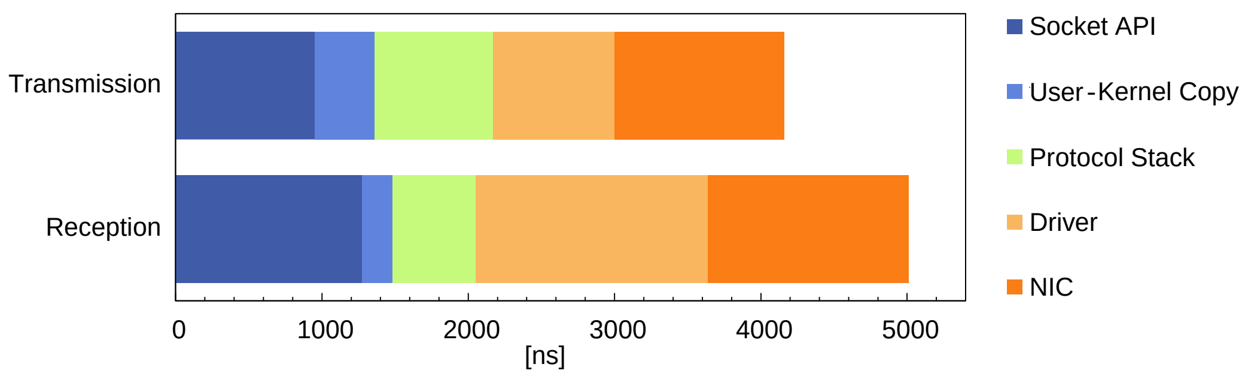
It's Time to Combine Network Advances and Databases

Motivation

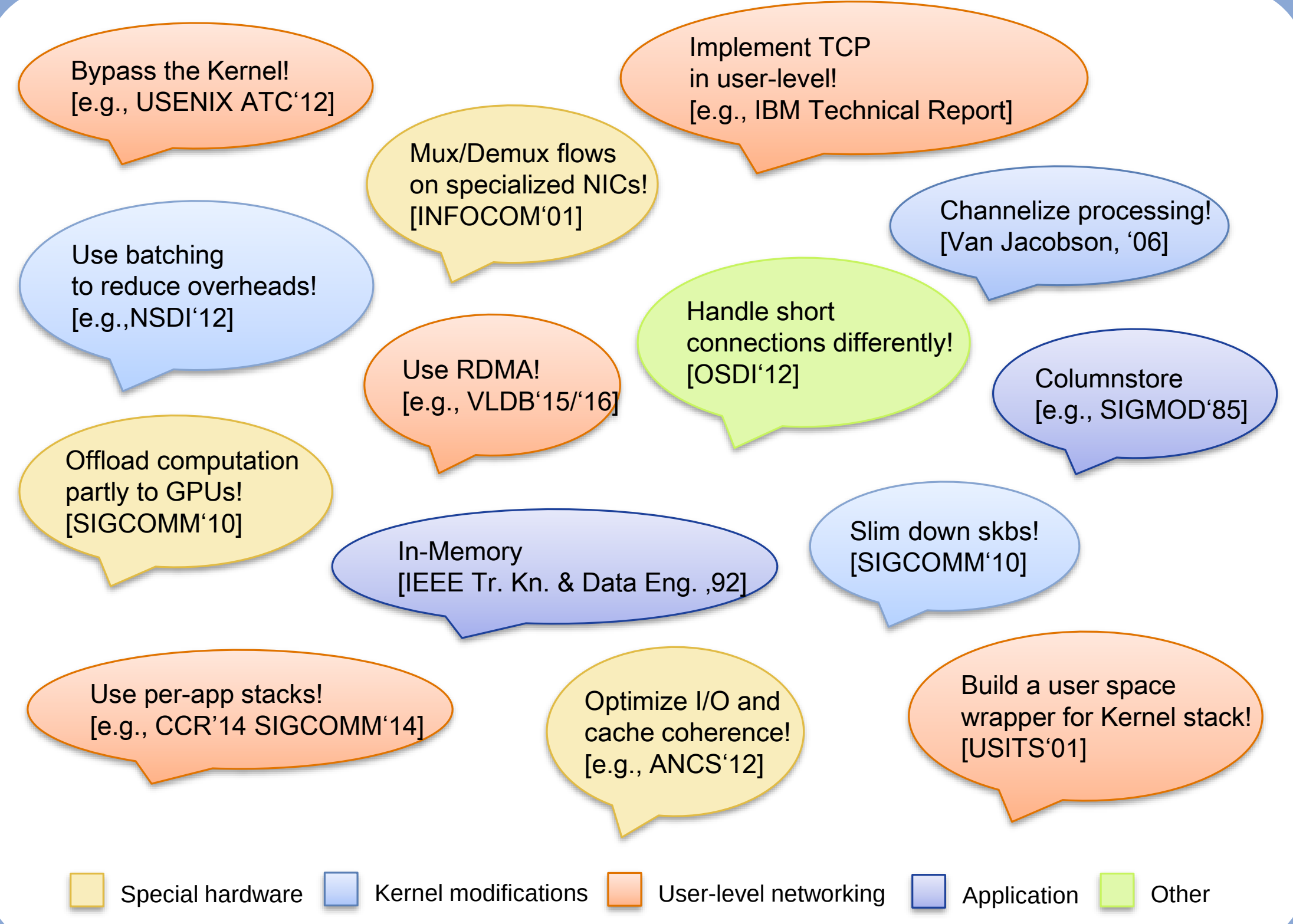
The Quest for Speed

- **Ever increasing database performance demands**
  - Better hardware (faster/multiple CPUs, more RAM, SSDs)
  - Better software (caching, in-memory, …)
  - Scaling out (distribution, scheduling, partitioning, …)
- **Classical networking has significant overheads**
  - Memory allocations and copy operations
  - System calls and context switches



Source: Larsen et al., "Architectural Breakdown of End-to-End Latency in a TCP/IP network, J Parallel Prog, 37:6, (2009)

Related Work



Bypass the Kernel! [e.g., USENIX ATC'12]

Implement TCP in user-level! [e.g., IBM Technical Report]

Mux/Demux flows on specialized NICs! [INFOCOM'01]

Channelize processing! [Van Jacobson, '06]

Use batching to reduce overheads! [e.g.,NSDI'12]

Handle short connections differently! [OSDI'12]

Use RDMA! [e.g., VLDB'15/'16]

Columnstore [e.g., SIGMOD'85]

Offload computation partly to GPUs! [SIGCOMM'10]

In-Memory [IEEE Tr. Kn. & Data Eng. ,92]

Slim down skbs! [SIGCOMM'10]

Use per-app stacks! [e.g., CCR'14 SIGCOMM'14]

Optimize I/O and cache coherence! [e.g., ANCS'12]

Build a user space wrapper for Kernel stack! [USITS'01]

Special hardware · Kernel modifications · User-level networking · Application · Other

Our Solution

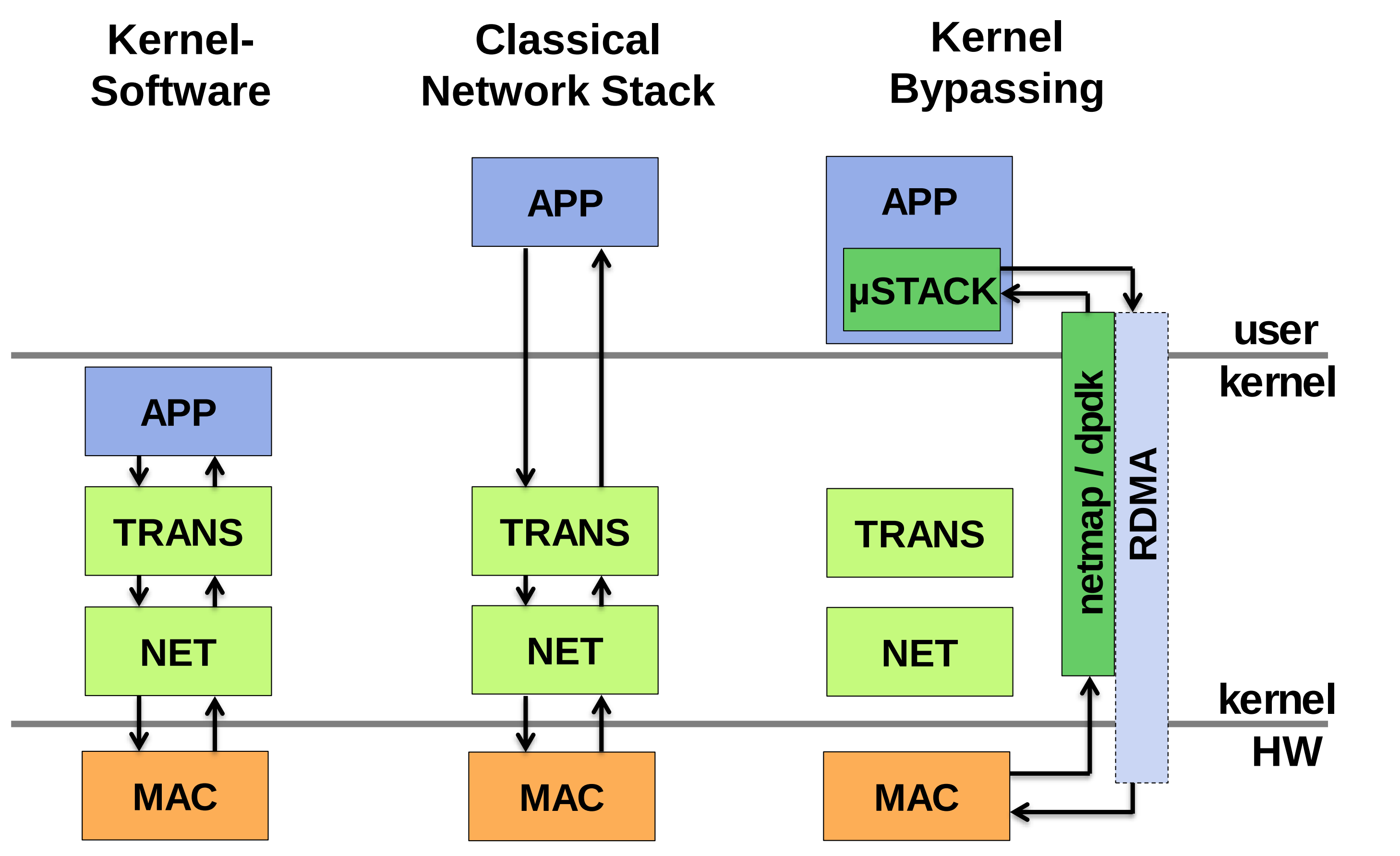
Current Trend: Remote Direct Memory Access

- Drastic performance improvements by bypassing the kernel & CPU; user-level networking
- Highly specialized hardware, infrastructure & software

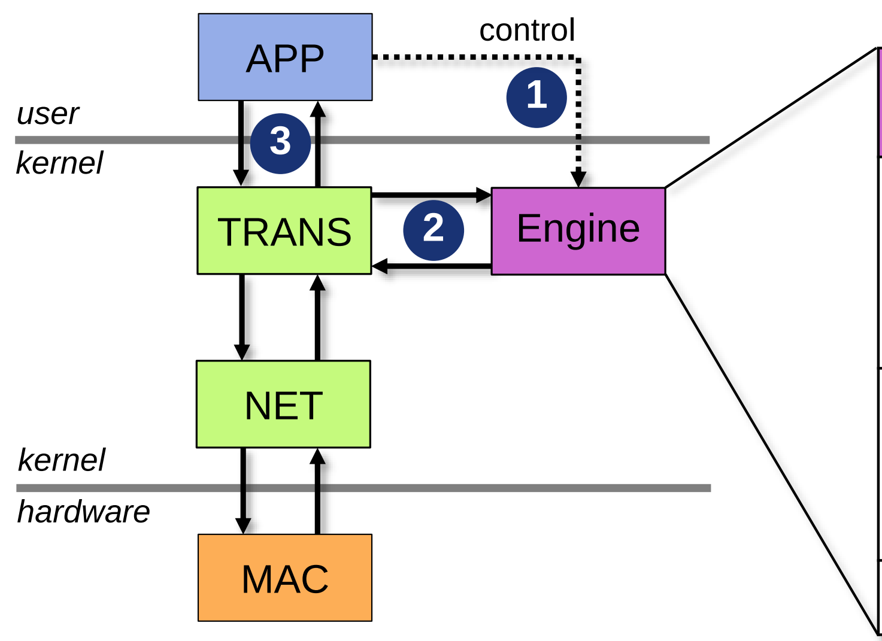
Our Approach:

- **Propose middle ground:**
  - Move parts of application logic into the stack
  - Benefits from well-established TCP/IP network stack
- **Solution: application agnostic offloading scheme**
  - Generic rule execution engine
  - Allows applications to install custom rules (condition/processors) for common requests
  - If condition matches, engine replies using processors instead of application

Other Solutions



Santa Architecture



Rule #	Condition	Reply-Processors
1	Offset: 0 Content: "GET key\r\n END\r\n"	Offset: 0 Content: "VALUE key 0 5\r\n value\r\n END"
2	Offset: 12 Content: "SELECT * FROM table"	Offset: 0 Copy: bytes 0–1 Offset: 2 Content: "all table rows"
…	…	…

Santa Setup

1. Application inserts rule

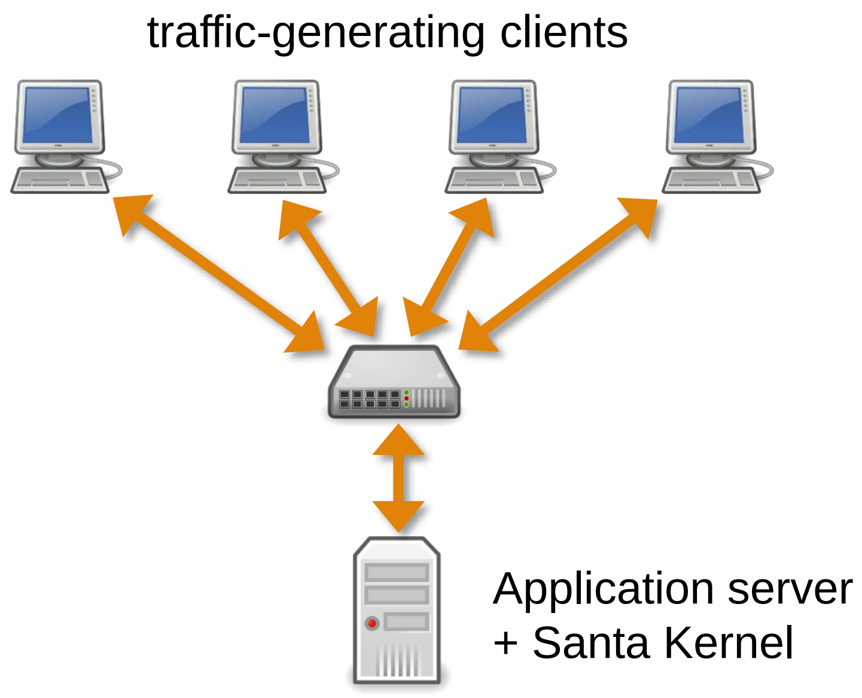
On Receive:

2. If packet matches rule, send pre-determined reply
3. If not, application handles the packet as usual

Engine

- Condition as byte-pattern
- Recipe for reply using processors, e.g.:
  - Write string into packet
  - Copy data from input packet to output packet

Testbed



- 4 traffic generating clients
  - Unmodified Linux kernel
  - Generate workload
- 1 Server
  - Different applications
  - Santa Linux kernel
- 10 Gbit/s Ethernet links

Memcached (KV-Store)

- UDP transport
- Modified multi-socket server
- Pre-populated keys (16 Byte)
- Varying value size
- Modified memaslap
- Four clients

MySQL (RDBMS)

- TCP transport
- Single column indexed table
- Query cache on/off
- Varying payload size
- mysqlslap
- Single client

Acknowledgements

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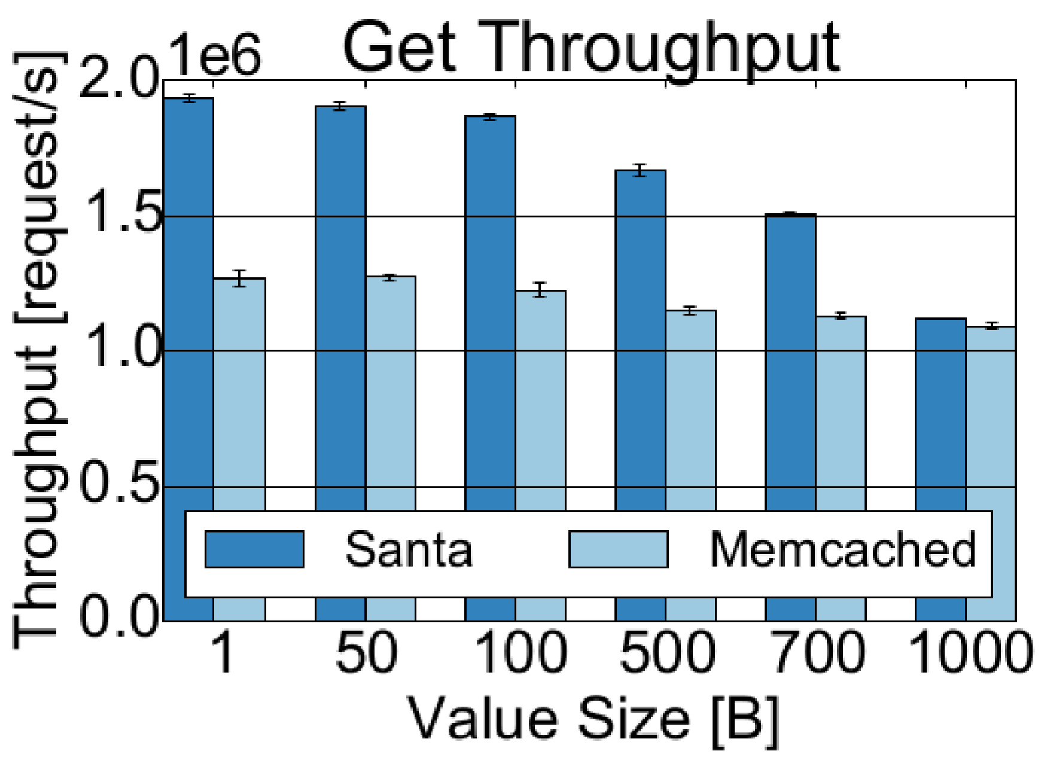
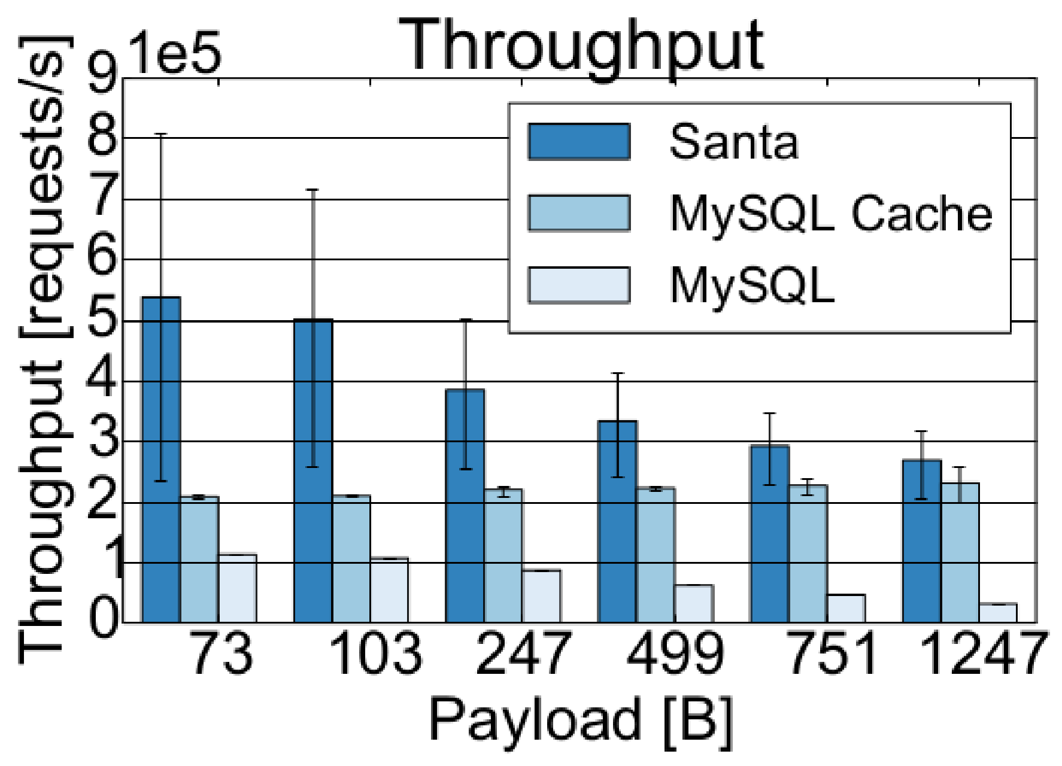
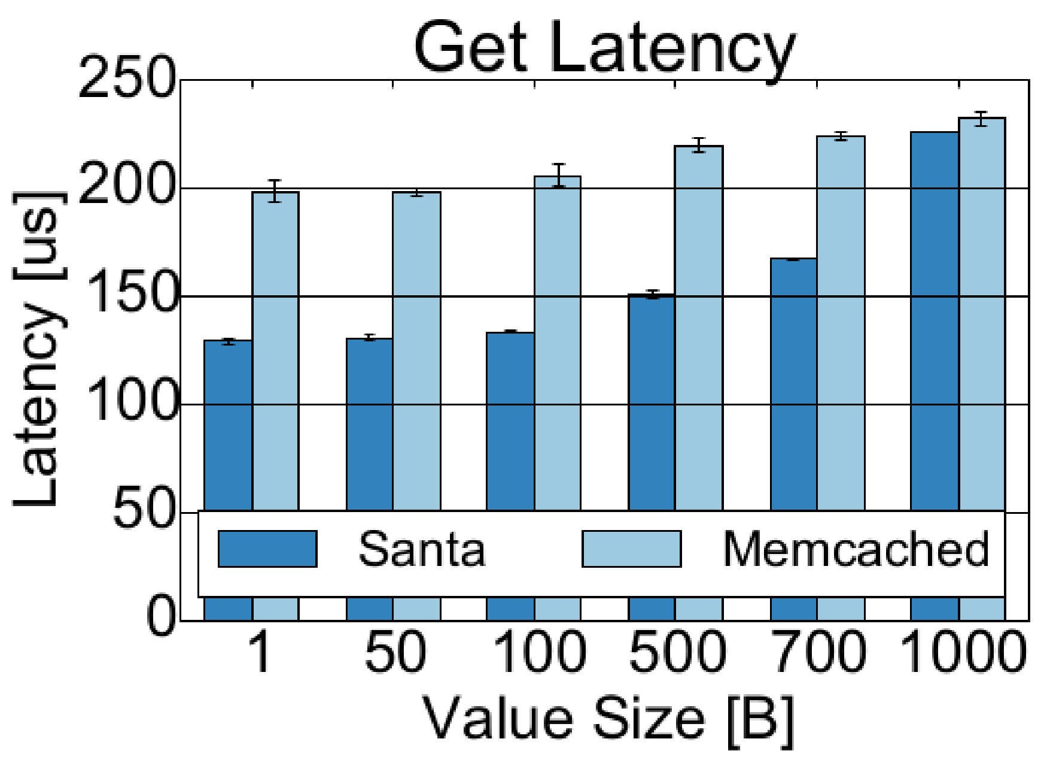
Evaluation

UDP: Memcached



TCP: MySQL





Conclusion

- Reduced computational expenses
- Santa increases throughput significantly
- Latency is significantly decreased
- At higher payloads, copy operations still become dominant
- Highly optimized user-space applications are slower (Memcached, MySQL query cache)
- Recent new networking techniques can speed up databases in general

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