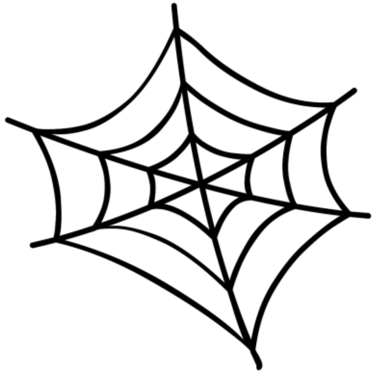
CUSTOMIZING DATA SERVICES FOR FUN AND PROFIT

# BEST PRACTICES (GOTCHAS, TIPS, AND DEBUGGING)



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## SESSION OBJECTIVE

**Share helpful tips that didn't fit in the other sessions**

- How do you run Mochi on other platforms?
- How do you debug a Mochi service?
- How do you diagnose and improve Mochi performance?

- This is just a starting point; talk to us during the hacking session if you have specific questions.
- Hands-on examples can be found in these directories:
  - mochi-boot-camp/ecp-am-2020/sessions/hands-on/rpc-profiling/
  - mochi-boot-camp/ecp-am-2020/sessions/hands-on/libfabric-config/

## NETWORK FABRIC SUPPORT IN MOCHI

# CONFIGURING MOCHI NETWORK TRANSPORTS

- Build libfabric with appropriate network provider support compiled in
  - Add "`variant: fabrics=<list>`" to libfabric section of packages.yaml or add "`fabrics=<list>`" to spack install command line
- Load libfabric package with "`spack load -r libfabric`"
- Use "`fi_info`" command line tool to probe compatible interfaces
  - "`fi_info`" is very verbose!
  - This is a good way to confirm that your build and platform are in agreement
  - Make sure to run fi_info on the correct node (compute nodes may not use the same fabric as login or management nodes).
- Load Mochi software
- At runtime, use appropriate protocol name (e.g., "`verbs://`") to initialize Margo

# MERCURY LIBFABRIC: IB/VERBS

## The essentials for Summit and other InfiniBand systems

- Required fabric providers (selected at compile time): “verbs” *and* “rxm”
- Address prefix (selected at run time): “verbs://”
  - Mercury will internally translate that to a more verbose “ofi+verbs;ofi_rxm://”
- Examples:
  - https://xgitlab.cels.anl.gov/sds/sds-tests/tree/master/perf-regression/cooley
  - Any hands-on example in this tutorial
-

```
mercury:
        variants: ~boostsys+ofi
libfabric:
        variants: fabrics=verbs,rxm
```

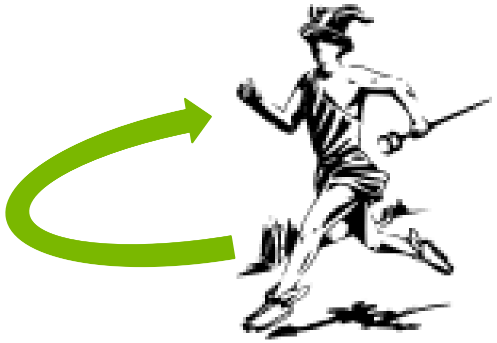
## MERCURY LIBFABRIC: IB/VERBS

### Gotchas

- If using libfabric version >= 1.8: "`export FI_MR_CACHE_MAX_COUNT=0`"
  - Disables new memory registration cache, which has some performance flaws that impact Mochi (for now, hopefully fixed soon)
- If using libfabric versions < 1.8: "`export FI_FORK_UNSAFE=1`"
  - Mochi doesn't actually care about fork; this is a compatibility issue with MPI
- Aside from above caveats, works great!  Fast and stable.
- Performance tuning: be aware that memory registration can be relatively expensive (margo_bulk_create()), especially for small transfers
  - We don't have a silver bullet yet, but for some size ranges we have better performance by copying through pre-pinned buffer rather than pinning in place

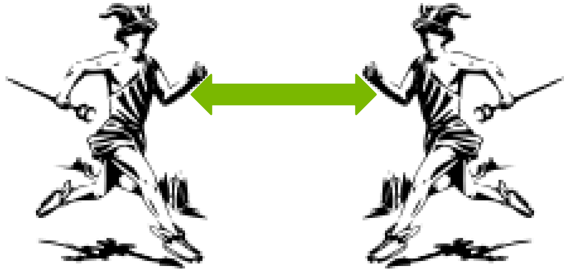
# MERCURY “SELF” RPCS

## Not really a transport, but good to know about!



- What if a process sends an RPC to itself?
- Mercury detects this and skips all NA plugins
  - RPC handler functions are invoked directly
  - They are still delegated to the same Margo thread pool they would have been
  - Bulk transfers become memory copies
- Why is this important?
  - Flexible composition!
  - Components can communicate with other components using RPCs, regardless of whether peer component is in-process, on-node, or remote
- This functionality is enabled by default

## MERCURY NA SM PLUGIN



- Can be selected explicitly using the “na+sm://” network address prefix
- Will also be used implicitly when a remote process is detected locally
- On Linux:
  - Uses Cross-Memory Attach capability (single copy)
  - If bulk transfers fail, on some system you may need (as root): “`echo 0 > /proc/sys/kernel/yama/ptrace_scope`”
- Other operating systems:
  - Uses conventional POSIX shared memory (2 copies)
- Enabled by default in spack or with NA_USE_SM variable in cmake

# POLLING MODES (ANY TRANSPORT)

## Hey network card: Are you done? Are you done? Are you done?

- Ok, how about now?
- Generally speaking, any of the network transports can be driven in "polling mode", where a CPU core constantly checks for progress.
  - This is fast - no interrupt or context switch when messages complete
  - This also eats a CPU core. The value of this tradeoff depends on the use case
  - Network benchmarks almost always busy poll.
- Margo defaults to an adaptive model: it idles gracefully when there is nothing to do, switches to busy mode under load.
- You can force it to always busy poll by setting progress_mode to NA_NO_BLOCK

https://xgitlab.cels.anl.gov/sds/sds-tests/blob/master/perf-regression/margo-p2p-latency.c#L91

## DEBUGGING

## CHANGING SPACK BUILD OPTIONS

### E.g. adding debugging symbols

- If you want to set specific CFLAGS for a particular stack build (a “concretization” in Spack terminology), you can do it on the command line:

```
[pcarns@carns-x1 ~]$ spack install margo cflags="-g -fno-omit-frame-pointer"
```

- IMPORTANT: if you already had margo installed, this will give you ***another*** margo build, with different cflags on the entire stack.  Load either one by specifying the cflags on the load command, or referencing specific hashes
  – Example on next slide

## CHANGING SPACK BUILD OPTIONS

### E.g. adding debugging symbols

```
[pcarns@carns-x1 ~]$ spack load -r margo
==> Error: the constraint '['margo']' matches multiple packages:
              vomtnss margo@0.5.2%gcc@8.3.0 arch=linux-ubuntu19.04-x86_64
              iwplbrr margo@0.5.2%gcc@8.3.0 cflags="-g -fno-omit-frame-pointer"
arch=linux-ubuntu19.04-x86_64

==> Error: In this context exactly **one** match is needed: please specify your
constraints better.
[pcarns@carns-x1 ~]$ spack load -r margo cflags="-g -fno-omit-frame-pointer"
[pcarns@carns-x1 ~]$ spack unload -r margo cflags="-g -fno-omit-frame-pointer"
[pcarns@carns-x1 ~]$ spack load -r margo/iwplbrr
```

# MEMORY DEBUGGING WITH VALGRIND

- Some tools (like gcc’s own –fsanitize-address) do not recognize Argobots context switches correctly, making their output somewhat unreliable.
- Argobots definitively supports one memory debugging tool, though: **Valgrind**
- Check valgrind documentation if you aren’t familiar with it, but the (very) short story is that valgrind reports problems with dynamic memory usage.
  - “valgrind ./my-server –my args”
- To use Valgrind, you must compile Argobots with Valgrind support
- AND make sure that all of your other mochi components use that version of Argobots

## MEMORY DEBUGGING WITH VALGRIND

### How to enable Valgrind support in Argobots

- Do the following to get a one-off build that depends on Argobots with valgrind support.  As in earlier example, this gives you another margo build; you must load the one you want (or uninstall others):

```
[pcarns@carns-x1 ~]$ spack install margo ^argobots@develop+valgrind
```

- Alternatively make a persistent change in your packages.yaml file:

```
argobots:
        variants: +valgrind
```

- This (at least for now) has a performance penalty, even when you aren't using valgrind.  This is being improved right now.

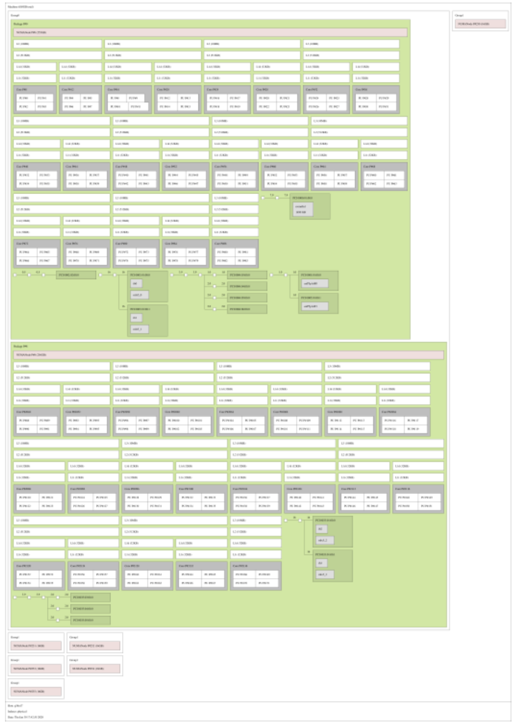
## PROCESS AFFINITY

## HOW CAN WE LEARN ABOUT OUR TARGET SYSTEM?

*hwloc*

- Provides a portable abstraction of the hierarchical topology of modern computer architectures

Using hwloc’s ‘lstopo’ command, we can generate graphical representations of the node architecture (warning, the output may be complex on some systems):



One summit compute node: two sockets, each with 22 cores. Each core has support for 4 hardware threads.

## CONTROLLING PROCESSOR AFFINITY

Now that you've learned more about your architecture, how can you actually take advantage of it?

*Numactl*

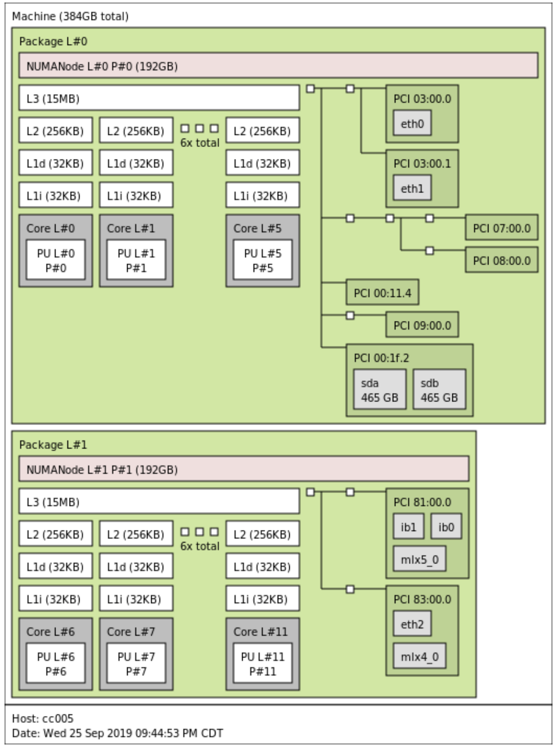
- Allows control of the NUMA scheduling and memory policies for a given executable
- Can specify which cores/sockets to run processes  on, as well as which NUMA memory domain these processes allocate memory from
  - --cpunodebind=sockets, -N sockets  :  only execute on sockets
  - --physcpubind=cpus, -C cpus :  only execute on cpus
  - --membind=sockets, -m sockets  :  only allocate memory from sockets

## HWLOC/NUMACTL EXAMPLE

Cooley Linux cluster @ ALCF, which uses an IB network

We prefer to pin a Mochi service on socket 1, since this socket shares locality with the IB controller for this node

```
numactl  -N 1 -m 1 <executable>
```



## RPC PROFILING

## BUILT-IN RPC PROFILING

Credit:
Srinivasan Ramesh
of the University of Oregon

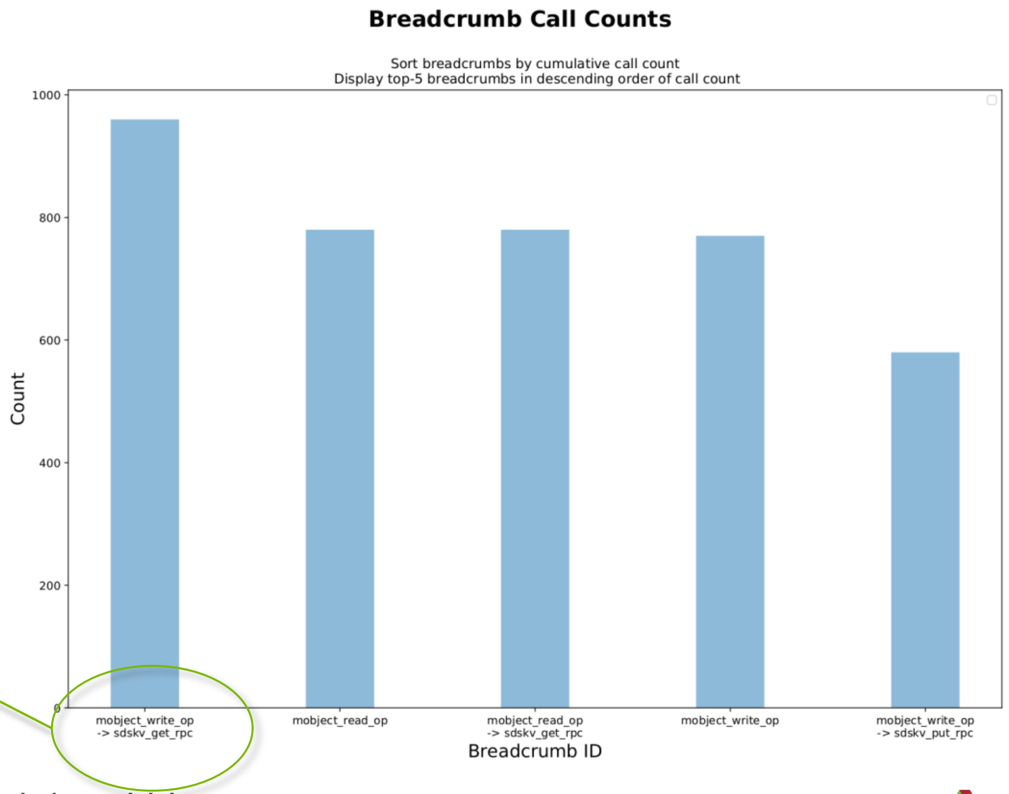
### New feature!

- How do you tune a Mochi service, or at least understand it's performance?
- Almost every major operation in Mochi is an RPC
  - RPCs can be chained, local, remote, etc.
  - RPCs have human-readable names
- This means that we can get a good initial picture of overall Mochi service performance by characterizing RPCs and how they are connected
- Basic usage is modeled after Darshan:
  - Characterization capability is compiled in, no code modification needed
  - Simple command line tools to produce a PDF with plots to use as a starting point for performance tuning

## MOCHI RPC BREADCRUMBS

### Which RPCs are most prolific

- This graph shows ranked list of 5 most frequently called RPCs
- Each includes lineage if applicable (the chain of RPCs that led to the one being measured)

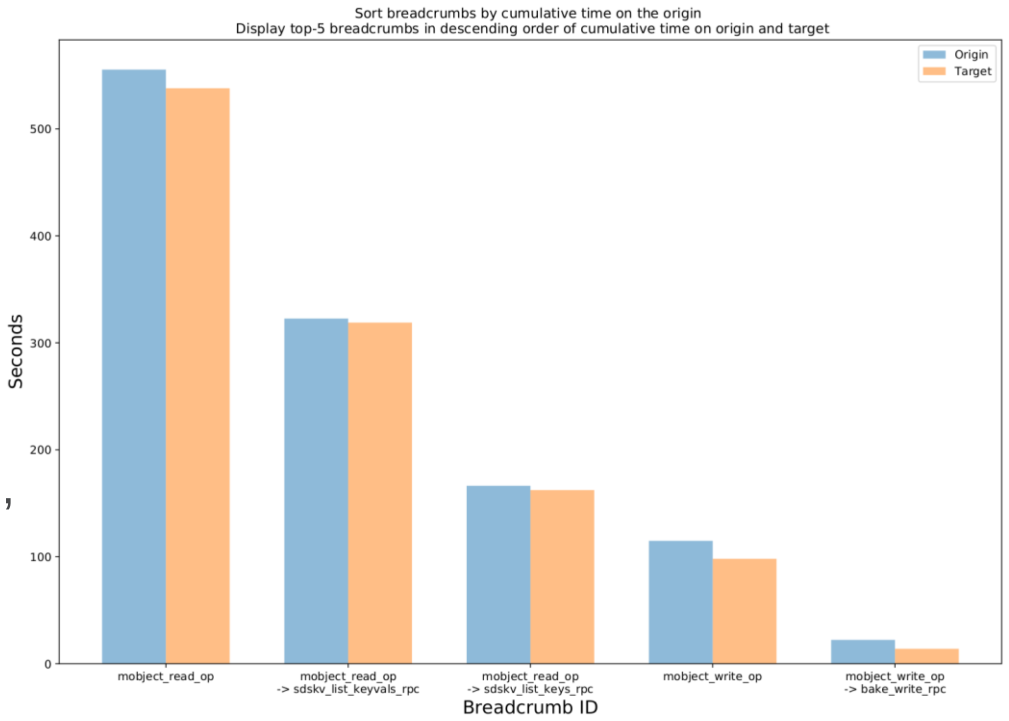


# MOCHI RPC BREADCRUMBS

## Which RPCs consumed the most time?

Cumulative Time

- This graph shows ranked list of 5 RPCs that cumulatively consumed the most service time
- Split by client and server side elapsed time
- Each includes lineage if applicable, just as in the previous graph.



## RPC BREADCRUMBS

### Hands-on exercise

- See mochi-boot-camp/ecp-am-2020/sessions/hands-on/rpc-profiling/ for an example of how to do this on Summit
- Keys:
  – Make sure your working directory is writeable (for log output)
  – Set an environment variable at jsrun time to enable instrumentation
  – Use a python script to parse the output and produce a summary pdf once the service has exited
- The RPC profiling example instruments the first hands-on example (“sum”)
  – It’s not a very interesting profiling example, but you can apply this same technique to ***any*** Mochi service.

## THANK YOU!

## SUPPLEMENTAL MATERIAL: OTHER NETWORK TRANSPORTS

# MERCURY NETWORK SUPPORT

## "NA" plugins interface with communication libraries

- **Libfabric**
  - Most important library for remote communication
  - Actively supported and improving
  - Supports many networks

OPENFABRICS ALLIANCE

Thank you to Intel for contributing the libfabric driver in Mercury.

- **NA SM**
  - Mercury's own transport for shared memory, on-node communication
  - Automatically used when "remote" peers are actually reachable on local node
- **Self RPCs**
  - Not really a transport, but a fast execution mechanism for in-process RPCs
- MPI: strictly for prototyping, not performant
- BMI: legacy code, stable but not recommended for long-term use

## MERCURY LIBFABRIC: OMNIPATH

### The essentials

- Address prefix: “psm2://”
  - Mercury will internally translate that to a more verbose “ofi+psm2://”
- Libfabric provider that will be used: “psm2”
- Example:
  - https://xgitlab.cels.anl.gov/sds/sds-tests/tree/master/perf-regression/bebop
- packages.yaml:

```
mercury:
        variants: ~boostsys+ofi
libfabric:
        variants: fabrics=psm2
```

## MERCURY LIBFABRIC: OMNIPATH

### Gotchas

- For any version: "`export PSM2_MULTI_EP=1`"
  - Allows Mochi and MPI to share interface if needed
- Performance: excellent
- Stability: YMMV depending on system, library versions, and workload.  We don't have universal solution to recommend yet.
- All OmniPath systems also support verbs through emulation, at a performance penalty.  In the worst case, use verbs if you have to.
- Memory registration is free (noop), but not really because you pay performance cost at communication time on cold memory access.
- OmniPath/PSM2 consumes more host CPU than other high performance networks.

# MERCURY LIBFABRIC: ARIES/GNI

## The essentials

- Address prefix: “gni://”
  - Mercury will internally translate that to a more verbose “ofi+gni://”
- Libfabric provider that will be used: “gni”
- Example:
  - https://xgitlab.cels.anl.gov/sds/sds-tests/tree/master/perf-regression/theta
- packages.yaml:

```
mercury:
        variants: ~boostsys+ofi
libfabric:
        variants: fabrics=gni
```

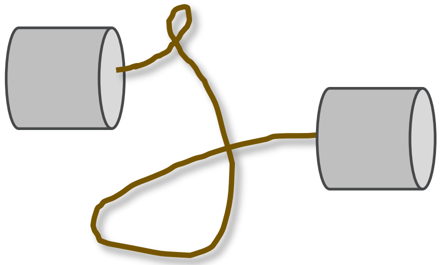
NOTE: This can only be built on a Cray machine, and you might need to load “ugni” module in your environment. Ugni is not a spack package.

## MERCURY LIBFABRIC: ARIES/GNI

- "`export MPICH_GNI_NDREG_ENTRIES=1024`"
  - Tells Cray-MPICH to be less aggressive with resource consumption
- Communication across separately launched executables requires either DRC (any launcher) or protection domains (if your system uses aprun)
  - DRC only works with libfabric 1.8.1 or newer and requires some explicit set up in your code (external to Mercury)
- Stability is great
- Performance is (mostly) great but there are gotchas:
  - Latency is poor when not busy-spinning (more on how to do this later)
  - Latency is poor (any polling mode) on KNL cores
  - Memory registration / copy tradeoffs are unclear, possibly similar to IB/Verbs

# MERCURY LIBFABRIC: TCP/IP

## The essentials

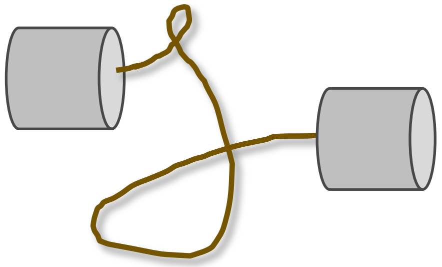


- Address prefix: “tcp://”
  - Mercury will internally translate that to a more verbose “ofi+tcp;ofi_rxm://”
- Libfabric providers that will be used: “tcp” and “rxm”
- Example:
  - https://xgitlab.cels.anl.gov/sds/sds-tests/tree/master/perf-regression/cooley/*tcp*
-

```
mercury:
        variants: ~boostsys+ofi
libfabric:
        variants: fabrics=tcp,rxm
```

NOTE: there are alternative TCP implementations, but this one is our recommendation.

# MERCURY LIBFABRIC: TCP



- Please use libfabric version >= 1.9.0
- Stability is good
- Performance is poor (when other alternatives are possible)
  - This is largely because of emulation of RDMA over sockets
- There are other options that you may see in previous examples:
  - “sockets://” activates the legacy/reference sockets implementation in libfabric
  - “bmi+tcp://” activates TCP support in the BMI library (if enabled)
  - All have similar performance characteristics; “tcp;ofi_rxm” is now the most actively maintained, though

## THE STATE OF MOCHI TRANSPORTS

### February 2020

- Things are continually improving, particularly in the interaction between Mochi, libfabric, and MPI
- The libfabric verbs provider in particular is advancing rapidly, look for big enhancements in the next version after 1.9.0
- There are usually some compatibility quirks.
- Want to keep up over time?  Your best option right now is to monitor the scripts that we use for regression testing on different transports:

https://xgitlab.cels.anl.gov/sds/sds-tests/tree/master/perf-regression

- We update these over time with best practice for platforms at ANL

## SUPPLEMENTAL MATERIAL:

## DEBUGGING AND TUNING

## DEBUGGING MOCHI COMPONENTS

Debugging Mochi components can be challenging for a few reasons:

- Spack build process
  - Spack intentionally abstracts many of the build steps
  - How do you (for example) add debugging symbols?
- User-level threading
  - Argobots saves and restores contexts in user space
  - This can confuse debugging tools that don't realize when the stack has been replaced, for example: could lead to false positives
- Many components are bleeding edge
  - Understanding how to switch them out to isolate problems can be helpful

## DEBUGGING MOCHI COMPONENTS

### Isolating component problems

- Many components are bleeding edge
  - A memory corruption in one might show up somewhere else entirely
- Do you suspect a particular component?
  - The suspicion often (rightly or wrongly) falls on networking libraries
  - Try swapping them for debugging purposes to help isolate the source of the problem
- For example: if you compile libfabric with “fabrics=tcp,rxm,sockets” then you have two valid ways to run TCP (from a functionality perspective):
  - Use the “tcp://” prefix on your addresses
  - Use the “sockets://” prefix on your addresses
- Will activate a different code path and help confirm/deny theories

# NOT ALL CORES ARE CREATED EQUAL

Computer architectures are increasingly complex, particularly the nodes we typically see in HPC systems:

- Multi-core, multi-socket
- Numa nodes
- Multiple NICs, GPUs

To make most efficient use of these systems, it is important to take note of the locality of these devices and to allocate resources accordingly

This problem is complicated by multi-threaded applications or by multiple applications/services sharing a node.  See numactl examples earlier in this presentation for tips.