The ABCs of Open MPI

Decoding the Alphabet Soup of the Modern HPC Ecosystem (Part 3)

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Presented in conjunction
with the EasyBuild community

Webex Logistics

- This session is being recorded
- Ask questions in the Q&A panel

Overview

- Background
- PMIx: What is it?
- Building Open MPI

$\left.\begin{array}{l}\\ \\ \\ \end{array}\right\}$ Covered in part 1

- PMIx (cont.)
- A breakdown of Open MPI:
  - The run-time stuff
  - The MPI stuff

$\left.\begin{array}{l}\\ \\ \\ \\ \end{array}\right\}$ Covered in part 2

- PRRTE
- Configuration / debugging tips
- The upcoming Open MPI v4.1.x series
- The upcoming Open MPI v5.0.x series

Recap

- Too much to cover for a real “recap”
- Part 1
  - YouTube video
  - PDF slides
- Part 2
  - YouTube video
  - PDF slides

PRRTE

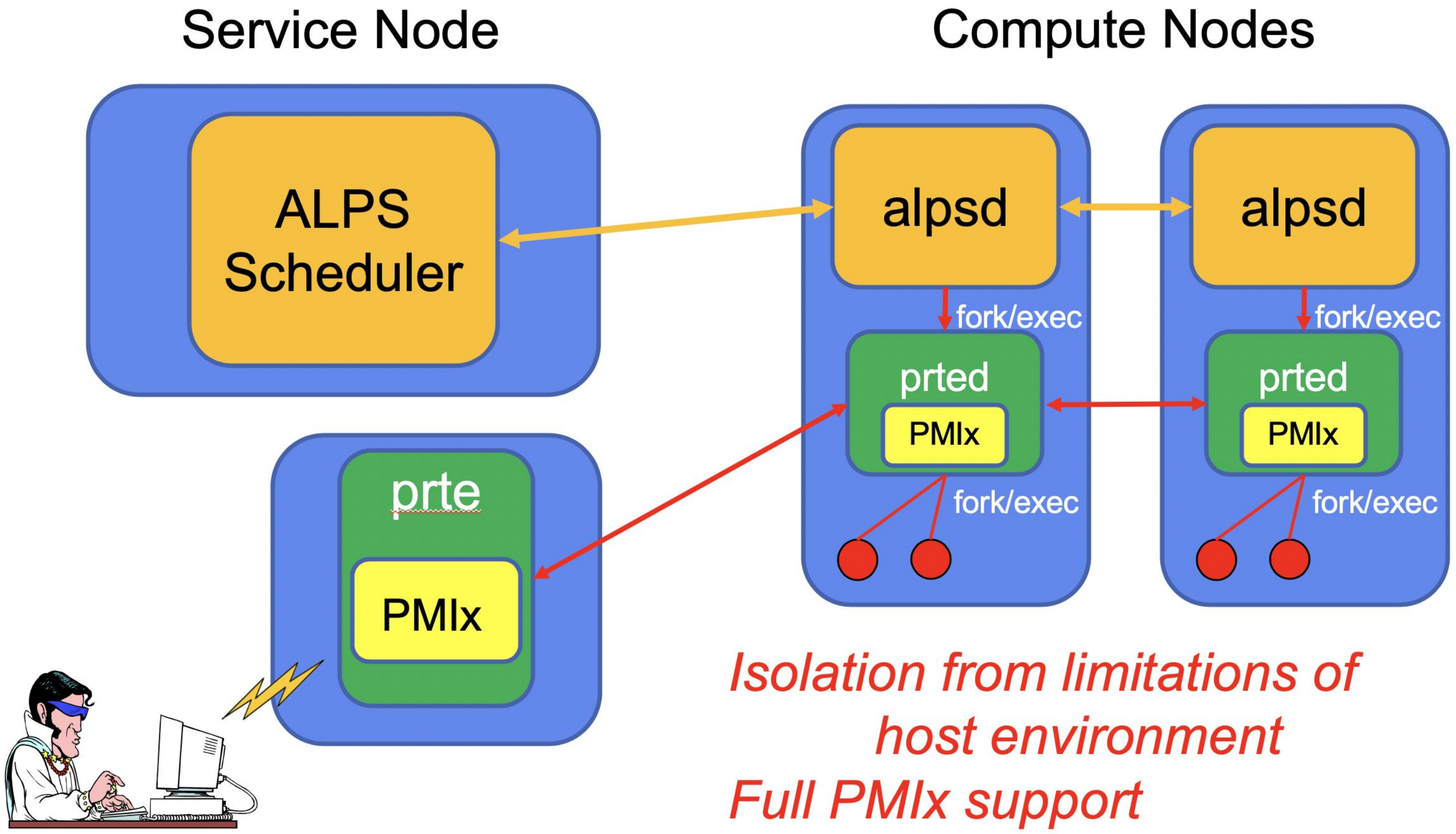
Open PMIx Questions from Session 2

- Examples of applications using async/cross-model stuff?
  - https://eurompi2018.bsc.es/sites/default/files/uploaded/eurompi2018-paper-vallee.pdf
- Pros/cons of srun vs mpirun
  - Mpirun
    - Offers more options, larger range of PMIx support
      - Dynamics, job control, monitoring
    - Historically was MPI implementation specific
      - Changes with OMPI v5’s use of PRRTE
  - Srun
    - Works the same (placement, binding) regardless of MPI implementation
- Separate talk by Ralph on PMIx Launch Orchestration?
  - Happy to do so - will schedule it

What is PRRTE?

- PMIx Reference RunTime Environment
    - Supports full range of PMIx
    - Per-user development environment for PMIx-based tools and apps
    - Provides a “shim” to environments that don’t have full PMIx support
- Persistent Distributed Virtual Machine (DVM)
    - Launches daemons on all allocated nodes at beginning of session
    - User launches applications against the DVM
    - Tear down DVM when user session is done (user commands)
- Derived from OpenRTE (ORTE)
    - Forked from OMPI several years ago
    - Standalone project within PMIx community
    - Moving towards distribution with PMIx (Spack, OpenHPC)

How Is It Used?



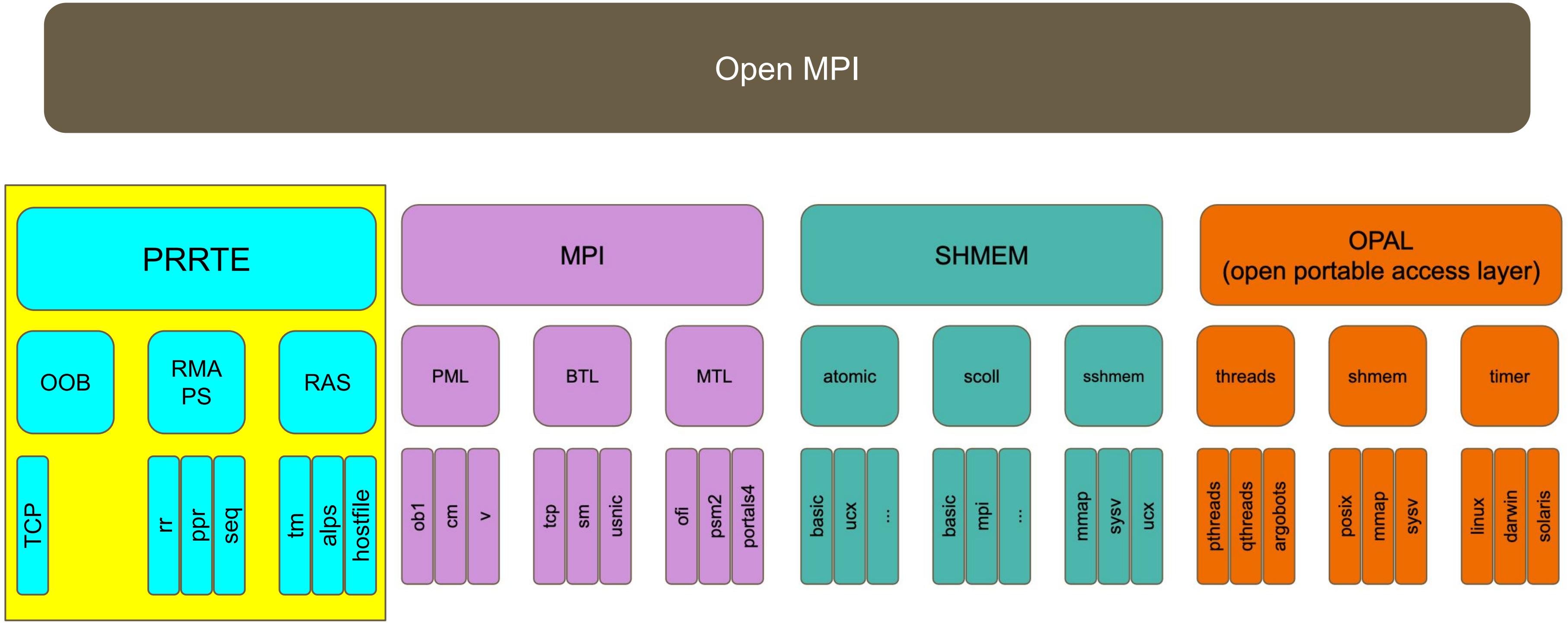
Isolation from limitations of host environment

Full PMIx support

Where Is It Used?

- As a shim in non-full-featured environments
    - Cray/ALPS - adds support for dynamic operations
    - Slurm - extends range of PMIx support beyond wireup
- User-level development environment
    - Tool, apps - develop PMIx-based code
    - Each user gets isolated environment
- Support for workflow managers
    - Full dynamic operations
    - Multi-app/tenant
    - Fast launch as daemons persist across apps
- Base runtime for Open MPI
    - Replacing ORTE in v5.0

Where Does It Fit?



PRRTE Architecture

- MCA Component Architecture
  - “Borrowed” from Open MPI
  - Same build system
- Dependencies
  - Required: libevent, HWLOC, PMIx (3.1+)
  - Optional: torque/pbs, ALPS, LSF, Gridengine
  - Autodetected: Slurm, Singularity, zlib
- Key frameworks
  - Rmaps - process placement
  - Oob - inter-daemon communication
  - Plm - daemon and application launch
  - State - proc/job state machine

No Embedded Libraries!

https://openpmix.github.io/code/getting-the-pmix-reference-server

Adaptive Command Line (schizo Framework)

- Supports multiple libraries
  - OMPI, various OSHMEM flavors, MPICH
  - Command line options fully configurable
  - Detect and utilize based on absolute path of argv[0]
- Runtime selection of "personality"
  - Obtain absolute path of argv[0]
    - Use PATH if no path information provided
  - Search PRRTE install `<prefix>/etc` for configuration files
    - `ompi.ini`, `oshmem-stb.ini`, `mpich.ini`
    - Compare absolute argv[0] to entries
  - Example ompi.ini
    - `/opt/local/openmpi/v5.0.0/bin/mpirun`
    - `/opt/local/openmpi/v5.0.0/bin/mpiexec`
    - `/opt/local/openmpi/v5.0.0/bin/oshrun`

→ Use OMPI schizo component for cmd line processing

MCA Parameter Usage

- Major difference from Open MPI in how these are handled
    - But you will see it in OMPI v5 as mpirun ⇒ prte
- Some apply only to start of DVM (e.g., oob, rml, routed, state)
    - Cannot be changed without restarting DVM
- Others only set default behavior (e.g., rmaps, hwloc)
    - Per-job behavior controlled via cmd line option
    - MCA param on cmd line is ignored for these values!
- Many ORTE params have been removed
    - Only applied to per-job behaviors
    - No longer supported

MCA Parameters

- Standardized way for querying / setting run-time parameters
- Multiple ways to set MCA parameters:

Command line:	`mpirun --mca <PARAM> <VALUE> …`
Environment variable:	`OMPI_MCA_<PARAM>=<VALUE>`
User-level file:	`$HOME/.openmpi/mca-params.conf`
System-level file:	`$prefix/etc/openmpi-mca-params.conf`

- Similar pattern for PMIx…

Environment variable:	`PMIX_MCA_<PARAM>=<VALUE>`
User-level file:	`$HOME/.pmix/mca-params.conf`
System-level file:	`$prefix/etc/pmix-mca-params.conf`

- …and for PRRTE

Environment variable:	`PRTE_MCA_<PARAM>=<VALUE>`
User-level file:	`$HOME/.prte/mca-params.conf`
System-level file:	`$prefix/etc/prte-mca-params.conf`

Some Differences For PRRTE

- PRRTE command lines
  - Uses “`prte`” to start the DVM
  - Uses “`prun`” to launch jobs
  - Open MPI params: prefix with “`--omca`” instead of “`--mca`”
  - PMIx params: prefix with “`--pmixmca`”
  - PRRTE params: prefix with “`--prtemca`”
  - Generic “`--mca`” picks best match based on framework and param name
    - Checks against list of known frameworks by project
- Envars and param files remain the same
  - PMIx will pickup and automatically forward the system and user default param values for Open MPI and PMIx
  - PRRTE will do the same for its default values

Build Tips

- No public APIs!
  - Applications never link against PRRTE
  - No need to worry about mix/match of PMIx, libevent, HWLOC with apps being launched
- Ensure symlinks setup to mpirun, mpiexec, etc.
  - All need to point to "`prte`" executable
  - Appropriate symlinks for each supported library
- Ensure `.ini` files created
  - Open MPI will automatically install its `ompi.ini` for embedded PRRTE
  - Need to manually create all others
- Setup any system-level default params
  - `<prefix>/etc/prte-mca-params.conf`

PRRTE vs PRTE

- “PRRTE” is the *project* name
  - Historical acronym
  - Package and libraries use it
- “PRTE” is the *operational* name
  - Avoids the “stutter” problem when typing
  - Covers all tool, MCA parameter names

PRRTE Tools

- `pcc` : wrapper compiler
  - Ensures build against same PMIx, libevent, HWLOC as PRRTE
  - Convenience only - not required (apps do not link against PRRTE)
- `prte` : start DVM
- `prte_info` : reports build information (ala `ompi_info`)
- `prted` : PRRTE daemon for remote nodes
- `prun` : PRRTE launcher
  - Used to start applications
- `pterm` : stop DVM

Debugging Tips

- Simulate large clusters on small allocation
  - Set "`--prtemca routed_radix 1`" to create linear chain of daemons
    - Tests scalable communication
  - Can use "`--prtemca ras_base_multiplier N`" to launch multiple daemons/node
    - Cannot run MPI jobs this way, useful for testing runtime scalability
- Use PMIx tools
  - Useful system info for help with diagnosis
- Verbosity is your friend (PRRTE MCA params)
  - Starting points: `plm_base_verbose`, `state_base_verbose` => set to 5
    - See `prted` cmd line, error output from remote daemons, state machine progress
  - Next: `oob_base_verbose`, `errmgr_base_verbose` => set to 5
  - If daemons are starting but procs aren't working:
    - `pmix_server_verbose` => set to 5

Ralph's Concluding Remarks

- Thank you…
  - for your attention!
  - EasyBuild (and especially Kenneth Hoste) for your hospitality!
- PMIx vs. OpenPMIx vs. PRRTE - a reminder
  - PMIx is the Standard (i.e., a document)
  - OpenPMIx is the library (i.e., a reference implementation of the PMIx Standard)
    - Someone, someday *might* implement their own version…but nothing so far
  - PRRTE is a full-featured PMIx environment
- If PMIx has things that interest you…
  - Include PMIx (at desired feature level) in your RFPs
  - Push your vendor to integrate with OpenPMIx for the desired feature level
  - Meantime, consider using PRRTE as a shim

Overall Open MPI Configuration / Debugging Tips

Start with the basics

1. Start trying to run a simple, non-MPI program locally
   This tests the basic Open MPI runtime system (without the MPI layer)
   ```
   mpirun -np 1 hostname
   ```

2. Then run MPI “hello world” locally (in Open MPI `examples` directory)
   This actually starts up / shuts down the MPI layer
   ```
   mpirun -np 1 hello_c
   ```

3. Then run MPI “ring” locally (in the Open MPI `examples` directory)
   This actually uses MPI communications (must have >=2 processes)
   ```
   mpirun -np 2 ring_c
   ```

Then add complexity

4. Then try to run a remote simple non-MPI program

   ```
   mpirun -np 3 --host host1:1,host2:1,host3:1 hostname
   ```

   (or run through your batch scheduler)

5. Then do the same with hello world

   ```
   mpirun -np 3 --host host1:1,host2:1,host3:1 hello_c
   ```

6. Then do the same with ring

   ```
   mpirun -np 3 --host host1:1,host2:1,host3:1 ring_c
   ```

Standard troubleshooting (things we hear often)

1. Check your PATH and LD_LIBRARY_PATH
   - Both locally and remote (for non-interactive logins and/or batch scripts)
   - Make sure they are both pointing to where you think they are pointing to
   - Bonus points: run "`ldd my_mpi_program`" to check where the linker will find libmpi

2. MacOS has a very lengthy default temporary directory (in $TMPDIR)
   - This can cause problems with shared memory files in Open MPI (they can exceed the max filename size)
   - Suggestion (on MacOS):

     ```
     mkdir $HOME/tmp
     export TMPDIR=$HOME/tmp
     ```

Standard troubleshooting (things we hear often)

3. Isolate the real error message
    a. Open MPI (and/or PMIx) is sometimes blamed for app issues
    b. E.g., one application process crashes, which subsequently triggers MPI and/or PMIx error messages
    c. Scroll back up and make sure you find the initial error

How can I tell which (MPI) network I'm using?

Refer back to part 2 of this seminar:

- Force the use of a given network via the PML, MTL, and BTL MCA params
- Use in conjunction with MPI benchmarks to see performance differences

- ...also, stay tuned for v5.0.0 😊

Not-uncommon question (mostly from ISVs)

"I want to re-locate an Open MPI installation"

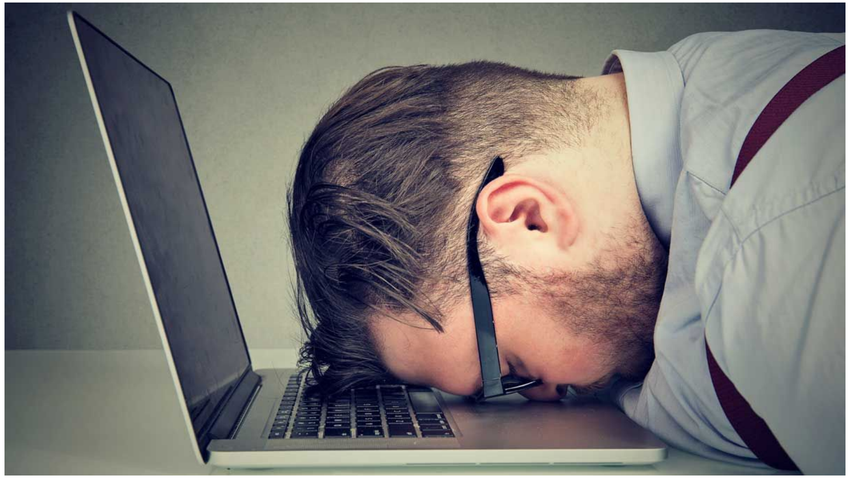
You must set the following three environment variables:

1. OPAL_PREFIX
2. PMIX_PREFIX
3. PRTE_PREFIX

More subtle issue: duplicated libraries

- If multiple -- potentially [slightly] different -- copies of a shared library are loaded in to an MPI process space, Bad Things can (will) happen
  - Symptoms can be Random Bad Things happening (segv, etc.)

- Check for implicit linker loads of the following (especially if the application itself is using these libraries):
  - Hwloc
  - Libevent
  - PMIx



How to get help

General help page: https://www.open-mpi.org/community/help/

- Supply as much detail as possible
  - Do not assume that we know what you know
  - Describe your environment
  - Describe what your program is supposed to do
  - Describe what your program is actually doing

- Provide a (small!) reproducer program

- Check the baseline MPI performance in your environment
  - Run the Ohio State MPI micro benchmarks

The Open MPI v4.1.x Series (upcoming)

v4.1.0: Expected ~August 2020

- General performance improvements
- Libfabric / OFI improvements
    - Support multi-device environments
    - One-sided performance improvements
- OMPIO improvements
    - Support IME, GPFS

- Backwards compatible with the v4.0.x series
    - Including ABI compatibility

v4.1.0: Collective performance improvements

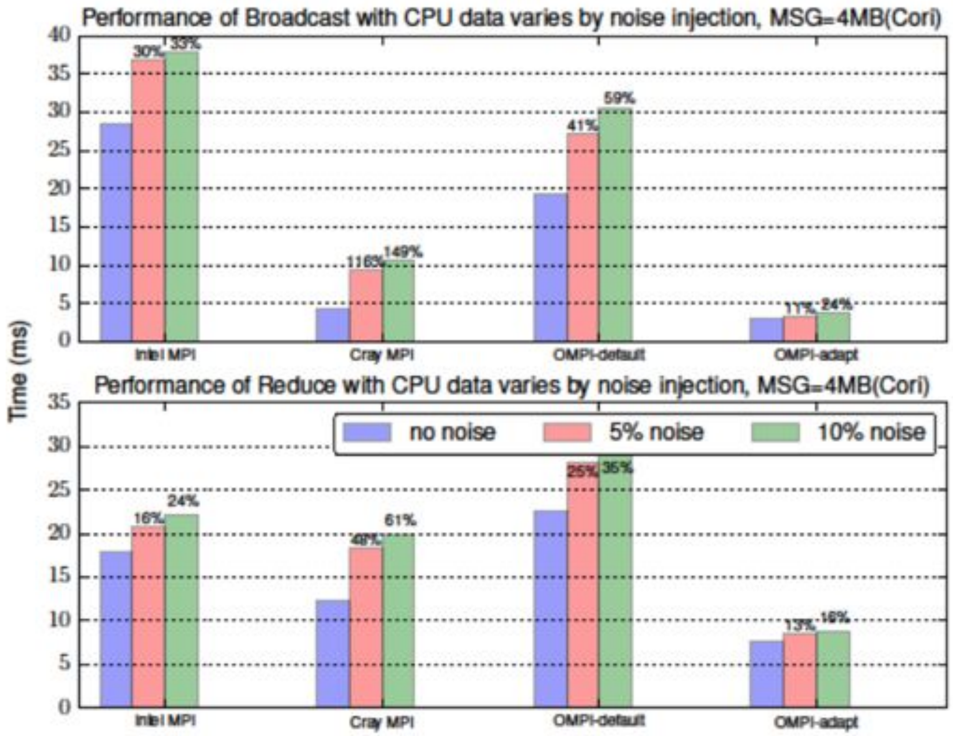
Two levels of improvements:

1. General algorithm tuning selection improvements
2. New ADAPT and HAN collective modules
    a. All-new code base from research at U. Tennessee
    b. These modules do not activate by default -- must be manually enabled
    c. Shows significant performance improvements compared to prior generation
    d. We need real-world testing!

v4.1.0: ADAPT collectives

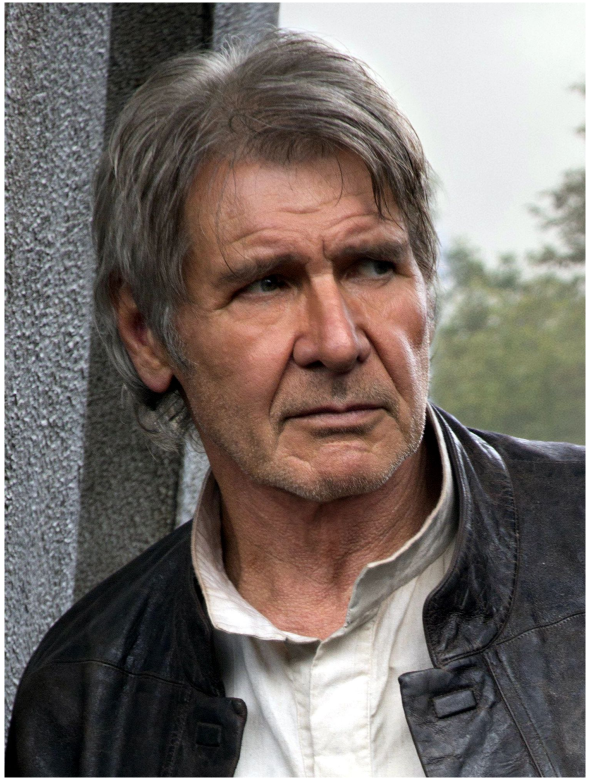
- Main idea: tolerate scheduling noise
  - Processes that are de-scheduled
  - Processes that are “late”
- Relaxes unnecessary synchronizations

- Performance on Cori (US LBNL), 1K cores
  - Every 0.1s, each process randomly inject 0-10ms noise (average 5%) and 0-20ms noise (average 10%)
  - Top: MPI_BCAST, bottom: MPI_REDUCE



v4.1.0: HAN collectives

- Hierarchical-Aware Networking (HAN)
- Support two-level hierarchies:
  - Intra-node
  - Inter-node
- Reshape the collective to minimize the amount of data transferred over the slowest link
  - Selects / orchestrates the base set of collective algorithms in Open MPI



v4.1.0: HAN collectives

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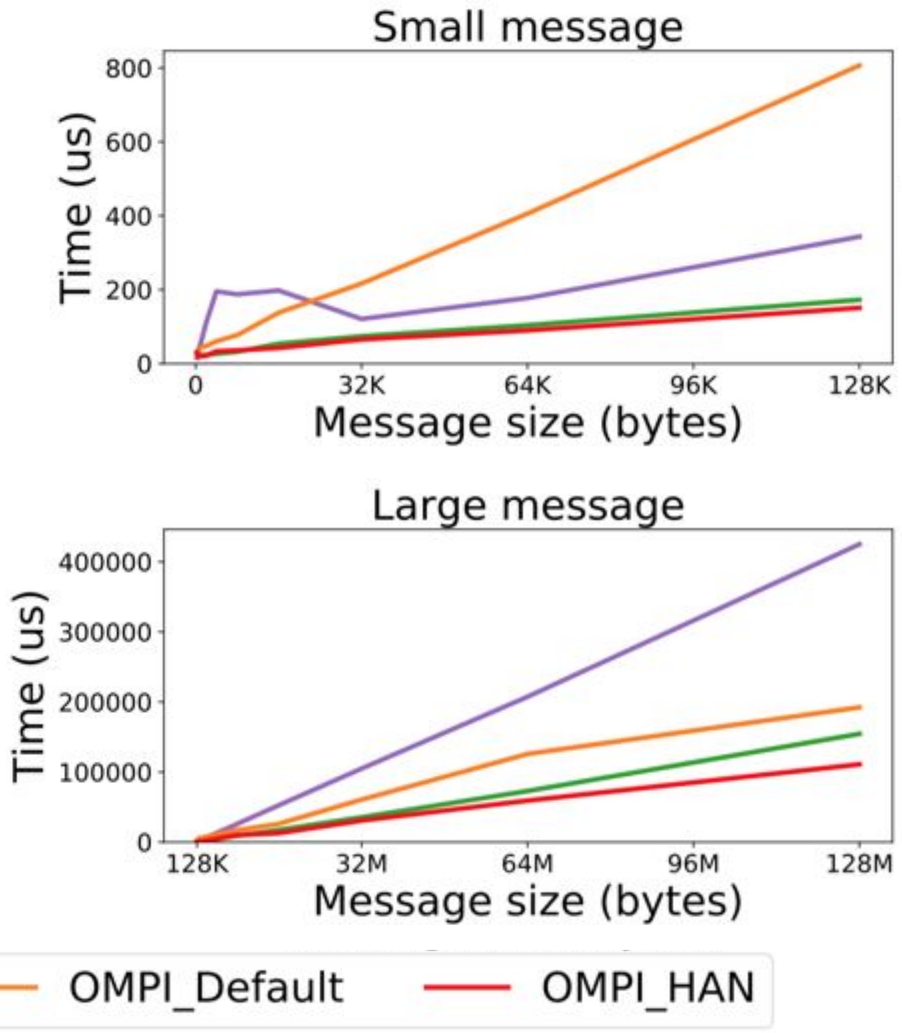
- Performance on Stampede 2
  - MPI_BCAST on 1,536 processes (24ppn)



How do I enable ADAPT and/or HAN?

- Either of two different ways:
  a. Set the MCA priority of `adapt` and/or `han` to 100. For example:
     ```
     $ mpirun --mca coll_adapt_priority 100 --mca coll_han_priority 100 …
     ```
  b. Include `adapt` and/or `han` in the `coll` MCA parameter. For example:
     ```
     $ mpirun --mca coll han,adapt,tuned,sm,basic …
     ```

- Do I have to enable *both* ADAPT and HAN?
  a. No.
  b. Specifically: you can use them idependently <u>*or*</u> together.

PLEASE TEST WITH REAL APPS!

The Open MPI v5.0.x Series (upcoming)

v5.0.0: Expected ~2020

- Originally expected 1H2020
  - Has been delayed (COVID, development complications, etc)
  - Hopefully will still release in 2020… (!)
  - Some backward compatible pieces moved to v4.1
- Many, many minor improvements

- Breaks backwards compatibility with v4.x series
  - ABI, `mpirun` command line arguments, etc.
- Requires new debuggers and tools!
  - MPIR no longer supported
  - TotalView, DDT releasing updated support
  - Shim to ease transition from MPIR
    - https://github.com/openpmix/mpir-to-pmix-guide

v5.0.0: Expected ~2020

Some ***Big Changes*** are coming in the runtime

- No support for PMI-1, PMI-2 from Slurm and Cray
  - Only PMIx is supported
- ORTE replaced by PRRTE
  - No longer support (most) `mpirun` single-dash, multi-char options (small exceptions)
  - Adaptive command line requires additional setup
  - Different syntax for MCA parameters on command line
- PMIx (v4.0.x) as first-class citizen
  - Can configure/build just MPI layer with no runtime for direct-launch only environments
  - PMIx symbols exposed for use by application
  - All non-standardized Open MPI-defined MPI info key names replaced by PMIx attributes!
    - PMIx equivalents available for standardized keys

v5.0.0: more features

- Support for User-Level Fault Mitigation (ULFM)
- Support for AVX instructions in MPI_Op operations
- Support for user-level threads packages
  - Qthreads
  - Argobots
- ADAPT and HAN will be the default for MPI collectives (hopefully!)
- Openib BTL fully replaced by UCX PML
- `vader` BTL was renamed to `sm` (but still has a `vader` alias)
- At least some elements of MPI-4
  - Sidenote: MPI-4.0 document due by end of 2020
  - Still working on which specific MPI-4 features will be included

v5.0.0: Connectivity map

- A long-asked-for feature: show which networks are used at run time
- Not a perfect system (e.g., it does not show inside Libfabric or UCX)

```
$ mpirun -np 4 --host mpi002:2,mpi004:2 --mca hook_comm_method_enable_mpi_init 1 hello_c
Host 0 [mpi002] ranks 0 - 1
Host 1 [mpi004] ranks 2 - 3

 host | 0     1
======|=============
    0 : sm    usnic
    1 : usnic sm

Connection summary: (btl)
  on-host:  all connections are sm
  off-host: all connections are usnic
...
```

Subject to change before v5.0.0

Questions?

easybuild

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with the EasyBuild community

Thank you!