Scalable Workload Models for System Simulations

John Thompson

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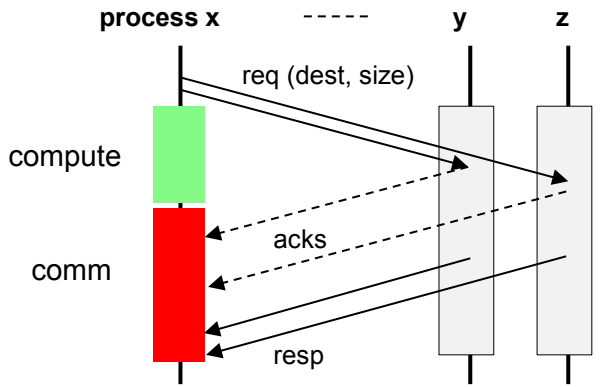
DCG
Data Center Group

Background and Motivation

- Intel Omni Scale Fabrics
- There are a few things we need to get right
  - Accurate workload representations
    - Traffic rates
    - Compute/communication overlaps
    - Message sizes
    - Data dependencies
    - Synchronization
    - Load Imbalance
  - Fast and scalable simulations
  - Revealing analytics and visualization
- SWM framework requirements
  - Scalability
  - Composability
  - Extensibility
  - Portability



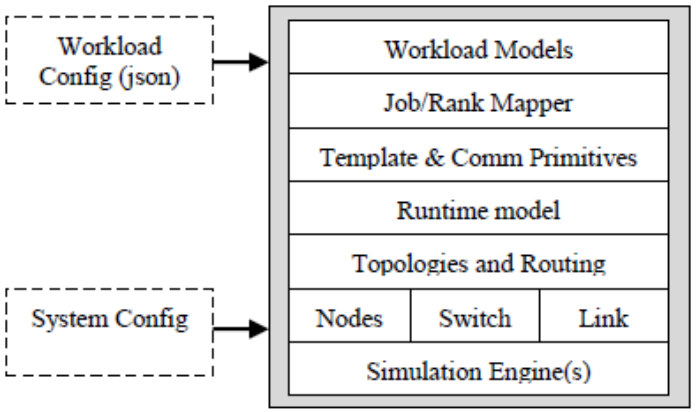
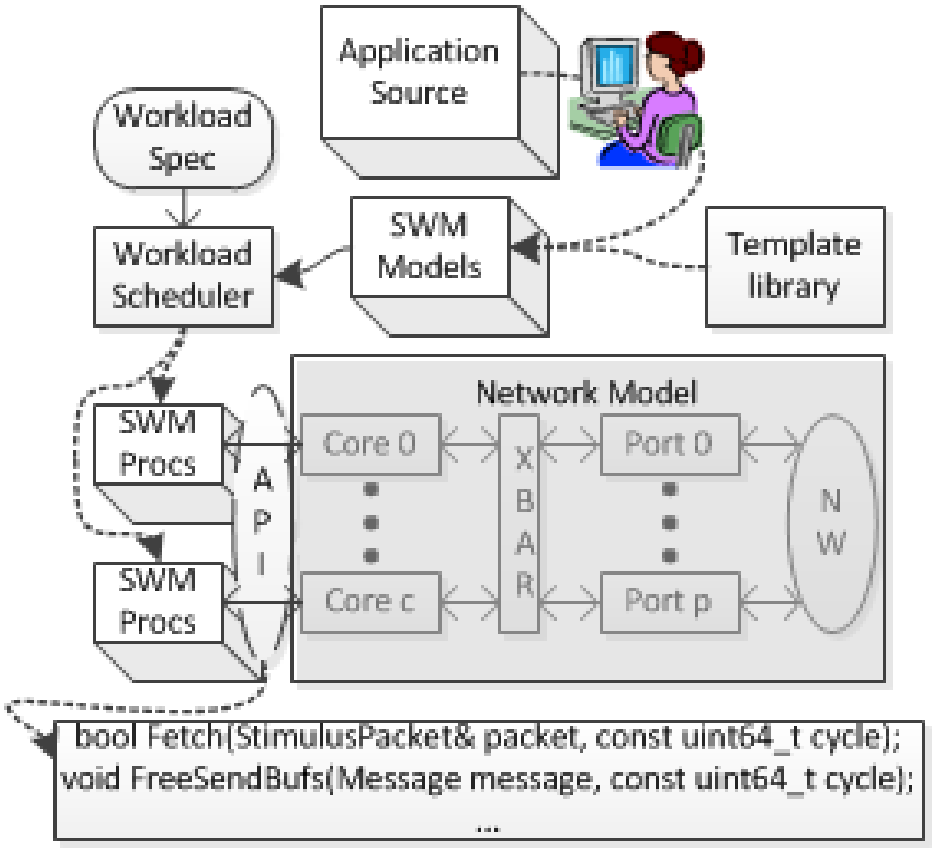
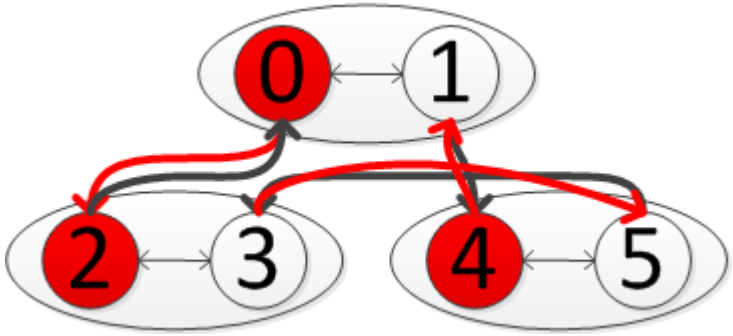


Figure 3. System simulation framework

SWM Framework






```
{
   "jobs": [
      {
         "name": "aggressor",
         "app":  "tornado",
         "size": 3,
         "time": 0,
         "yells": false,
         "cfg": {
            "iteration_cnt":    -1,
            "hierarchy_depth":          2,
            "hierarchical_sizes":       "3,1",
            "hierarchical_mappings":    "right,right",
            "req_traffic": [
               {
                  "parts": 1,
                  "routing_type": "minimal",
                  "bytes": 32,
                  "vcs": 0
               }
            ]
         },
         "placement": {
            "type":     "offset_stride_weight",
            "offset":   0,
            "stride":   2,
            "weight":   1
         }
      },
      {
```

SWM Template Library

- The SWM Template Library features a variety of calls and support to model:
  - MPI (eg: TMPL_Send, TMPL_Isend, TMPL_Alltoall, TMPL_Wait)
  - SHMEM (eg: TMPL_Intmalloc, TMPL_Putmem, TMPL_Intadd, TMPL_Fence)
  - Synthetics (eg: TMPL_Synthetic)
- It is not restricted to the API of a commercial library
  - Fine-grained virtual channel configuration is useful in fabric space
  - Could explore proposed library extensions (ie: non-blocking collectives)

```
#include "point_to_point_template_user_code.h"

P2PTemplateUserCode::P2PTemplateUserCode(
        TemplateProcess* process,
        boost::property_tree::ptree cfg,
        void**& generic_ptrs,
        template_topology* topology
        ) :
    AppBaseTemplateUserCode(process, cfg),
    src_rank_id(cfg.get<uint32_t>("src_rank_id")),
    dst_rank_id(cfg.get<uint32_t>("dst_rank_id")),
    compute_delay(cfg.get<uint32_t>("compute_delay",0)),
    topology(topology)
{
}

void
P2PTemplateUserCode::call()
{
    if (process->process_id == src_rank_id) {
        for(uint32_t iter=0; iter<iteration_cnt; iter++)
        {
            GetReqDetails(
                req_rt, rsp_rt,
                req_vc, rsp_vc,
                msg_req_bytes,msg_rsp_bytes,pkt_rsp_bytes
```

SWM Template Library

```
void RingTemplateUserCode::call() {
  uint32_t handle;
  for(uint32_t iter=0; iter<iteration_cnt; iter++) {
    if(process_id == 0) {
      //send to 1
      TMPL_Isend(
            1,          //dst
            0,          //comm
            process_id,   //tag
            request_vc,   //reqvc
            response_vc,  //rspvc
            0,          //buf
            message_size,  //bytes
            &handle,
            req_rt,
            rsp_rt
            );
      TMPL_Wait(handle);
      //recv from process_cnt -1
      TMPL_Irecv(
            process_cnt -1, //src
            0,          //comm
            process_cnt -1, //tag
            0,          //buf
            &handle
            );
      TMPL_Wait(handle);
    }
    else {
      //recv from process_id -1
      TMPL_Irecv(
            ...
            );
      TMPL_Wait(handle);
      if(process_id == process_cnt -1) {
        //send to 0
        TMPL_Isend(
              ...
              );
        TMPL_Wait(handle);
      }
      else {
        //send to process_id +1
        TMPL_Isend(
              ...
              );
        TMPL_Wait(handle);
      }
    }
  }
  TMPL_Finalize();
  assert(0);
}
```

SWM Template Library

- Several SWMs exist today
  - Synthetics (ie: UR, Permutation, Nearest Neighbor, …)
  - Toy (ie: Ring, MDFFT, QCD, …)
  - Application (HACC, Nekbone, and eight others)

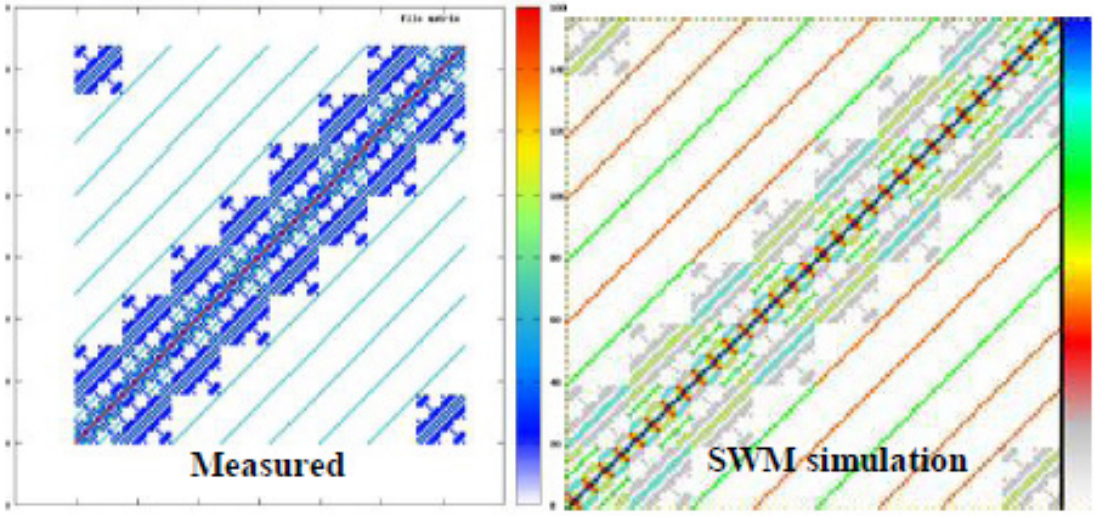
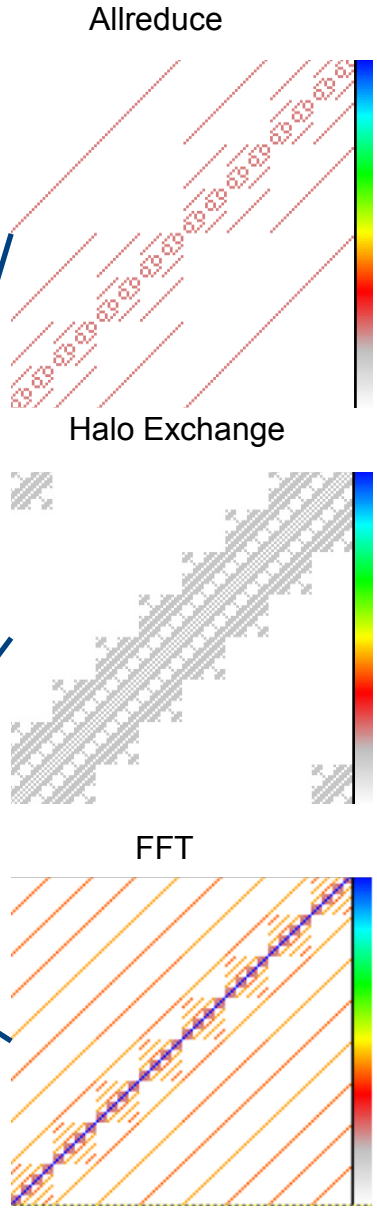
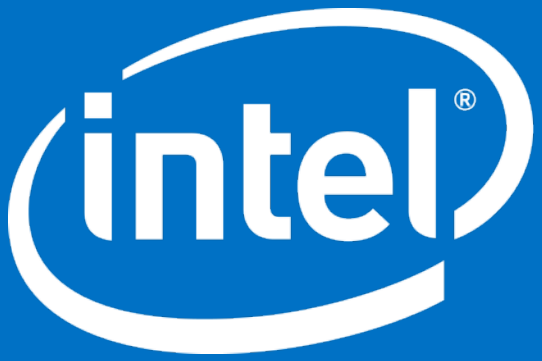


Figure 4. Src-Dest traffic matrix – Measured vs. SWM (HACC workload)



Successes, Challenges, To-dos, and Wishes

- Successes
  - Enables at-scale system simulation
  - Full-featured -- constructed a comprehensive suite of stimulus
    - MPI, SHMEM, and Synthetic support
    - Many CORAL (DOE) applications have accurate SWM representations now
  - Easily adopted by SWM developers (application experts)
  - Easily interfaced to multiple simulators
  - Allows for the construction of workloads composed of many SWMs
- Challenges
  - Requires a deep understanding of application behavior
  - How do you guarantee an SWM's accuracy, especially at increasing scales?
- To-dos
  - Continue to support an ever increase set of template calls
  - Interface review and refinement
  - More flexible meta-data abstraction (I might want to append VC data, you might want something else)
- Wishes
  - Wider adoption of some such common framework
  - Obtain SWM models from 3rd parties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