Native LaunchMON Prototype Support on FLUX

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# Goal

This prototyping effort aims to demonstrate that FLUX can natively support LaunchMON. The LaunchMON software layer that natively resides in this resource manager (RM) can leverage the underlying RM mechanisms to enhance its capability and performance. This layer will then form a basis within FLUX for providing seamless daemon launching to many existing run-time tools and infrastructure, and further make it extremely easy to create new run-time tools. Rich support for run-time tools is essential for FLUX, as its workloads are expected to be increasingly larger, more diverse and complex. Thus, the native LaunchMON support will position FLUX to meet some of the emerging usability challenges with scalable and easily-composable run-time tools and middleware.

# Background

Many run-time tools that target parallel and distributed environments must co-locate and synchronize a set of daemons with the distributed processes of the target application. However, efficient and portable deployment of these daemons on large-scale systems had been an unsolved problem. Since 2008, we have responded to this gap with LaunchMON, a scalable and portable general-purpose infrastructure for launching tool daemons. Its API allows tools to identify all processes of a target application, and to launch daemons on the relevant nodes and control daemon interaction.

Since its inception, the LaunchMON project has been highly successful. Many run-time tools and middleware have used this API so that they do not have to rely on ad hoc launching mechanisms, which often present both portability and scalability challenges. With LaunchMON support, tools/middleware builders could quickly focus on the core functionality that they wanted and needed to innovate. Further, as we have ported LaunchMON to an increasingly wider range of RMs and platforms—e.g., SLURM, OpenRTE, Cray ALPS and the Blue Gene family, the client tools have gained portability and scalability for free on high-end machines.

Client software that uses LaunchMON includes code-development tools like LLNL’s Stack Trace Analysis Tool (STAT), Allinea DDT and Rogue Wave Software ThreadSpotter, as well as middleware like a Scalable Checkpoint/Restart (SCR) prototype, and SPINDLE (Scalable Parallel Input Network for Dynamic Environment).

# Problems

As part of its core services, LaunchMON provides the tool with compute-nodes information relevant to the target application processes and also synchronizes the co-located tool processes with these target processes. For high portability, we decided, very early on, to use a de factor standard interface called the MPIR process acquisition interface, which provides most of the desired functionality portably on many RMs.

Unfortunately, the portability of this interface comes with several disadvantages. In particular, it is designed as a debug interface and hence requires its user to trace (i.e., via the ptrace system call) the states of the RM starter process (e.g., srun) through spawning and controlling the target application. Because ptrace keeps multiple tracing processes from attaching to a same target process, it is often not easy to coordinate and combine the tools that use this mechanism. Tools must coordinate the use of this mechanism among themselves through an ad hoc attach-and-detach scheme by which each takes turns to to trace the starter process. Because this approach is error-prone, only few tools that use LaunchMON currently implement it.

# Approach

It is our view that the current LaunchMON implementation is a stepping stone towards a more ideal service form whereby its API is more deeply integrated into the RM software and hence directly uses the native RM mechanisms. However, such tight interactions require that LaunchMON and the RM must be designed and implemented together to be effective. Through co-design efforts, the RM will implement and provide some of missing native mechanisms that LaunchMON needs to address its deficiencies such as composability issues and to improve its performance and scalability further. With the FLUX project newly started, we have a unique opportunity to realize this potential.

As part of this prototyping effort, therefore, we will modify LaunchMON to have a deeper RM integration. Using the native FLUX mechanisms, we will get rid of needing to trace the RM starter process. With this approach, we will be able to better combine and coordinate distinct, yet complementary, tools/middleware sessions together. Further, we can enhance the overall performance and memory utilization of LaunchMON.

More specifically, LaunchMON will collect the global MPIR process table by gathering through CMB the relevant information distributed across the key-vale stores. This distributed MPIR process table associated with the target application will rid LaunchMON front-end of needing to broadcast the entire global process table, which can become relatively big at large scale, to the back-end daemons. Each back-end will also discover the local process table by directly querying the key-value stores. Finally, LaunchMON will use the native APIs of FLUX to spawn back-end daemons, to co-locate them with the application processes, and to monitor and detect the liveliness and failures of these daemons.

The following further details the FLUX mechanisms the new approach requires as well as a concrete modification proposal based on the LaunchMON 1.0 release branch.

# New Engine

In our current implementation, LaunchMON Engine is the main bridge between the target RM and the distributed APIs of LaunchMON. On one hand, the Engine gets co-located with the RM starter process, traces the states of this process, and converts low-level debug events generated from the tracing into a set of well-defined RM events. On the other hand, the Engine also establishes a TCP/IP socket connection with the run-time of the front-end API, which runs in a POSIX thread of the client software’s front-end. Through a communication protocol called LMONP, the Engine receives commands from the front-end and also sends RM state information back to the front-end.

LaunchMON Engine code is quite complex mainly because it must trace the RM starter process, and to do this its code has debugger internals such as symbol table parsing and management, process-tracing through ptrace and various machine models. Further, it must also abstract out several key differences in the MPIR process acquisition interface implementations as different RMs can provide different interface extensions. (Note that a recently published, MPI forum-sanctioned document called [the MPIR Process Acquisition Interface Version 1.0](http://www.mpi-forum.org/docs/mpir-specification-10-11-2010.pdf) describes all of the extensions.) To deal with the complexity, the Engine uses complex object-oriented design patterns such as class templates to parameterize the Engine code with different machine models and class inheritance to package up the basic Engine actions into an abstract base class etc.

|  |  |  |  |
| --- | --- | --- | --- |
| **Events** (lmonp\_fe\_to\_fe\_msg\_e) | Direction | **Description** | **RM** |
| lmonp\_conn\_ack\_no\_error | Engine🡪FE | Connect-ack with no parse error | No |
| lmonp\_conn\_ack\_parse\_error | Engine🡪FE | Connect-ack with parse errors found | No |
| lmonp\_stop\_at\_launch\_bp\_spawned | Engine🡪FE | RM starter process hits the MPIR\_Breakpoint function with MPIR\_DEBUG\_SPAWNED state | Yes |
| lmonp\_rminfo | Engine🡪FE | rminfo is filled (e.g., RM type etc) | Yes |
| lmonp\_stop\_at\_launch\_bp\_abort | Engine🡪FE | RM starter hits the MPIR\_Breakpoint function with MPIR\_DEBUG\_ABORTING state | Yes |
| lmonp\_proctable\_avail | Engine🡪FE | MPIR process table filled–typically right after  lmonp\_stop\_at\_launch\_bp\_spawned | Yes |
| lmonp\_resourcehandle\_avail | Engine🡪FE | Resource handle info filled–typically right after  lmonp\_stop\_at\_launch\_bp\_spawned | Yes |
| lmonp\_stop\_at\_first\_exec  lmonp\_stop\_at\_first\_attach  lmonp\_stop\_at\_loader\_bp  lmonp\_stop\_at\_thread\_creation  lmonp\_stop\_at\_thread\_death  lmonp\_stop\_at\_fork\_bp  lmonp\_stop\_not\_interested |  | These are not communicated thus far. But we may need some RM support to implement their equivalent handlers. (Further reviews are needed) | Maybe |
| lmonp\_terminated | Engine🡪FE | RM starter terminated | Yes |
| lmonp\_exited | Engine🡪FE | The main thread of the RM starter exited | Yes |
| lmonp\_detach\_done | Engine🡪FE | Detach done | Yes |
| lmonp\_kill\_done | Engine🡪FE | Kill done | Yes |
| lmonp\_stop\_tracing | Engine🡪FE | Engine failed and done its cleanup | Yes |
| lmonp\_bedmon\_exited | Engine🡪FE | Back-end daemons exited | Yes |
| lmonp\_mwdmon\_exited | Engine🡪FE | Middleware daemons exited | Yes |
| lmonp\_detach | FE🡪Engine | Please-detach cmd | Yes |
| lmonp\_kill | FE🡪Engine | Please-kill cmd | Yes |
| lmonp\_shutdownbe | FE🡪Engine | Please-shutdown-back-ends cmd | Yes |
| lmonp\_cont\_launch\_bp | FE🡪Engine | Please-continue-from-MPIR\_Breakpoint cmd | Yes |

Table 1: Communication protocol between LaunchMON Engine and Front-End (FE)

As part of our modification plan, we propose to create a new Engine implementation that directly uses native RM APIs instead of the MPIR debug interface, while still communicating with the front-end through the same wire protocol (LMONP). This proposal has three main advantages in contrast to modifying the LaunchMON API implementation : 1) it will significantly reduce the code complexity of the Engine, which then can improve the robustness of LaunchMON under FLUX; 2) it will minimize the changes needed for the LaunchMON front-end API and thus reduce backward-compatible and portability concerns: i.e., we desire the same code base of the LaunchMON front-end API work well on other RMs as well; and 3) it will then still continue to allow the client software’s front-end to be run on any arbitrary location with TCP/IP connectivity (e.g., a user’s desktop).

Clearly, this new Engine implementation will need alternative mechanisms using FLUX-provided primitives to be able to continue to serve as the bridge between the front-end and FLUX. To show the interactions between the Engine and the front-end, Table 1 lists the current wire protocol defined between these two components, which is a part of LMONP. The new Engine will use FLUX mechanisms including launch, control, query and monitor APIs to enable this commands and control communication structure. In this table, the events shaded in blue will likely require new RM APIs within the new Engine. The events in yellow need further reviews. The lmonp\_fe\_to\_fe\_msg\_e enumerator is currently defined in a file: [launchmon/src/lmon\_api/lmon\_lmonp\_msg.h#l93](http://sourceforge.net/p/launchmon/code/470/tree/branches/launchmon-1.0-release/launchmon/src/lmon_api/lmon_lmonp_msg.h#l93).

# Failure Handling Semantics Enforcement

LaunchMON defines a rigorous failure handing semantics when one or more LaunchMON components failed, which is described in one of the README files: [README.ERROR\_HANDLING](http://sourceforge.net/p/launchmon/code/470/tree/branches/launchmon-1.0-release/README.ERROR_HANDLING). Some of the handling mechanisms will need support from the RM. For example, when back-end tool processes fail, LaunchMON wants to get notified of this event to react to this properly. Some RMs do provide these mechanisms better than others, and certainly we want FLUX to provide all of the mechanisms that enable us to detect a failure of any component in a tool session as well as in the target application.

# Proposed FLUX Mechanisms and Interfaces

This section describes some of the RM mechanisms and interfaces that the new approach will need. At a high level, the new scheme will require new mechanisms to launch, control, and destroy the target application processes and tool daemons, monitoring or notification mechanisms to synchronize between them, and query mechanisms to fetch information about these processes. We propose the following API set as a starting point for this co-design process.

### Data Types

/\*! MPIR\_PROCDESC\_EXT is an extension to the vanilla mpir process descriptor type \*/

typedef struct {

char \*host\_name; /\* Something we can pass to inet\_addr \*/

char \*executable\_name; /\* The name of the image \*/

int pid; /\* The pid of the process \*/

} MPIR\_PROCDESC;

typedef struct {

MPIR\_PROCDESC pd;

int mpirank;

int cnodeid;

} MPIR\_PROCDESC\_EXT;

enum flux\_rc\_e defines various return code.

### Query, Update and Monitor API

/\*! Interface that creates a lightweight job (LWJ) job context \*/

flux\_rc\_e

FLUX\_update\_createLWJCxt (flux\_lwj\_id\_t \*lwj)

/\*! Interface that converts the pid of the RM starter process to its LWJ id. If the tool wants to work on an LWJ that is already running, this will come in handy. \*/

flux\_rc\_e

FLUX\_query\_pid2LWJId (const char \*hn, pid\_t pid, flux\_lwj\_id\_t \*lwj)

/\*! Interface that converts the target LWJ id to the LWJ information that includes the information on the RM starter process. flux\_lwj\_info\_t needs to be defined \*/

flux\_rc\_e

FLUX\_query\_LWJId2JobInfo (const flux\_lwj\_id\_t \*lwj, flux\_lwj\_info\_t \*info)

/\*! Interface that returns the size of the global MPIR process table \*/

flux\_rc\_e

FLUX\_query\_globalProcTableSize (const flux\_lwj\_id\_t \*lwj, size\_t \*count)

/\*! Interface that returns the global MPIR process table associated with lwj into ptab \*/

flux\_rc\_e

FLUX\_query\_globalProcTable (const flux\_lwj\_id\_t \*lwj, MPIR\_PROCDESC\_EXT\* ptab, size\_t count);

/\*! Interface that returns the size of the local MPIR process table associated with lwj into count based on the hostname (hn) or where this call is made if hn is NULL \*/

flux\_rc\_e

FLUX\_query\_localProcTableSize (flux\_lwj\_id\_t \*lwj, const char \*hn, size\_t \*count)

/\*! Interface that returns the local MPIR process table associated with lwj into pbuf based on the hostname (hn) or where this call is made if hn is NULL. \*/

flux\_rc\_e

FLUX\_query\_localProcTable (const flux\_lwj\_id\_t \*lwj, const char \*hn, MPIR\_PROCDESC\_EXT\* buf, size\_t count);

/\*! Interface that allows the caller to register a status callback function, which is invoked whenever the status of lwj is changed – e.g., just created and stopped for sync; lwj terminiated (we will need to design the state changes of an lwj and notify many state changes to the callback with some mask support). If we don’t want the callback style as this might require the API implementation to be muli-process or multi-threaded, we can alternatively design a polling mechanism \*/

flux\_rc\_e

FLUX\_monitor\_registerStatusCb (const flux\_lwj\_id\_t \*lwj, int (\*cb) (int \*status))

### Launch and Co-locate API

/\*! Interface that launches target application or tool daemons given an executable and a list of arguments. If the sync flag is true, this interface should spawn the processes and leave them stopped. If the target LWJ is not NULL, this will co-locate the specified executable (e.g., tool daemon path) with the processes of the “target” LWJ. Note that we need to determine the rest of the options/arguments so that we can overload this interface for launching of both application processes and tool/middleware daemons. For the co-location, we need to express subset vs. full-set launching etc. \*/

flux\_rc\_e

FLUX\_launch\_spawn (const flux\_lwj\_id\_t \*me, int sync, const flux\_lwj\_id\_t \*target, int nn, int np)

### Control API

/\*! Interface that kills and cleans up all of the processes associated with the target LWJs \*/

flux\_rc\_e

FLUX\_control\_killLWJs (const flux\_lwj\_id\_t target[], int size)