Title: Software Defined Networking for HPC Interconnect and its Extension across Domains

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Software Defined Networking for HPC Interconnect and its Extension across Domains

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Focus of our project: OpenFlow-style SDN for HPC Interconnects

- Internally: within the interconnect
  - Optimize routing for individual applications and system
- Externally: match external network resources to HPC cluster
  - Remote users, remote resources
  - Storage systems
  - Data Analytics and Visualization clusters
  - Experimental Facilities (MaRie LANL)

HPC Interconnects: State of the Art

- Existing interconnection networking technology for HPC systems
  - InfiniBand:
    - high bandwidth and low latency
    - Flexible topologies: Fat-tree topology for most operational systems, also support other topologies
    - Simple control: destination based routing - inflexible and inefficient
    - Performance issues when scale up
  - Proprietary technologies:
    - Less flexible topologies
    - Complex control
      - Cray Cascade (Edison):
        - Dragonfly topology
        - Global adaptive routing
      - IBM Bluegene:
        - 3D and 5D torus topologies
        - Adaptive routing

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**Ethernet and SDN/Openflow will be persistent!

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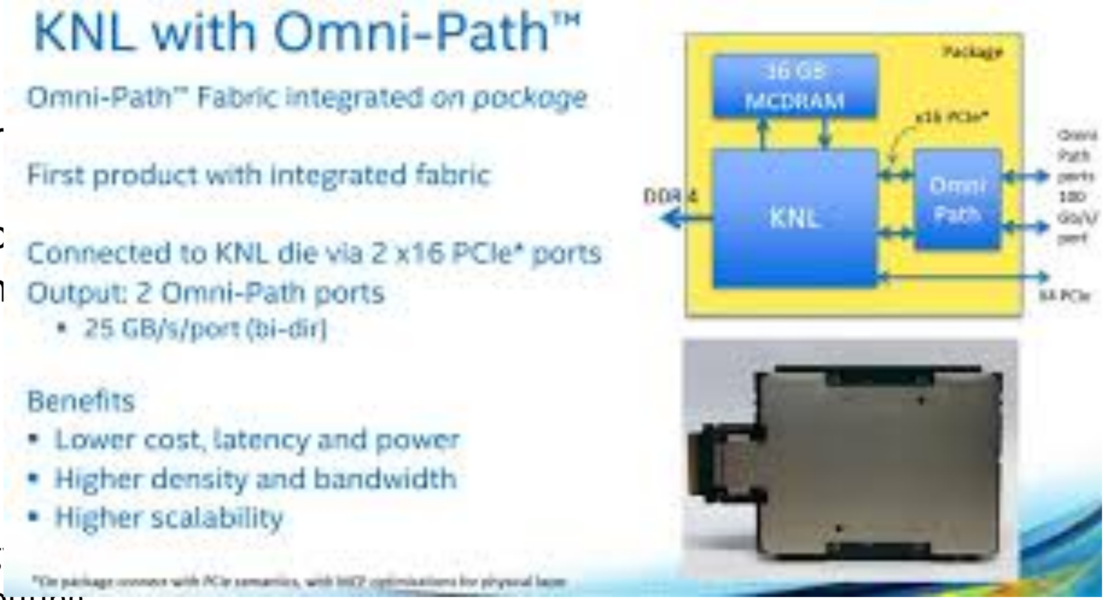

KNL with Omni-Path™

Omni-Path™ Fabric integrated on package

First product with integrated fabric

Connected to KNL die via 2 x16 PCIe* ports

Output: 2 Omni-Path ports

- 25 GB/s/port (bi-dir)

Benefits

- Lower cost, latency and power
- Higher density and bandwidth
- Higher scalability

*On package connect with PCIe semantics, with MCP optimizations for physical layer

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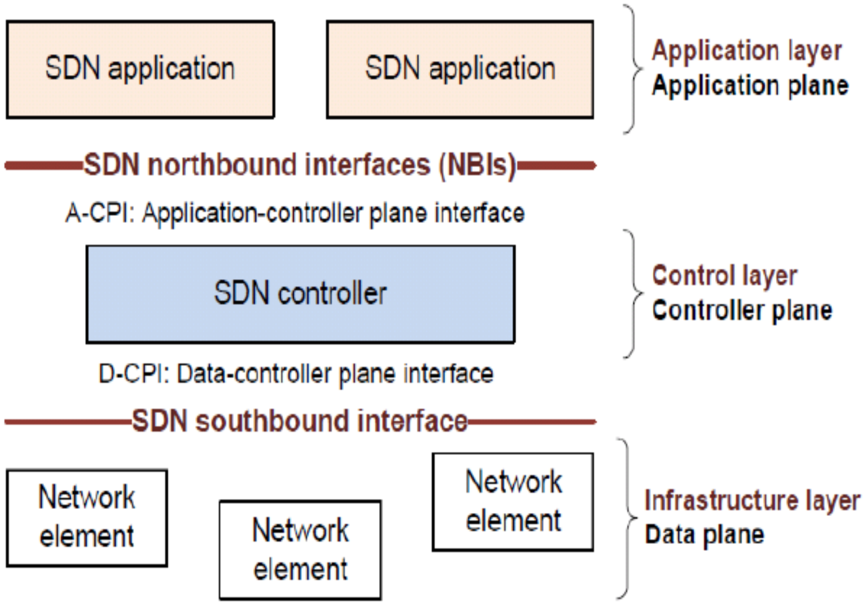
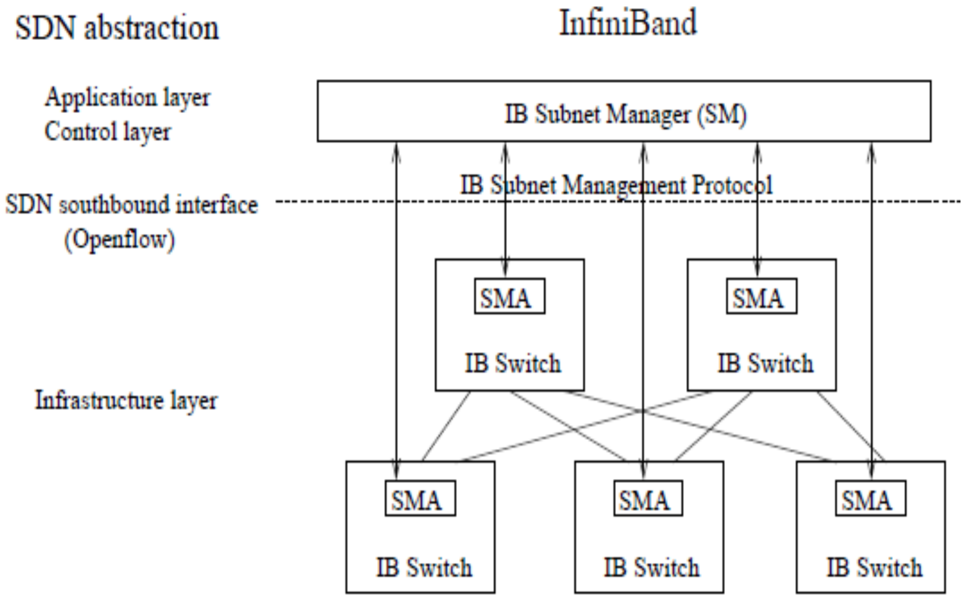
Ethernet and SDN/Openflow will be persistent!

InfiniBand and SDN





- InfiniBand has some SDN functionality.
- What is lacking is the per-flow resource management capability.

Research Tasks

- Intra-domain
  1. Design OpenFlow-style SDN capability into InfiniBand
  2. Investigate the potential benefits come with the added capability
  3. Develop techniques to explore SDN capability in HPC systems
  4. Demonstrate a working SDN-enabled InfiniBand system
- Inter-domain - Demonstrate a working SDN-enabled InfiniBand system with inter-domain SDN capability

  5. Multi-domain (OpenFlow <-> OpenSM)
  6. Wide area (ex OSCARS)

Task 1: Develop SDN-enabled InfiniBand for HPC systems.

– How to incorporate OpenFlow-style SDN capability into InfiniBand for HPC systems?

  - What is a flow for HPC application?
  - How SDN-enabled InfiniBand should work (like OpenFlow network or with modification)?
  - What changes need to be made to switches, subnet manager, subnet management agent?

Task 2: Evaluate the potential performance benefits of SDN-enabled InfiniBand

- Assuming the best-case scenario.
- Where the SDN capability can be explored? (job scheduler, HPC application, etc)
- Active and Passive SDN
- Benefits for different types of applications (MPI, PGAS, etc)
- Simulation and modeling for small and large systems.

Task 3: Develop techniques for exploring SDN-enabled InfiniBand

– How can the HPC system and/or HPC application effectively explore the SDN capability?

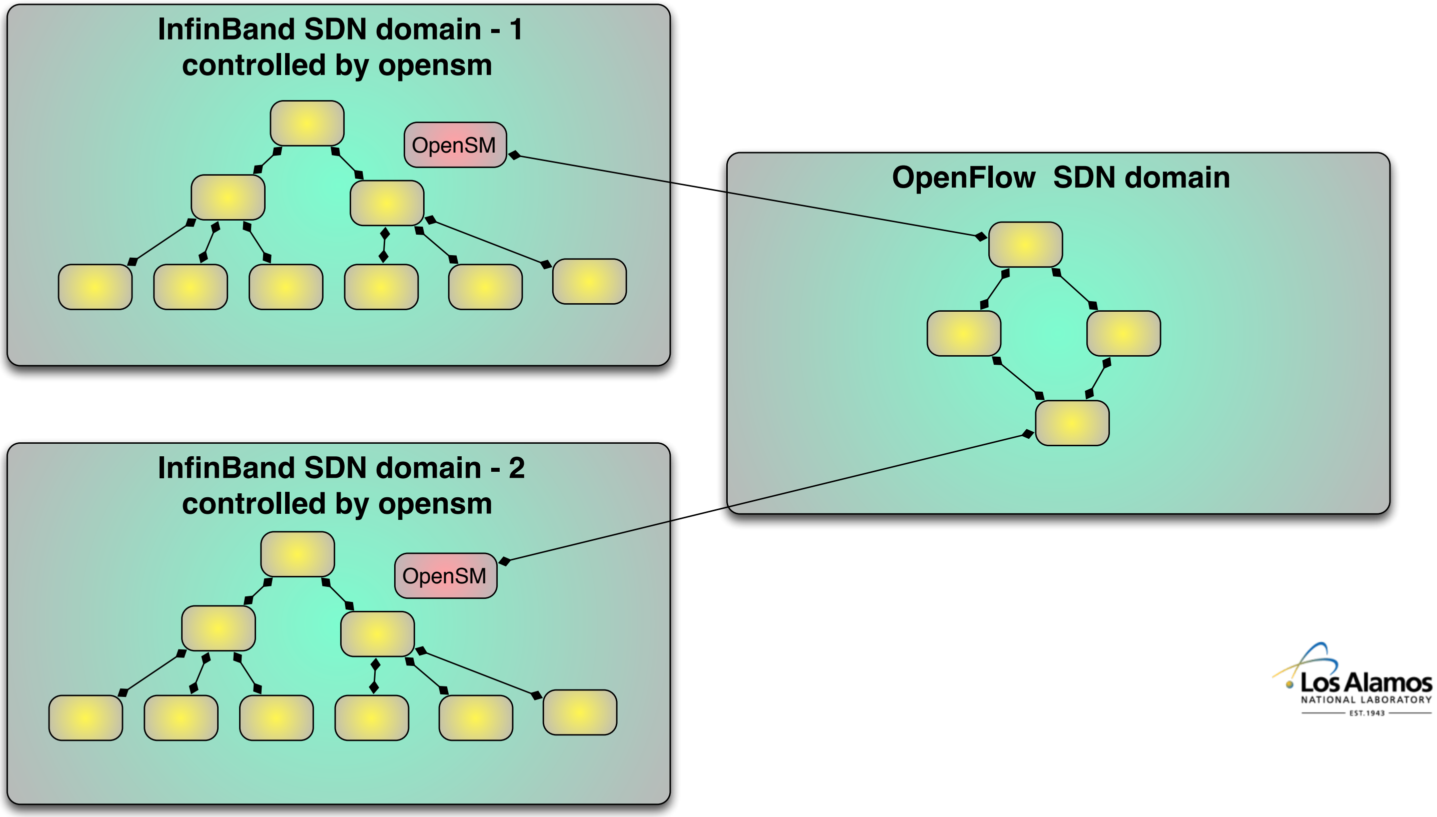
- Techniques for exploring passive SDN
  - Systems level techniques – recognize flows and adjust.
- Techniques for exploring active SDN
  - Scheduler/Application level techniques
- SDN interface for HPC systems/applications
- Resilience for SDN-enabled InfiniBand

Task 4: Incorporate the **intra**-domain SDN functionality in OpenSM

- OpenSM is the current InfiniBand subnet management software
- Use the current multi-pathing with multiple DLIDs to emulate per-flow management functionality
- Add OpenFlow-style per-flow management capability to OpenSM
  - SDN controller functions may be incorporated into OpenSM or may be an independent entity that interacts with OpenSM
- Demonstrate OpenFlow-style SDN capability in a small scale cluster.

Task 5: Augment OpenSM with distributed SDN controller functionality

- Multi-domain SDN deployment
- Add **inter**-domain functionality



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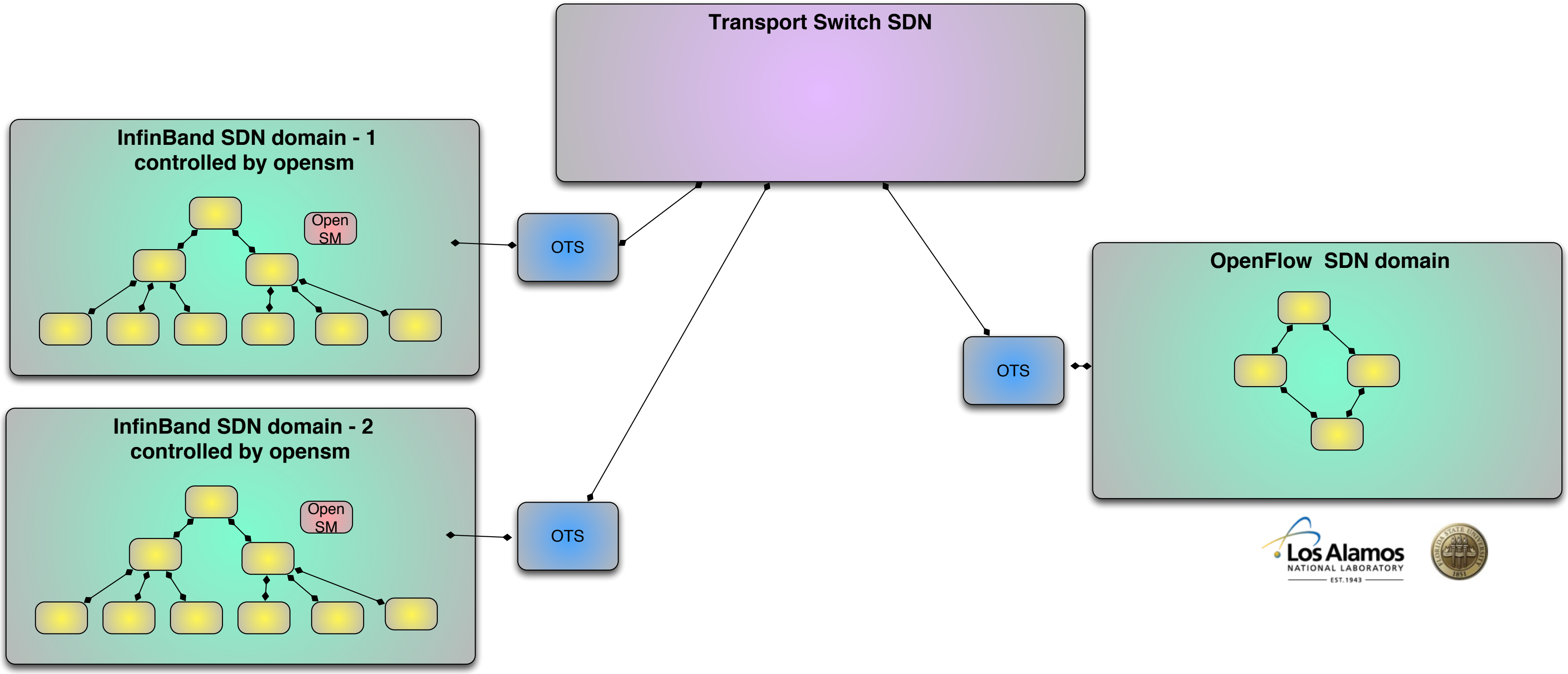
Task 6: Map intra-domain SDN into inter-domain SDN frameworks

- Leverage existing inter-domain frameworks, DOE OSCARS (“orchestrators”)
- Expose internal resource and query/request external resources via OSCARS



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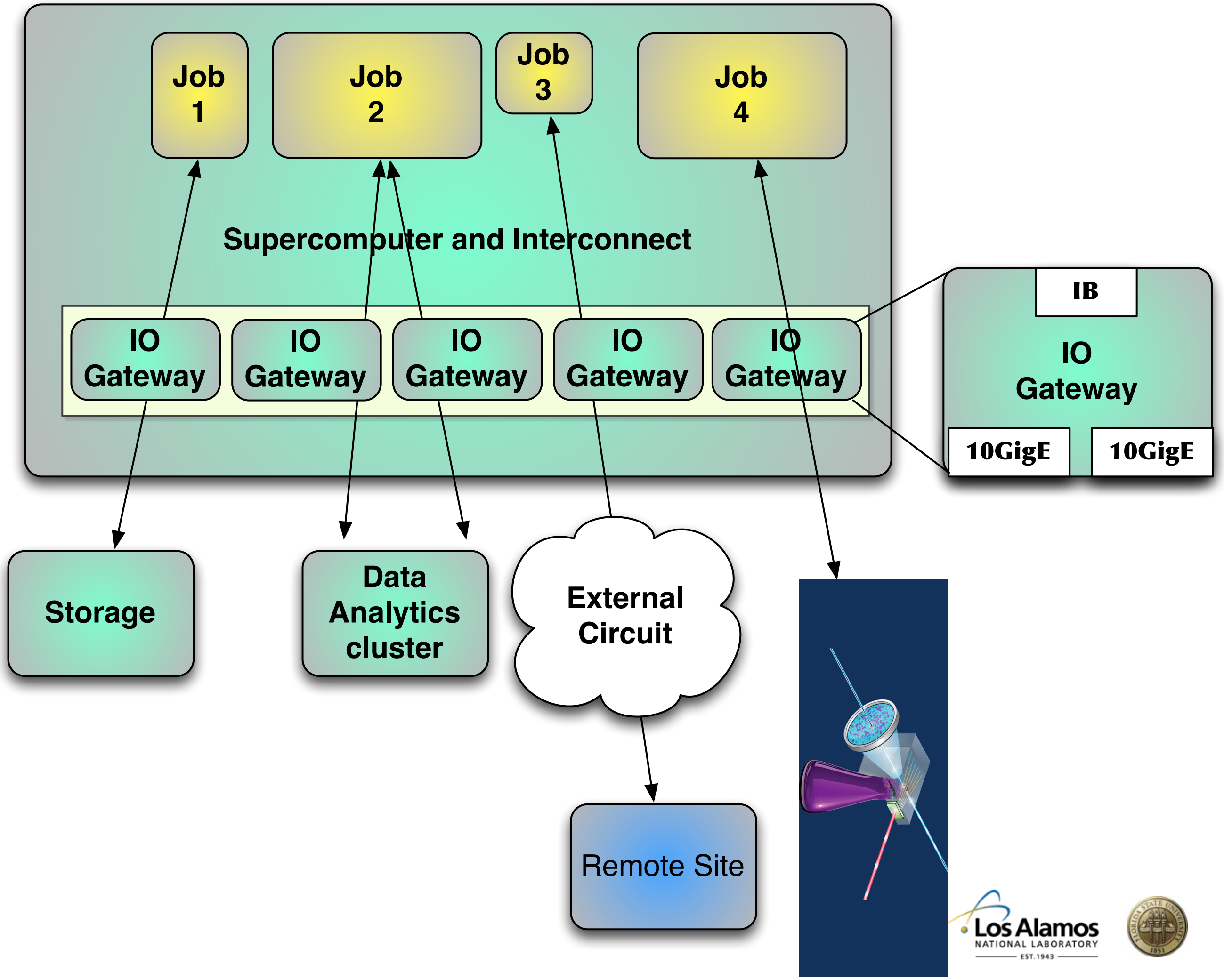
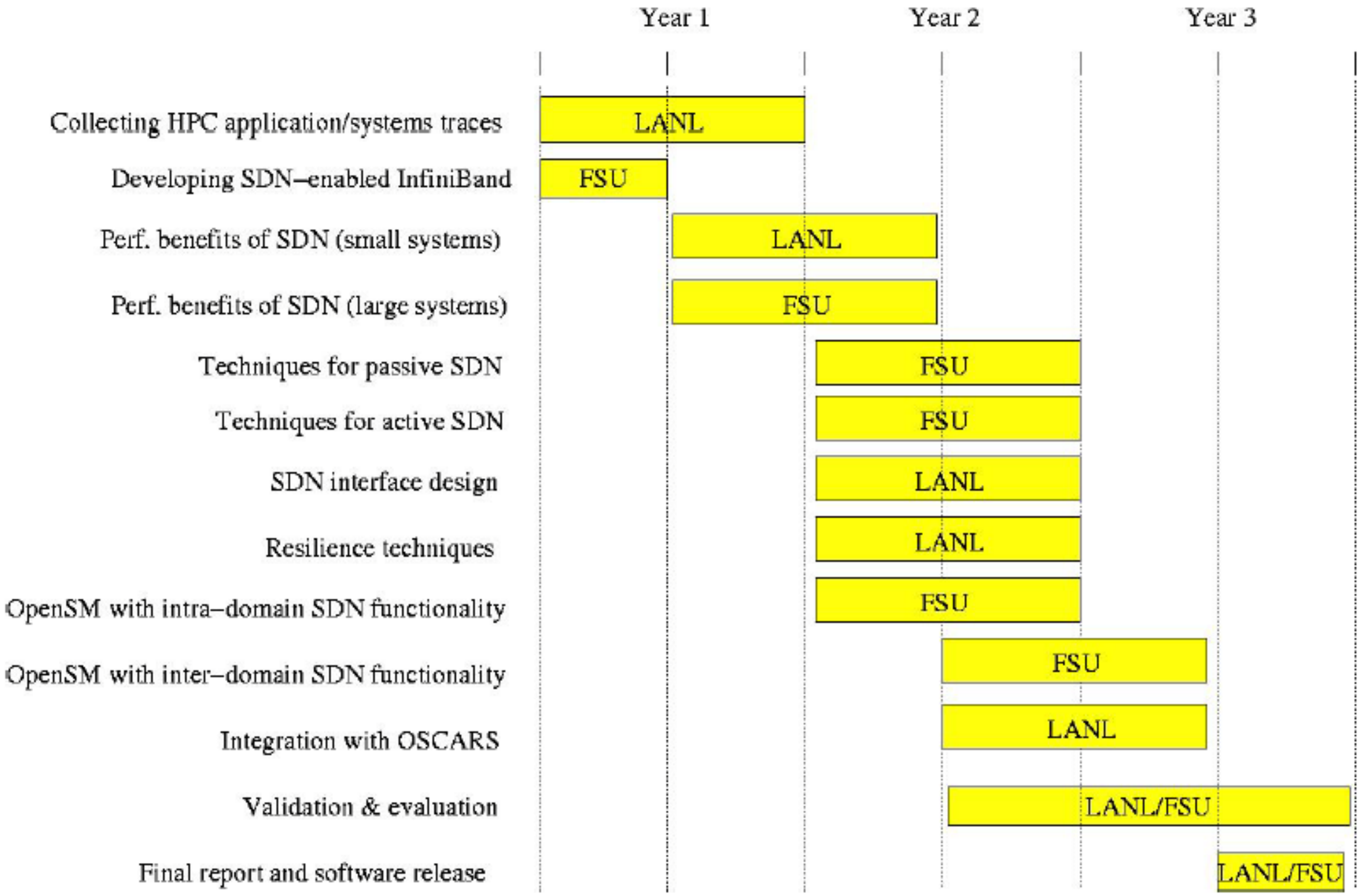
Use cases supported with multi-domain support

- Match job requirements to external “to cluster” resources

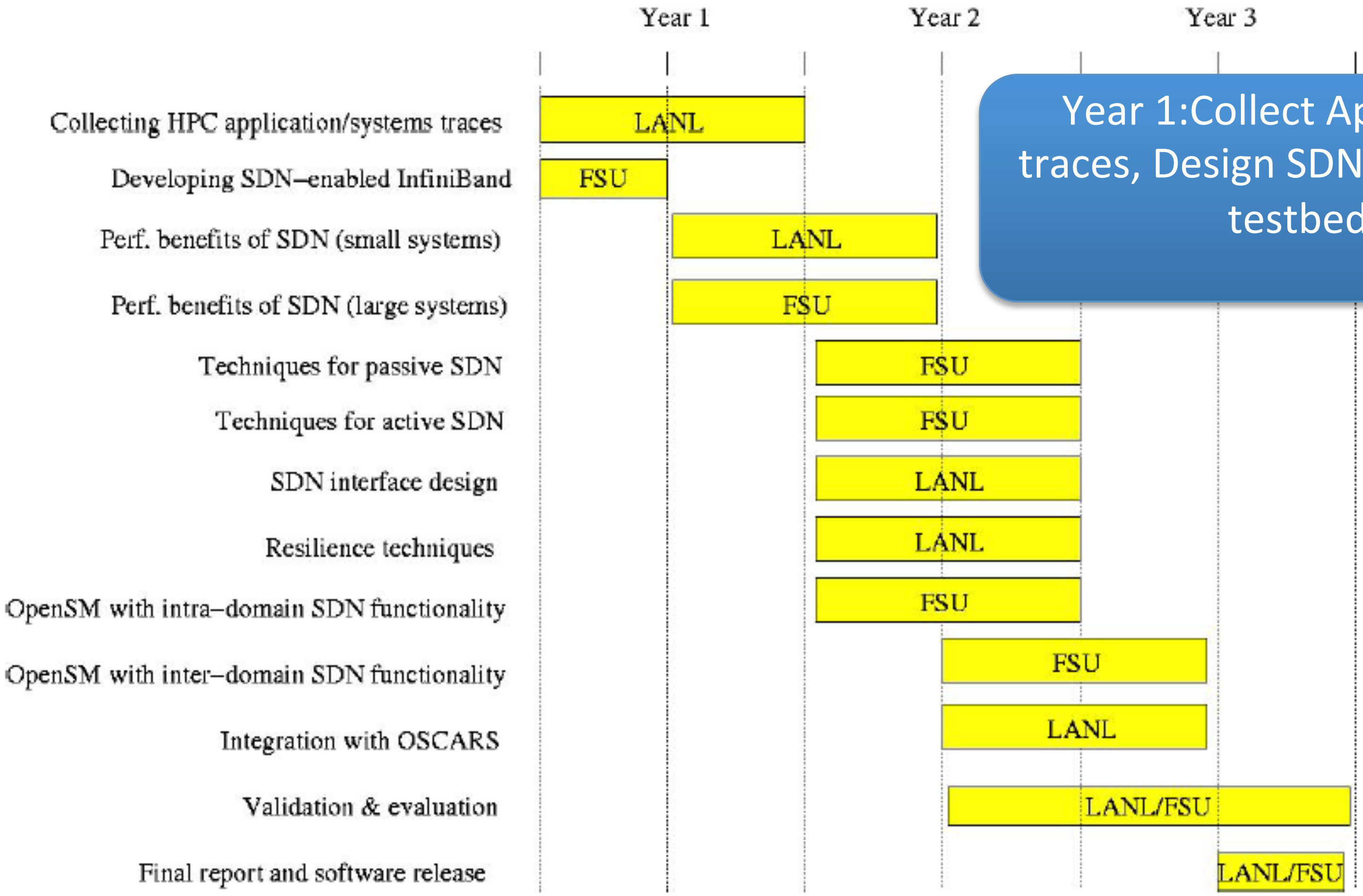


Timeline



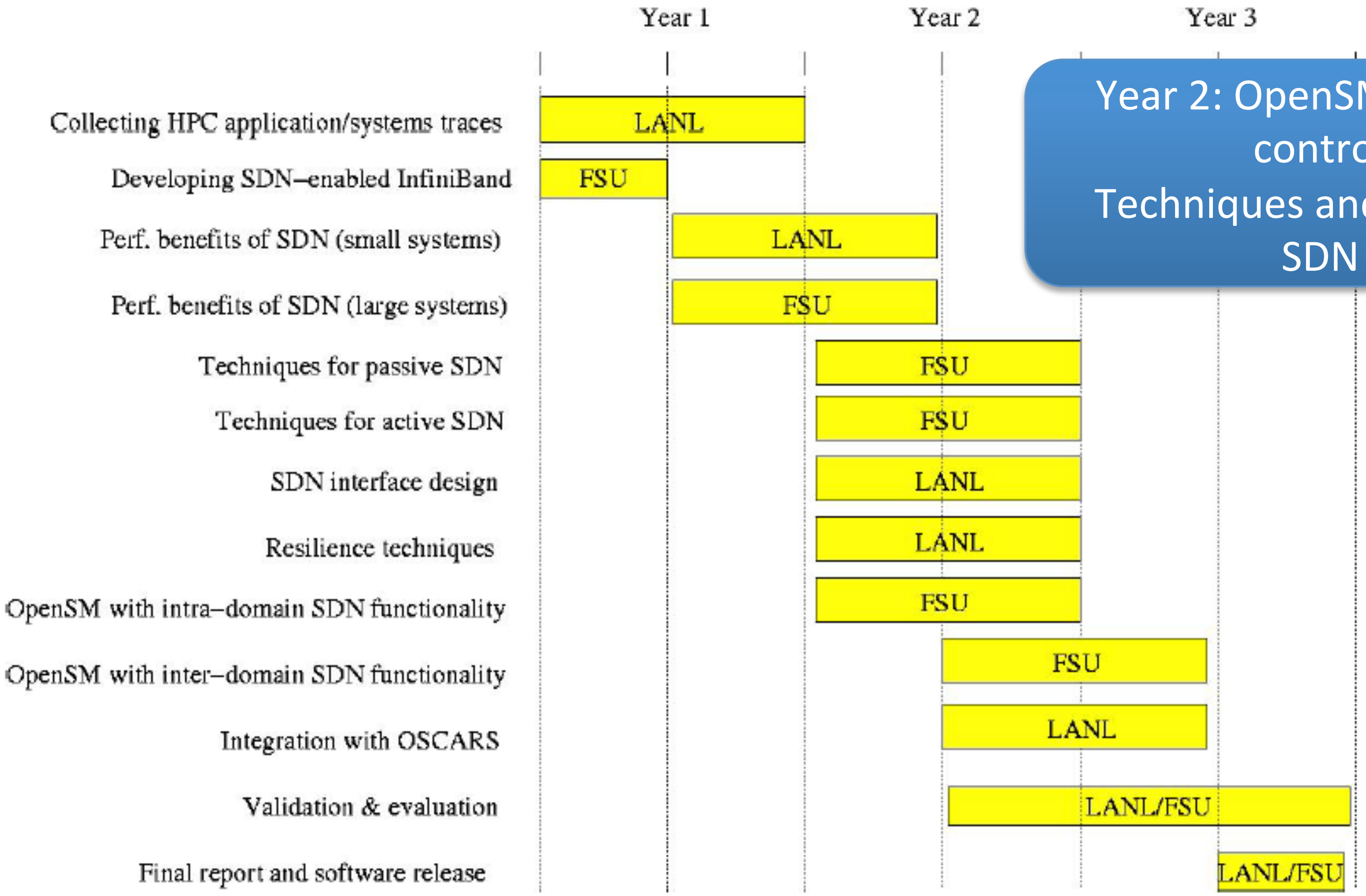
Collecting HPC application/systems traces	LANL
Developing SDN–enabled InfiniBand	FSU
Perf. benefits of SDN (small systems)	LANL
Perf. benefits of SDN (large systems)	FSU
Techniques for passive SDN	FSU
Techniques for active SDN	FSU
SDN interface design	LANL
Resilience techniques	LANL
OpenSM with intra–domain SDN functionality	FSU
OpenSM with inter–domain SDN functionality	FSU
Integration with OSCARS	LANL
Validation & evaluation	LANL/FSU
Final report and software release	LANL/FSU

Timeline



Year 1:Collect Application traces, Design SDN IB, Prepare testbed

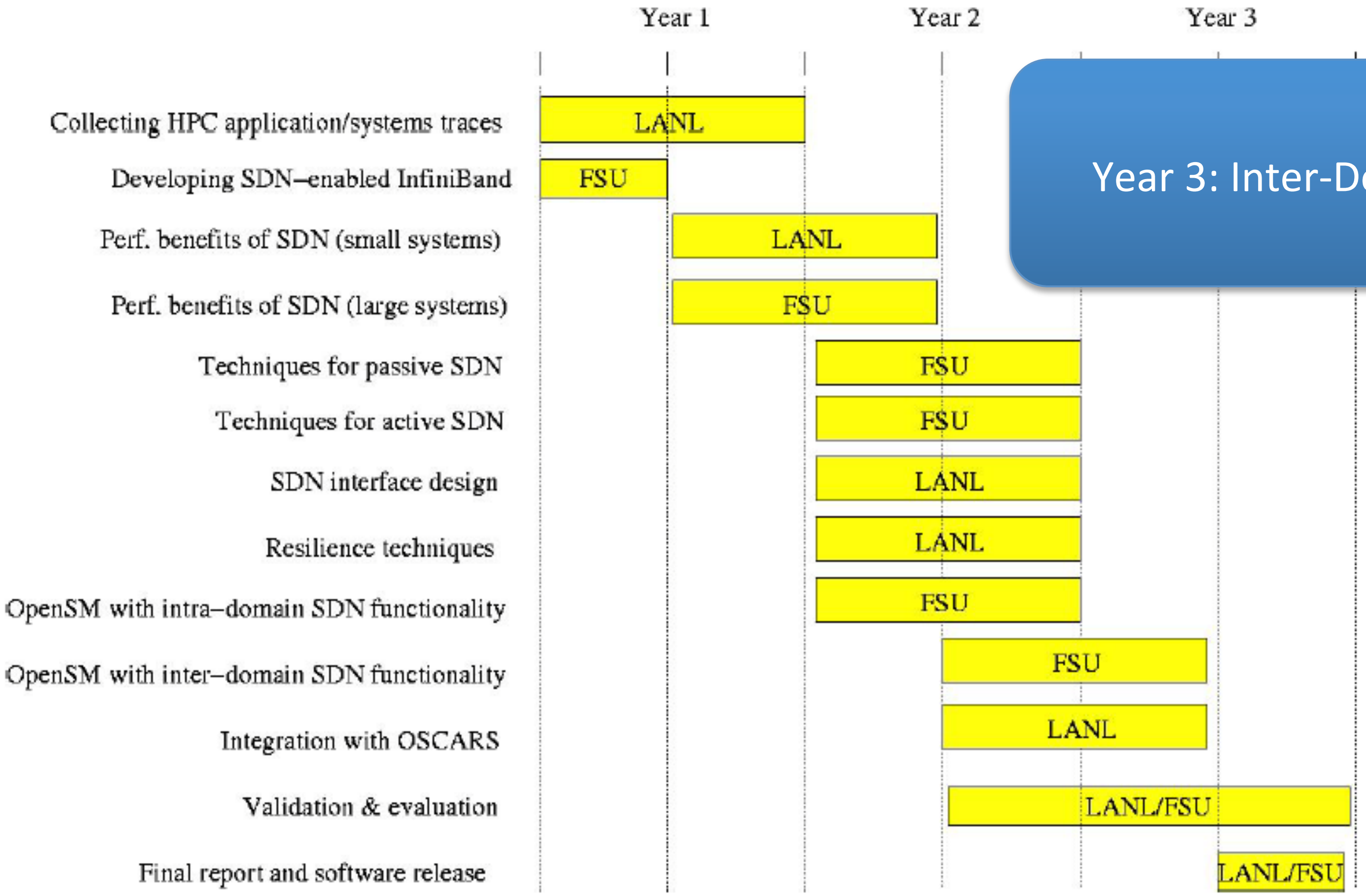
Timeline



Year 2: OpenSM/Openflow controller

Techniques and Benefits of SDN IB

Timeline



Year 3: Inter-Domain SDN

SDN-enabled InfiniBand for HPC: a preliminary design

- Objective: Add per-flow resource management into InfiniBand

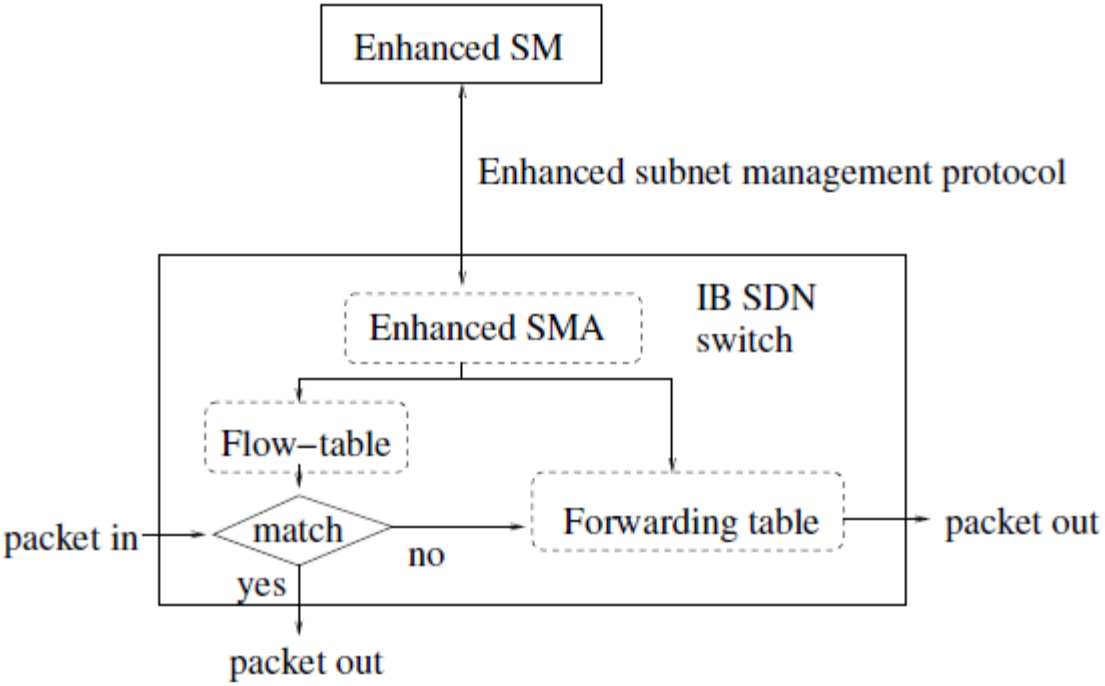
  - Pre-establishment of flow table entries
    - Flow table in addition to forwarding table
    - Flow table entries are pre-established at either job launch time or during job execution before the communication starts
      - HPC applications have phase behavior
    - Fall back to forwarding table in case of flow table miss.
      - forwarding table remains also for the network initialization.

SDN-enabled InfiniBand for HPC: a preliminary design

- The flow concept
  - Use header fields in the existing InfiniBand packets
  - Flow identifier depending on per-flow functionality needed and flow table constraints.
    - DLID: allows for per application destination based routing
    - DLID+SLID: allows for per application source/destination routing
    - DLID+SLID+SL: allows for per application source/destination routing with multiple levels of service quality
    - DLID+SLID+SL+DestQP: per application multi-path routing based on flows
    - DLID+SLID+SL+DestQP+PSN: packets for the same message follow different routes

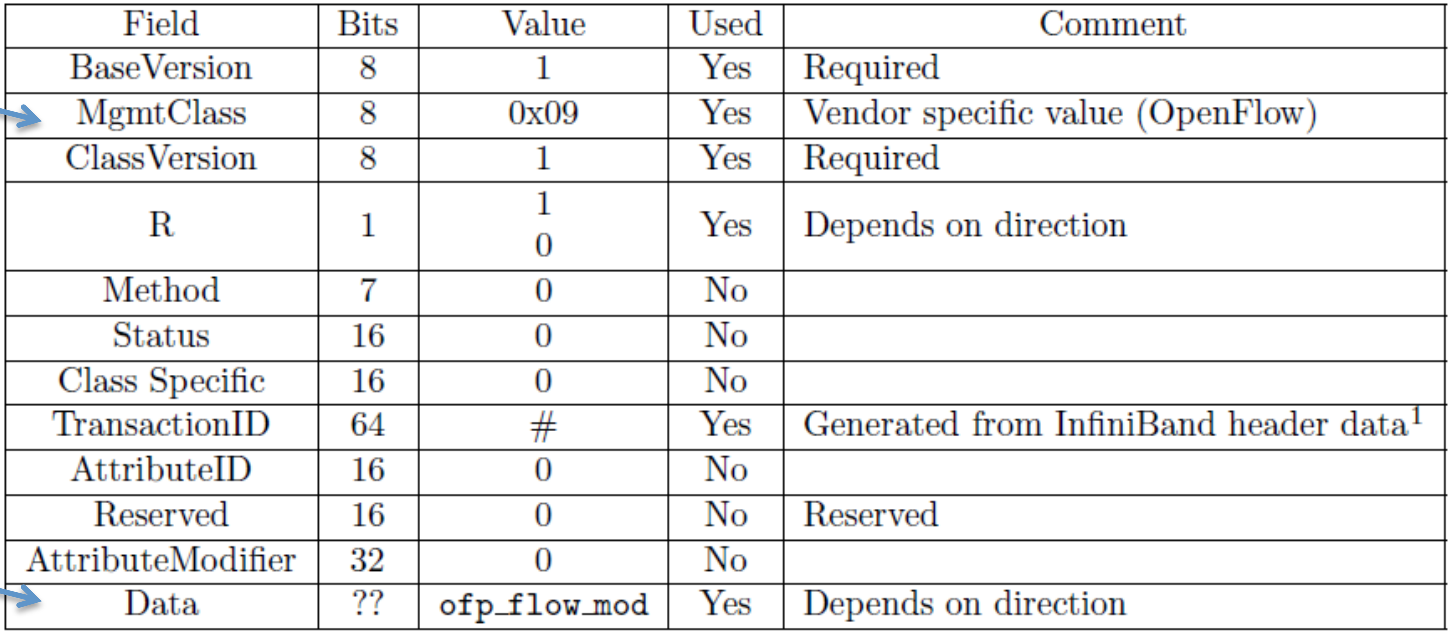
SDN-enabled InfiniBand for HPC: a preliminary design

– SDN-enabled InfiniBand Switch



SDN-enabled InfiniBand for HPC: preliminary design

- OpenFlow Control packet Modification:
  - Add a new subnet management class for OpenFlow functionality (ManagementClass 0x09)
  - The data field follows OpenFlow packet format.



Field	Bits	Value	Used	Comment
BaseVersion	8	1	Yes	Required
MgmtClass	8	0x09	Yes	Vendor specific value (OpenFlow)
ClassVersion	8	1	Yes	Required
R	1	1 0	Yes	Depends on direction
Method	7	0	No	
Status	16	0	No	
Class Specific	16	0	No	
TransactionID	64	#	Yes	Generated from InfiniBand header data[1]
AttributeID	16	0	No	
Reserved	16	0	No	Reserved
AttributeModifier	32	0	No	
Data	??	`ofp_flow_mod`	Yes	Depends on direction

SDN-enabled InfiniBand for HPC: a preliminary design

- Addition to OpenSM
  - Implement subset of OpenFlow SDN controller functions
    - Maintain the global status of flow tables in the network
    - Interacting with applications, compute flow table entries, and set-up forwarding table entries
  - Two implementation choices:
    - Integrated within OpenSM
    - An independent controller outside OpenSM

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SDN-enabled InfiniBand for HPC

Summary:

- Software deliverables
  - OpenSM + OpenFlow interoperability
- Design of IB + SDN
- Demonstrate capability of IB + SDN
- Evaluation of possible performance improvements

Baseline: IB independently managed from external networks.

New functionality: IB and SDN managed, in concert, to allow "*smarter* IB" for scientific applications and workflows

Synergy: *Expose* IB resources/interact with SENSE, FLOWS, "orchestrators"

* Try to influence future Infiniband hardware

Questions

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