UNM SCHOOL *of* ENGINEERING
Department of Computer Science

Scalable Systems Lab

LIBI: The Lightweight Infrastructure-Bootstrapping Infrastructure

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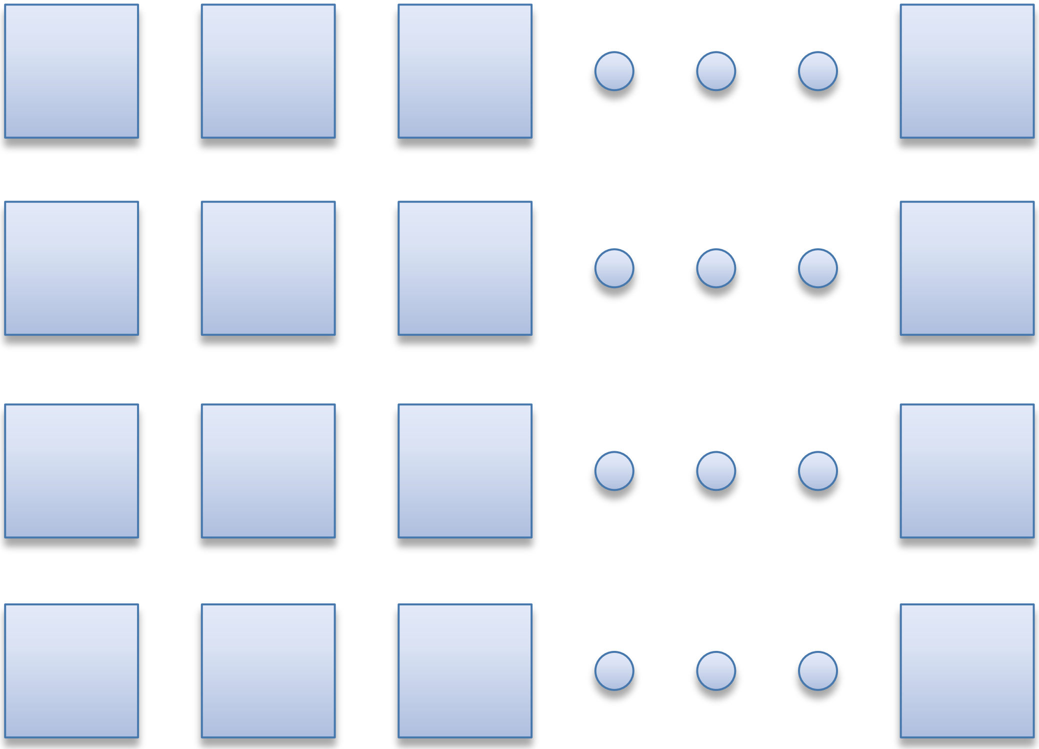
Infrastructure-bootstrapping

Given an infrastructure’s binary image(s) and a process/host distribution, start all relevant processes on their respective hosts and propagate necessary startup information.

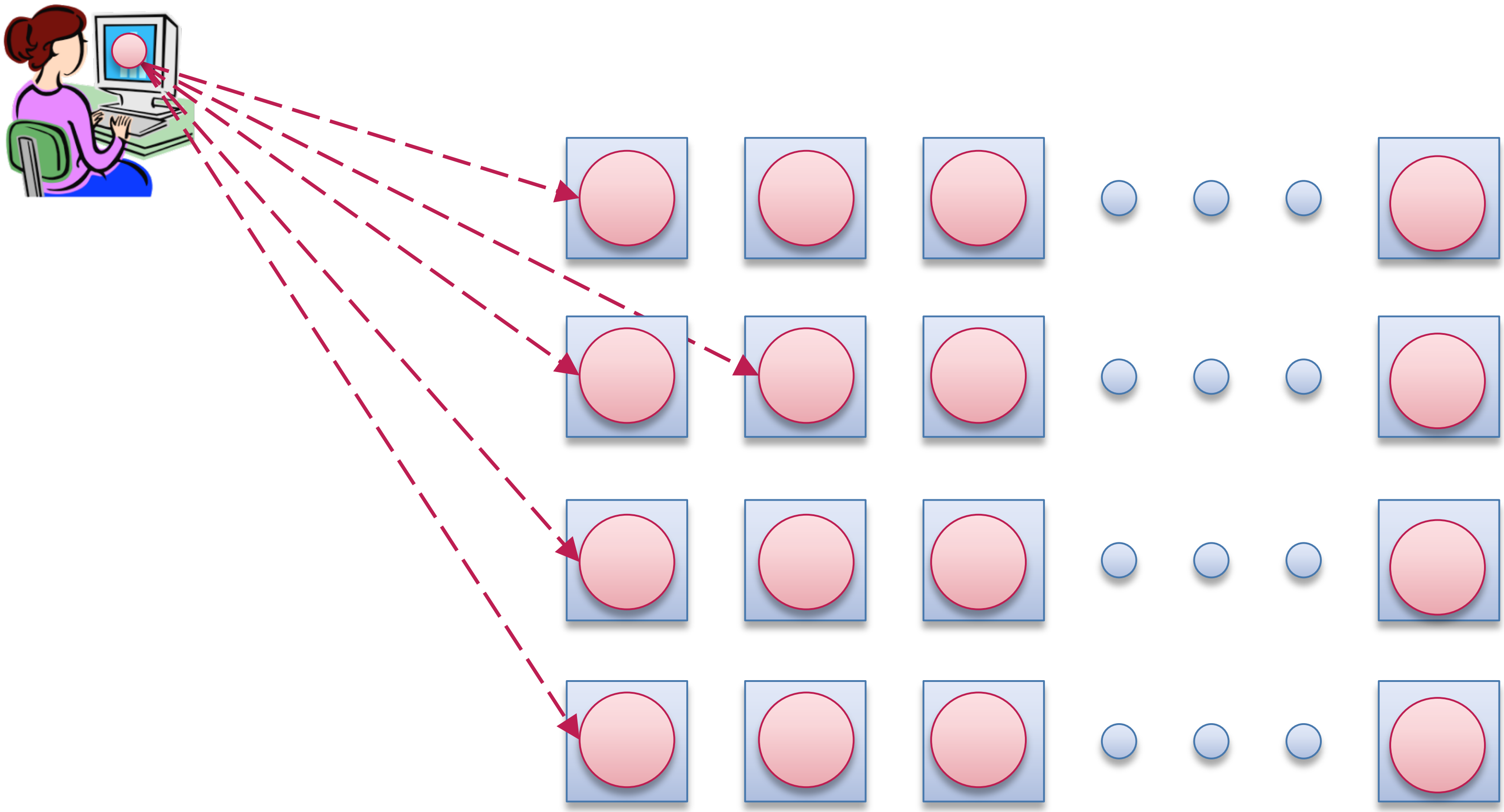
- Before bootstrapping:
  - Program image on storage device
  - Set of (allocated) computer nodes
- After bootstrapping:
  - Application processes started on computer nodes
  - Application’s configuration complete
    - ready for primary operation

What Infrastructures Need Bootstrapping?

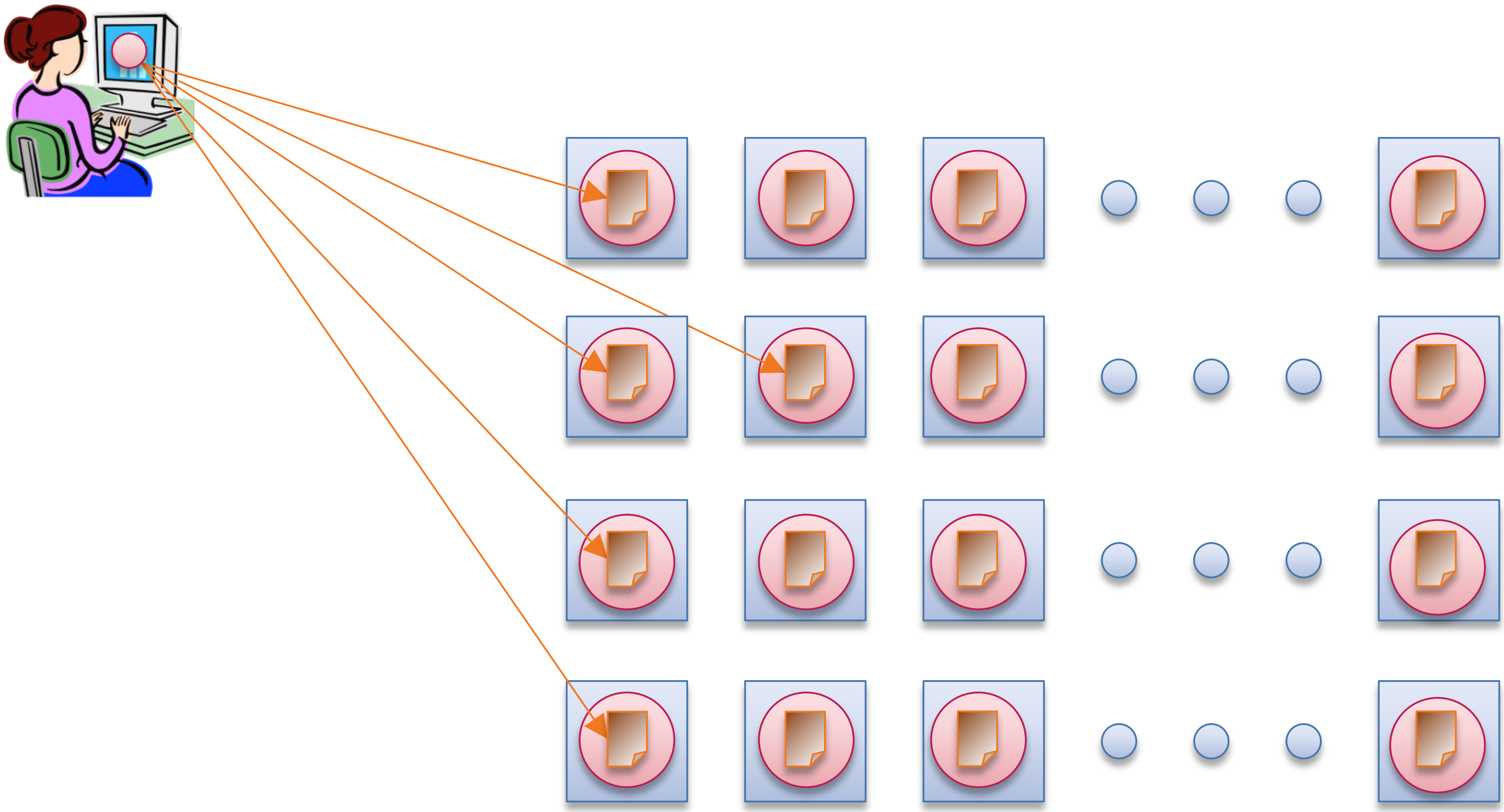
- They all do! Every piece of distributed software needs to be instantiated at some point
  - Applications
  - Tools
  - System services



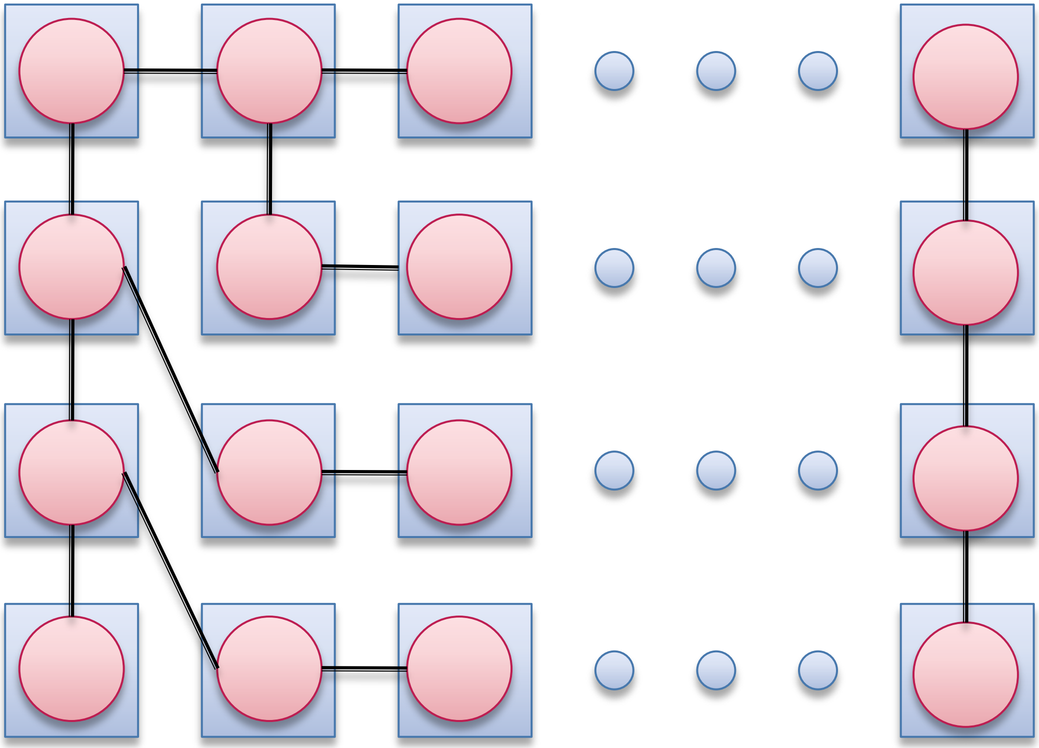
“I gotta get my application up and running!”



(1) “First, I start all the processes on the appropriate nodes”



(2) “Next, I must disseminate some initialization information”



Bootstrapping is complete when the infrastructure is ready for steady-state usage.

Bootstrapping Operations

- Process Launching

- Information Dissemination

Bulk Launching Alternatives

- All Strategies Employ Daemons
  - Service daemons or node level agents to start application processes

- Strategies vary along two dimensions
  - Degree of daemon persistence
    - service infrastructure ➔ more persistent
    - application specific ➔ less persistent
  - Daemon interconnection topology
    - simple ➔ less scalabilty
    - hierarchical ➔ more scalability

Degree of (daemon) Persistence

- Persistent daemons, persistent connections
  - MPD
- Persistent daemons, transient connections
  - SLURM, ALPS
- Transient daemons, transient connections
  - Scela, MRNet default, MRNet on XT

(Daemon) Interconnection Hierarchy

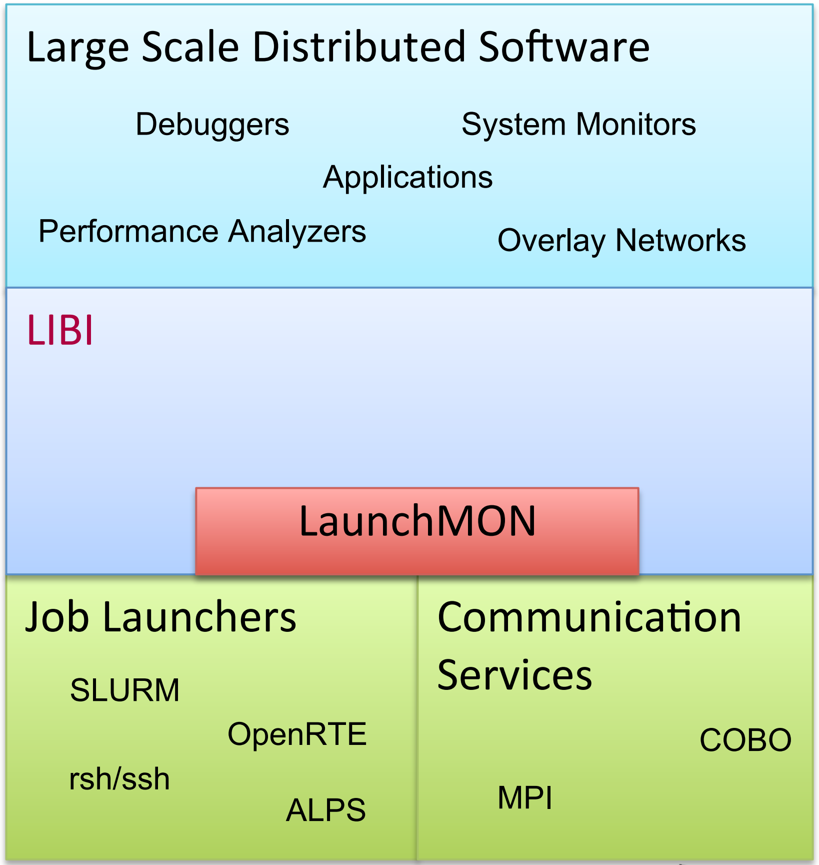
- Centralized
- Rings
- Trees

Scalable Bootstrapping Alternatives

- Infrastructure-specific, scalable mechanisms
  - Still limited by sequential operations
  - Not portable to other infrastructures
- Using high-performance resource managers
  - Myriad interfaces
  - No communication facilities
- Generic bootstrapping infrastructures
  - LaunchMON: targets tools with wrapper for existing RMs

LIBI Approach

- LIBI: Lightweight infrastructure-bootstrapping infrastructure
  - Generic service for scalable distributed software infrastructure bootstrapping
    - Process launch
    - Scalable, low-level collectives



Large Scale Distributed Software

Debuggers

System Monitors

Applications

Performance Analyzers

Overlay Networks

LIBI

LaunchMON

Job Launchers

SLURM

OpenRTE

rsh/ssh

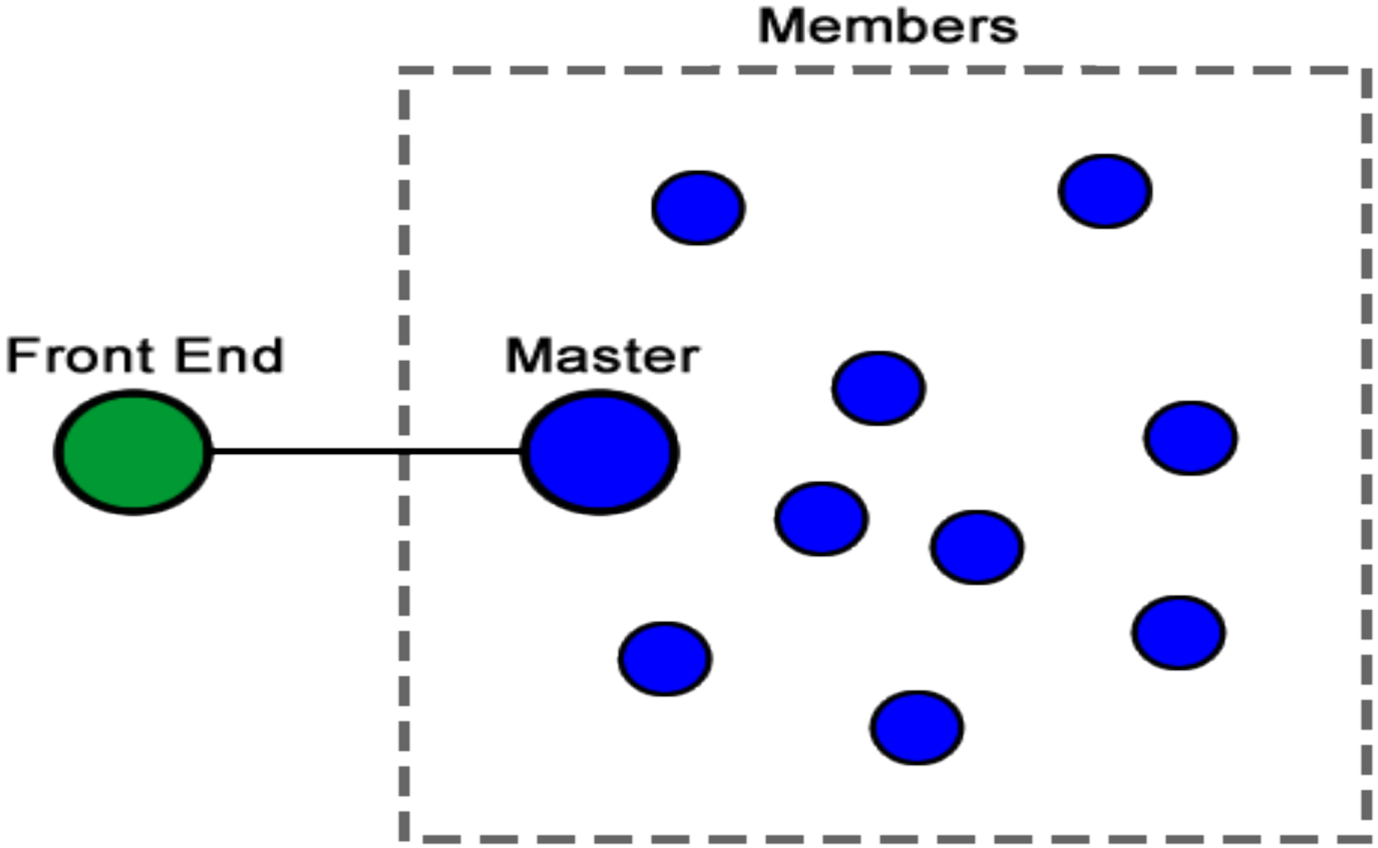
ALPS

Communication Services

COBO

MPI

LIBI Architecture



LIBI API

- *session*: set of processes (to be) deployed
  - *session master* manages other members
  - *session front-end* interacts with session master
  - LIBI currently supports only master/member communication
- *host-distribution*: where to create processes
  - <hostname, num-processes>
- *process distribution*: how/where to create processes
  - <session-id, executable, arguments, host-distribution, environment>

LIBI API (cont’d)

```
launch(process-distribution-array)
```

- instantiate processes according to input distributions

```
[send|recv]UsrData(session-id, msg)
```

- communicate between front-end and session master

```
broadcast(), scatter(), gather(), barrier()
```

- communicate amongst session members

Example LIBI Front-end

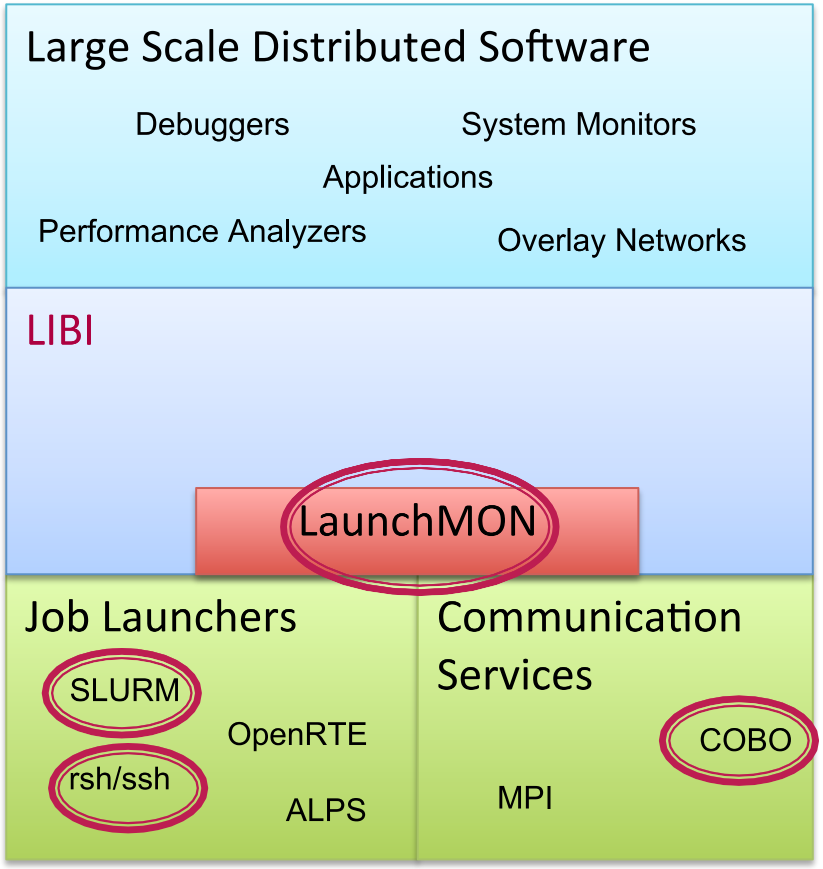
```
front-end( ){
   LIBI_fe_init();
   LIBI_fe_createSession(sess);

   proc_dist_req_t pd;
   pd.sessionHandle = sess;
   pd.proc_path = get_ExePath();
   pd.proc_argv = get_ProgArgs();
   pd.hd = get_HostDistribution();

   LIBI_fe_launch(pd);

   //test broadcast and barrier
   LIBI_fe_sendUsrData(sess1, msg, len );
   LIBI_fe_recvUsrData(sess1, msg, len);

   //test scatter and gather
   LIBI_fe_sendUsrData(sess1, msg, len );
   LIBI_fe_recvUsrData(sess1, msg, len);

   return 0;
}
```

Example LIBI-launched Application

```
session_member() {
  LIBI_init();

  //test broadcast and barrier
  LIBI_recvUsrData(msg, msg_length);
  LIBI_broadcast(msg, msg_length);
  LIBI_barrier();
  LIBI_sendUsrData(msg, msg_length)

  //test scatter and gather
  LIBI_recvUsrData(msg, msg_length);
  LIBI_scatter(msg, sizeof(rcvmsg), rcvmsg);
  LIBI_gather(sndmsg, sizeof(sndmsg), msg);
  LIBI_sendUsrData(msg, msg_length);

  LIBI_finalize();
}
```

LIBI Implementation Status

- LaunchMON-based runtime
  - Tested SLURM or rsh launching
  - COBO PMGR service
- Rsh-based default
  - Pluggable launch topologies
  - Devised a provably optimal algorithm!



Optimal Launching Topology

- Assumptions
  - Homogenous computing environment
    - All nodes have the same computational power
    - Constant wait time between each local launch command
    - Constant remote launch time
      - physical network topology?
      - file system (and other resource) contention?

- Algorithm Overview
  - Inspired by Park et al's optimal multicast tree [ICPP '96]
  - Pick first node as root
  - For every subsequent node, place at minimal launch point

Algorithm for Optimal Launch Topology

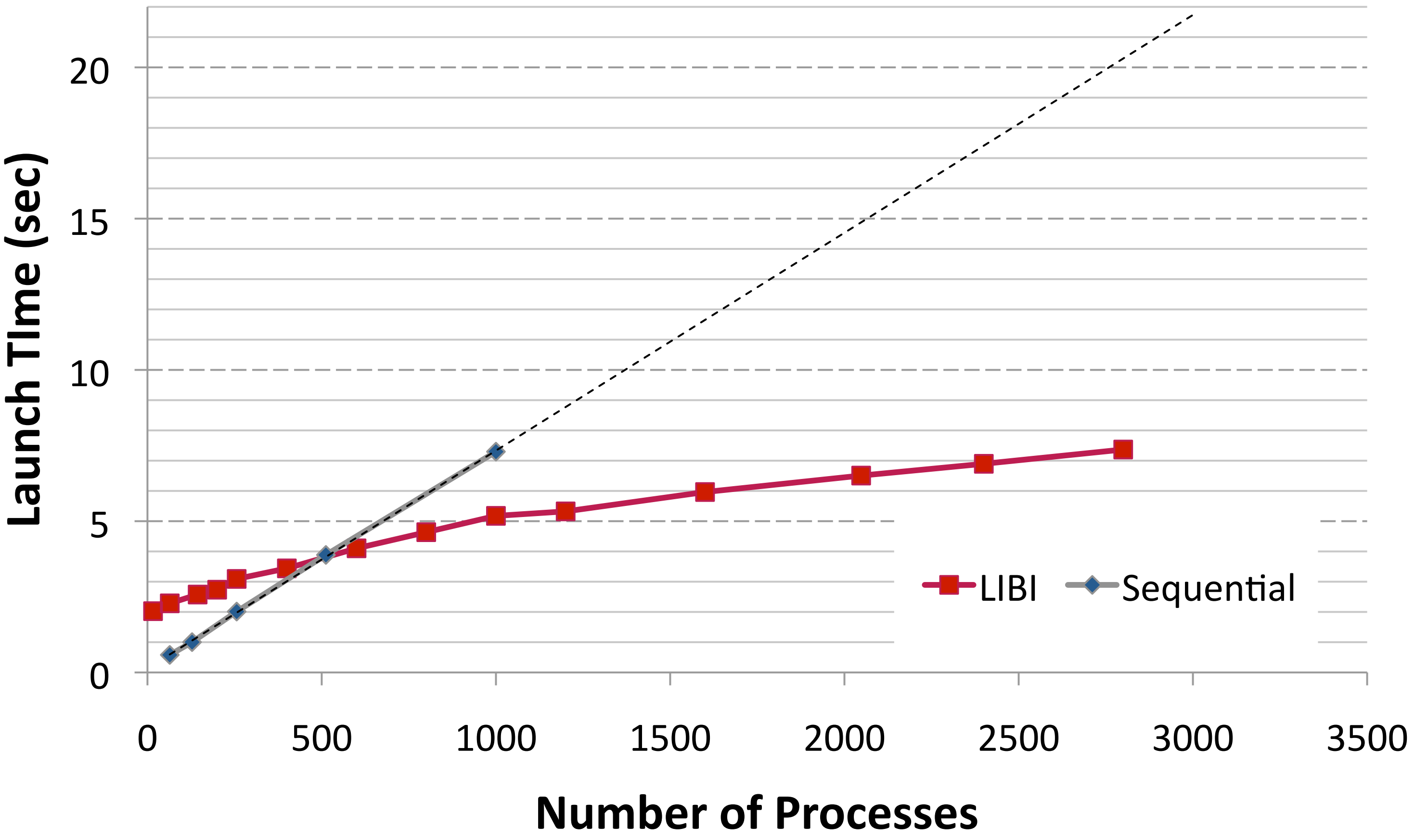
```
find_optimal_topology( node_list, model_params ){
    dequeue list head, set as root of tree
    compute root’s “ready time”

    while( node_list not empty ) {
        dequeue list head

        add node to tree at smallest “ready time” node
        compute node’s “ready time”
        recompute parent’s “ready time”
    }
}
```

Performance Results

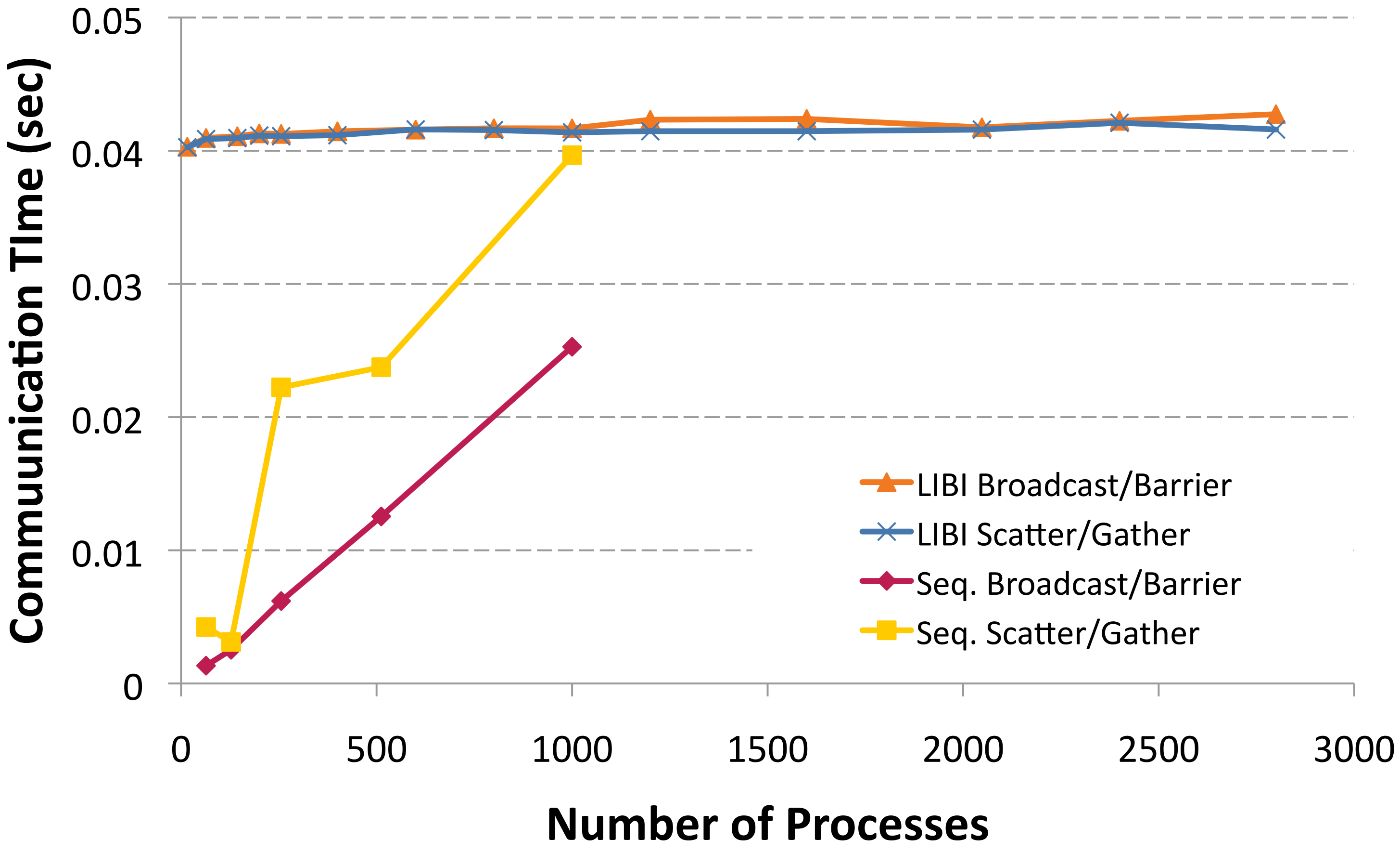
- Focus on task launching
  - Lots of data available for communication topologies

- MRNet Start-up improvements

LIBI Microbenchmark Results



LIBI Microbenchmark Results

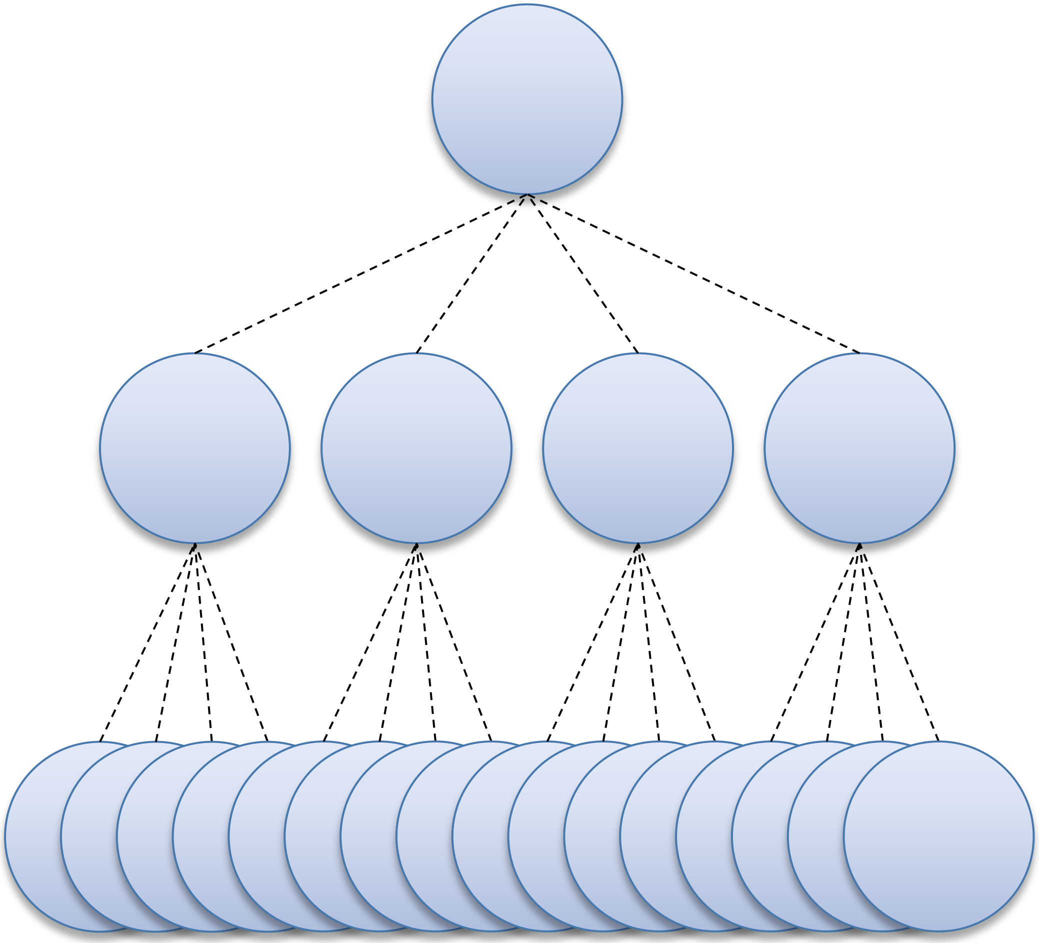


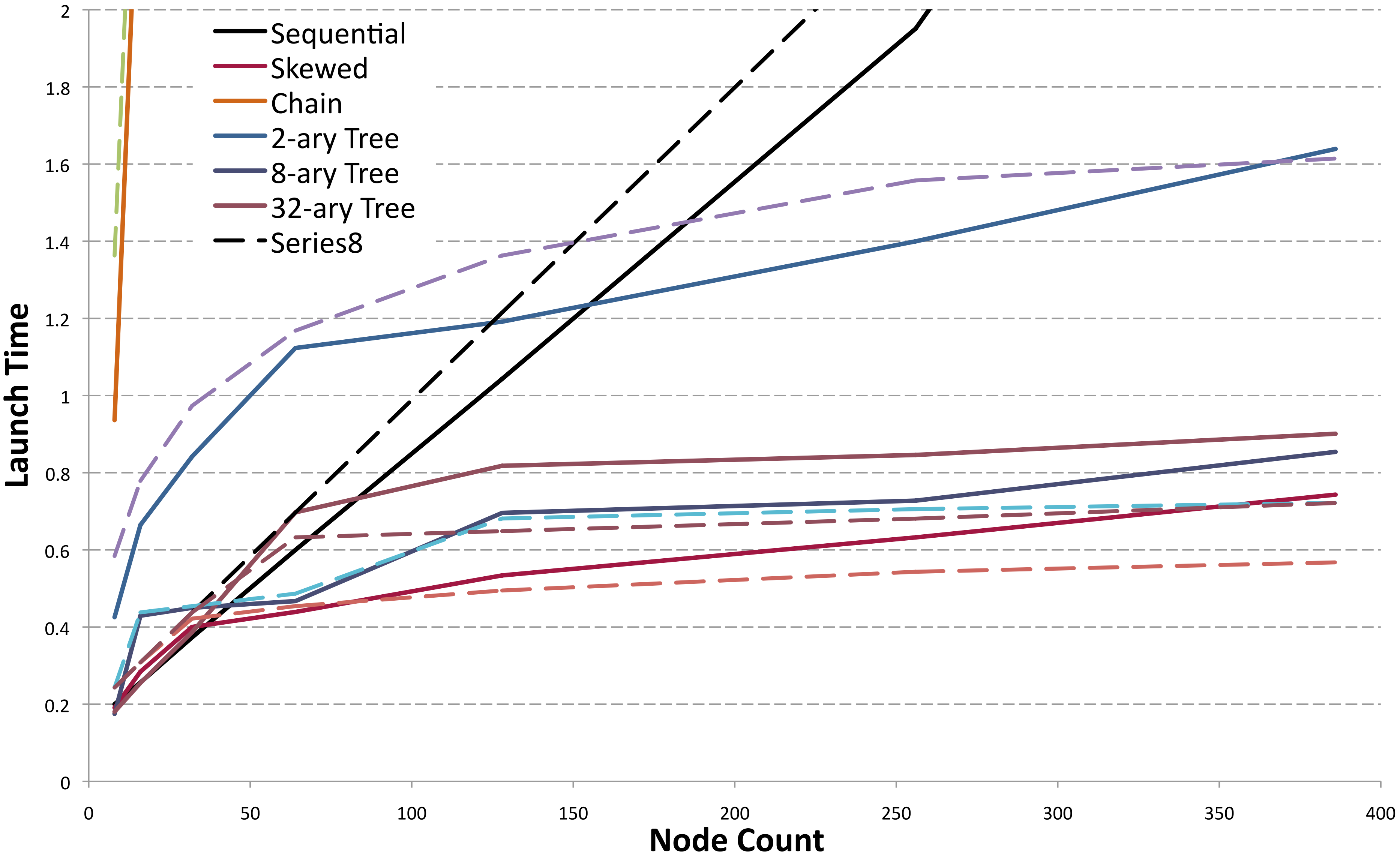
MRNet/LIBI Integration

- MRNet uses LIBI to launch all MRNet processes
  - Parse topology file and setup/call `LIBI_launch()`
- Session front-end gathers/scatters startup information
  - Parent listening socket (IP/port)

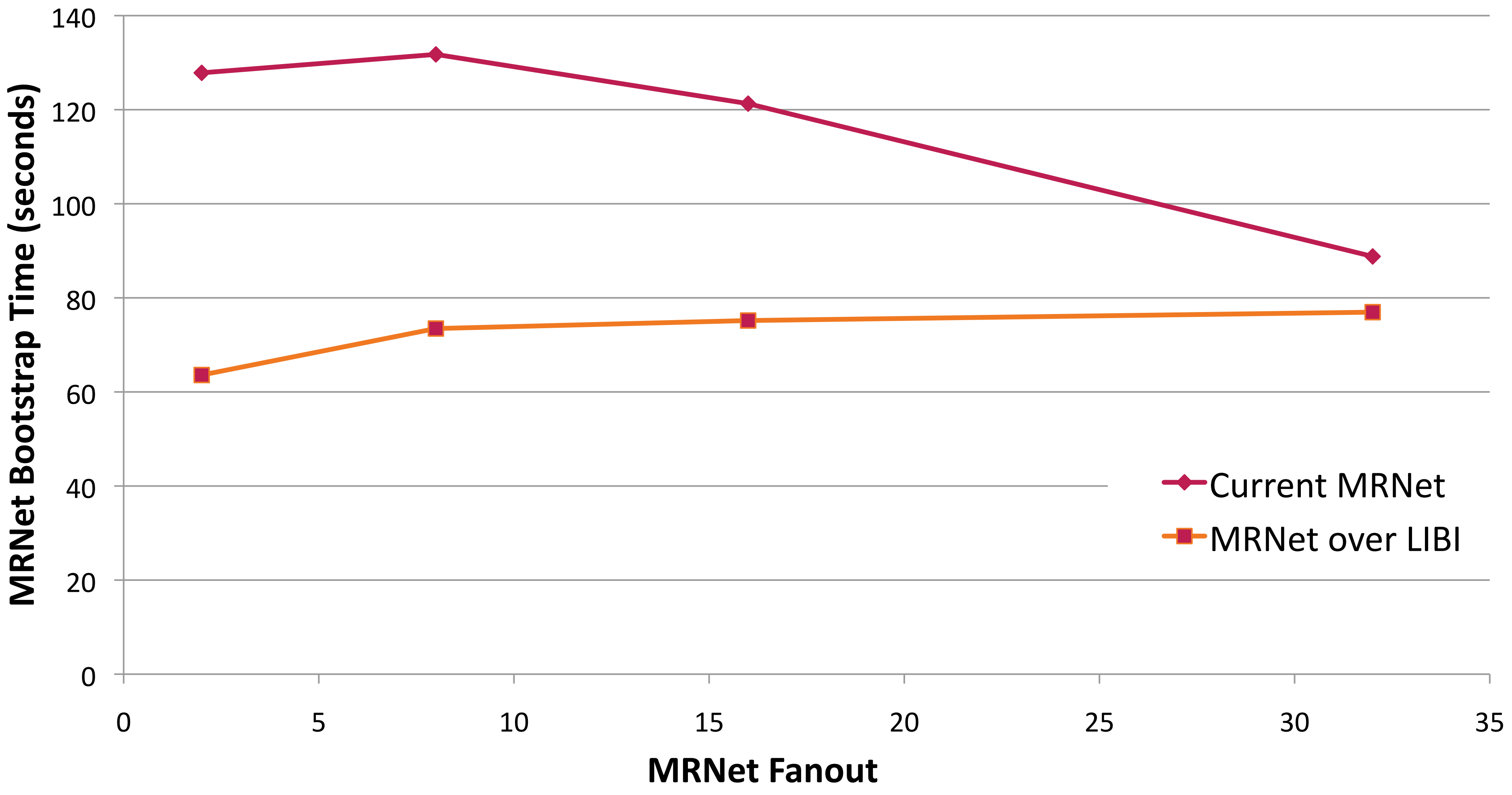
MRNet Sequential-ish Bootstrapping

- Parent creates children
  - Local ➔ fork()/exec()
  - Remote ➔ rsh-based mechanism
- Integrated instantiation and information propagation
- MRNet's "standard"

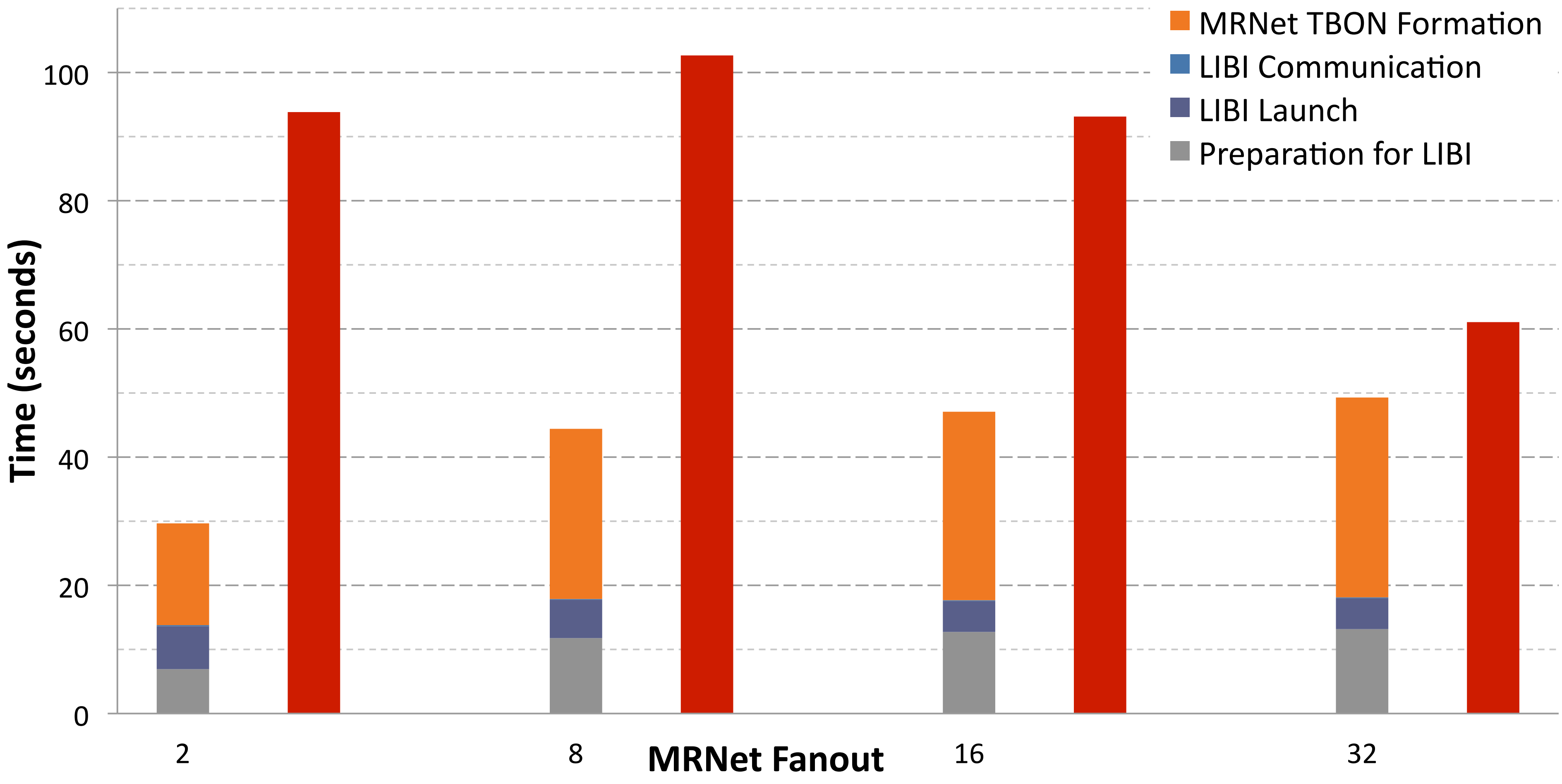



Launch Time
Node Count
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
50
100
150
200
250
300
350
400
Sequential
Skewed
Chain
2-ary Tree
8-ary Tree
32-ary Tree
Series8

LIBI v.s. MRNet default



LIBI v.s. MRNet default (broken down)



Future Research and Development

- Optimal Launch Topology
  - Performance analysis
  - Scalability bounds
  - Optimization heuristics
  - Impact of resource contention and other simplifications
- Mechanisms to alleviate file system contention
  - Like our scalable binary relocation service
- More flexible process and host distributions
  - Instantiating different images in same session
  - Integrating allocating and launching
- Integrated scalable communication infrastructure
- Refactoring LaunchMON