High-Speed Query Processing over High-Speed Networks

- Aboli

Introduction

- Networks - no longer a bottleneck (InfiniBand TCP, RDMA)
- Only increasing bandwidth - not much benefit
- Distributed query engines should adapt

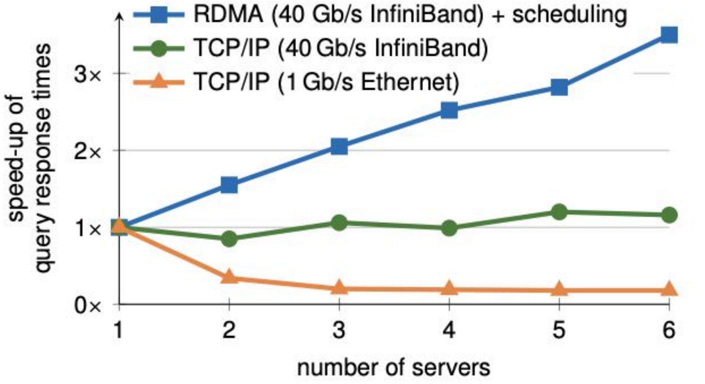
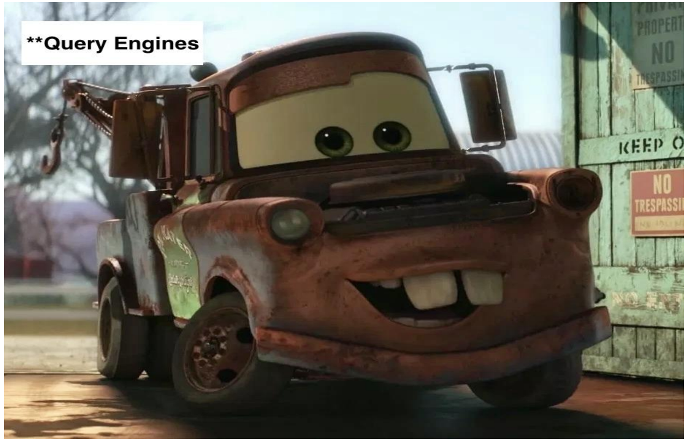


Figure 3: Simply increasing the network bandwidth is not enough; a novel RDMA-based communication multiplexer is required (HyPer, TPC-H, SF 100)



High Speed Networks

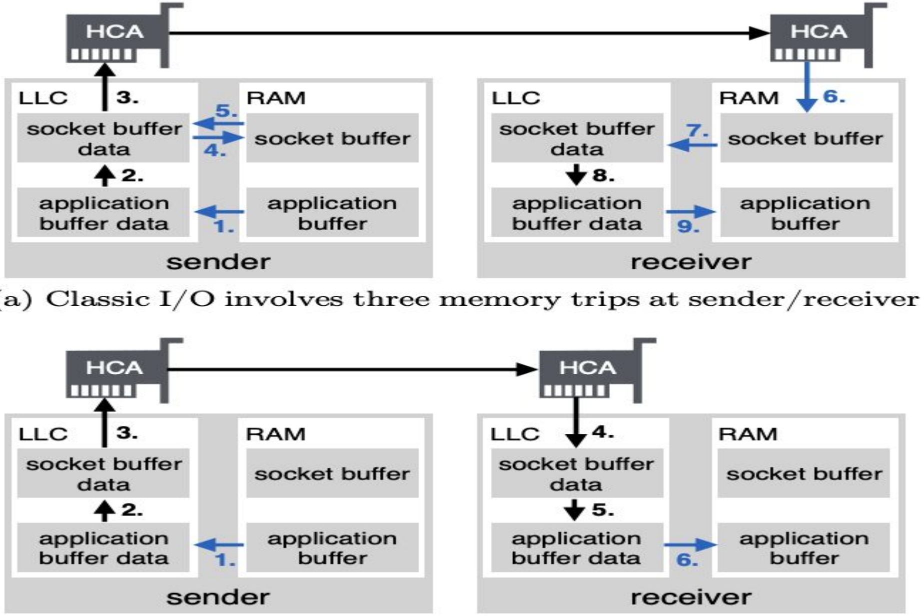
- InfiniBand
  (High bandwidth, low latency cluster connect)

- Large amount of data shuffled during
  joins and aggregations

- Tune existing protocol for analytical workloads

Tuning TCP

- Use data direct I/O



(a) Classic I/O involves three memory trips at sender/receiver

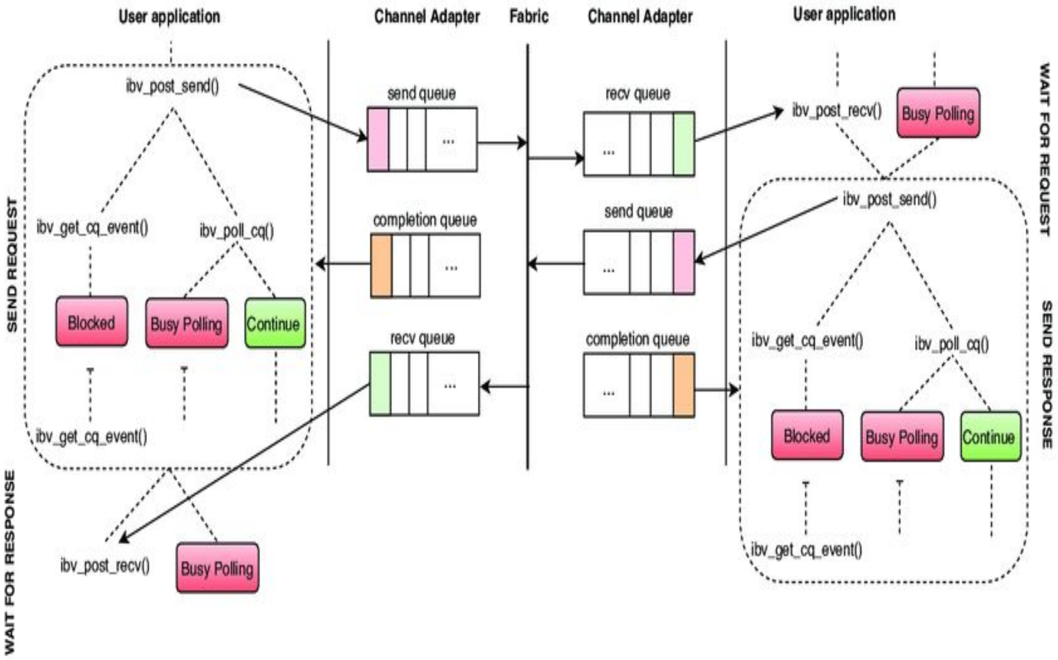
(b) Data direct I/O reduces this to only one memory trip each

Figure 4: Data direct I/O significantly reduces the memory bus traffic for TCP compared to classic I/O

Tuning RDMA

- Asynchronous operation
  - Infinibands verbs API - Asynchronous
  - Work requests handled async via queue

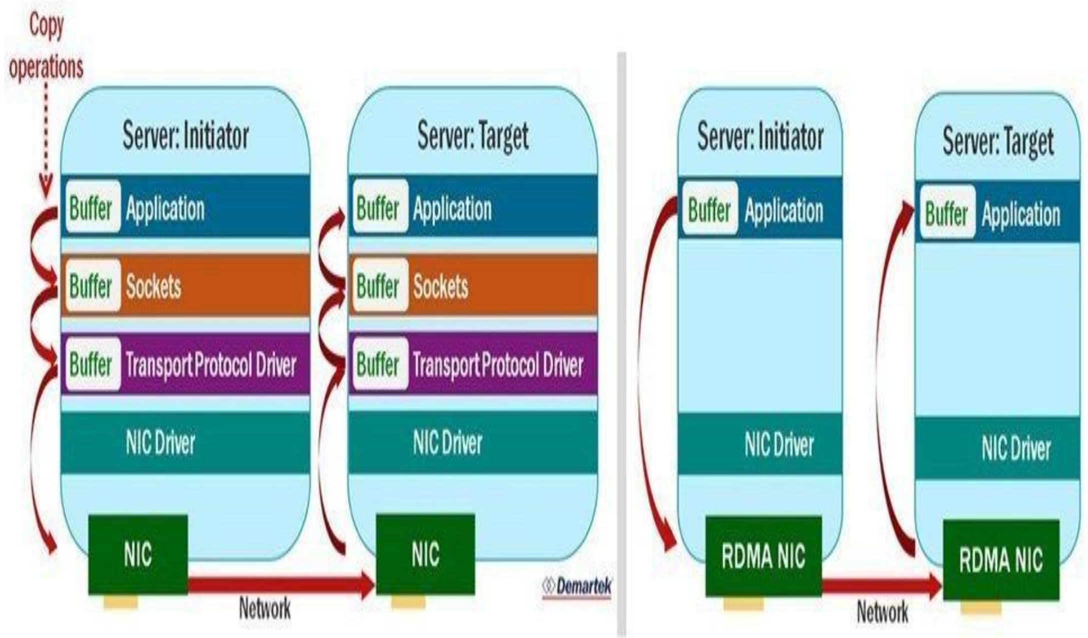
- Kernel Bypassing
  - No copying between buffers -> no sys calls
  - Memory regions -> map virtual to physical
  - Message pools



Tuning RDMA

- Channel semantics
  - Read/write needs to have memory key
  - 2 sided operations
  - No separate exchange of memory keys

- Event notification
  - Polling vs Interrupt
  - CPU use vs latency



High Speed Queries

CLASSIC EXCHANGE OPERATORS

- Introduced in Volcano - Goetz Graefe (UW-Madison)
  [Paper link]
- Allows parallel query evaluation (Exchange operator)
- Parent process consumes data from child process
  (Bushy parallelism - diff subtrees, Intra-operator - same operator on diff data)
- Threads execute parallel copies - communicate via exchange operator

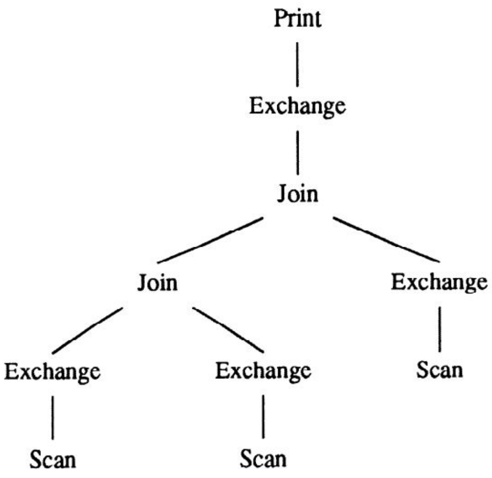


Fig. 5. Operator model of parallelization.

Issues with classical exchange operator

- All parallel units are same - local or remote
- Every exchange operator talks to other
  - $(n \times t) - 1$ for n servers and t local exchange operators per server
  - Limits use of broadcast join
  - Many connections required - scalability issues

ANSWER - **Hybrid Parallelism**

- Decoupled exchange operator
- RDMA based, NUMA aware multiplexer
- Application level Network Scheduling

Decoupled Exchange Operators

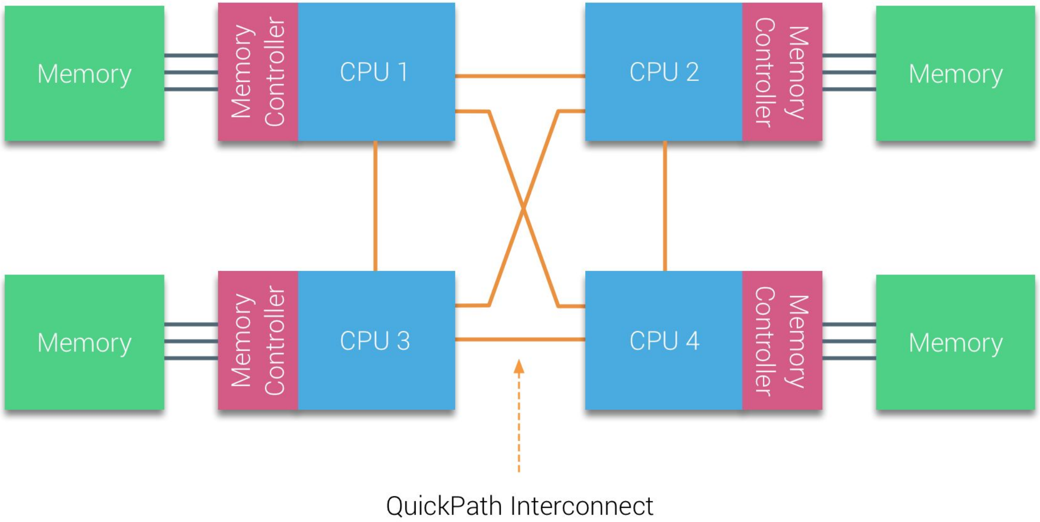
- All parallel units only interact with the multiplexer
    - Minimizes the number of connections

- Locally units can steal work
    - Better load balancing

- Further optimizations
    - Efficient serialization/deserialization
    - Unnecessary columns pruned

NUMA

- Every CPU - local memory controller
- Access remote memory via QPI - slower, expensive



Query engine - CPUs must access local memory addresses as much as possible

RDMA-based, NUMA aware multiplexer

- Network thread - exchange between local and remote servers via RDMA
- Multiplexers connected together
- Maintains message pools - registered with HCA for RDMA
- One receive queue per NUMA socket
  - Work stealing - NUMA local empty -> take from remote

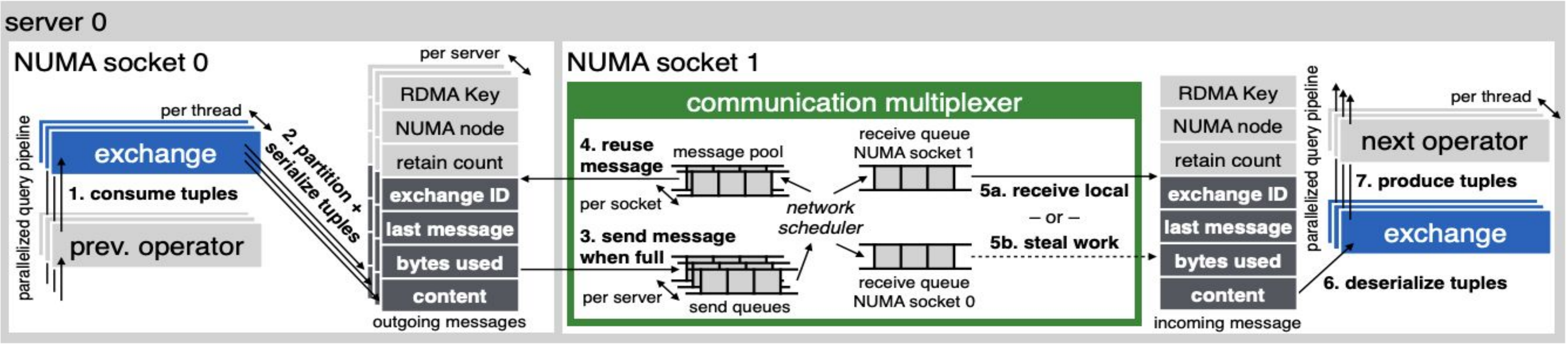
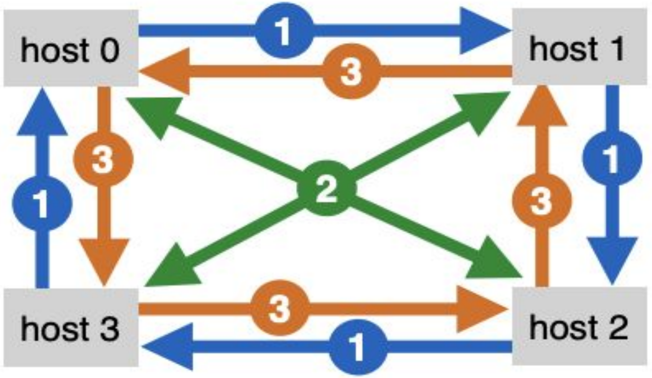


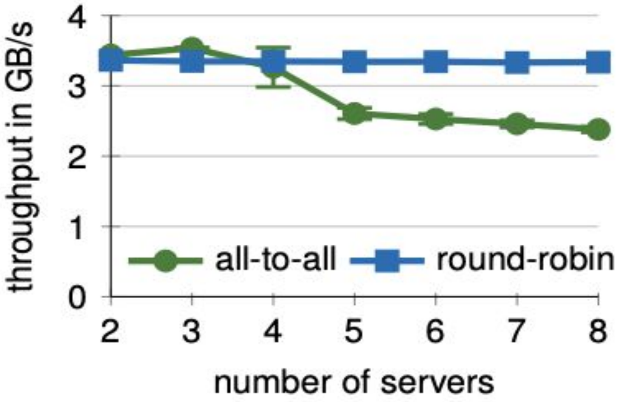
Figure 7: Interaction of decoupled exchange operators with the RDMA-based, NUMA-aware multiplexer

Application level network scheduling

- All to all traffic - switch contention
- Round robin algorithm
  - Send and receive from one server in each phase



(a) Round-robin scheduling with conflict-free phases; three phases for four servers



(b) Application-level network scheduling improves throughput by up to 40 %

Evaluations

- HyPer - in-memory database, columnar storage
- TPC-H queries for different servers

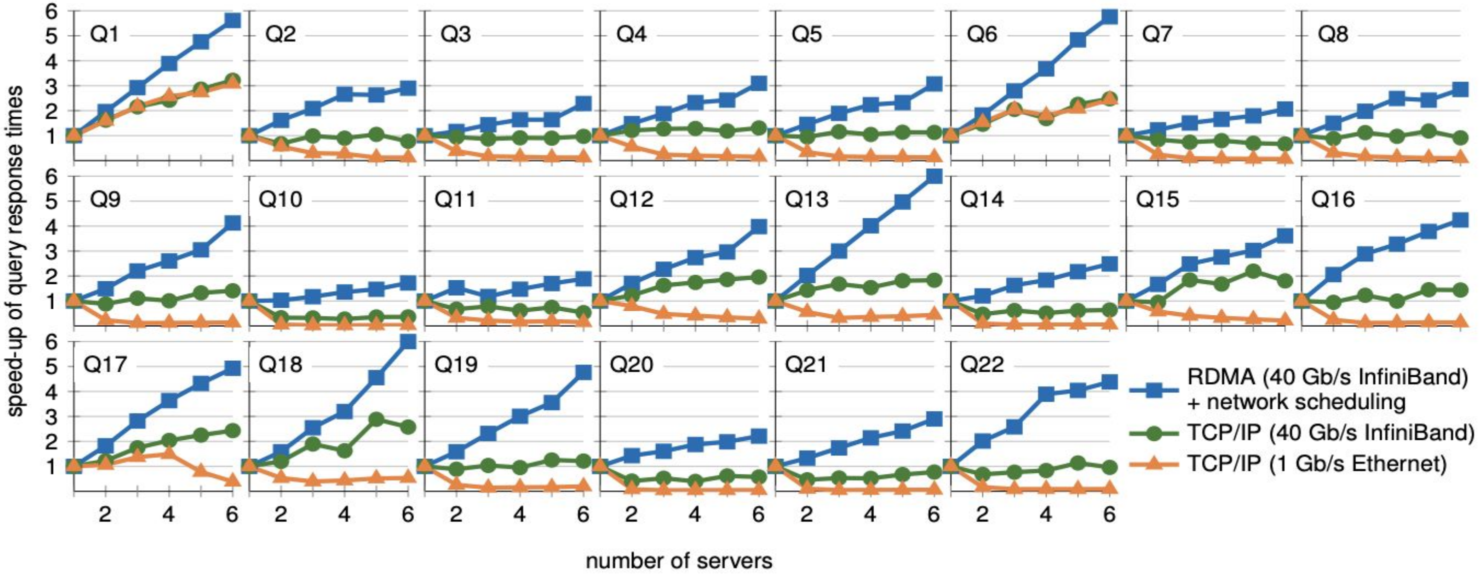
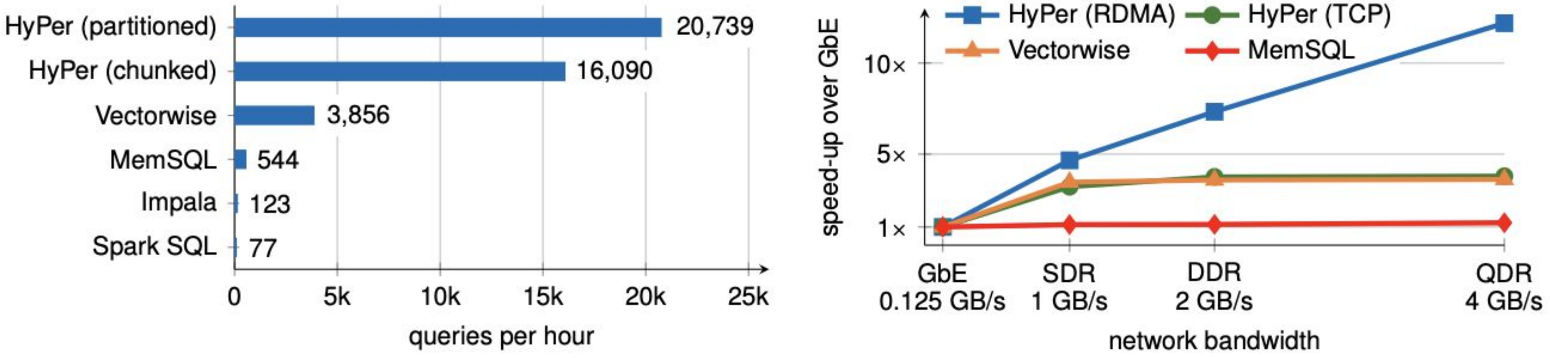


Figure 11: Scalability of the individual TPC-H queries for different query execution engines (HyPer, SF 100)

Evaluations

- Distributed SQL systems comparison
- Spark SQL, Impala, MemSQL, Vectorwise



(a) Queries per hour for each distributed SQL system

(b) Impact of network bandwidth on TPC-H performance

Figure 12: Comparing distributed analytical SQL systems for the TPC-H benchmark (6 servers, SF 100)

Concluding Remarks

- Full fledged query engine based on RDMA - good approach
- Implementation on HyPer - other databases?

THOUGHTS?