Work In Progress: FLUX Runtime Environment

FLUX Meeting

Sep 17 2013

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This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC.
LLNL-PRES-643938

Work in progress on two initial phases on run-time areas

- Phase I – conceptualized next-generation resource management challenges and design space
- Phase II – gaining experiences and insights by producing prototype software
- Today, an interim report on the runtime system
  - Highlight key concepts in runtime (Phase I)
  - Experiences with early prototyping efforts (Phase II)

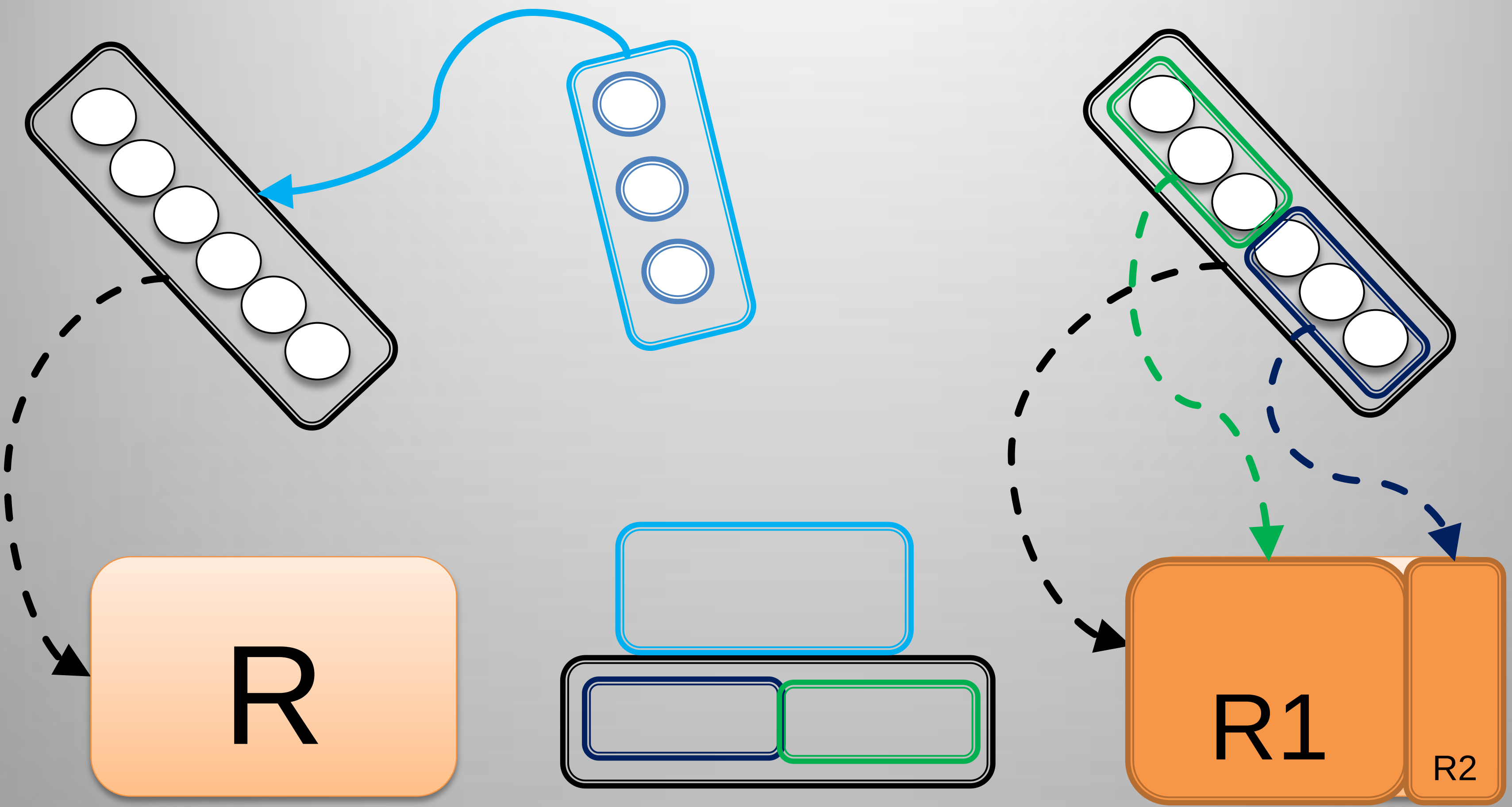
A scalable run-time to execute various transactions in a job in the new paradigm

- A paradigm shift in resource management
  - Capable of imposing complex resource bound
  - Highest operational efficiency at any level across the computing facility
- Scheduler sets the overall bound for resources and the duration for a job—now what?
- Workload Runtime And Placement (WRAP) thrust area
  - A job consists of various transactions
  - Need a powerful run-time system to execute a wide range of transactions of a job efficiently while under the overall bound

The new paradigm needs new ways to organize and group processes of a job

- The traditional approach models transactions of a job as a set of compute steps (e.g., job steps)
- Limits next-generation computing in many ways
- Designing WRAP after this model would be an under-design

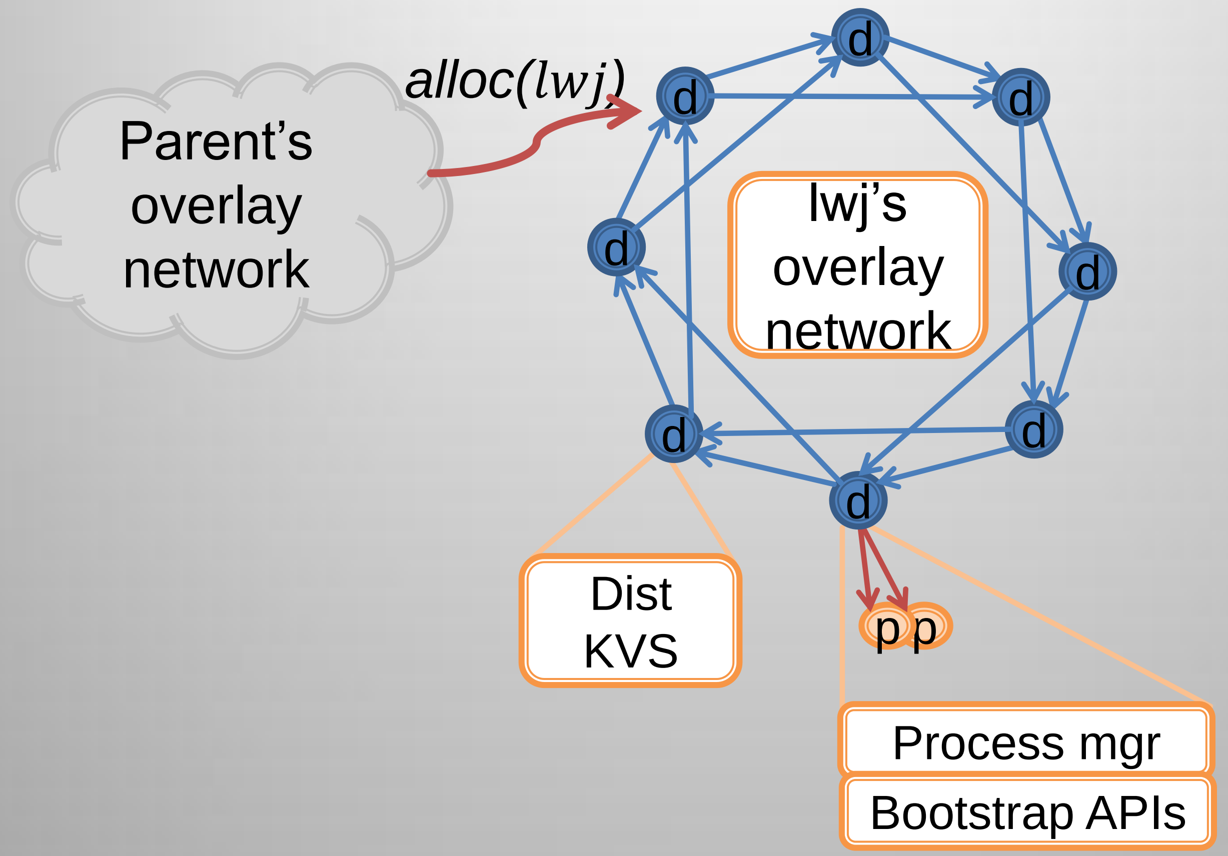
Lightweight job (LWJ) as our model to capture a transaction—i.e., grouping processes



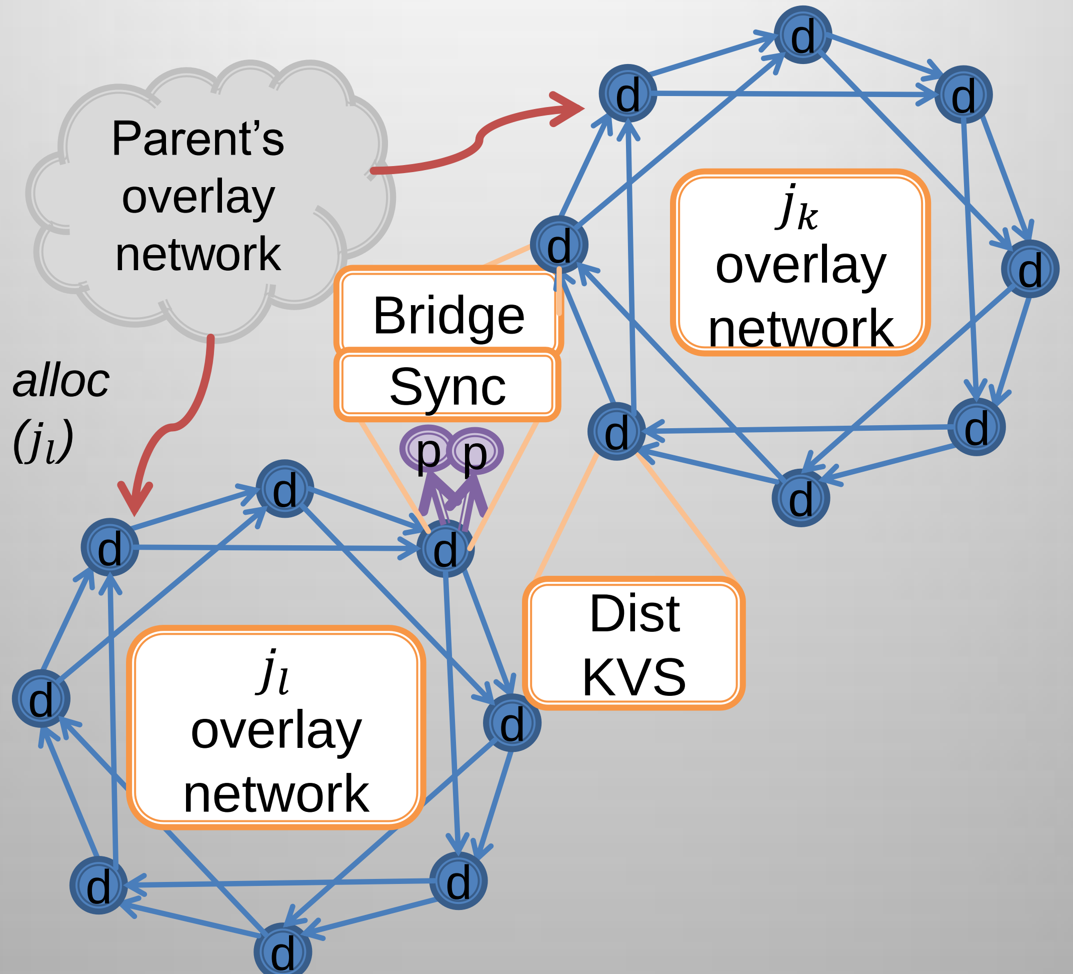
LWJ enables us to express various run-time services concisely under the new paradigm

- Serves as group identifiers to relate a group of processes to resources as well as to other groups of processes
- Resource allocation and elasticity: ***alloc(lwj, c)***, ***realloc(lwj,c)***, and ***release(lwj, c)***
- Process management/confinement: ***launch(lwj)***, ***destroy(ljw)***
- Synchronization: ***sync(lwj(i), lwj(k))***
- Resource discovery and provenance: ***query(lwj)***, ***record(lwj)***

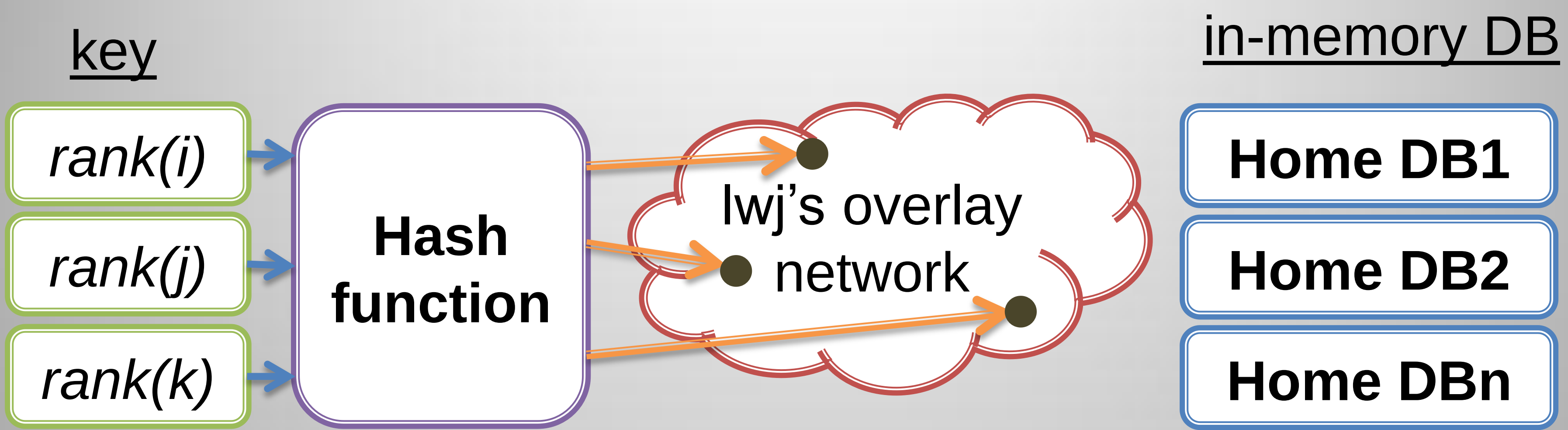
The base WRAP architecture builds on comms. framework and distributed key-value store



We can easily extend the base architecture to implement *sync*



DKVS is scalable distributed shared memory for an LWJ and its descendants



- Get/put for data access
- Collective Fence for memory consistency

lwj(1)::resource	cores (128)	power(10KW)	lic (10 tokens)	…
lwj(1)::rank(10)	host(1)	pid(345)	port(445)	
lwj(1)::record	info1	info2	…	…
lwj(1)::lwj(2)::resource	cores(64)	power(4KW)	lic (2 tokens)	

Scalable KVS allows ease integration with various types of LWJs beyond MPI

- PMI 1, 2 will be a very thin layer on top of KVS
- PMGR, PMGR Collective, COBO, LaunchMON, and LIBI use essentially the same bootstrapping technique that KVS can easily enable
- Our plug-ins for these well-known bootstrappers will serve as the reference implementation
- Other types of LWJs can write their own plug-ins for ease integration into WRAP

Phase II aims to strategic prototyping to gain insight into the detailed design

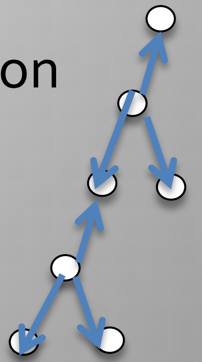
- Goal
  - Gain experiences for the final design
  - Prove that FLUX's rich run-time will significantly boost user productivity
- Plan
  - Bring up COBO on top of KVS
  - Native LaunchMON API Support
  - Bring up MRNet by porting the LIBI interface
  - Bring up STAT on top of LaunchMON and MRNet
  - Bring up and enhance SPINDLE
- Show FLUX can bring in rich sets of scalable productivity tools
- Show FLUX can start up massive applications
  - By enabling seamless integration with a specialize software system

KVS service via CMB solved a notorious chicken-and-egg problem for bootstrapping

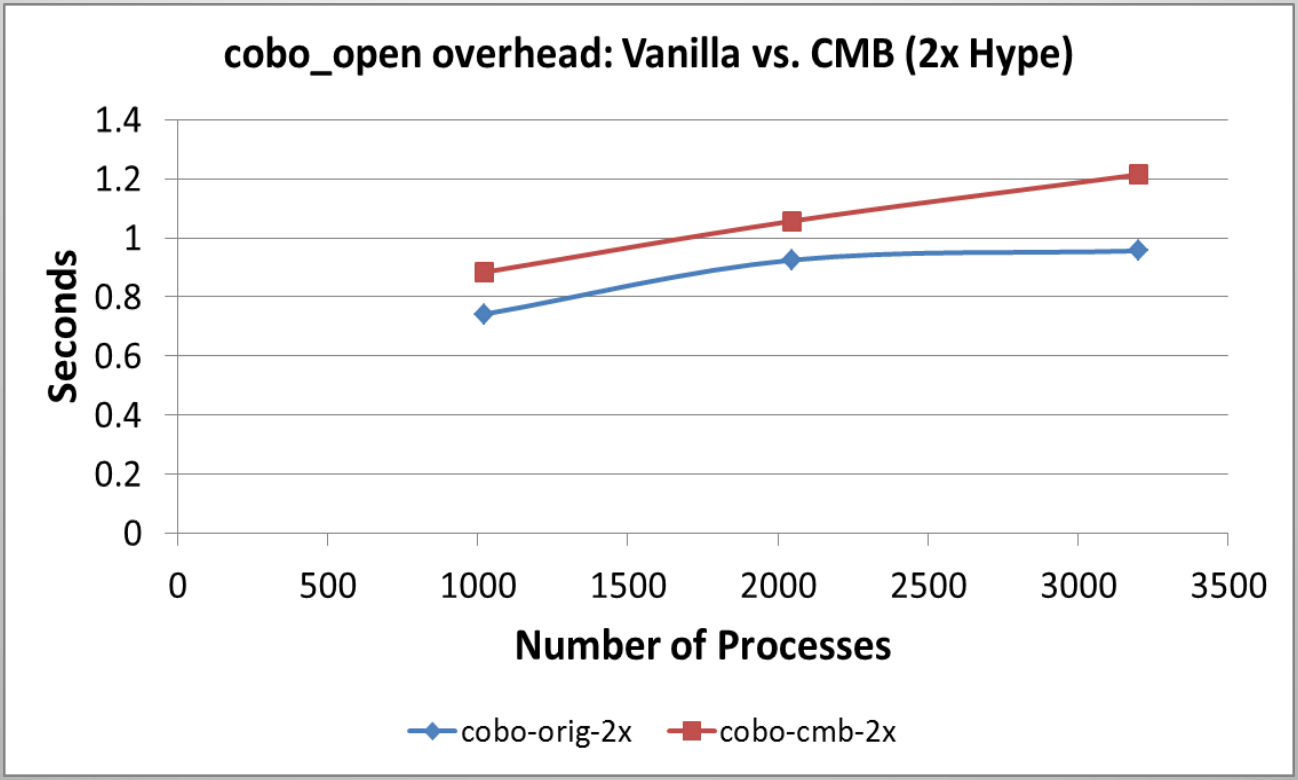
- COBO: a bootsrapper used in scalable tools infrastructure
- A simple TCP-based tree-based overlay network
- Chicken-and-egg problem: no common mechanism exists to bootstrap this bootstrapper!
  - Initial version used all-send-to-one algorithm—not scalable
  - Current version uses ad hoc port-range scheme—scalable but not ideal
- Use CMB's KVS service to address this problem

CMB/KVS-based COBO Connection algorithm and implementation

- Extended its tree open call in pmgr_collective_client_tree.c
  - #include "cmb.h"
  - int pmgr_tree_open_cmb (pmgr_tree_t *t, …
- Each spawned process creates a key-value tuple (key=its rank, value= ip:port) and push it to KVS
  - cmb_kvs_put (cmb_cxt, keystr, valstr) /* keystr=rank, valstr=ip:port */
  - cmb_kvs_commit (cmb_cxt, &error_cnt, &put_cnt)
  - cmb_barrier (cmb_cxt, "topen-cmb", ranks) /* named barrier */
- Each process computes its position in the binary tree based on it rank and size and fetch ip/port of its parent and children:
  - res_val = cmb_kvs_get (cmb_cxt, (const char *) keystr)
- Then, a simple two-step connection algorithm



Initial performance under a single KVS server (no KVS optimization)

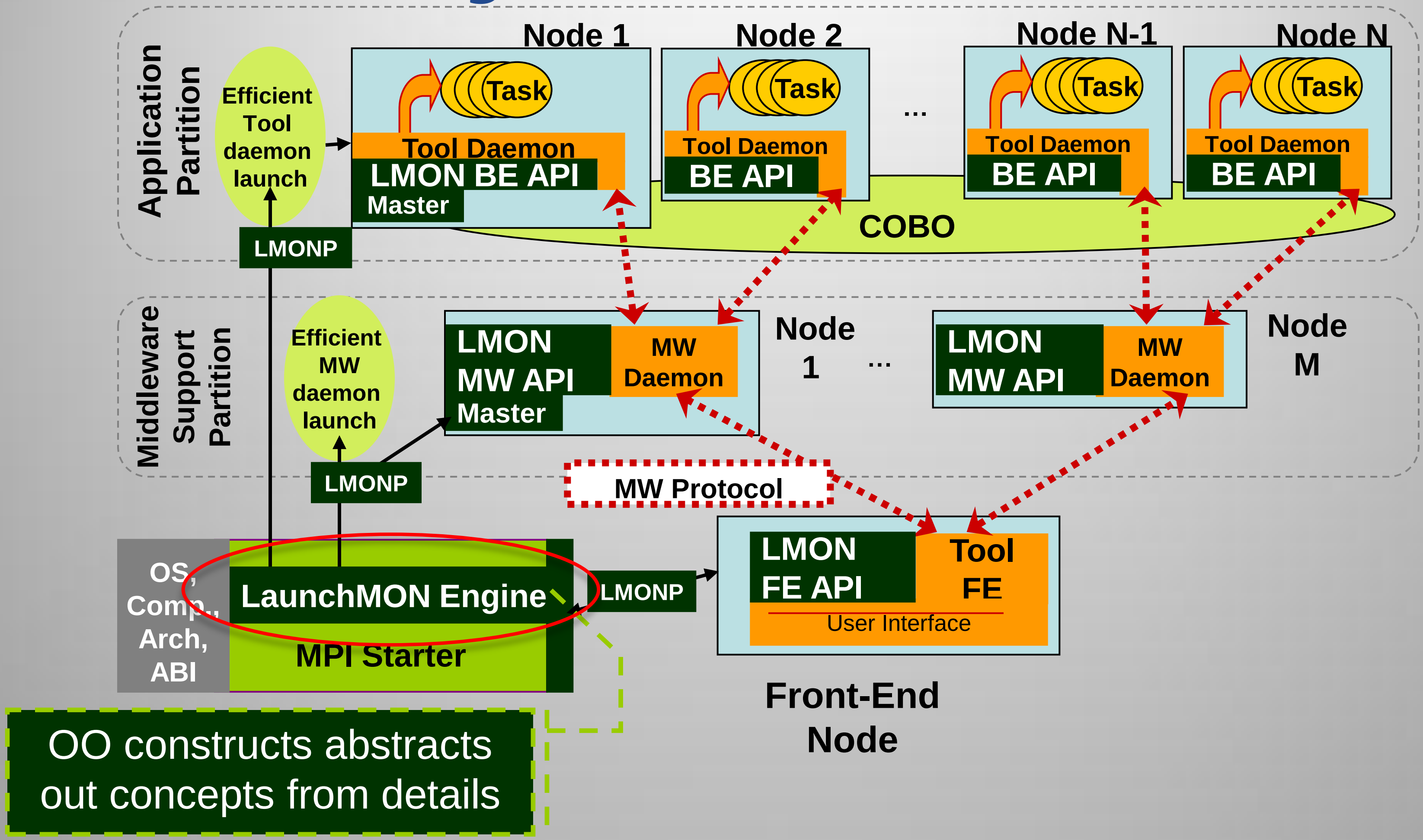


Code at the cobo-tester directory in git@github.com:chaos/ngrm.git

Native LaunchMON API support under FLUX

- LaunchMON: tool daemon launching infrastructure
- Used by many scalable tools
- For high portability, it uses the MPIR process acquisition interface (a de factor standard RM interface for debuggers)
- Requires tracing a MPI starter process and this makes it difficult to compose multiple tools
- Many problems can be addressed when LaunchMON is more deeply into the resource manager

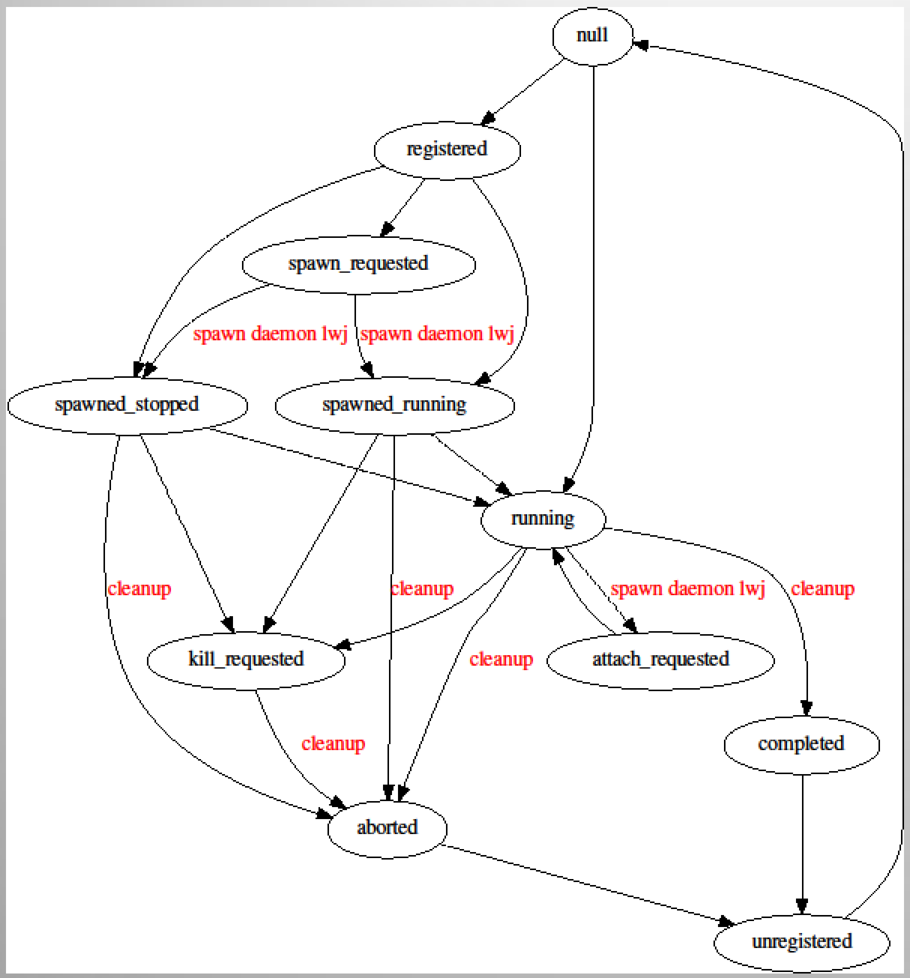
Adding a new LaunchMON engine that interacts with RM through its API



FLUX API mockup committed

enum	_flux_rc_e { FLUX_OK, FLUX_ERROR, FLUX_OK, FLUX_ERROR }
enum	_flux_lwj_event_e { status_null = 0, status_registered, status_spawn_requested, status_spawned_stopped, status_spawned_running, status_running, status_attach_requested, status_kill_requested, status_aborted, status_completed, status_unregistered, status_reserved, status_null = 0, status_registered, status_spawn_requested, status_spawned_stopped, status_spawned_running, status_running, status_attach_requested, status_kill_requested, status_aborted, status_completed, status_unregistered, status_reserved }
flux_rc_e	FLUX_init ()
flux_rc_e	FLUX_update_createLWJCxt (flux_lwj_id_t *lwj)
flux_rc_e	FLUX_update_destoryLWJCxt (flux_lwj_id_t *lwj)
flux_rc_e	FLUX_query_pid2LWJId (const char *hn, pid_t pid, flux_lwj_id_t *lwj)
flux_rc_e	FLUX_query_LWJId2JobInfo (const flux_lwj_id_t *lwj, flux_lwj_info_t *info)
flux_rc_e	FLUX_query_globalProcTableSize (const flux_lwj_id_t *lwj, size_t *count)
flux_rc_e	FLUX_query_globalProcTable (const flux_lwj_id_t *lwj, MPIR_PROCDESC_EXT *pt, size_t count)
flux_rc_e	FLUX_query_localProcTableSize (flux_lwj_id_t *lwj, const char *hn, size_t *count)
flux_rc_e	FLUX_query_localProcTable (const flux_lwj_id_t *lwj, const char *hn, MPIR_PROCDESC_EXT *pt, size_t count)
flux_rc_e	FLUX_query_LWJStatus (flux_lwj_id_t *lwj, int *status)
flux_rc_e	FLUX_monitor_registerStatusCb (const flux_lwj_id_t *lwj, int(*cb)(int *status))
flux_rc_e	FLUX_launch_spawn (const flux_lwj_id_t *me, int sync, const flux_lwj_id_t *target, const char *lwjpath, char *const lwjargv[], int coloc, int nn, int np)
flux_rc_e	FLUX_control_killLWJs (const flux_lwj_id_t target[], int size)
flux_rc_e	error_log (const char *format,...)

Good progress made in new LaunchMON engine implementation



- Event-based system
- Many of the actions on LWJ state changes implemented
- Need to complete all of the actions and wire-up with FEN API through LMONP
- Mostly importantly, bring this up when the real FLUX API is in place

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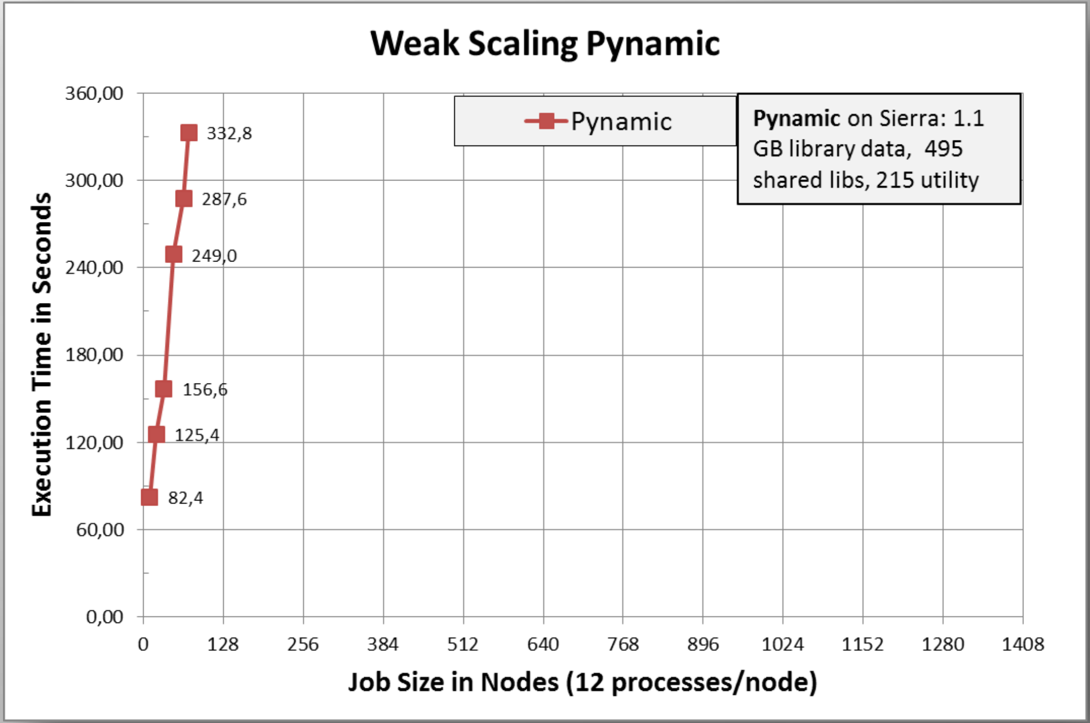
- Show that FLUX can start up massive applications
  - By enabling seamless integration with middleware software like SPINDLE

Dynamic linking and loading causes major disruption at large scale

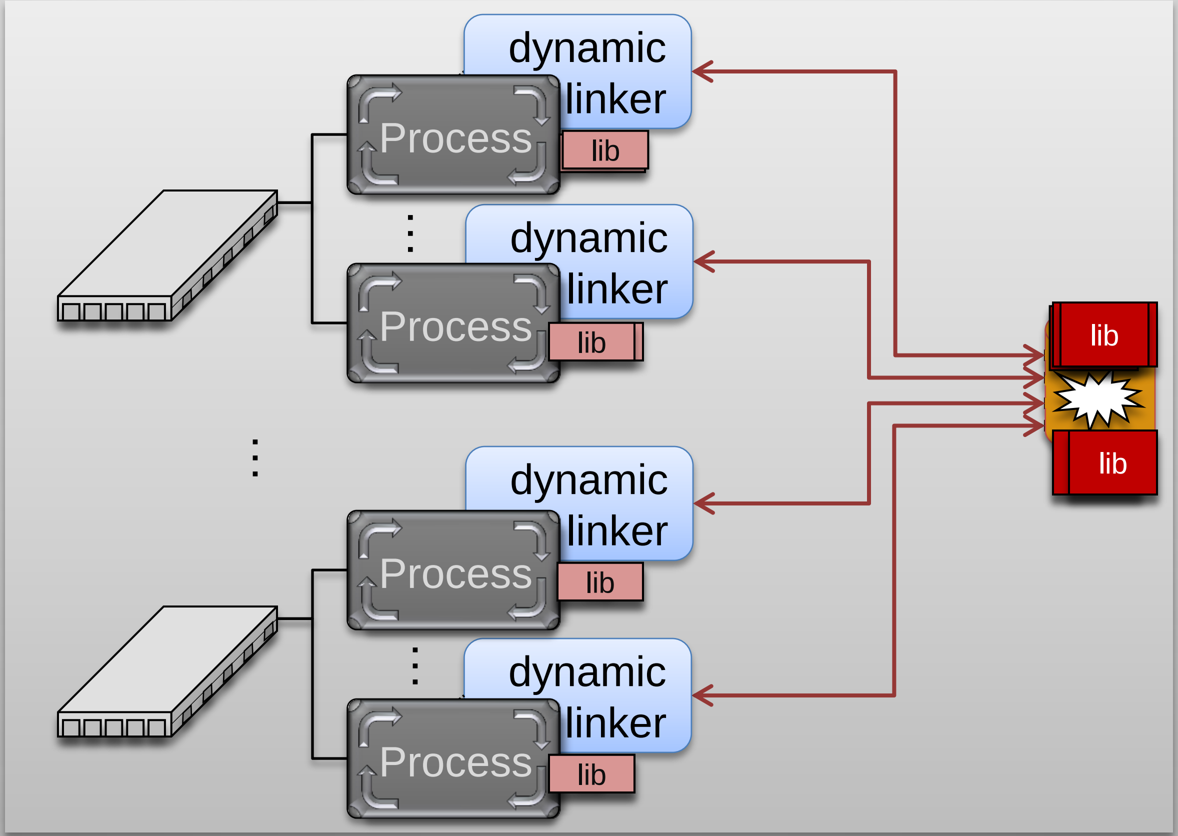
- **Multi-physics applications at LLNL**
  - 848 shared library files
  - Load time on BG/P:
    - 2k tasks → 1 hour
    - 16k tasks → 10 hours
- **Pynamic**
  - LLNL Benchmark
  - Loads shared libraries and python files
  - 495 shared objects → 1.1 GB



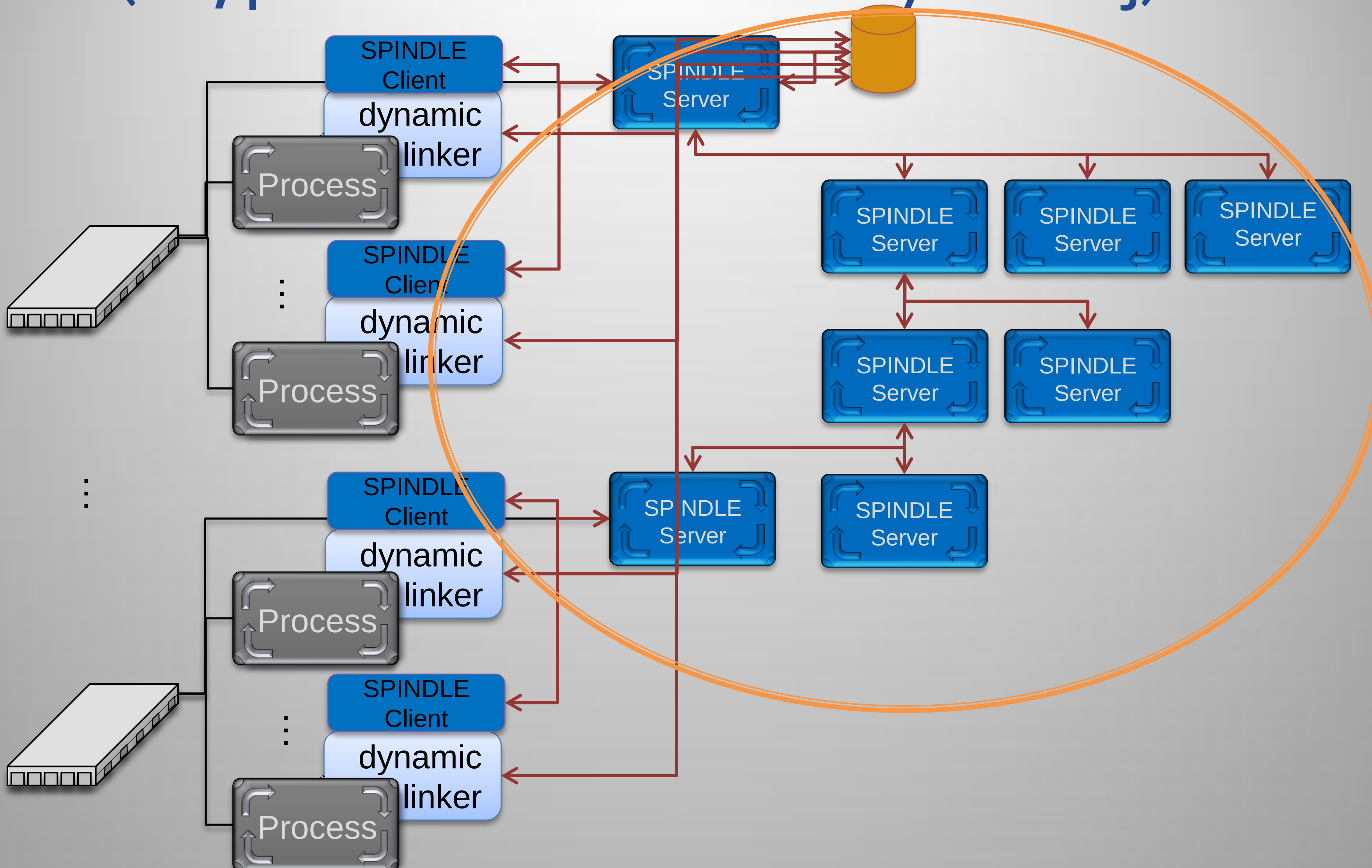
Pynamic running on LLNL Sierra Cluster
1944 nodes, 12 tasks/node,
NFS and Lustre file system

File Access is uncoordinated!

- Loading is nearly unchanged since 1964 (MULTICS)
- ld-linux.so uses serial POSIX file operations that are not coordinated among process.



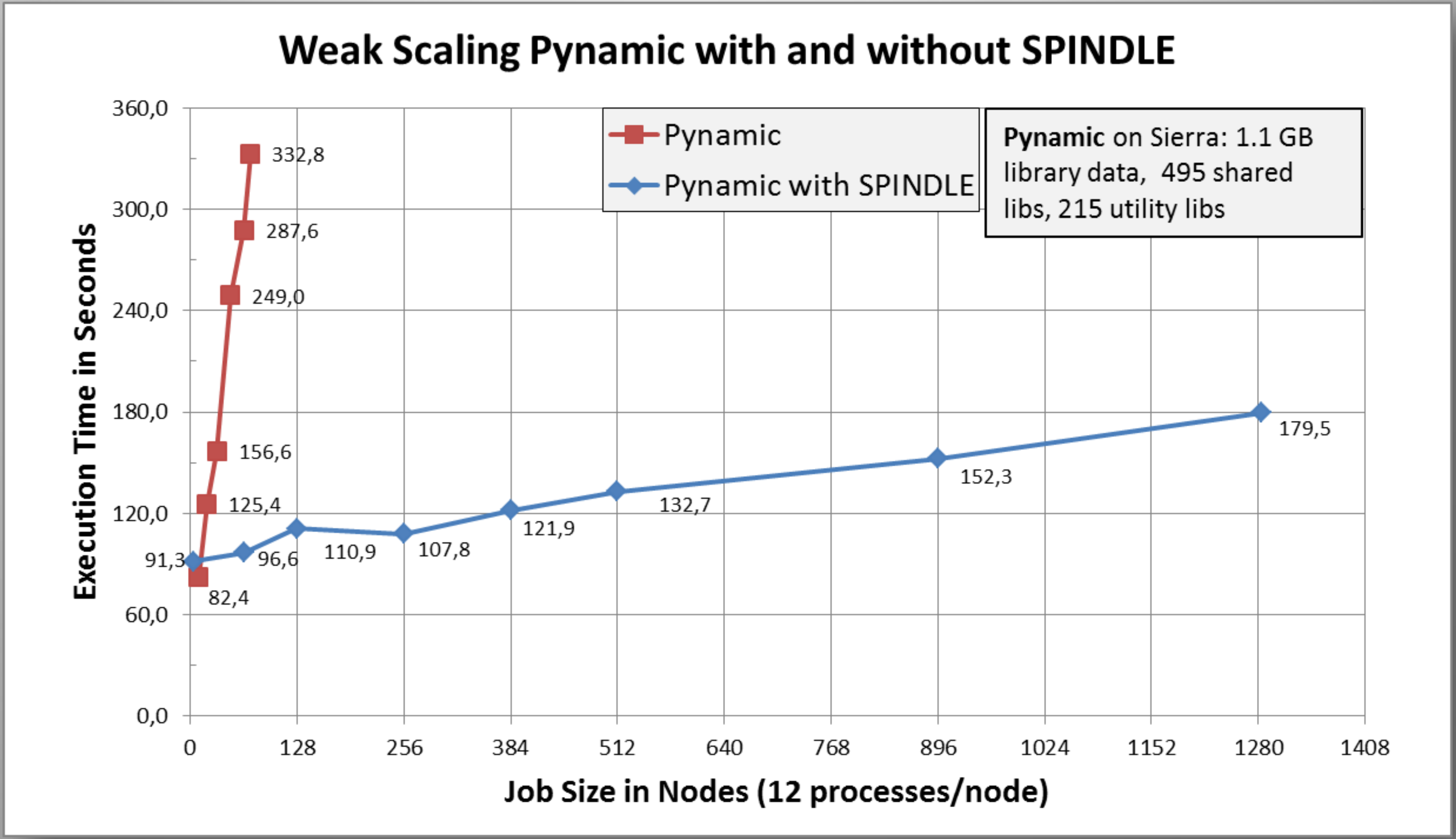
SPINDLE server components will be supported as a LWJ (i.e., performance booster subsystem lwj)



Concluding remarks

- Interim report on the first two phases in our effort to provide a rich and scalable run-time system for FLUX
- Phase I: conceptualized our run-time system around the notion of LWJ
- Phase II: made good process with strategic prototyping
- To prove rich FLUX run-time can solve many next-generation computing challenges by leveraging other technologies through easy integration

Back-up: SPINDLE's Performance



Back-up: Constant Overhead of SPINDLE's Data Distribution