ULFM User Level Failure Mitigation

User Level Failure Mitigation is a set of MPI extensions to report errors, provide interfaces to stabilize the distributed state, and restore the communication capabilities in applications affected by process failures. Relevant communicators, RMA windows, and I/O files can be reconstructed online, without restarting the application, as required by the user recovery strategy.

ULFM's capability to restore communication after a fault is crucial infrastructure for supporting the design and deployment of production-grade recovery strategies. Multiple applications and programming frameworks are already taking advantage of ULFM constructs to deliver varied fault tolerance strategies—from run-through algorithms that continue without rejuvenating the lost processes, to methods that restore the lost processes and their dataset—either from checkpoints or from checkpoint-free forward recovery techniques.

Open MPI ULFM 4.0.2

- Derived from the latest stable Open MPI 4.0.2:
  - All new features of OpenMPI with resilience support
  - Same simplified build and runtime arguments as Open MPI
- Resilience support with most networks and job schedulers:
  - Networks: UCX, uGNI, Open IB, TCP, and CMA Shared-memory
  - Launchers: Slurm, ALPS, and PBS
- No measurable failure-free overhead on HPC networks
- Beta resilience support for RMA and FILE operations

ULFM User Communities

- Programming languages:
  - X10 over MPI with "DeadPlace" exception support
  - CoArrays Fortran with "FailedImages" extension
- Checkpointing Frameworks:
  - Fenix, CRAFTS, LFLR, and VELOC
- Applications:
  - PDE solvers and FTLA
- Non-HPC workloads:
  - SAP Databases and Hadoop over MPI

ULFM FEATURES

Flexibility

- No predefined recovery model is imposed or favored. Instead, a set of versatile APIs is included to provide support for different recovery styles (e.g., checkpoint, ABFT, iterative, and Master-Worker).
- Application directs the recovery, and it only pays for the level of protection it needs.
- Recovery can be restricted to a subgroup, thereby preserving scalability and easing the composition of libraries.

Performance

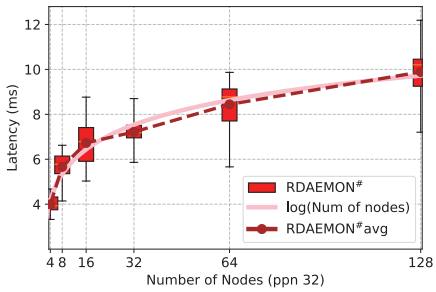
- Protective actions are outside of critical MPI routines.
- MPI implementors can uphold communication, collective, one-sided, and I/O management algorithms unmodified.
- Encourages programs to be reactive to failures, and cost manifests only at recovery.

Productivity

- Backward compatible with legacy, fragile applications.
- Simple and familiar concepts to repair MPI.
- Provides key MPI concepts to enable FT support from library, runtime, and language extensions.

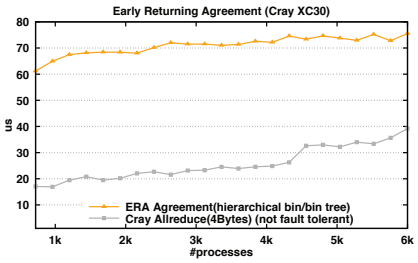
Failure Detection

The Failure Detection and notification service of ULFM is available as a PMIx component (called RDaemon) and can report failures in a matter of milliseconds at 4k ranks.



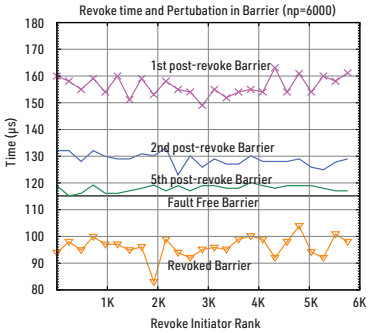
Agreement

Users can stabilize the global state after a failure with this consensus operation. Early returning agreement (ERA) latency is only double Cray's optimized, non-resilient Allreduce.



Reliable Broadcast

Revoke permits disseminating fault information. Its latency is lower than a barrier. A reliable broadcast causes only a short burst of network activity (~700 µs).



ULFM AT SC19

Monday, November 18
8:30 a.m. to 5:00 p.m.
Fault Tolerance for High Performance and Big Data Applications: Theory and Practice
Room 403

Tuesday, November 19
12:15 p.m. to 1:15 p.m.
MPI 4.0 Is Coming – What Is in It and What Is next?
Rooms 201-203

Wednesday, November 20
12:15 p.m. to 1:15 p.m.
Open MPI State of the Union
Rooms 201-203

Wednesday, November 20
12:15 p.m. to 1:15 p.m.
Charting the PMIx Roadmap
Room 210-212

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FIND OUT MORE AT
http://fault-tolerance.org/

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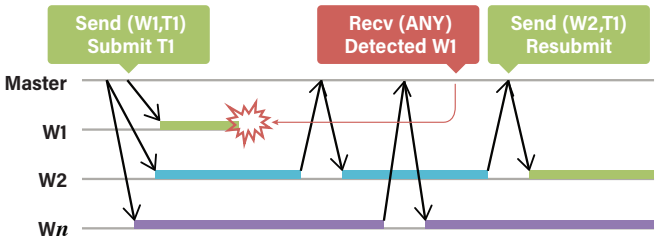
Resilience Extensions for MPI: **ULFM**

ULFM provides targeted interfaces to empower recovery strategies with adequate options to restore communication capabilities and global consistency, at the necessary levels only.

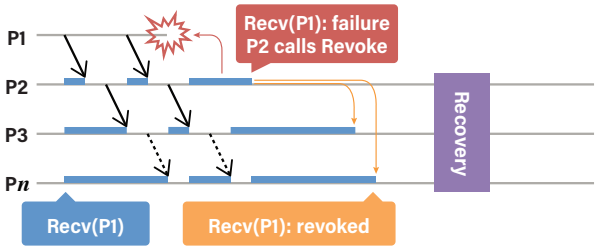
Continue across Errors

In ULFM, failures do not alter the state of MPI communicators. Point-to-point operations can continue undisturbed between non-faulty processes. ULFM imposes no recovery cost on simple communication patterns that can proceed despite failures.



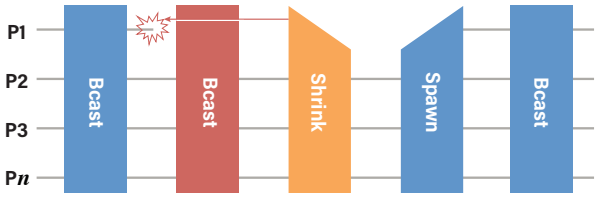
Exceptions in Contained Domains

A process can use MPI_[Comm,Win,File]_revoke to propagate an error notification on the entire group, and could, for example, interrupt other ranks to join a coordinated recovery.



Full-Capability Recovery

Allowing collective operations to operate on damaged MPI objects (communicators, RMA windows, or files) would incur unacceptable overhead. The MPI_Comm_shrink routine builds a replacement communicator—excluding failed processes—that can be used to resume collective operations in malleable applications, spawn replacement processes in non-moldable applications, and rebuild RMA windows and files.



Ongoing Research: Evaluate the Cost and Expressivity of Asynchronous Recovery

Error Scoping

Adding per-communicator (window/file) control knobs for the application to control the scope of error reporting: set Info key **mpix_error_scope** on a communicator to control which errors interrupt MPI calls.

- "local": current ULFM behavior: report an error only **when communicating with a failed peer** (e.g., recv from failed process, and collective communication) **default, current ULFM**
- "group": report errors (i.e., REVOKE) for a failure at **any process with a rank in the comm/win/file** (e.g., in recv from an alive process in comm)
- "global": report errors (i.e., REVOKE) for a failure **anywhere in "universe"**

Error Uniformity

All processes partake in a collective operation, should they return an error in unison? The user sets the info key **mpix_error_uniform** on a communicator to control if error reports need to be uniform.

- "local": errors reported as needed to inform of invalid outputs (buffers/comms) at the reporting rank (i.e., other ranks may report success); **default, current ULFM**
- "create": if communicator/win/file creation operations (e.g., comm_split, file_open, win_create, and comm_spawn) reports at a rank, it has reported the same ERR_PROC_FAILED/REVOKED at all ranks
- "coll": same as above, for all collective calls (including creates)

Asynchronous Error Recovery

Error recovery is difficult to overlap, because MPI currently misses asynchronous dynamic processes constructs.

- Adding **MPI_COMM_ISHRINK** to enable asynchronous failed processes exclusion
- Adding **MPI_COMM_ISPAWN** (and ICONNECT/IACCEPT) to enable asynchronous spare respawn (as well as many other non-fault-tolerant application use cases)

Uniformity example:

An error is reported only at some leaf node in a broadcast topology with a failure.