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Practical experiences with a BFT middleware database

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Outline

- Protocol
- Implementation
- Evaluation (local and wide- area)
- Conclusion

Replication

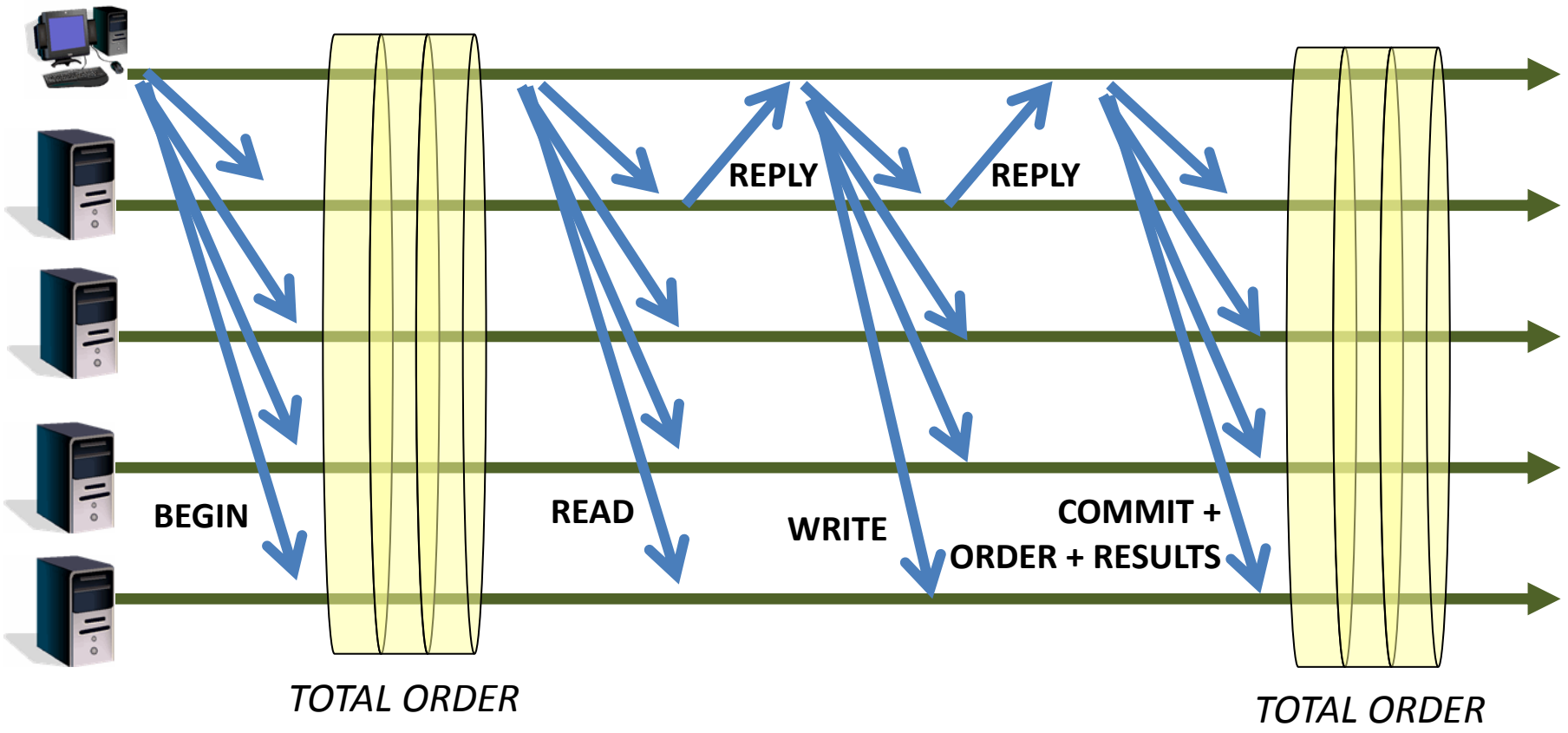
- Sharing information to ensure consistency between redundant resources
- Data/computations are propagated to a set of hosts known as **replicas**
- Purposes:
  - Improve performance;
  - Enforce availability;
  - Provide **fault-tolerance**.
- Two replication approaches: passive and **active**

Byzantium (EuroSys'11)

- Middleware for transactional replicated databases
- Descentralized and concurrent transaction execution
- Tolerates Byzantine faults
- Supports *off-the-shelf* Database management systems (DBMS)
- Requires total order broadcast primitive
  - Original paper uses PBFT (OSDI'99)
- Provides *snapshot isolation* semantics

Byzantium (single master)

Comunication steps



Slaves only execute operations at commit time

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Byzantium

The original evaluation was done in a local network. How does it fare on a geo-replicated environment?

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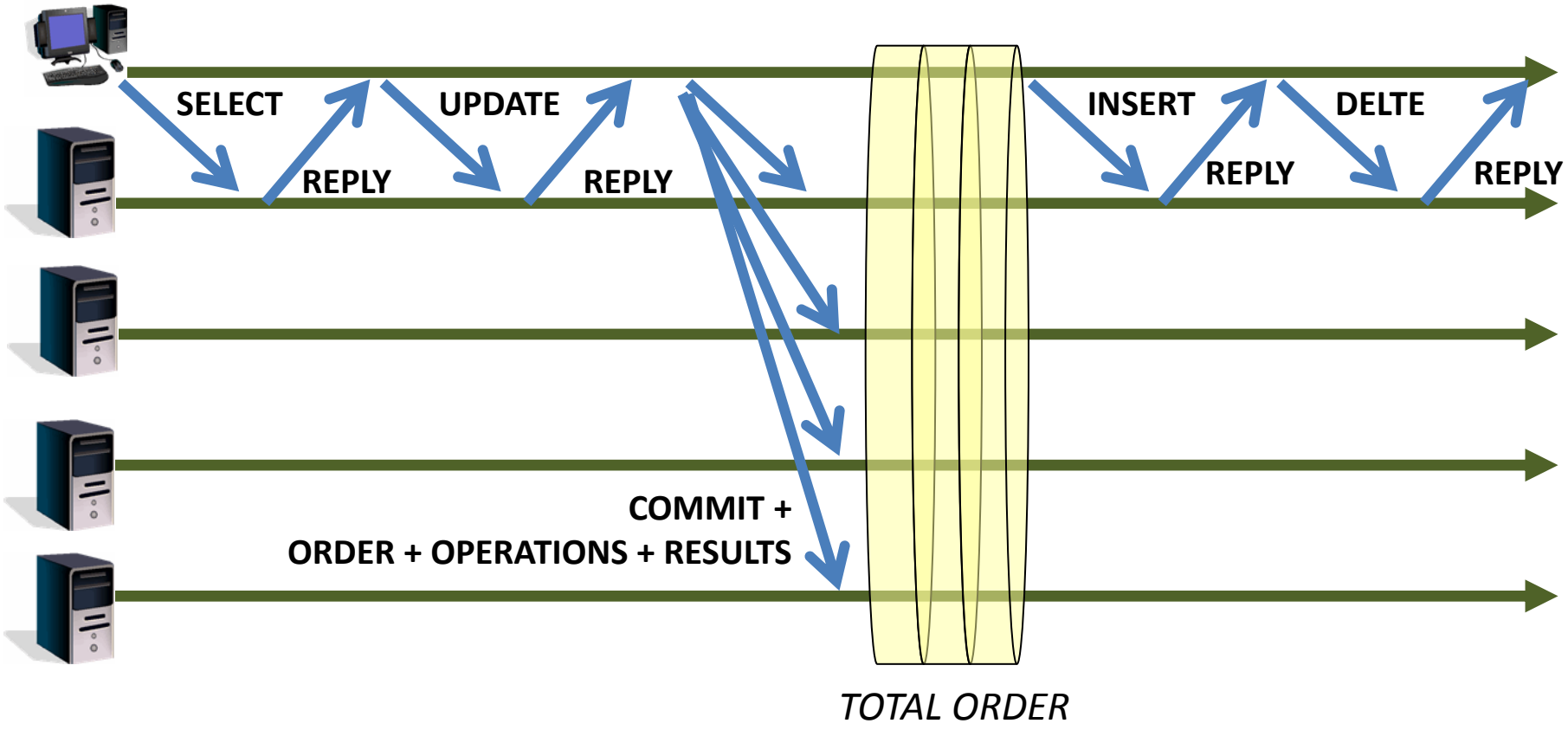
SteelDB

- JDBC driver implemented by Navigators (Tclouds project, Master Thesis of Marcel Santos)
- Simplified version of Byzantium
- Tested with PostgreSQL
- Uses BFT-SMaRt as communication layer
- 2 variants (normal & optimized)

SteelDB

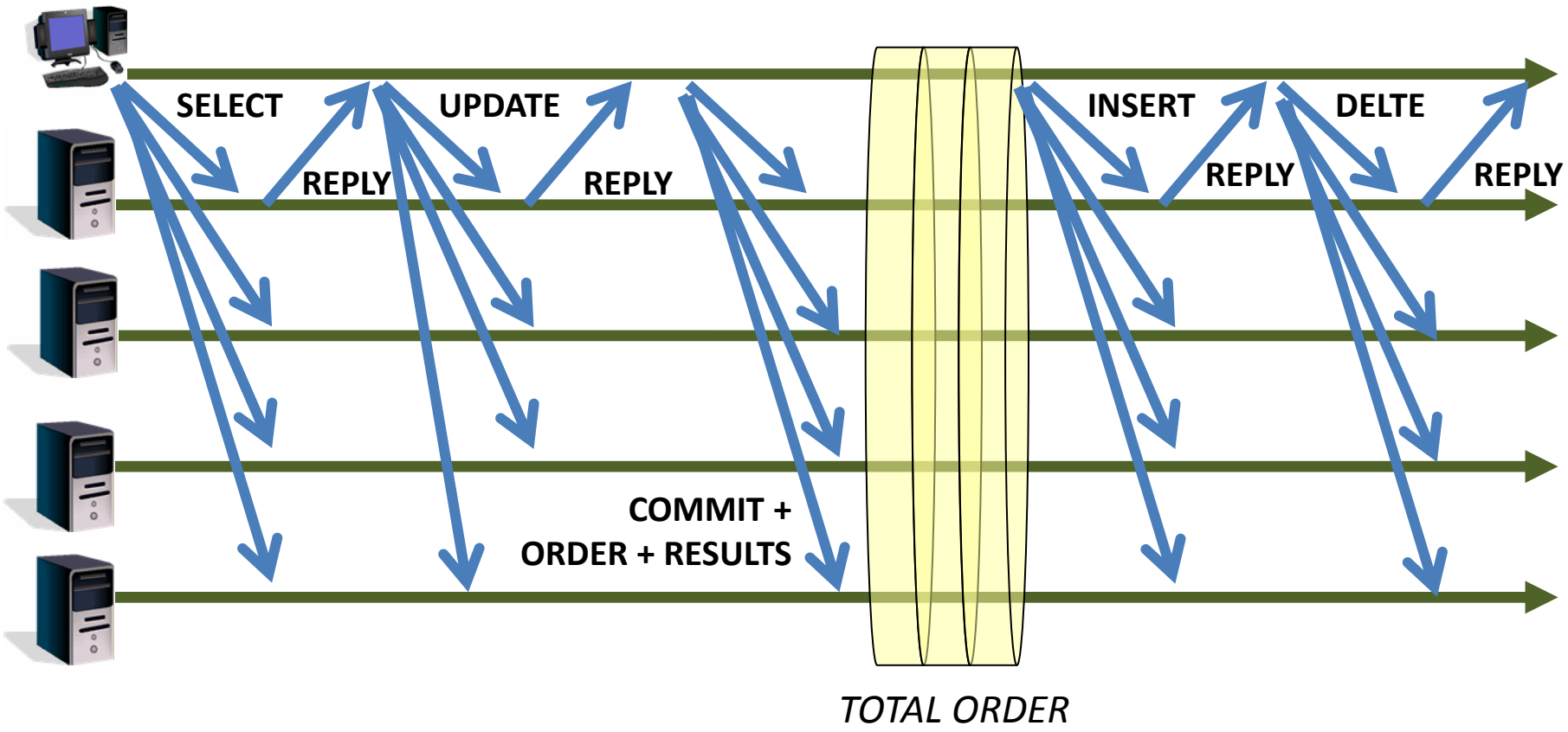
Communication steps (normal)



Clients only contact slaves at commit time

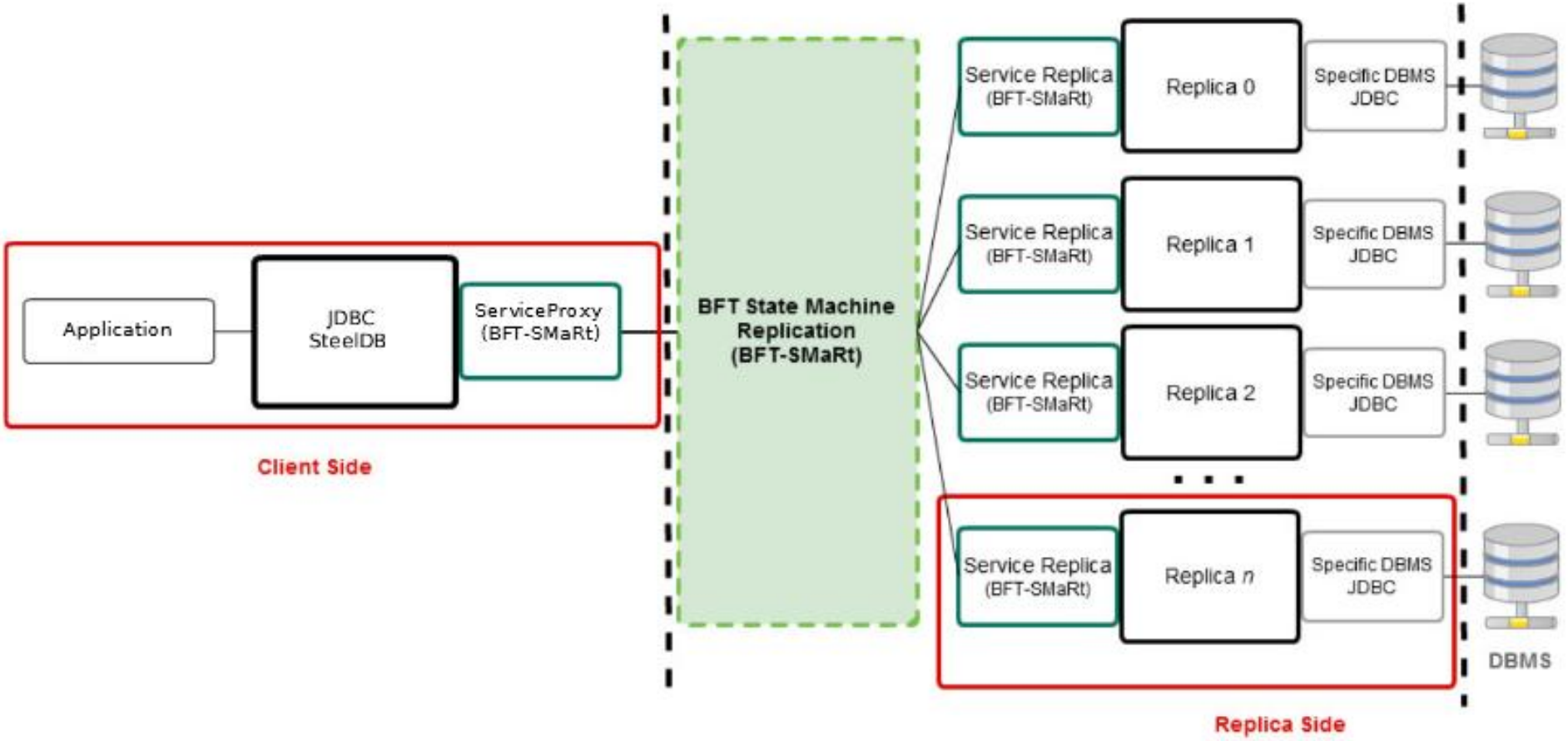
SteelDB

Communication steps (optimized)



Slaves execute operations speculatively (SOSP'07)

Architecture

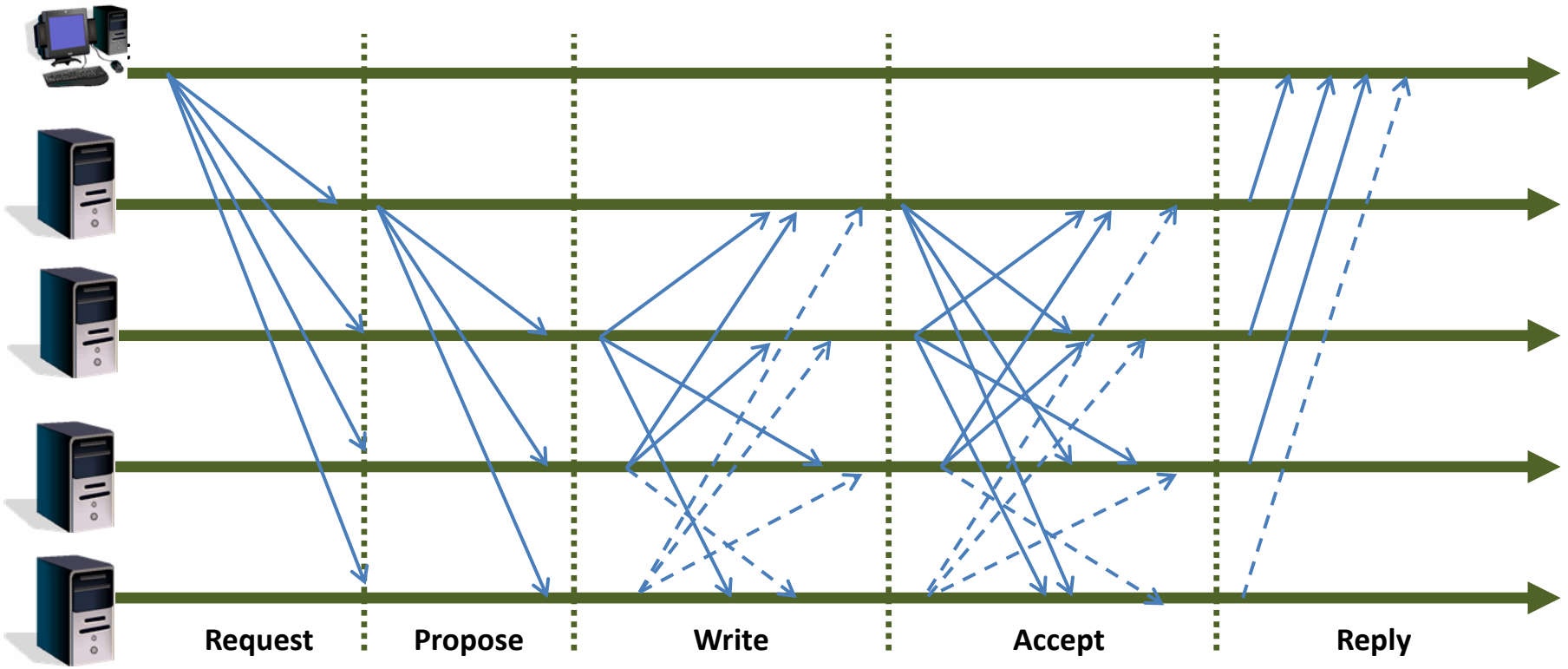


Total Order Broadcast

- BFT-SMaRt (DSN'14): Standard algorithm
- WHEAT (SRDS'15): BFT-SMaRt optimized for wide-area replication

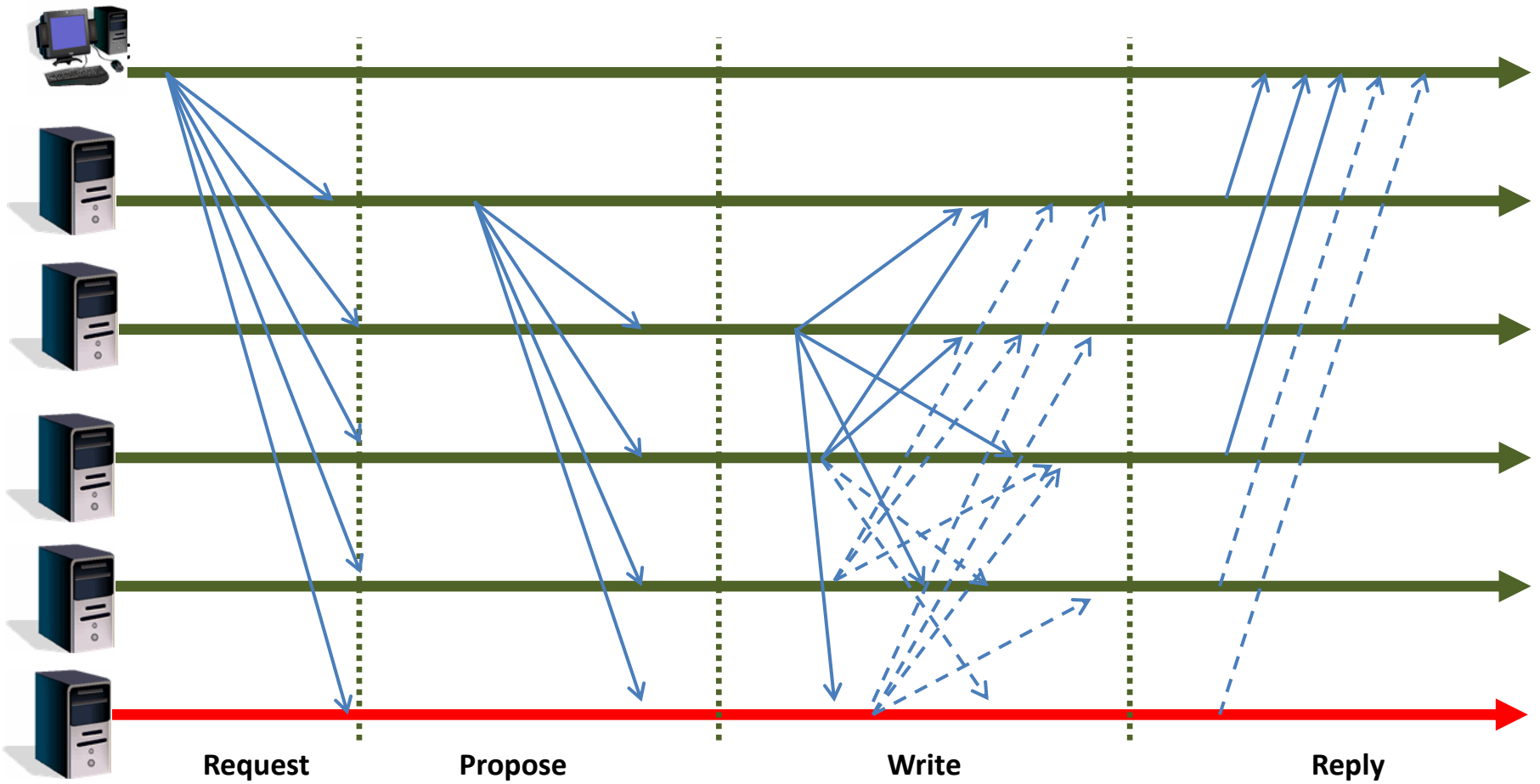
BFT-SMaRt

Communication steps



WHEAT

Communication steps



TPC Benchmark C

- Standard specification to evaluate scalability of OLTP systems
- Simulates a wholesale supplier comprised by multiple warehouses and districts
- Terminals send 5 operation types: New Order, Payment, Delivery, Order Status e Stock Level

Personal Experience

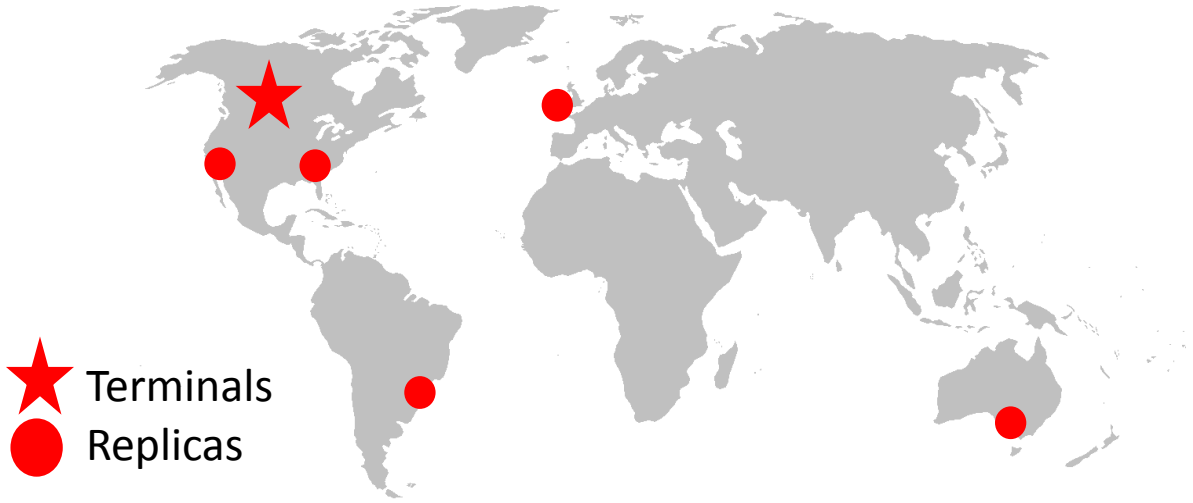
Evaluation

- 4 (BFT-SMaRt) or 5 (WHEAT) replicas
  - Both tolerating a single failure
- 30 terminals
- Default TPC-C workload with 50 warehouses
  - 45% New Orders
  - 43% Payments
  - 4% Delivery, Order Status & Stock Level

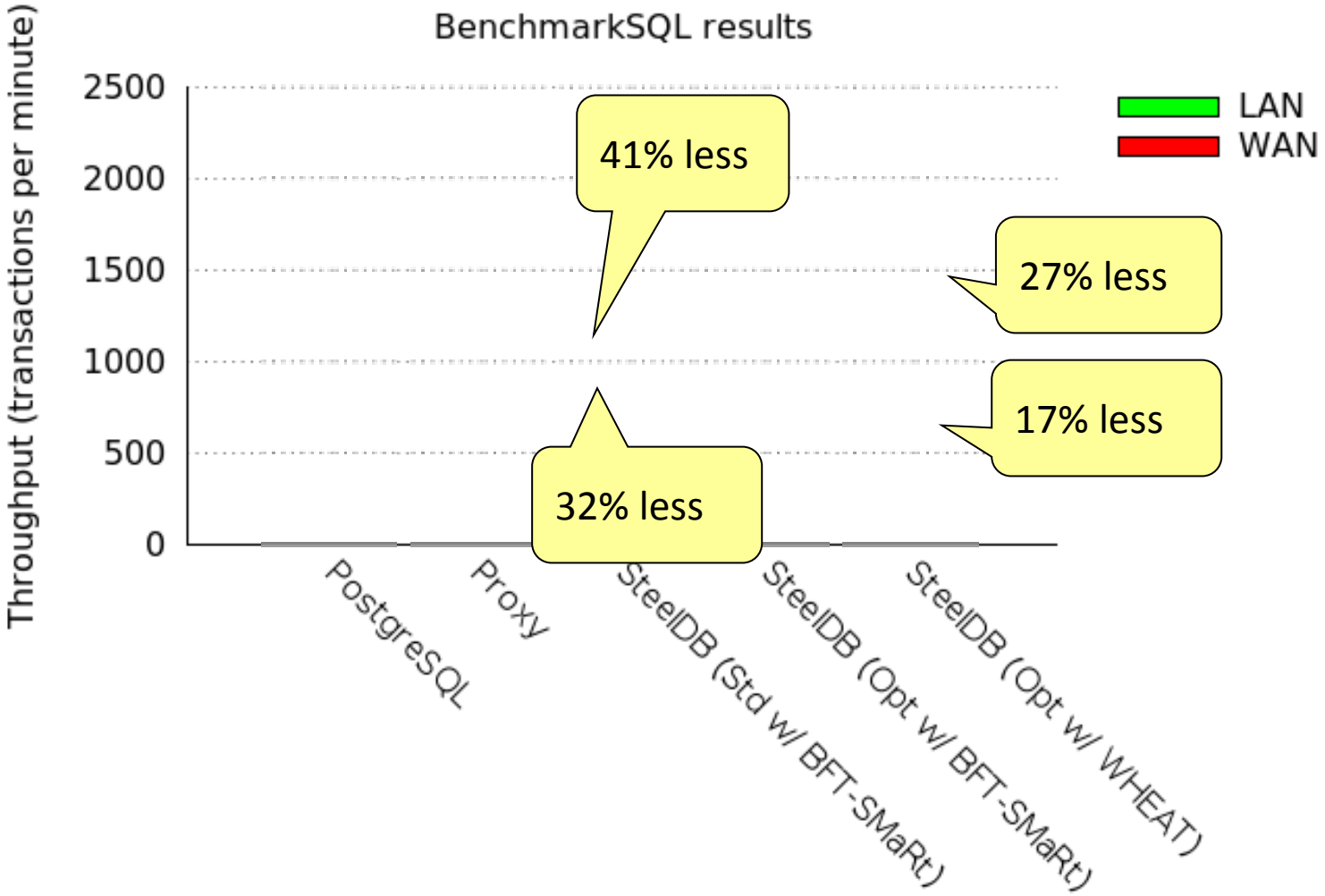
  (92% of transactions are write-heavy)
- PostgresSQL 9.6, Ubuntu 14.04

Evaluation

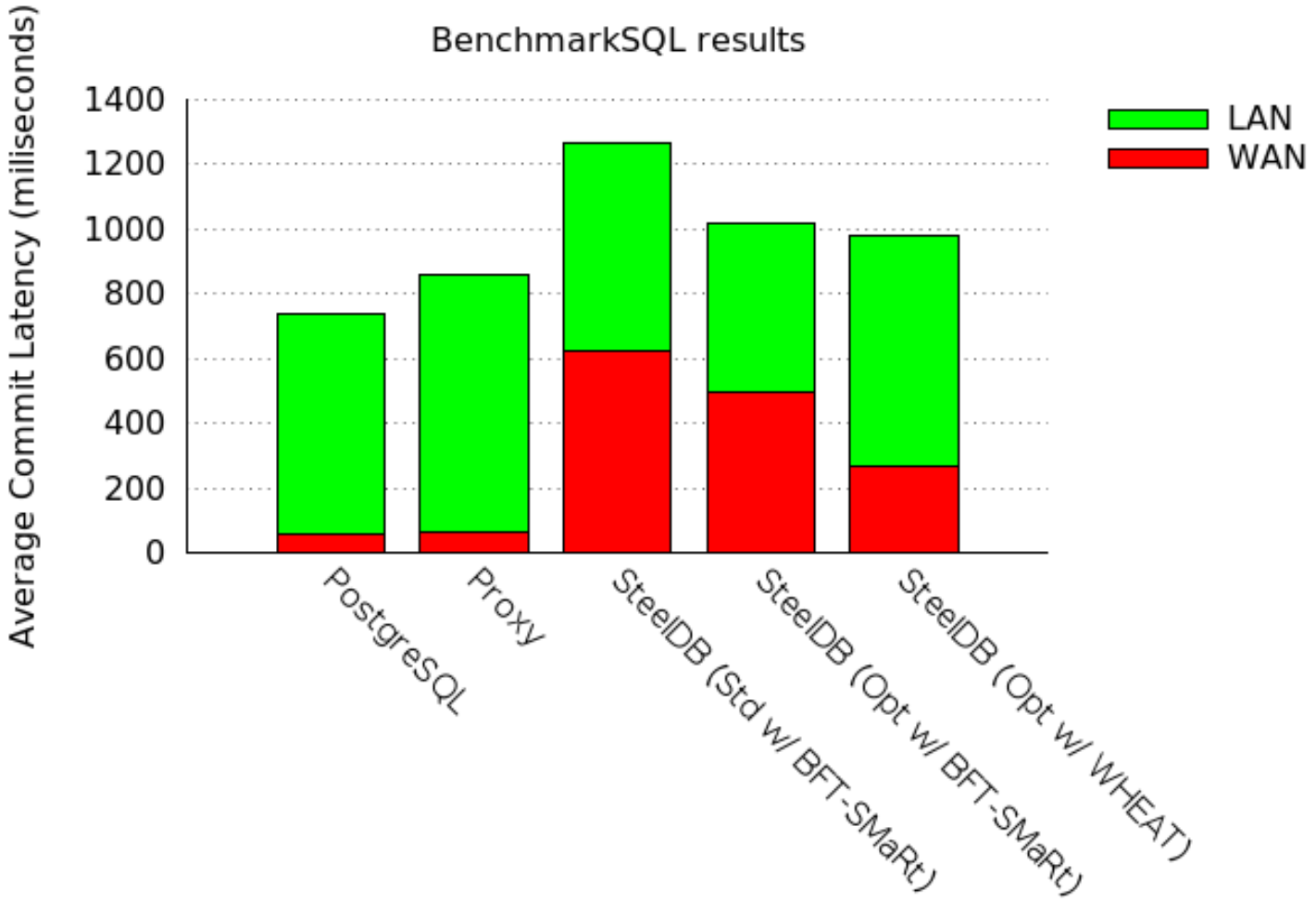
- Local network: quinta.navigators.di.fc.ul.pt
  - 32 GB memory, 2 quadcores with hyperthreading, magnetic disks
- Geo-distributed network: Amazon EC2 (t2.medium)
  - 4 GB memory, 2 vCPU, SSD disks



Evaluation


BenchmarkSQL results
Throughput (transactions per minute)
2500
2000
1500
1000
500
0
LAN
WAN
41% less
27% less
17% less
32% less
PostgreSQL
Proxy
SteelDB (Std w/ BFT-SMaRt)
SteelDB (Opt w/ BFT-SMaRt)
SteelDB (Opt w/ WHEAT)

Evaluation

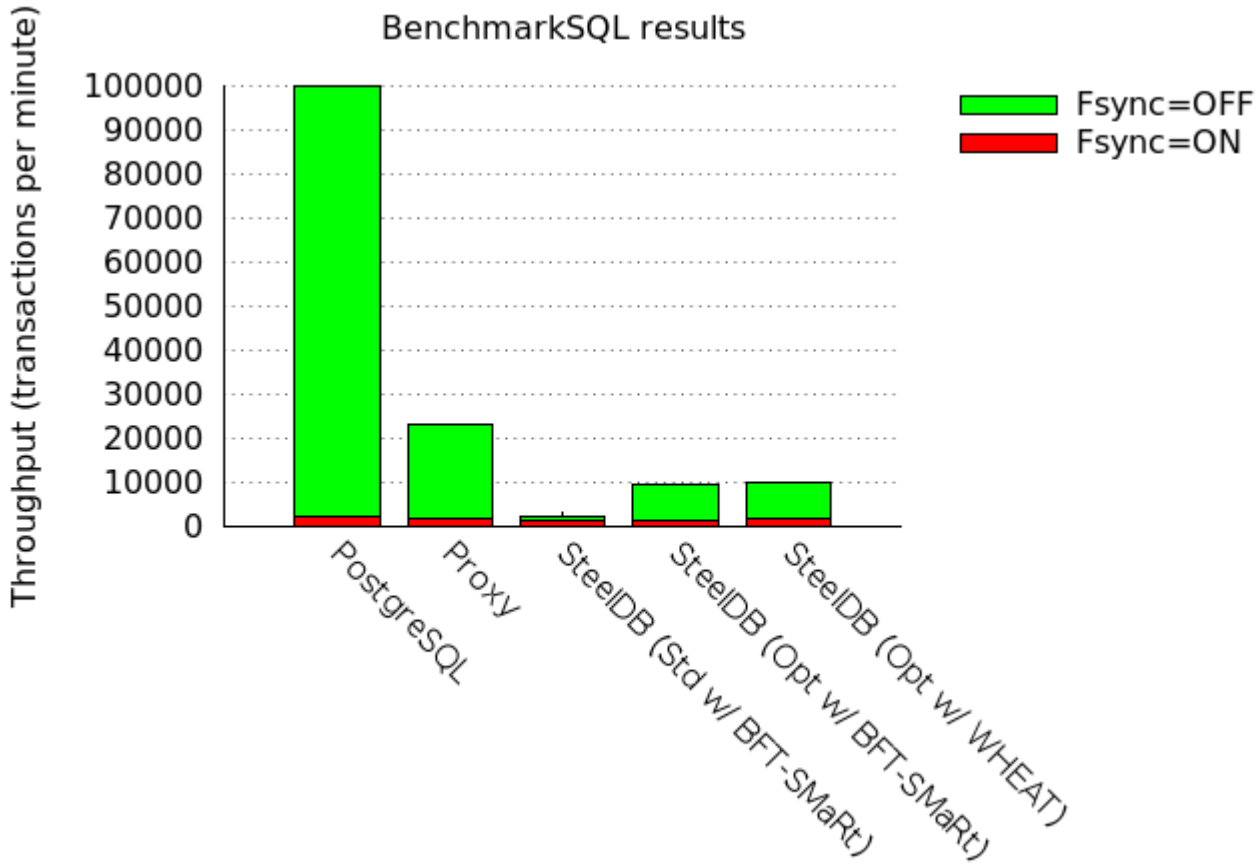

BenchmarkSQL results
Average Commit Latency (miliseconds)
1400
1200
1000
800
600
400
200
0
LAN
WAN
PostgreSQL
Proxy
SteelDB (Std w/ BFT-SMaRt)
SteelDB (Opt w/ BFT-SMaRt)
SteelDB (Opt w/ WHEAT)

Evaluation

- Commit latency (normal SteelDB w/ BFT-SMaRt):
  - $L_{roundtrip} + L_{total\_order} + L_{contention} + L_{exec\_ops} + L_{disk\_write}$
- LAN (30 terminals):
  - 2 x ~1 ms + ~1000 ms + ~13 ms + ~33 ms
- WAN (30 terminals):
  - ~170 ms + ~410 ms + ~35 ms + ~13 ms + ~1 ms
  - = ~630 ms
- By default, PostgreSQL flushes buffers to disk (fsync)
- Amazon EC2 provides storage on SSD

Evaluation

What if Fsync is turned off in the local network?



Is SteelDB worth it?

- A non-replicated database should have Fsync turned on to prevent data loss/corruption
  - PostgreSQL throughput was around 2300 transactions/minute
- SteelDB provides redundancy, so Fsync can be turned off
  - Normal SteelDB throughput was a around 2400 transactions/minute
  - Optimized SteelDB throughput was 8700 transactions/minute

Conclusions

- Byzantium: database middleware for Byzantine fault tolerance
- SteelDB: our implementation of (part of) Byzantium
- Sound solution both for local and wide-area networks

Questions?