BARISTA

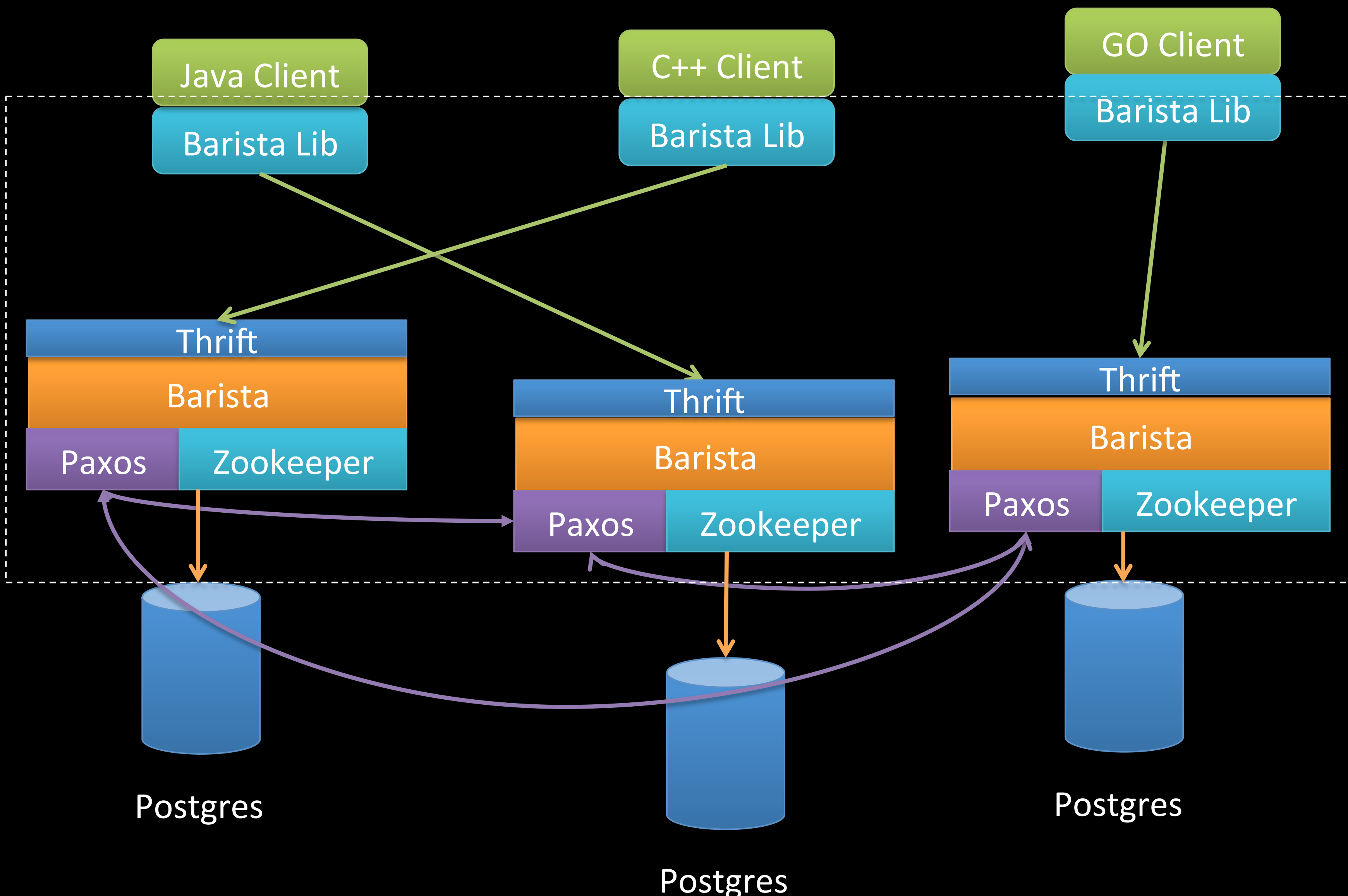
A distributed, synchronously replicated, fault tolerant, relational data store

Anant Bhardwaj Rebecca Taft Manasi Vartak David Goehring

Why Barista?

- Lots of applications use DBMS backend
- Machine failure or network outages common
- Barista provides
  - fault-tolerance through multiple DB replicas
  - strong consistency
  - automatic failover
  - automatic recovery
  - clients use the same SQL they used before

Architecture



Design Choice: Paxos Agreement

- Track the opening and closing of connections in the log in addition to query operations.
  - the presence of replication must be transparent to clients (no need to connect to different instances separately)

```
// open connection to  machine 1
con, err = clerk.OpenConnection(machine_1)

// create the table on  machine 2
_, err = clerk.ExecuteSQL(machine_2, con,
    "CREATE TABLE IF NOT EXISTS courses (
    id text, name text)", nil)

// insert a record on machine 3
_, err = clerk.ExecuteSQL(machine_3, con,
    "INSERT INTO courses values('6.831', 'UID')", nil)
```

- Other ops: SQL queries, transactions

- All operations must affect all the machines in the same order

Design Choice: Enforcing Ordering

- Postgres is multi-threaded
  - transactions can run as different threads.
  - the threads might get scheduled in any order
    - the commit order can be different from the order in which the transactions are submitted

- Our solution: only one transaction executing at a time

Design Choice: State Safety

- For each paxos instance
  - there is a node in the ZooKeeper with the path `/barista/paxos/{machine_name}/store/{seq_num} = Paxo {N_P, N_A, V_A, Decided}`
- ZooKeeper's `Write()` and `Read()` APIs are atomic
  - we don't have to worry about consistency
- Paxos code update the state in ZooKeeper

```
if px.use_zookeeper {
  px.Write(
    px.path + "/store/" + strconv.Itoa(args.Seq), paxo)
} else {
  px.store[args.Seq] = paxo
}
```

Design Choice: Log Purging

- When `paxos.Done()` from other peers updates `paxos.Min()`
  - all paxos instances in ZooKeeper with `seq_num < paxos.Min()` are purged.
  - this is done by removing all `/barista/paxos/{machine_name}/store/{seq_num}` nodes if the `{seq_num} < paxos.Min()`

- The purging allows us to keep the ZooKeeper logs small

- The choice of ZooKeeper allows us to do efficient purging
  - if we used file, it'd require us to implement efficient purging mchanism
  - we also considered using sqlite

Design Choice: Recovery

- `AP` : the last applied `seq_num` to the database
  - this is not stored in ZooKeeper?
    - no, we need this to be atomic with the client query execution
    - store this in `sqlpaxoslog(lastseqnum int)` table
  - intercept the client txn and make AP update as part of the client transaction to ensure atomicity

Design Choice: Recovery

- Recovery from crash & restart (no disk failure)
  - reconstruct the paxos state

```
if px.use_zookeeper {
  paxo, ok = px.Read(
    px.path + "/store/" + strconv.Itoa(args.Seq))
} else {
  paxo, ok = px.store[args.Seq]
}
```

  - the AP can be recovered by reading the sqlpaxoslog table.
  - paxos fills holes in its log to ensure that everything after the AP can be retrieved as part of the paxos protocol.

Design Choice: Recovery

- Recover from a complete disk wipe out
  - we provide a script that copies the database data files from a `{healthy_machine}`
  - the recovery requires that
    - the `{healthy_machine}` is not serving any request during the recovery
    - if it serves a new request it will change its state during the recovery and would lead to inconsistent data/state transfer.
  - once the data & the state `{AP}` is copied, the normal recovery protocol kicks in

Design Choice: Multi-Paxos

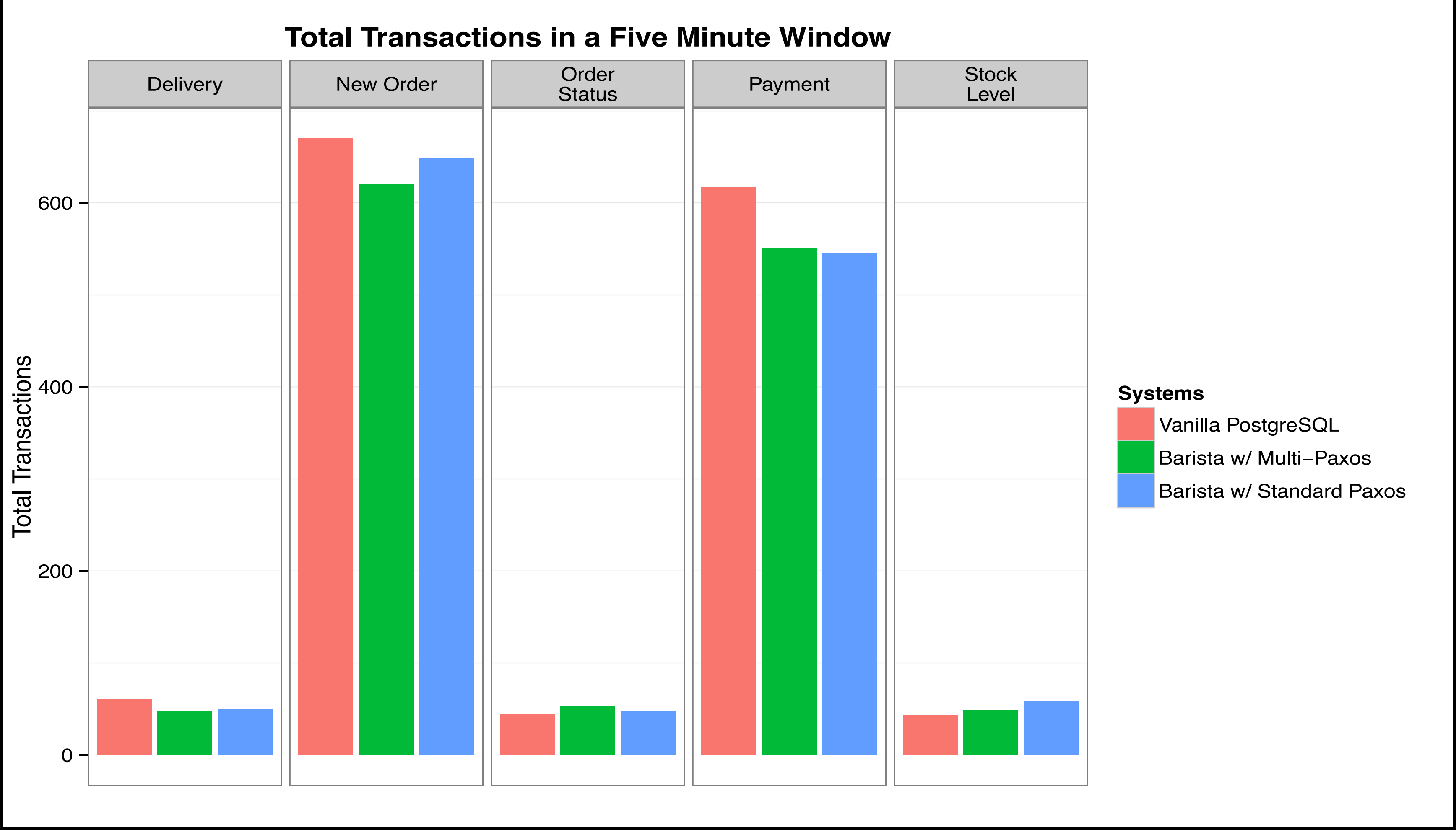
- We made the following optimizations to our paxos-based protocol by implementing a version of Multi-Paxos:
  - avoid 2 round-trips per agreement by having a server issue Prepare messages ahead of time
  - avoid dueling leaders under high client load by using a designated leader
- We present the effect of this optimization in the evaluation section

Evaluation

- We implemented the TPC-C benchmark
  - an industry standard for comparing the performance of OLTP database systems.
  - TPC-C simulates the operation of a wholesale parts supplier in which
    - a population of terminal operators executes a set of transactions against a database.
    - these transactions include monitoring the stock level of a warehouse, creating a new order for a customer, accepting payment from a customer, making a delivery to a set of customers, and checking the status of an order.

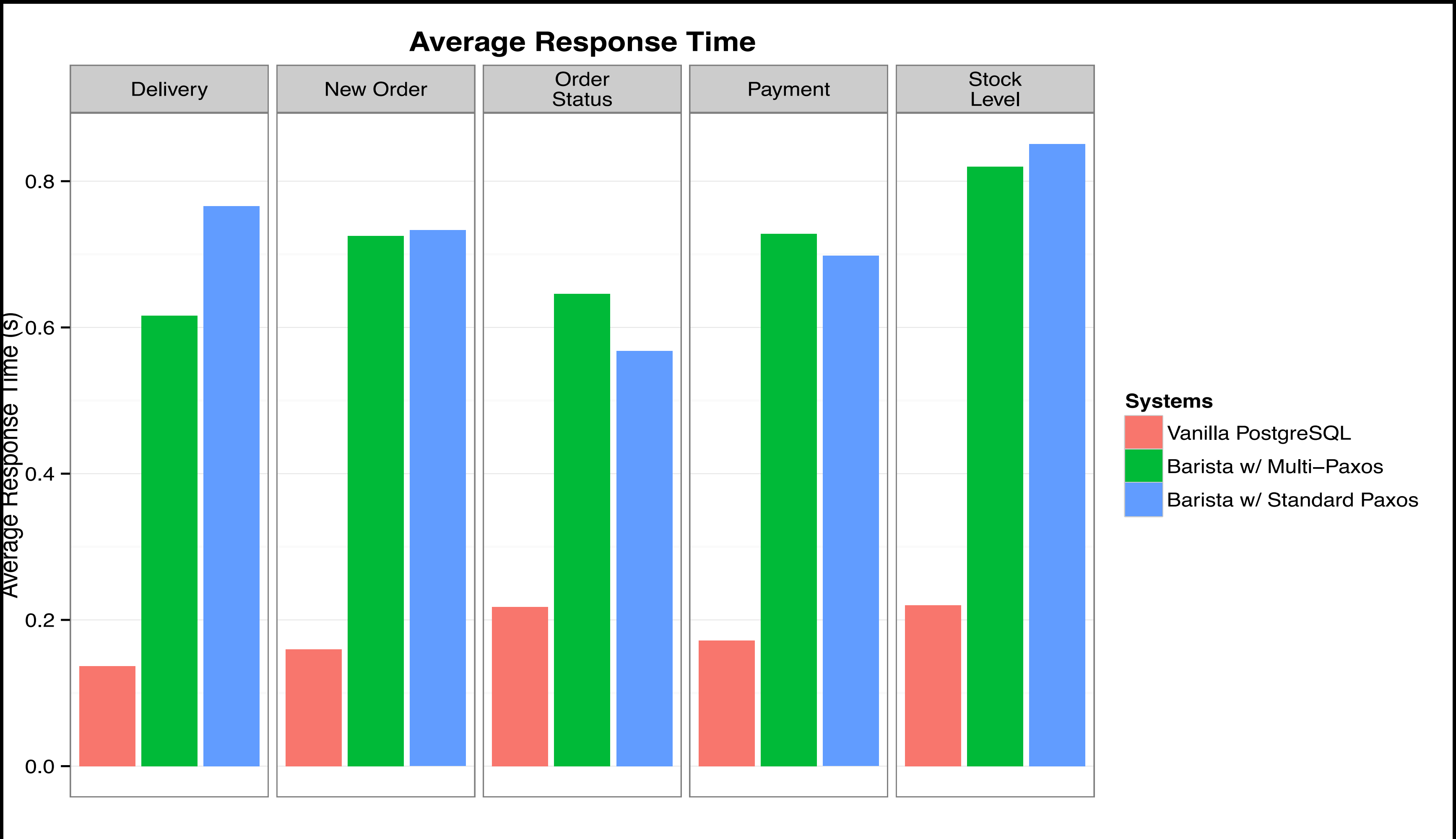
- The intent of this benchmark is to simulate a realistic real-time OLTP system.

Evaluation

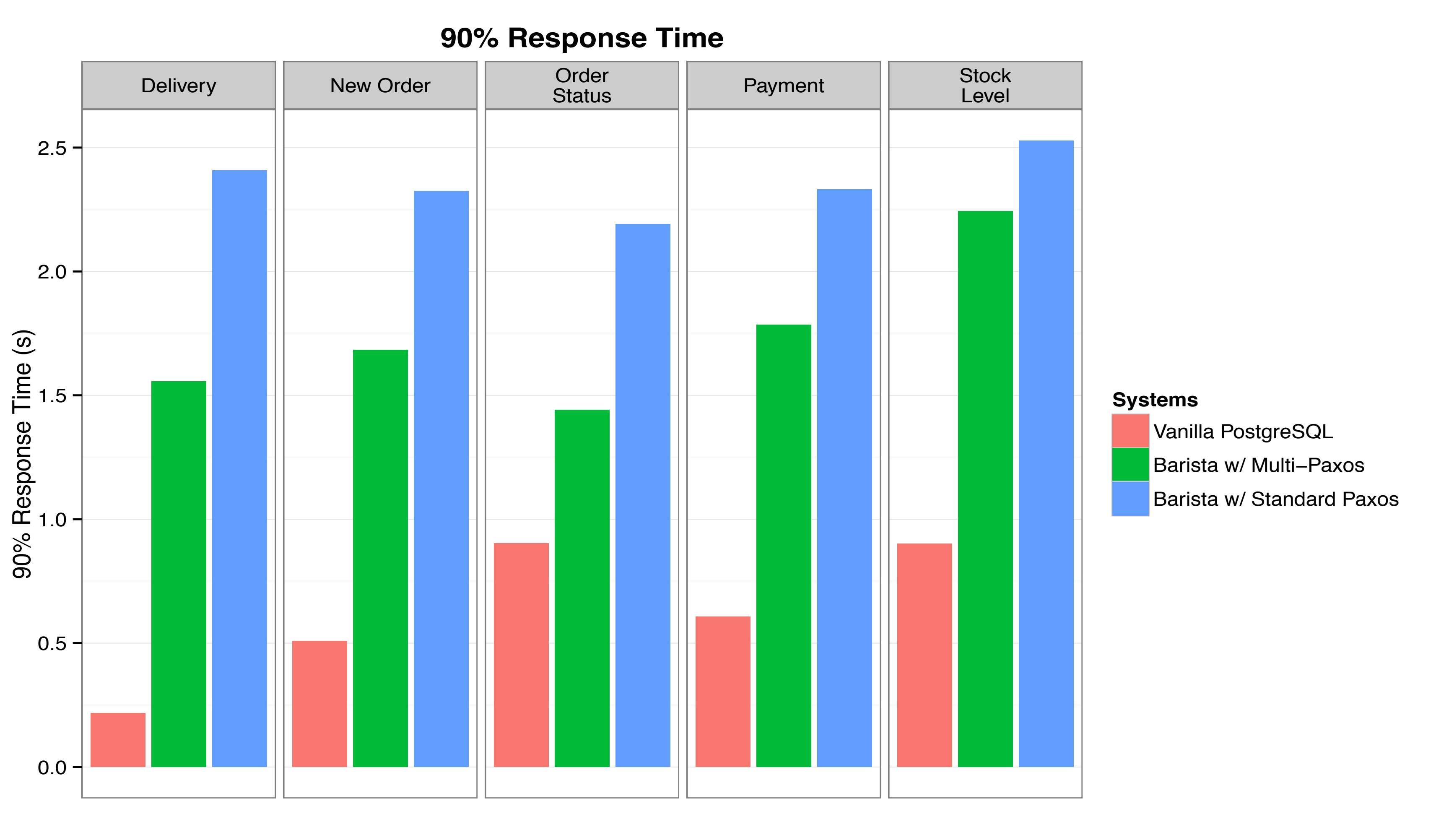


Total Transactions in a Five Minute Window
Delivery
New Order
Order Status
Payment
Stock Level
Total Transactions
0
200
400
600
Systems
Vanilla PostgreSQL
Barista w/ Multi–Paxos
Barista w/ Standard Paxos

Evaluation


Average Response Time
Delivery
New Order
Order Status
Payment
Stock Level
Average Response Time (s)
0.0
0.2
0.4
0.6
0.8
Systems
Vanilla PostgreSQL
Barista w/ Multi–Paxos
Barista w/ Standard Paxos

Evaluation



90% Response Time
Delivery
New Order
Order Status
Payment
Stock Level
90% Response Time (s)
0.0
0.5
1.0
1.5
2.0
2.5
Systems
Vanilla PostgreSQL
Barista w/ Multi–Paxos
Barista w/ Standard Paxos

Demo

- We will do a live demo of:
    1. synchronous replication with strong consistency
    2. fault-tolerance (auto failover)
    3. Recovery
        a. a crashed machine should catch up with other peer by executing all the missing queries after the restart
        b. paxos safety (paxos should tolerate server restarts)
        c. disk wipeout (reconstructing state by copying a healthy machine)

Barista Project: Summary

- A distributed, synchronously replicated, relational data store
  - fault-tolerance, recovery, ACID, strong consistency, SQL
- Cross-language support through Thrift
  - sample client code in Go, C++, Java, Python, and JavaScript
- State Safety with ZooKeeper
  - efficient purging and recovery
- Evaluation with the TPC-C Benchmark
  - validation against the industry-standard database benchmark
- Performance Optimizations
  - multi-paxos
- A comprehensive test-suite