Scalable Fabrics Interface

Lessons learned from MVAPICH

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The Path to Exascale …

Constrained power envelope

Data movement costs must be contained

i) Reduce power in the core to move data

ii) Reduce overheads of communication (finer-grain)

Communication stack is critical

Even in the current generation performance is gated by software overheads

Current OFA Verbs - Application send

Significant SW overhead

Application request

<buffer, length, context>

```
struct ibv_sge {
    uint64_t        addr;
    uint32_t        length;
    uint32_t        lkey;
};
```

3 x 8 = 24 bytes of data needed

SGE + WR = 88 bytes allocated

```
struct ibv_send_wr {
    uint64_t              wr_id;
    struct ibv_send_wr    *next;
    struct ibv_sge        *sg_list;
    int                   num_sge;
    enum ibv_wr_opcode    opcode;
    int                   send_flags;
    uint32_t              imm_data;
    ...
};
```

Requests may be linked - next must be set to NULL

Must link to separate SGL and initialize count

App must set and provider must switch on opcode

Must clear flags

28 additional bytes initialized

Current OFA Verbs - Provider Send

```
For each work request
    Check for available queue space
    Check SGL size
    Check valid opcode
    Check flags x 2
    Check specific opcode
    Switch on QP type
        Switch on opcode
    Check flags
        For each SGE
            Check size
            Loop over length
    Check flags
    Check
    Check for last request
Other checks x 3
```

Most often 1 (overlap operations)

Often 1 or 2 (fixed in source)

Artifact of API

QP type usually fixed in source

Flags may be fixed or app may have taken branches

19+ branches including loops

100+ lines of C code
50-60 lines of code to HW

OFI WG Charter

Develop an extensible, open source framework and interfaces

aligned with ULP and application

needs for high-performance fabric services

Enable …

Minimal footprint

Reduced cache and memory footprint

High performance

Optimized software path to hardware

- Independent of hardware interface, version, features

App-centric

Analyze application needs

- Implement them in a coherent, concise, high-performance manner

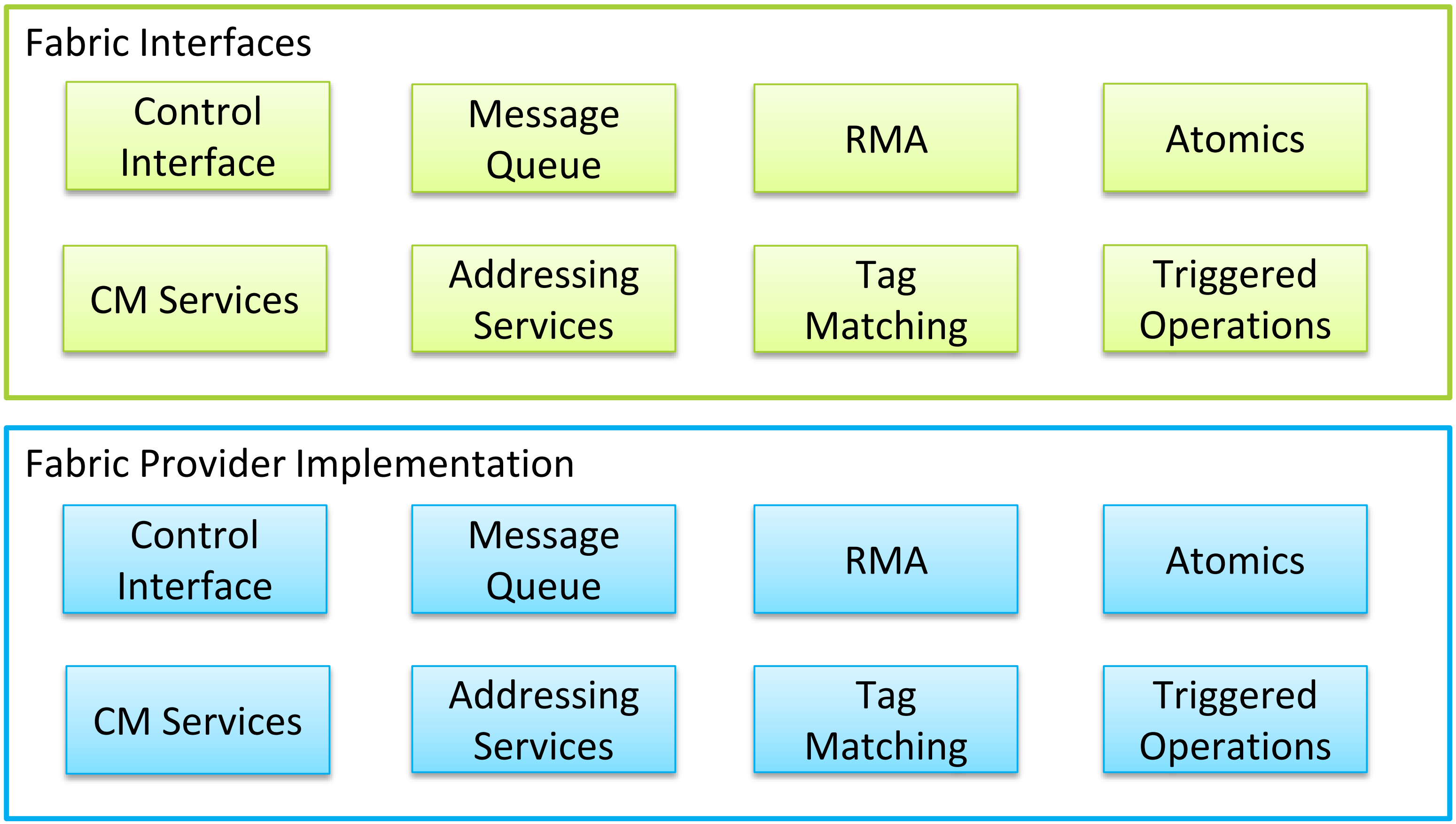
Extensible

More agile development

- Time-based, iterative development
- Application focused APIs
- Adaptable

SFI Model

Framework defines multiple interfaces



Vendors or Community provide optimal implementations

MVAPICH/MVAPICH2

MPI Implementation over InfiniBand, 10GE/iWarp, RoCE

Being developed since 2001

Continues tracking new developments in Verbs and HW

Rich history of strong research and publications

Huge impact to the Commodity HPC cluster community

Two major lessons from the research:

(i) Designing MPI/PGAS over verbs takes significant effort

(ii) Scaling MPI/PGAS over verbs also requires effort

MVAPICH Research and Design Topics

Performance

- Use hardware resources in an optimal fashion
- Optimize Protocols
- Collective Communications

Scalability

- Connection Management
- Buffer Management
- Flow Control

Other Topics

- Multiple generations of processors, adapters …
- Hybrid Programming Models

The cross-product of these are daunting!!

Performance Lessons (1)

RDMA vs Send-Recv

- RDMA P2P is better than Send-Recv, but only Send-Recv scales
- *Message Based transport is desired, with better performance*
- *Tag matching semantic offload, zero copy (SFI Tagged interface)*

Eager vs Rendezvous

- Eager/Rendezvous protocol switch (MV2_HOMOGENEOUS_CLUSTER)
- *Visibility of protocol is essential for interoperability (SFI info::protocol)*

Memory Registration

- Caching of recently used registration entries, intercept malloc, etc.
- *Remove memory registration from critical path (SFI Dynamic MR)*

Other optimizations

- Send queue sizes, huge pages, polling optimizations for fairness, …
- *Separate policy from code (SFI configuration file based optimizations)*

Performance Lessons (2)

Overlap of compute and communication

- RDMA w/ Interrupt, Asynchronous progress thread
- *Tagged API enables all provider optimizations*

Efficient completion mechanisms

- Completion processing can be expensive
- *Multiple completion formats (SFI FI_EQ_FORMAT_CONTEXT)*
- *Counters for aggregate completions*

Non-blocking Collectives with low noise

- Offload various steps of collective operations
- *Triggered operations to schedule communication using counters*

Locking and Progress

- Multi-threaded communication, internal threading
- *SFI threading modes, progress modes (FI_THREAD_PROGRESS, FI_PROGRESS_AUTO)*

Scalability Lessons

Transport Scalability

- Major design issue - RC, SRQ, XRC, UD, DCT, …
- *Reliable Datagram support is desired with zero copy (SFI FID_RDM)*

Buffer Management and Flow Control

- Dynamic buffer pools, asynchronous buffer management, locks, …
- Reduction in buffering/copying is better for performance
- *Tagged API tightly couples buffers at the provider level*

Connection Management

- User-level on-demand connection management and scalability
- Address resolution required for 3D torus and other topologies
- *Scalable and Integrated address resolution (SFI Address Vectors)*

An MPI Implementation example

```
/* Tagged provider */
hints.type          = FID_RDM;
#ifdef MPIDI_USE_AV_MAP
 hints.addr_format = FI_ADDR;
#else
 hints.addr_format = FI_ADDR_INDEX;
#endif
hints.protocol      = FI_PROTO_UNSPEC;
hints.ep_cap        = FI_TAGGED |
                      FI_BUFFERED_RECV |
                      FI_REMOTE_COMPLETE |
                      FI_CANCEL;
hints.op_flags      = FI_REMOTE_COMPLETE;
```

Reliable unconnected endpoint

Address vector optimized for minimal memory footprint and no internal lookups

Transport agnostic

Behavior required by endpoint

Default flags to apply to data transfer operations

Querying and Setting Limits

Query endpoint limits

```
optlen = sizeof(max_buffered_send);
fi_getopt(tagged_epfd, FI_OPT_ENDPOINT,
          FI_OPT_MAX_INJECTED_SEND,
          &max_buffered_send, &optlen);
```

Maximum 'inject' data size – buffer is reusable immediately after function call returns

```
optlen = sizeof(max_send);
fi_getopt(tagged_epfd, FI_OPT_ENDPOINT,
          FI_OPT_MAX_MSG_SIZE,
          &max_send, &optlen);
```

Maximum application level message size

Small Message Send

```
int MPIDI_Send(buf, count, datatype, rank, tag,
               comm, context_offset, **request)
{
    data_sz = get_size(count, datatype);
    if (data_sz <= max_buffered_send) {
        match_bits = init_sendtag(comm->context_id +
                                  context_offset,
                                  comm->rank, tag, 0);

        fi_tinjectto(tagged_epfd, buf, data_sz,
                     COMM_TO_PHYS(comm, rank),
                     match_bits);
    } else {
        ...
```

Small sends map directly to tagged-injectto call

Fabric address provided directly to provider

Large Message Send

```
int MPIDI_Send(buf, count, datatype, rank, tag,
               comm, context_offset, **request)
{
/* code for type calculations, tag creation, etc */
REQUEST_CREATE(sreq);
fi_tsendto(MPIDI_Global.tagged_epfd,send_buf,
           data_sz,
           NULL,
           COMM_TO_PHYS(comm,rank),
           match_bits,
           &(REQ_OF2(sreq)->of2_context));
*request = sreq;
}
```

Large sends require request allocation

SFI completion context embedded in request object

OFIWG

Request for direct participation as we move from architecture to implementation

Co-chairs – Sean Hefty and Paul Grun

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