATE_GROUP

- Still no explicit FT
- New non-collective communicator creation
  - MPI_COMM_CREATE_GROUP
  - Provides a functionally complete FT model
  - Expensive to use

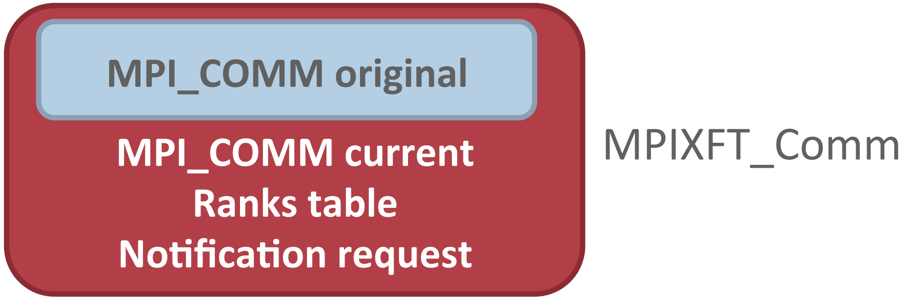
MPIXFT

- **Proof of concept for FT in MPI 3.0**
- Virtualize MPI objects
- Transparently map "virtual" user objects to "physical" objects



MPIXFT

- Add transparent metadata to MPI objects and cache when used
- Because (almost) everything has a NB equivalent, we can do notification
- Communicators are rebuilt via MPI_COMM_CREATE_GROUP



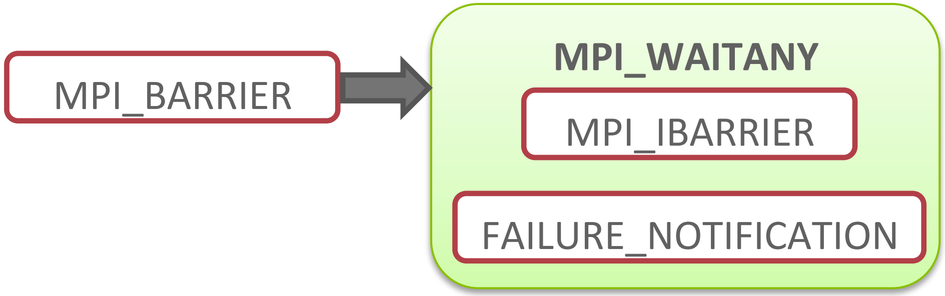
MPI_COMM original

MPI_COMM current

Ranks table

Notification request

MPIXFT_Comm



MPI_BARRIER

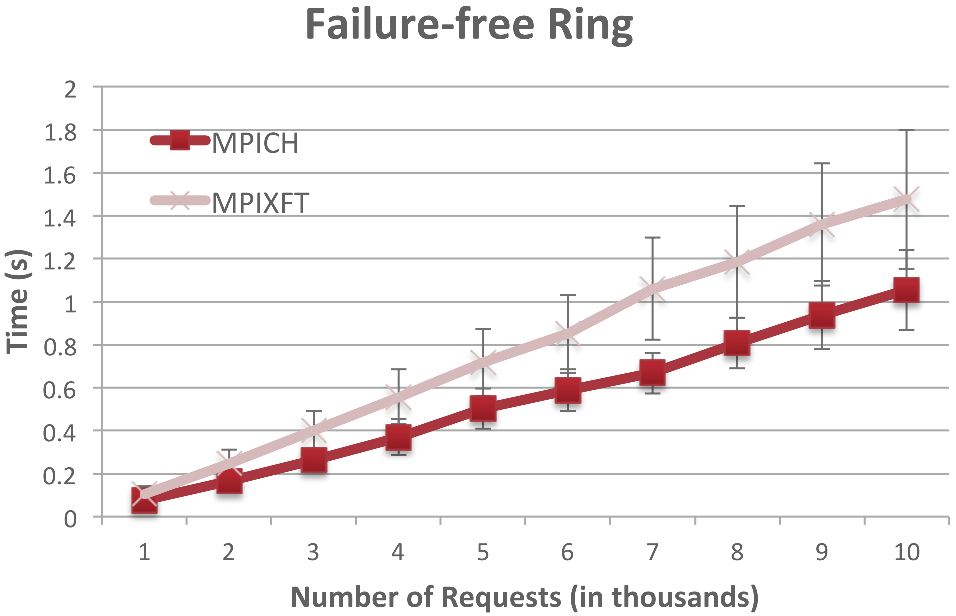
MPI_WAITANY

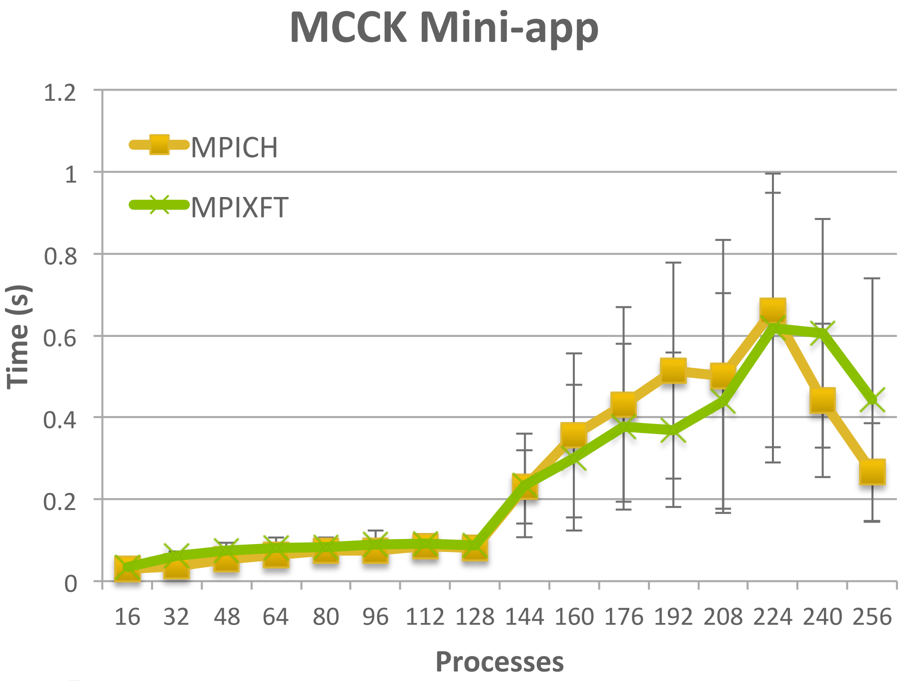
MPI_IBARRIER

FAILURE_NOTIFICATION

MPIXFT Early Results

- MCCK Mini-app
  - Domain decomposition communication kernel
  - Each process has 4 outstanding requests at a time
- Up to 256 nodes





- Non-blocking ring test
  - More tokens taxes request caching system
  - Extreme case with lots of outstanding requests
- 10 nodes

Process Fault Tolerance
MPI-<next> (User Level Failure Mitigation)

- Enable application-level recovery by providing minimal FT API to prevent deadlock and enable recovery
- Don’t do recovery for the application, but let the application (or a library) do what is best.
- Only handling process failures currently

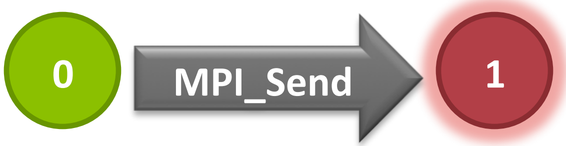
ULFM Overview

- Failure Notification
  - Error codes
  - New API for getting group of failed processes
- Failure Propagation
  - Local notification
  - New API for notifying other processes
- Failure Recovery
  - Point-to-point
    - Nothing required
  - Wildcard
    - New API to re-enable MPI_ANY_SOURCE
  - Communicator
    - New API to create communicator without failed processes

ULFM Mechanisms

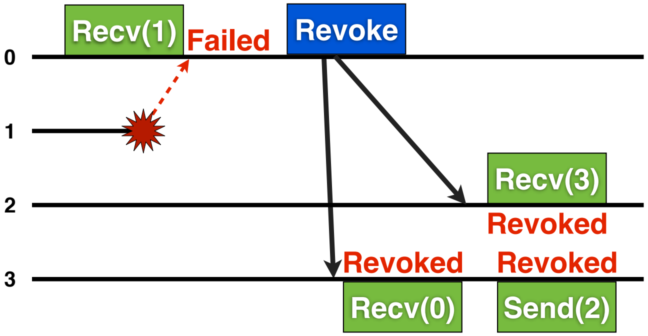
- Minimal API
  - 5 main functions
- Encourages FT libraries to sit on top of MPI and provide high level recovery abstractions

Failure Notification

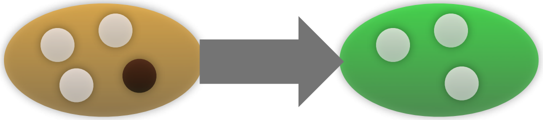


MPI_ERR_PROC_FAILED

Failure Propagation



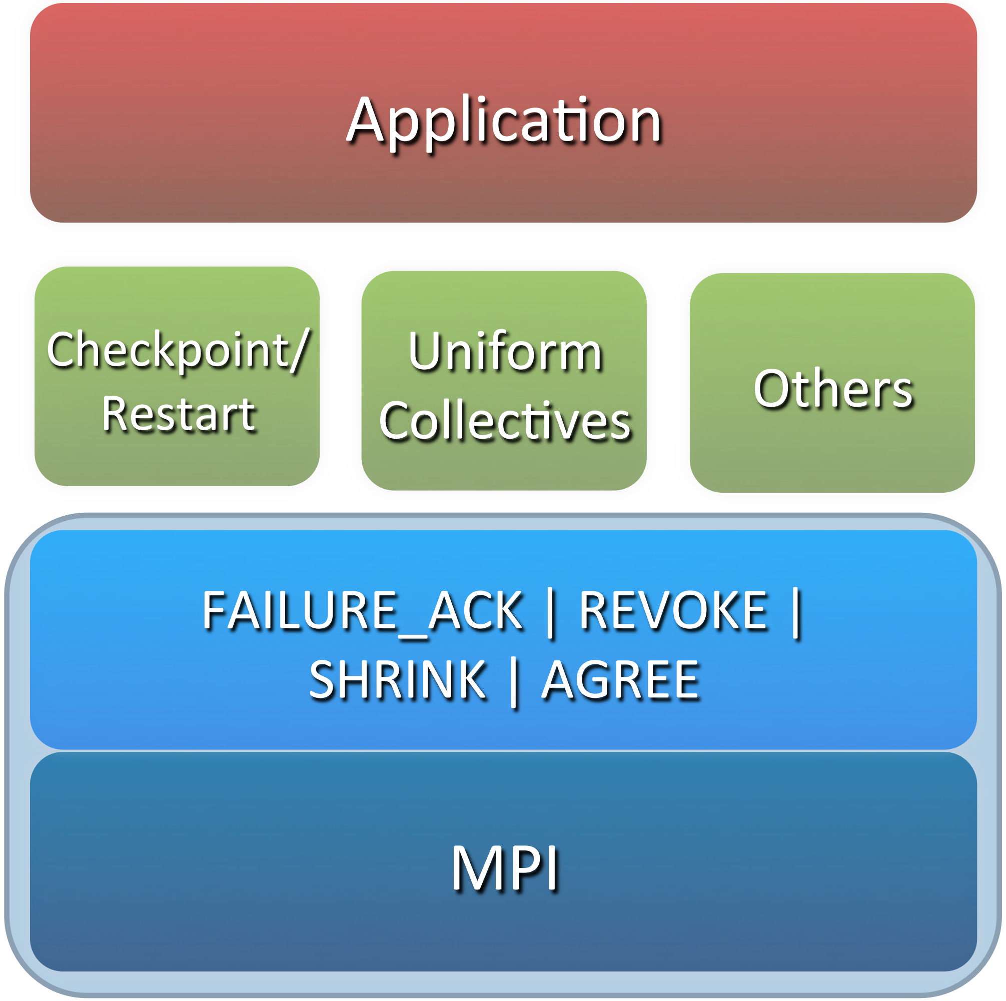
Failure Recovery



MPI_COMM_SHRINK()

ULFM Continued

- RMA Windows & Files must be recreated after failures
- Minimal additions to encourage FT libraries rather than direct usage
  - Doesn't restrict use cases
- Reference implementation complete
  - MPICH implementation in progress
- Standardization in progress



Application

Checkpoint/ Restart

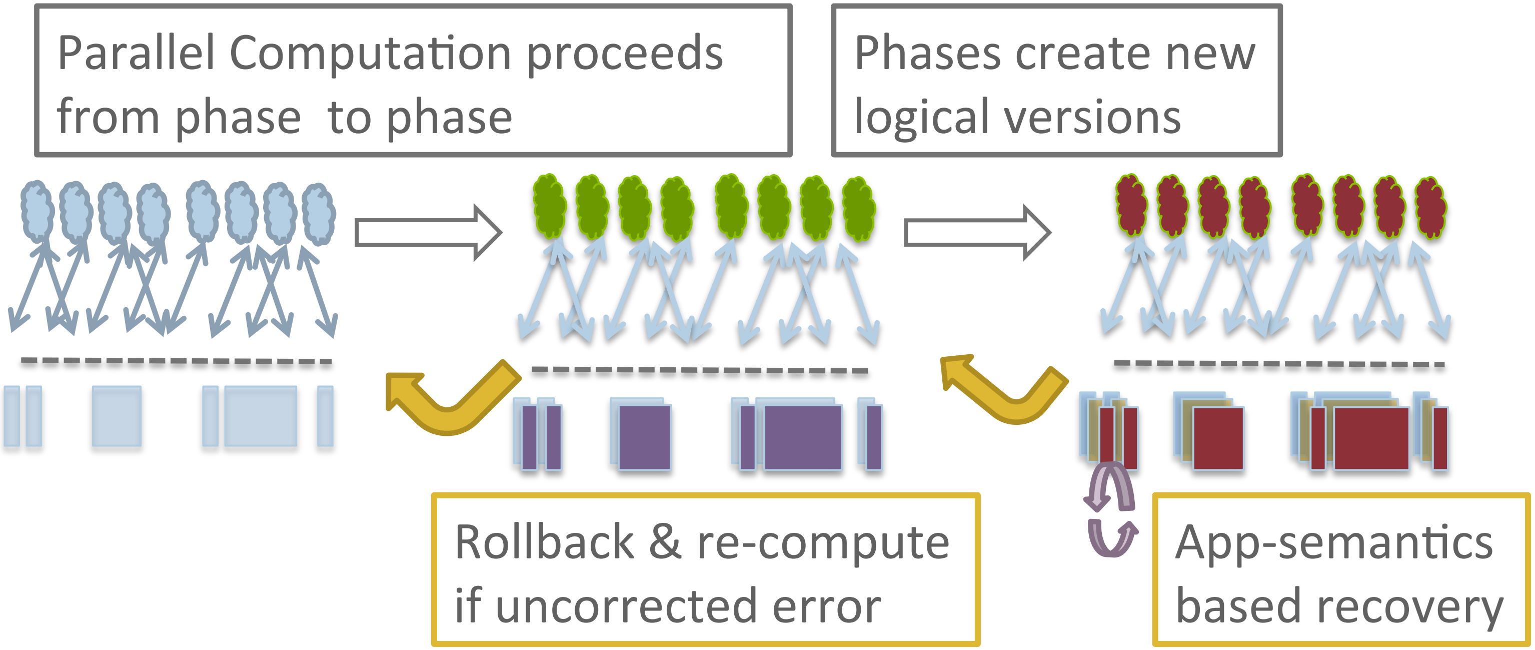
Uniform Collectives

Others

FAILURE_ACK | REVOKE | SHRINK | AGREE

MPI

Soft Errors
GVR (Global View Resilience)



Parallel Computation proceeds from phase to phase

Phases create new logical versions

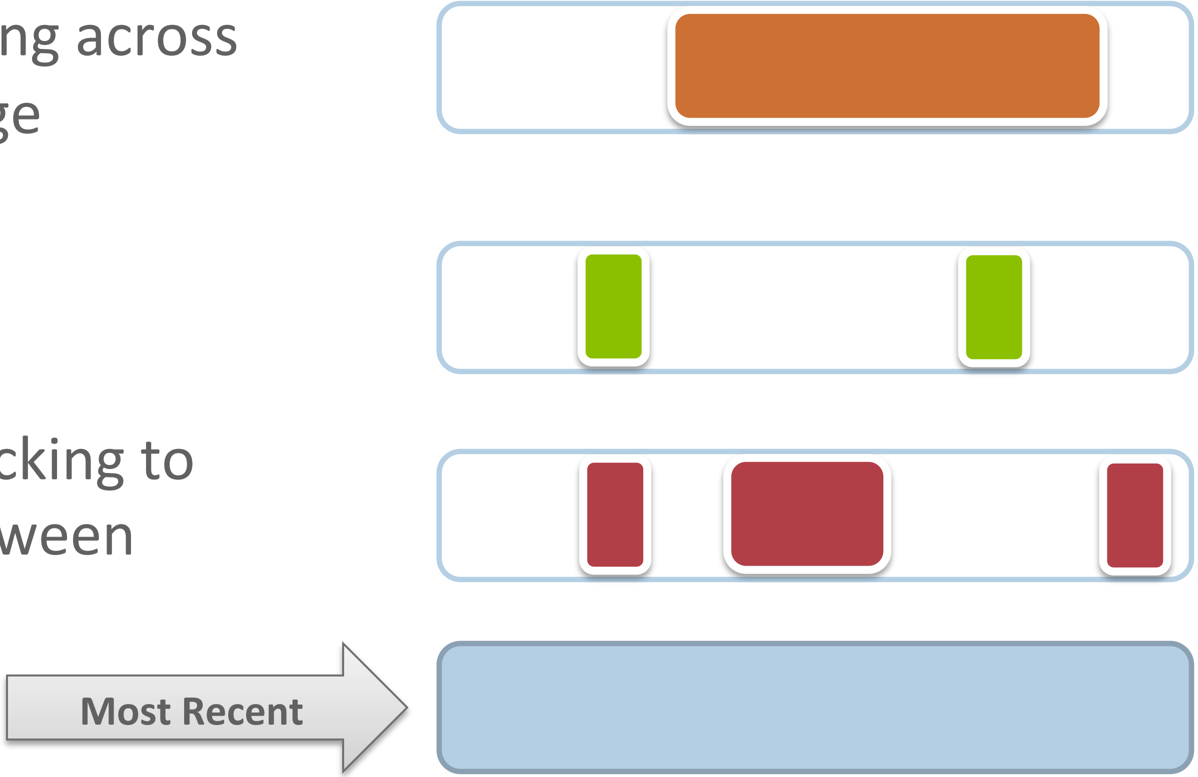
Rollback & re-compute if uncorrected error

App-semantics based recovery

- Multi-versioned, distributed memory
  - Application commits "versions" which are stored by a backend
  - Versions are coordinated across entire system
- Different from C/R
  - Don't roll back full application stack, just the specific data.

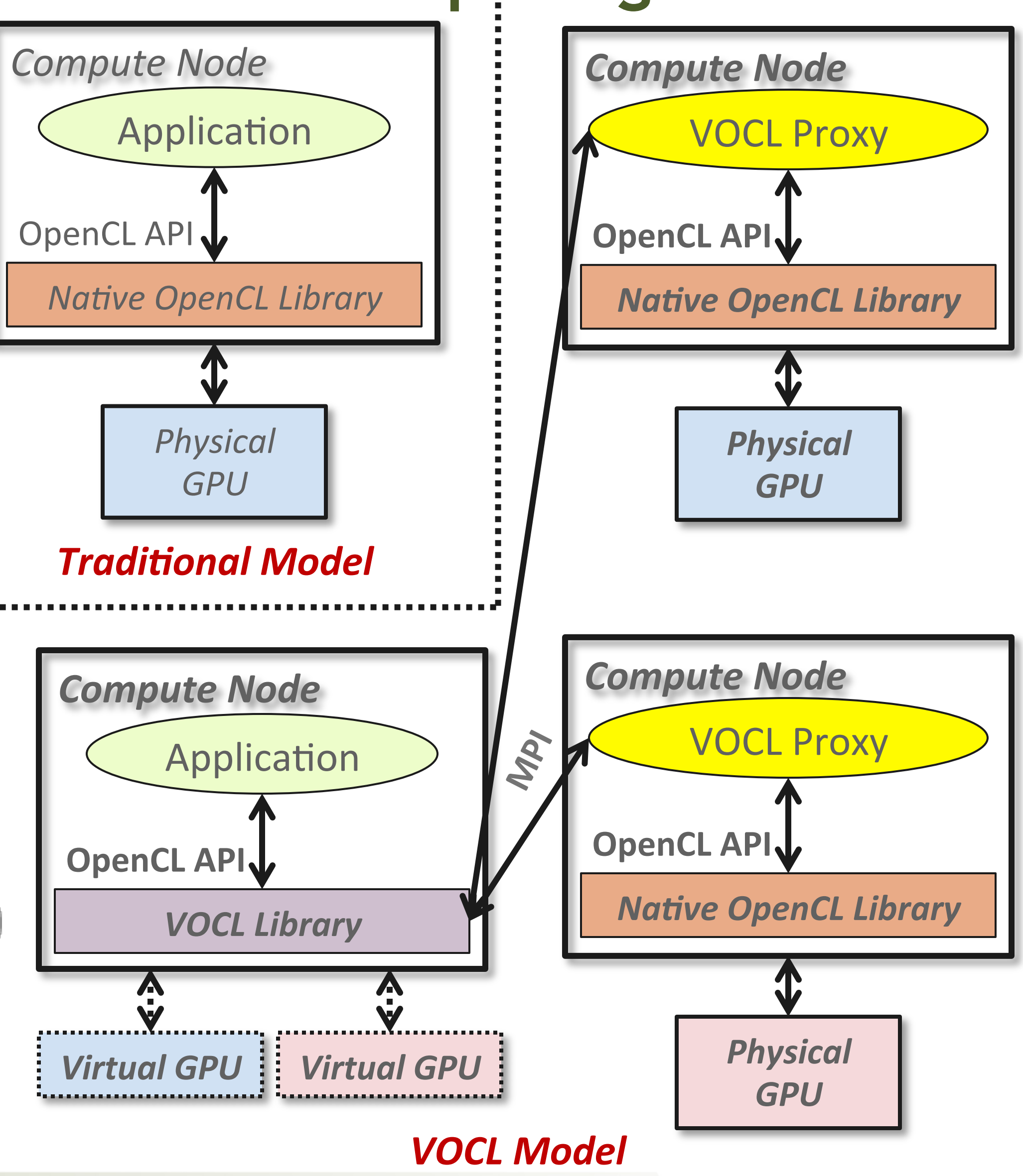
Soft Errors
LRDS (Local Reliable Data Storage)

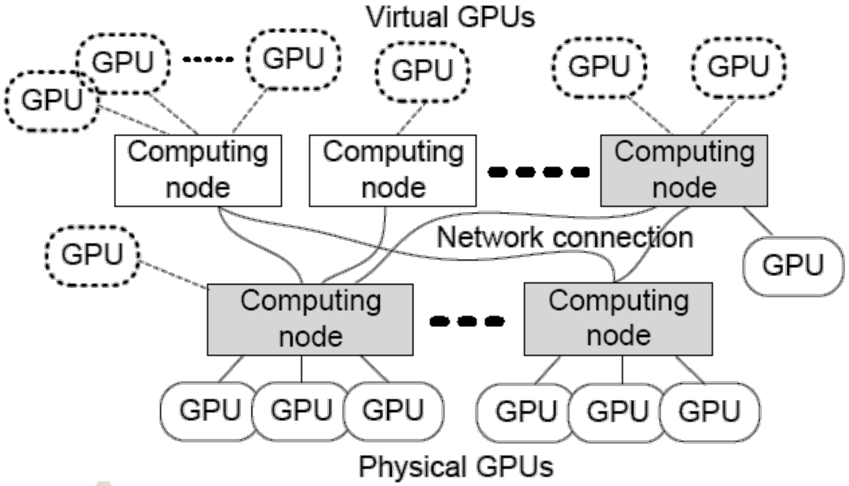
- Backend data store for GVR
- Provides versioning across all kinds of storage
  - In-memory
  - NVRAM
  - Disk
- Uses dirty-bit tracking to create deltas between versions



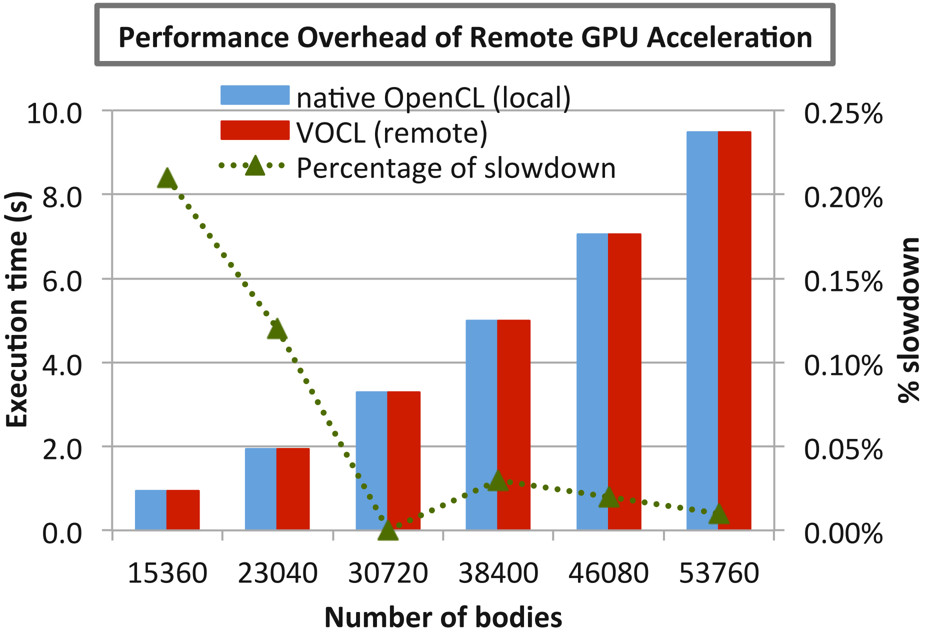
Soft Errors
VOCL: Transparent Remote GPU Computing

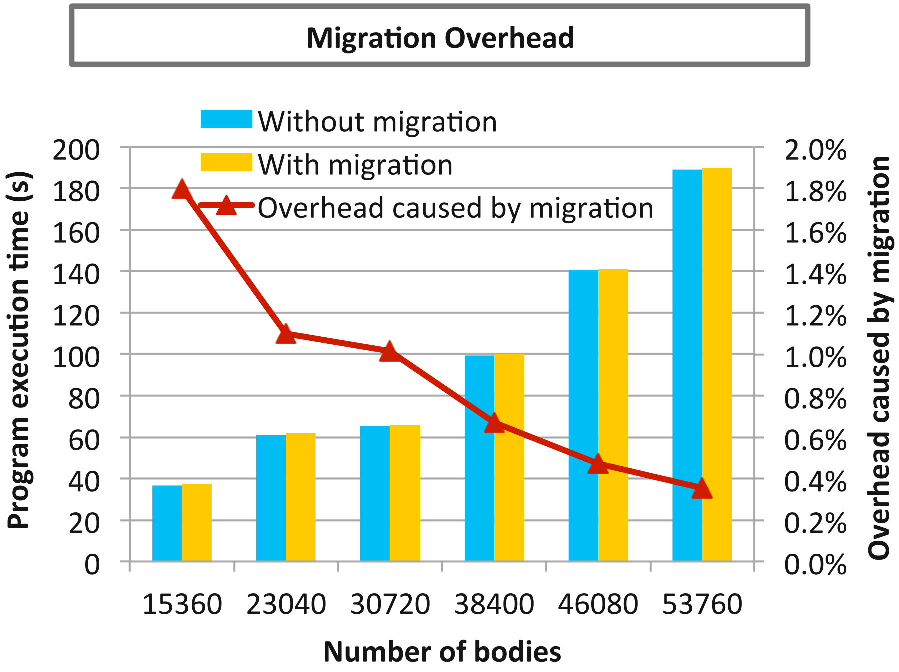
- Transparent utilization of remote GPUs
- Efficient GPU resource management:
  - Migration (GPU / server)
  - Power Management: pVOCL

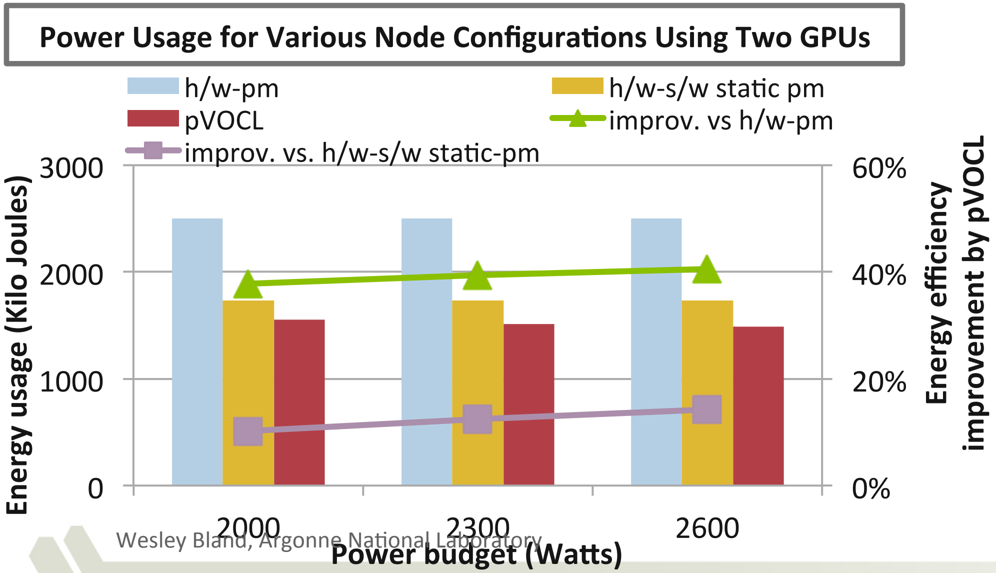




Efficient Virtualization of Accelerators with VOCL

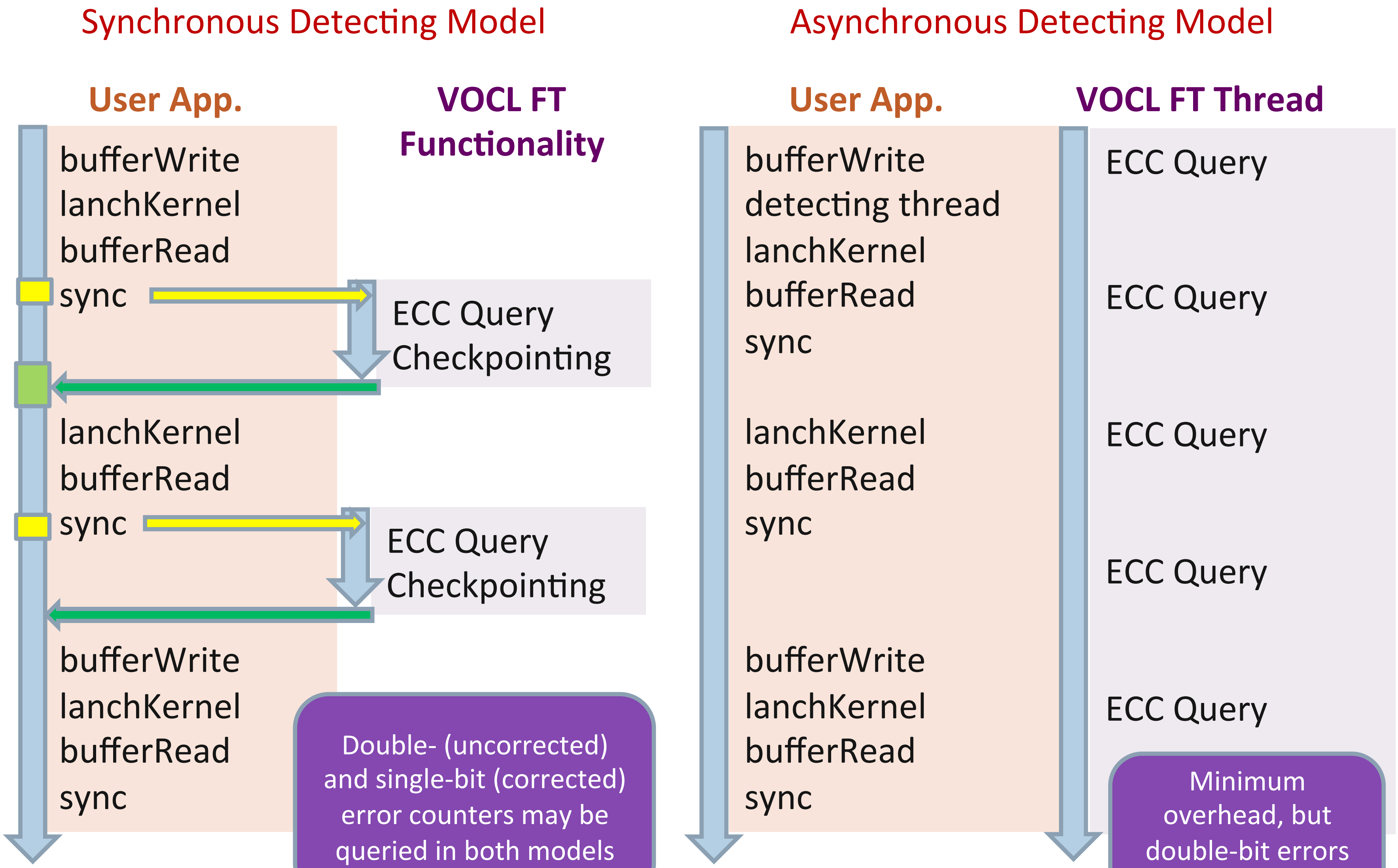






- P Lama, Y Li, AM Aji, P Balaji, JS Dinan, S Xiao, Y Zhang, W Feng, RS Thakur, and X Zhow. *"pVOCL: power-aware dynamic placement and migration in virtualized GPU environments"*. In ICDCS 2013.
- S Xiao, P Balaji, JS Dinan, Q Zhu, RS Thakur, S Coghlan, H Lin, G Wen, J Hong, and W Feng. *"Transparent accelerator migration in a virtualized GPU environment"*. In CCGrid 2012.
- S Xiao, P Balaji, Q Zhu, RS Thakur, S Coghlan, H Lin, G Wen, JH Hong, and W Feng. *"VOCL: an optimized environment for transparent virtualization of graphics processing units"*. In InPar 2012.

Soft Errors
VOCL-FT (Fault Tolerant Virtual OpenCL)



Synchronous Detecting Model

User App.

bufferWrite
lanchKernel
bufferRead
sync

lanchKernel
bufferRead
sync

bufferWrite
lanchKernel
bufferRead
sync

VOCL FT Functionality

ECC Query
Checkpointing

ECC Query
Checkpointing

Double- (uncorrected) and single-bit (corrected) error counters may be queried in both models

Asynchronous Detecting Model

User App.

bufferWrite
detecting thread
lanchKernel
bufferRead
sync

lanchKernel
bufferRead
sync

bufferWrite
lanchKernel
bufferRead
sync

VOCL FT Thread

ECC Query

ECC Query

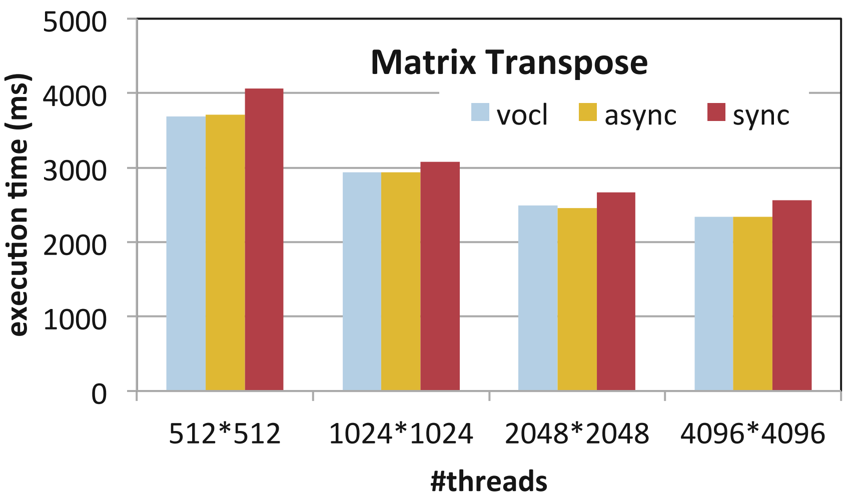
ECC Query

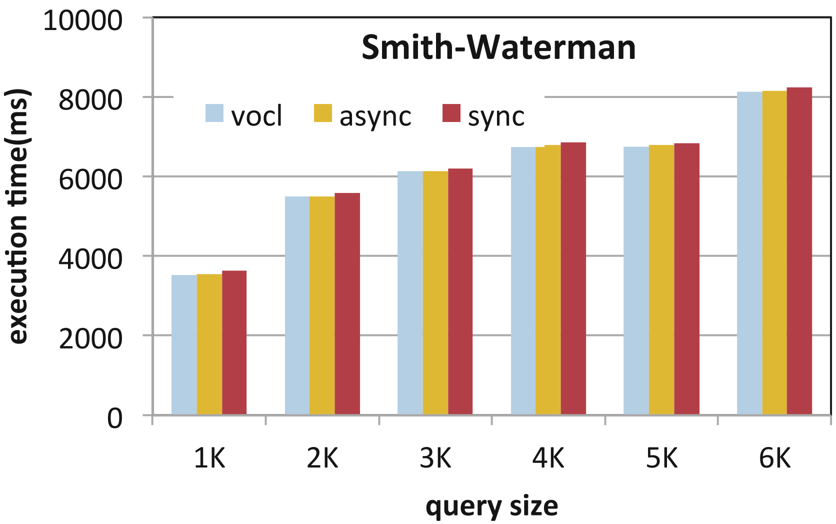
ECC Query

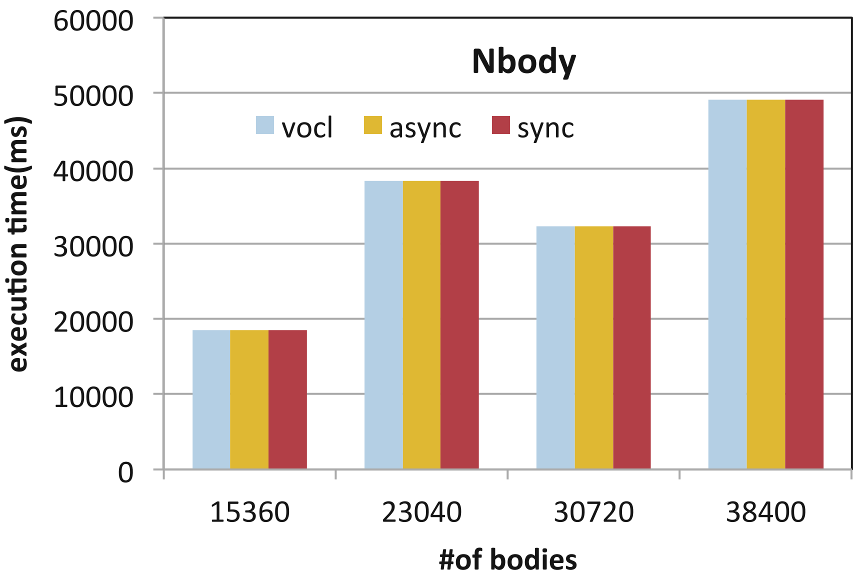
ECC Query

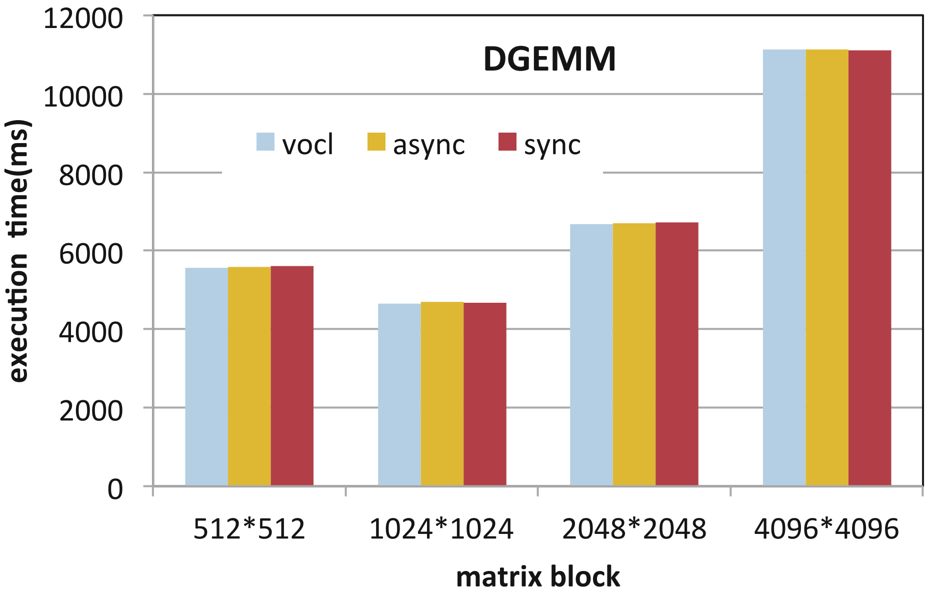
Minimum overhead, but double-bit errors will trash whole executions

VOCL-FT: Single and Double Bit Error Detection Overhead



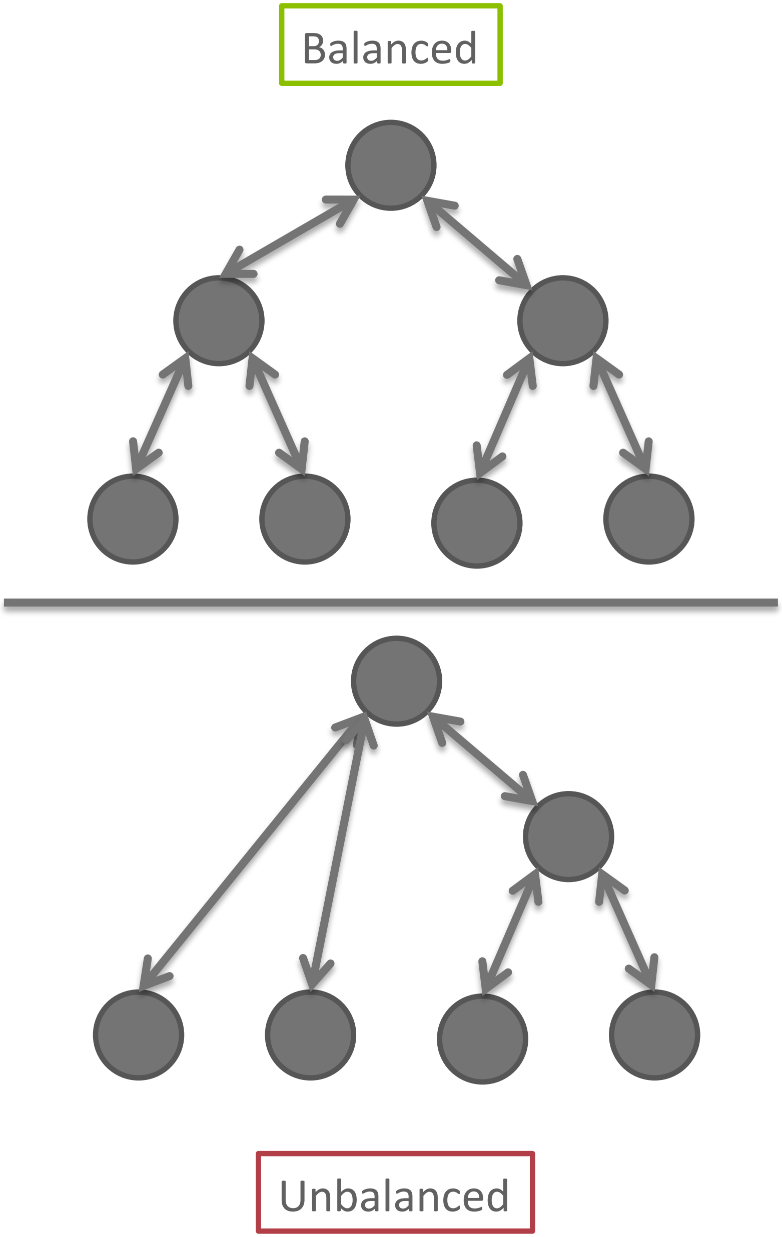






Future Work
Performance Faults

- What is the effect of a non-catastrophic error on performance?
  - Link failure
  - Corrected memory failures
- Is it better to mask these faults or perform a recovery action?


Balanced
Unbalanced