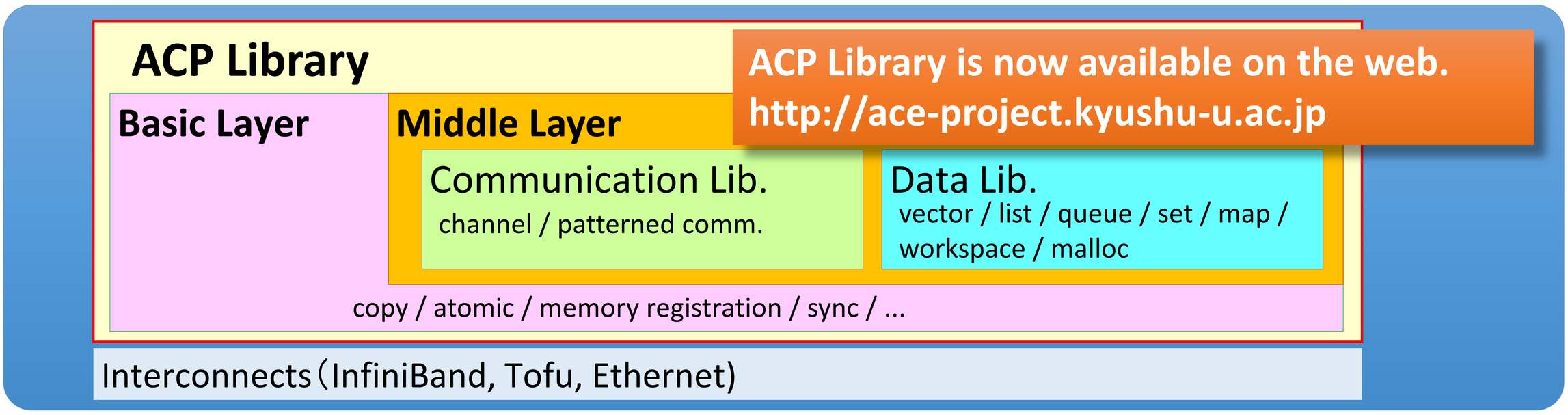
Advanced Communication for Exa (ACE)

- a project on memory-efficient communication library -

Motivation

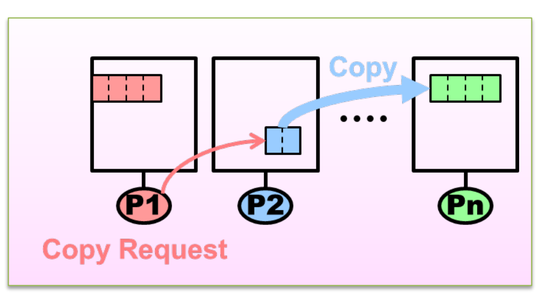
Memory-efficient communication towards exa-scale computing.

Advanced Communication Primitives (ACP) Library



Basic Layer

- PGAS-style global memory management
- Copy and Atomic Op on global address
- Express dependency between accesses

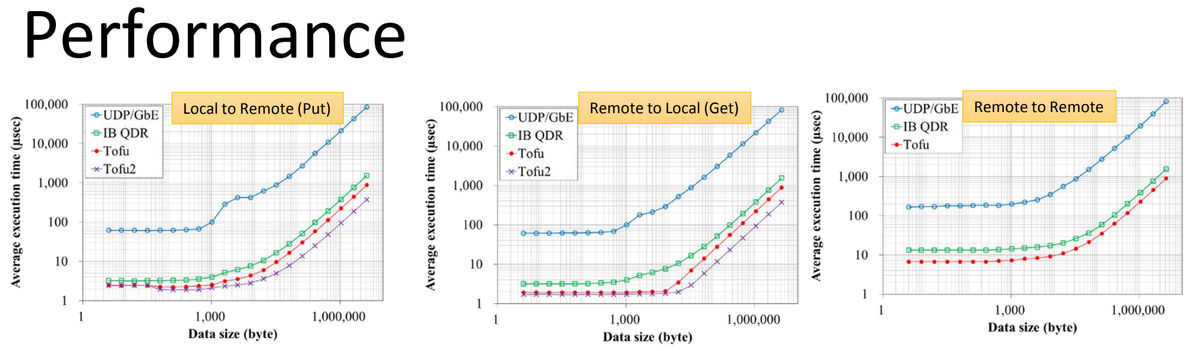



```
acp_handle_t h1, h2;

h1 = acp_copy(dstga1, srcga1, size1,
              ACP_HANDLE_NULL);
h2 = acp_copy(dstga2, srcga2, size2, h1);
acp_complete(h2);
```

Memory consumption ratio (1M procs)

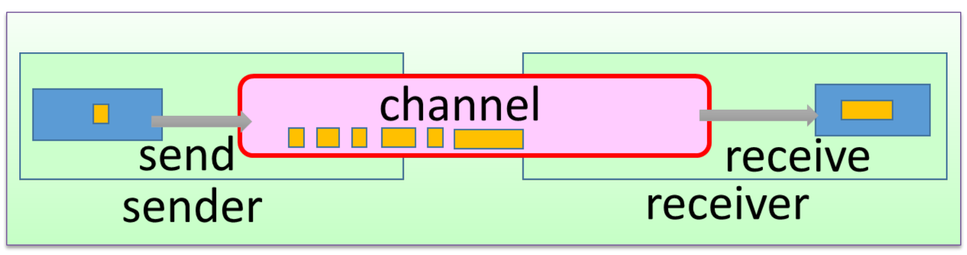
InfiniBand	Tofu	UDP
369 MiB / process	67MiB / process	34MiB / process

Performance



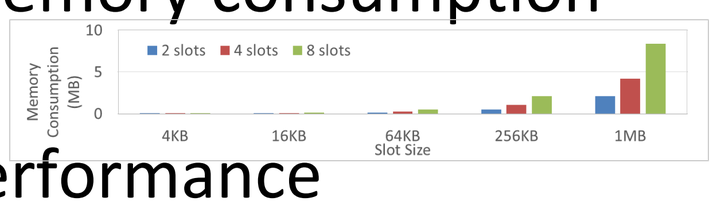
Communication Lib.

- Explicit creation / destruction of channels among processes
- 1 directional send / receive

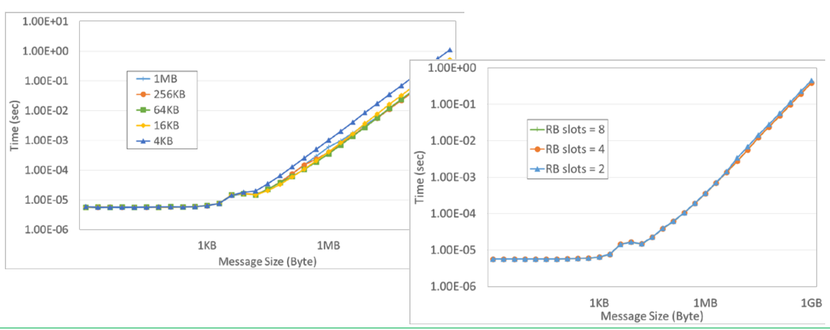



```
ch0 = acp_create_ch(left, myrank);
ch1 = acp_create_ch(myrank, right);

for (...){
  req0 = acp_nbsend(ch0, addr0, size);
  req1 = acp_nbrecv(ch1, addr1, size);
  acp_wait_ch(req0);
  acp_wait_ch(req1);
  calc();
}

req0 = acp_nbfree_ch(ch0);
req1 = acp_nbfree_ch(ch1);
acp_wait_ch(req0);
acp_wait_ch(req1);
```

Memory consumption

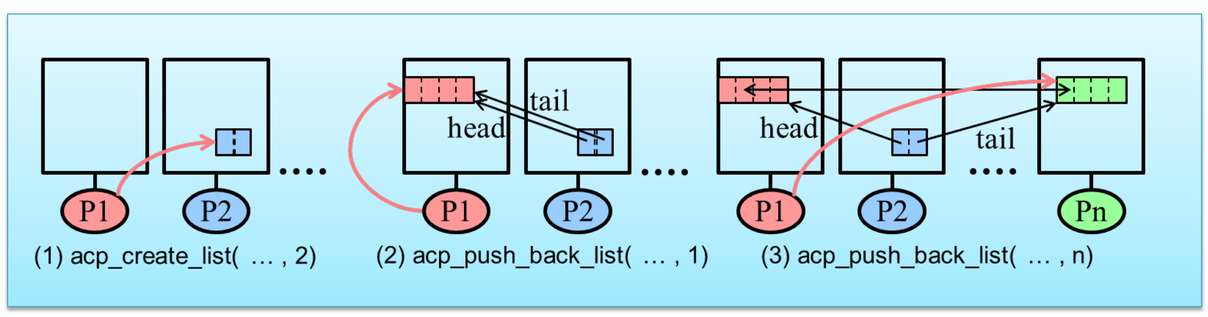


Performance



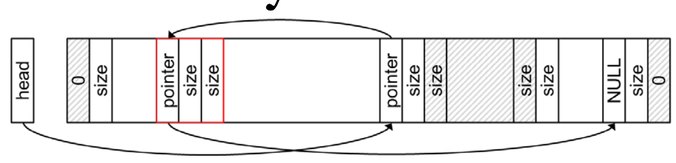
Data Lib.

- Create/modify/destruct data structures on global memory: vector, list, deque, map, set (from STL)

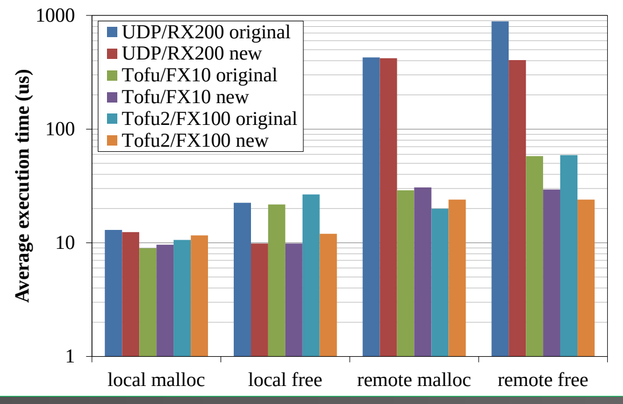


- Based on global memory allocator

```
acp_ga_t ga;

ga = acp_malloc(size, rank);
  ...
acp_free(ga);
```



Performance



Kyushu Univ.	Takeshi Nanri, Hiroaki Honda, Ryutaro Susukita, Taizo Kobayashi, Yoshiyuki Morie
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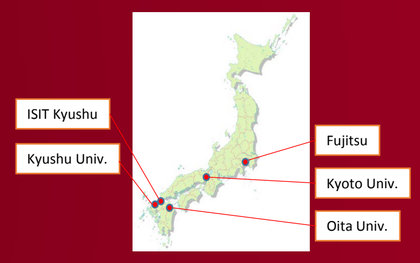
Kyoto Univ.	Keiichiro Fukazawa
Oita Univ.	Toshiya Takami

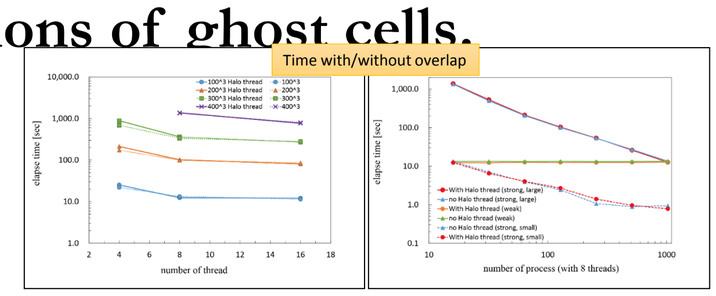


Applications

Halo Communications in MHD Simulation

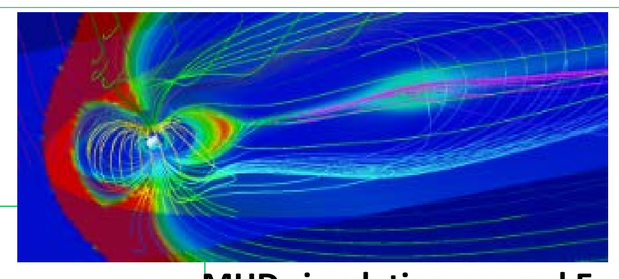
Halo thread

- Dedicated thread for communications and computations of ghost cells.
- Overlap with computations on other cells

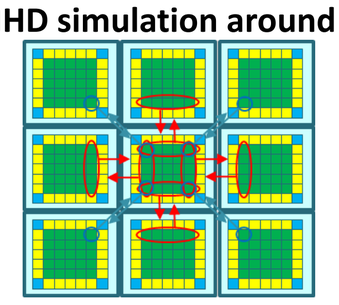


Halo framework

```
i=0;j=0;segnum=26;
hnd=halo_3d_init(nx,ny,nw,matrix,segsize);
for(j=0;j<snum[0];j++)
    halo_3d_isend(hndsxd[0][j],syd[0][j],szd[0][j]
                  ,sxs[0][j],sxs[0][j],sys[0][j],sye[0][j],szs[0][j],sze[0][j]);
for(i=0;i<segnum;i++) {
   for(j=0;j<rnum[i];j++) {
      halo_3d_irecv(hnd,sxd[i][j],syd[i][j],szd[i][j],sxs[i][j],sxs[i][j]
                    ,sys[i][j],sye[i][j],szs[i][j],sze[i][j]);
      halo_3d_wait(hnd);
   }
   compute ghost cells
   for(j=0;j<snum[i+1];j++)
       halo_3d_isend(hnd,sxd[i+1][j],syd[i+1][j],szd[i+1][j],sxs[i+1][j],sxs[i+1][j],
                     sys[i+1][j],sye[i+1][j],szs[i+1][j],sze[i+1][j]);
}
halo_3d_finalize(hnd);
```



MHD simulation around Earth

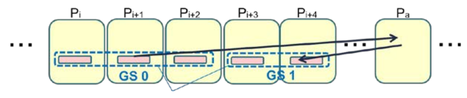


Master-Worker Model in FMO Method

Shared work-space

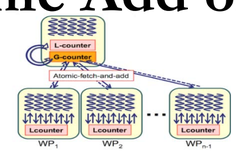
- Common continuous region asynchronously accessible from all of the processes.

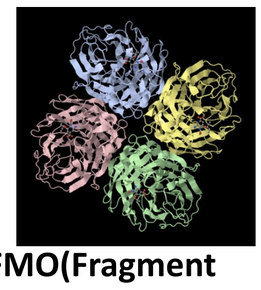
```
sws[0] = acp_create_sws( size0 );
sws[1] = acp_create_sws( size1 );
...
acp_write_sws( gds[0], size_write0, offset_write0, writebuf0 );
...
acp_read_sws(  gds[0], size_read1,  offset_read1,  readbuf1  );
...
acp_free_sws( gds[0] );
acp_free_sws( gds[1] );
```



Global counter

- Dynamic load balance with Atomic Add of ACP



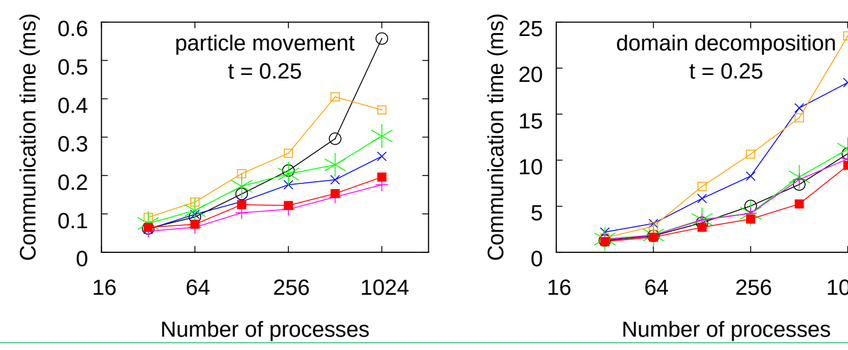


FMO(Fragment Molecular Orbital)

Particle Data Exchange in *N*-body Simulation

Irregular communication pattern

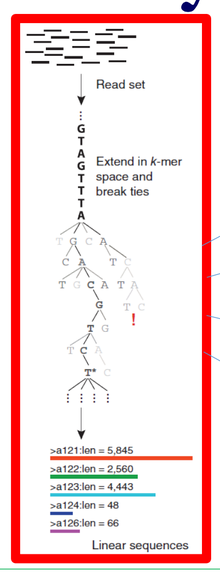
- Inter-process data exchange after particle movement
- Efficient data transfer and synchronization via Global Memory Access (copy and atomic) of ACP
- Better performance than MPI Remote Memory Access



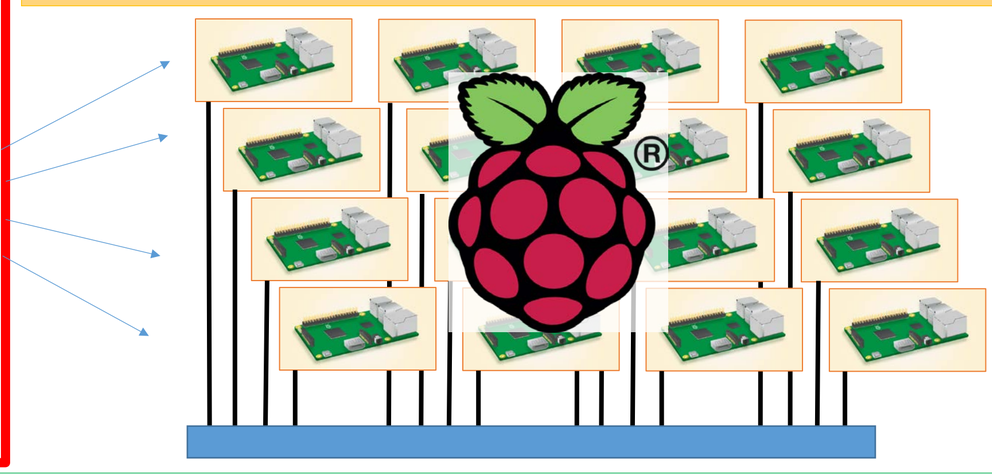
De Novo Transcript Assembly on Python

Concurrent *k*-mer Dictionary on Distributed Memory

- Split NGS short reads into small *k*-mers and store them into distributed dictionary on "map" data structure of ACP.
- Splice *k*-mers to build long sequences.
- Intending enhanced implementation via Python interface.



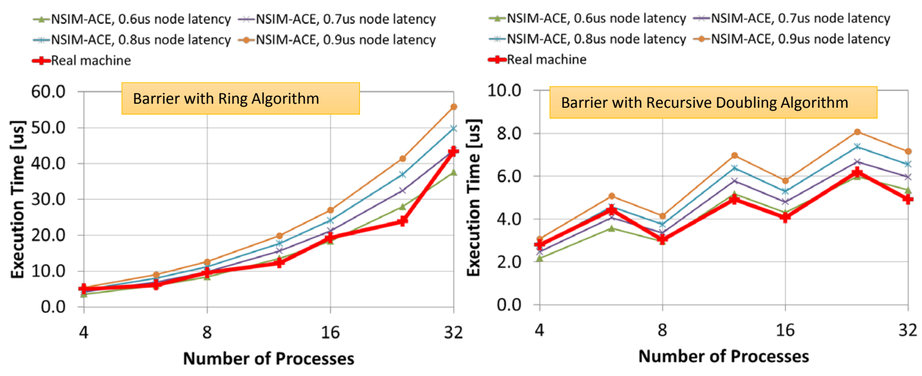
Live demo on a Raspberry Pi cluster



Performance Estimation Tool: NSIM-ACE

- Interconnect simulator for performance evaluation and communication analysis.
- Supports message-passing and/or one-sided communications.
- MGEN program: Skelton of communication pattern.
  = Easily extract from real programs.

```
if(rank == src_rank){
    handle = MGEN_acp_copy(src_rank,
                dest_rank, data_size, tag);
    MGEN_comp(time0);
    MGEN_acp_complete(handle);
}else if(rank == dest_rank){
    MGEN_comp(time1);
    MGEN_poll(tag);
}
```



Find posters in the booth with more detailed information