PgBouncer in Parallel: Bringing Multithreading to the Trusted Postgres Pooler

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Agenda

1. Why use PgBouncer

1. Architecture and Core Principles of PgBouncer

1. Why do we multithread PgBouncer?

1. Multithreaded PgBouncer: Implementation and Usage Tips

1. Takeaways

Why use PgBouncer

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PgBouncer: The Classic Postgres Pooler

- First released in **2007**, widely adopted across startups → hyperscalers
- Lightweight C implementation, proven in production for 15+ years

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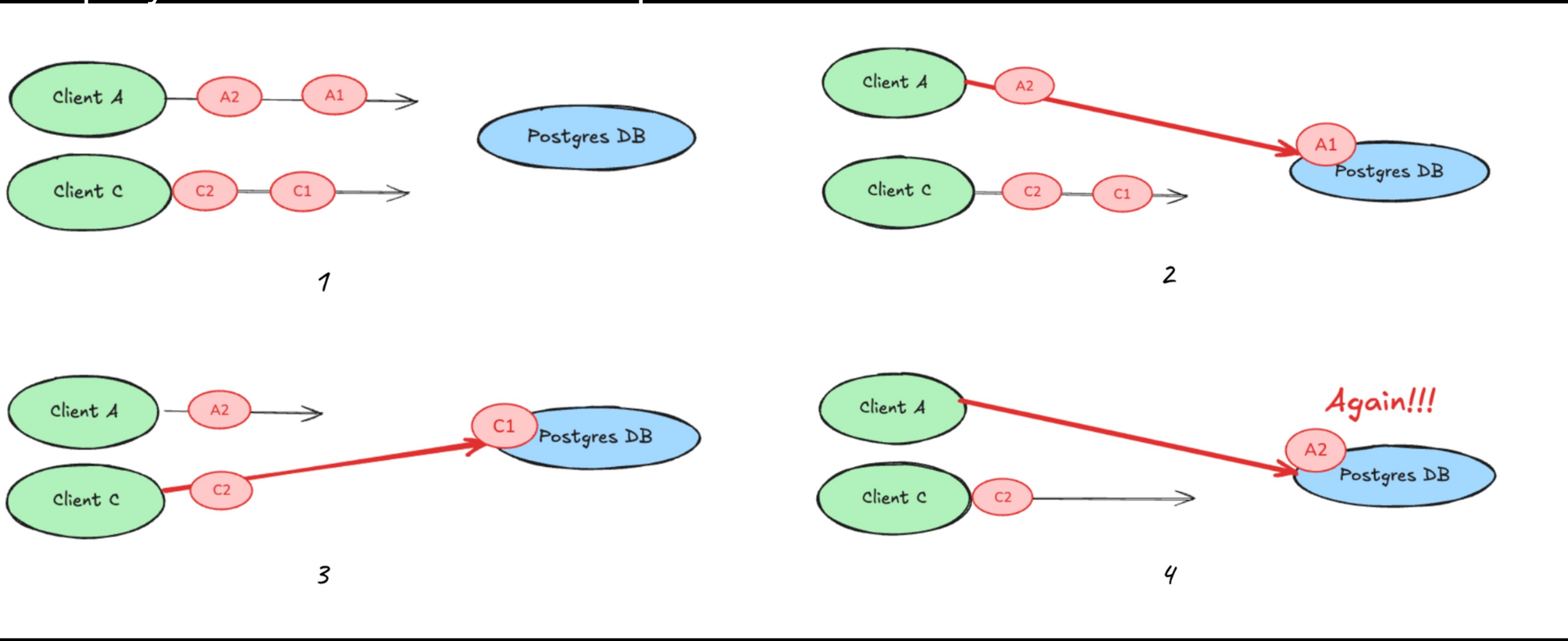
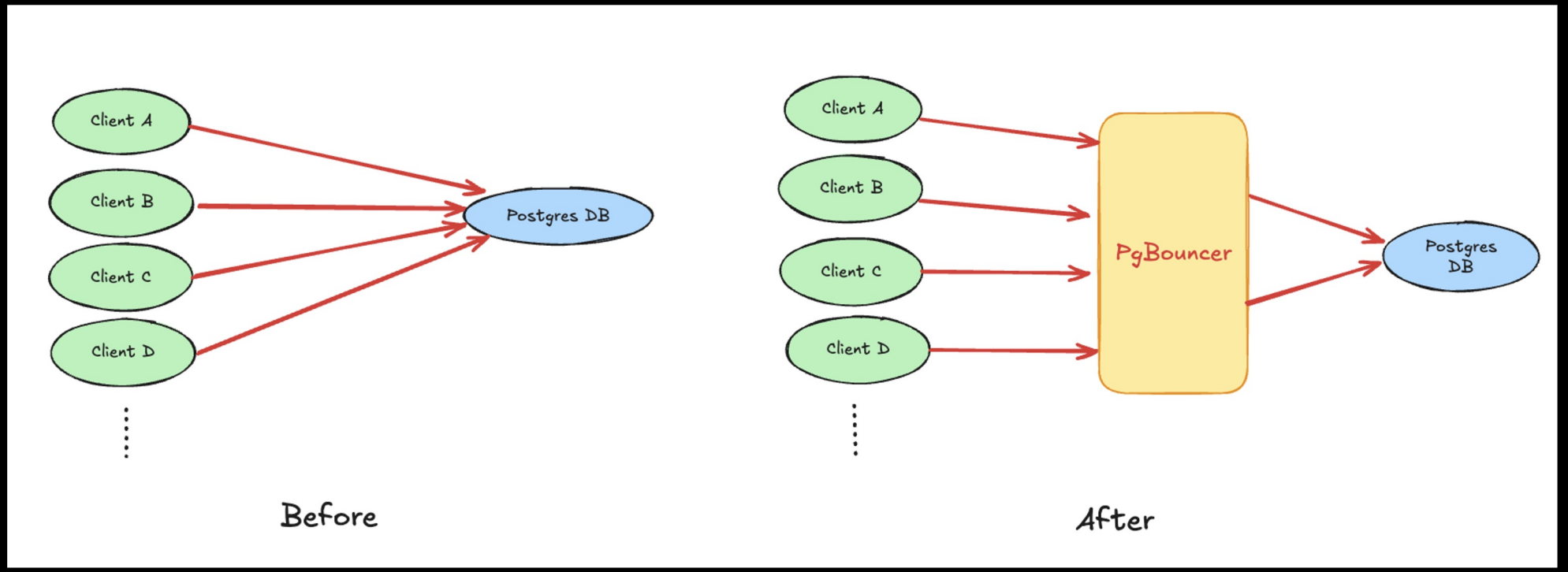
Why Connection Pooling Matters

Rapidly churn connections → frequent creation/teardown overhead



Why Connection Pooling Matters

- **Maintain many persistent connections**
  a. Less idle back-end connections
  b. Cuts connection setup time



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How is PgBouncer deployed?

Deployment Options for PgBouncer

- **Client-side / Server-side**
  - ✅ No extra network overhead
  - ❌ Consumes client or server CPU & memory resources

- **Middlebox**
  - ✅ Offloads resource usage from client/server
  - ✅ Enables more flexible functionality
  - ❌ Adds network latency and bandwidth cost

Architecture and Core Principles of PgBouncer

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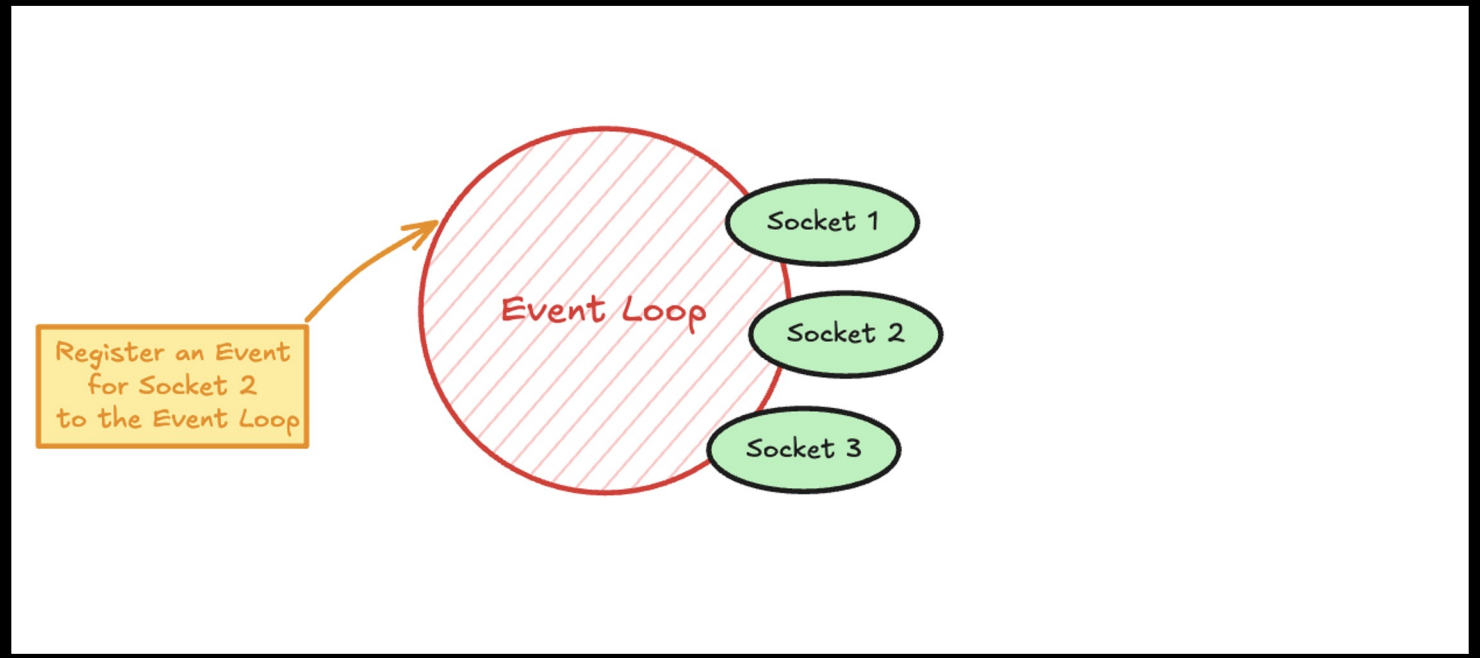
libevent at a Glance

- **Events:** The fundamental building blocks representing I/O readiness (read/write), timeouts, or signals
- **Callbacks:** Functions that libevent calls when an event becomes active
- **Event Loop:** The main loop that continuously checks for and dispatches active events to their respective callbacks

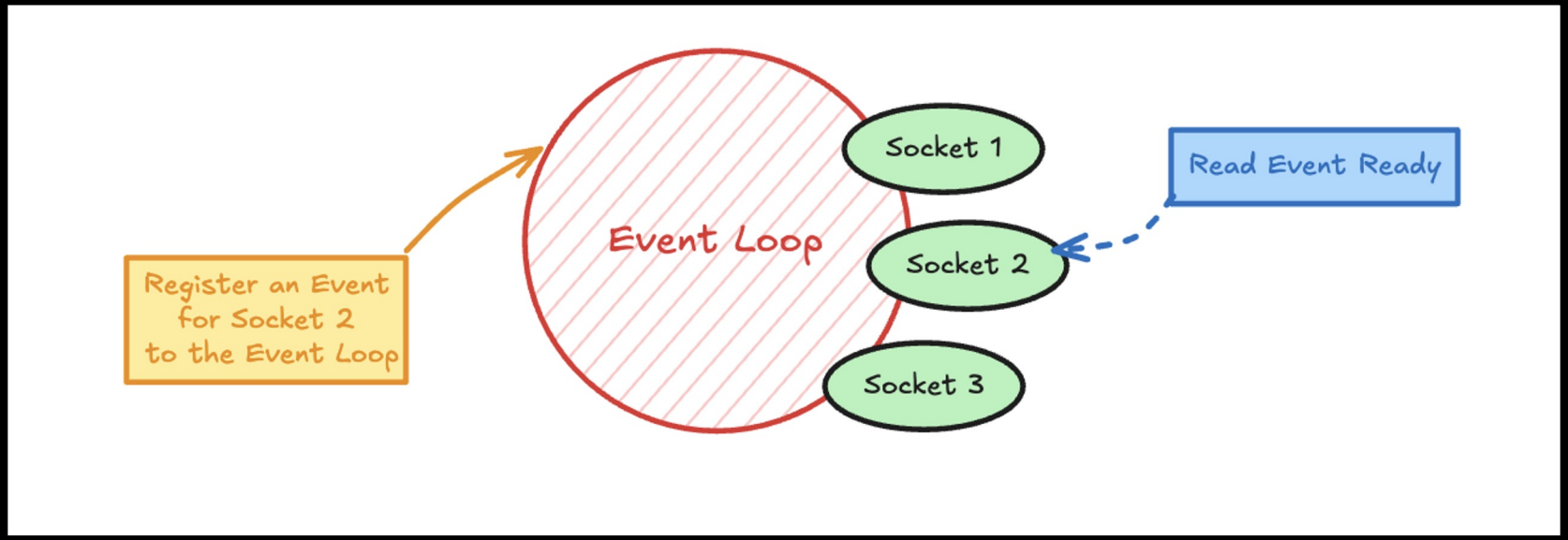
PgBouncer Architecture: Event Execution

1. Registration: PgBouncer register events. libevent starts monitoring that socket for readiness



PgBouncer Architecture: Event Execution

2. Kernel signals readiness:



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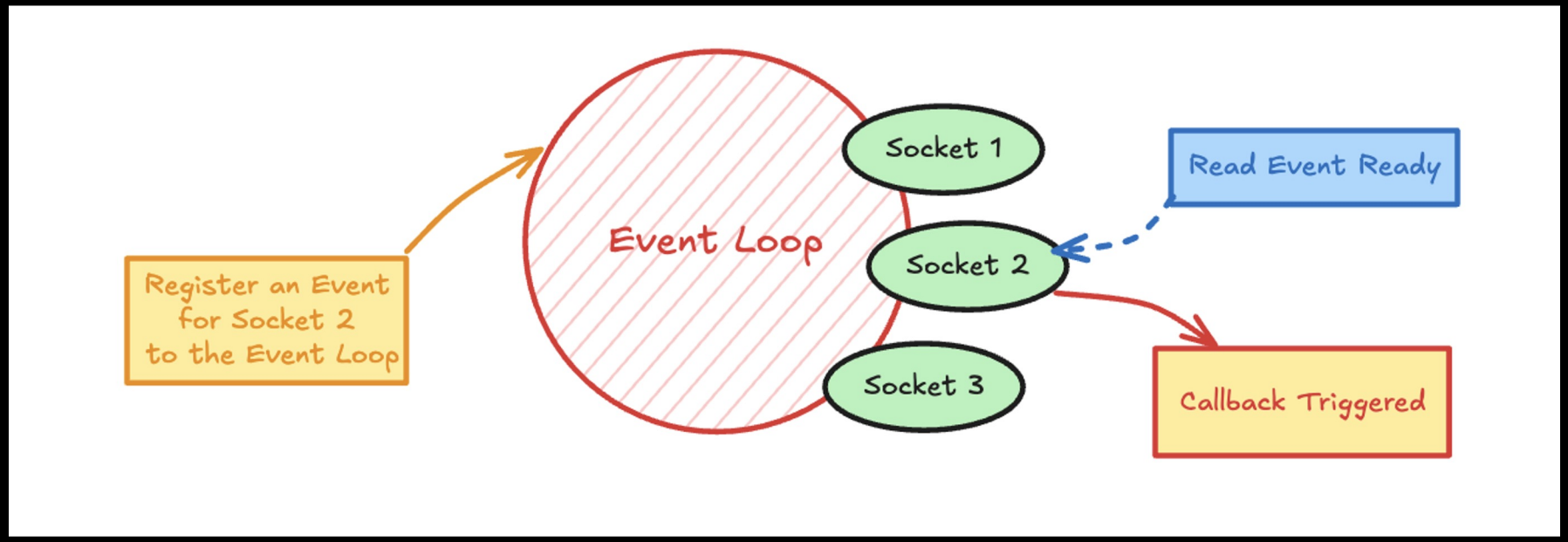
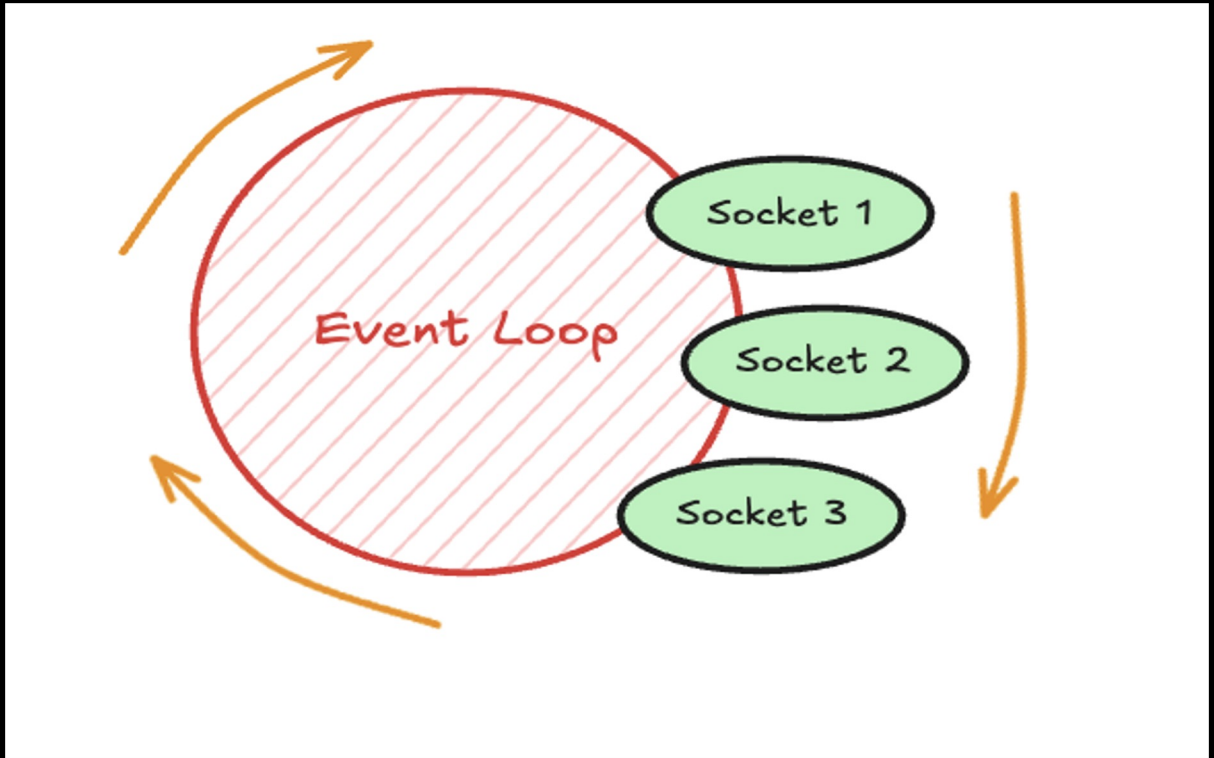
PgBouncer Architecture: Event Execution

3. libevent dispatches + Callback runs quickly: Event Loop triggers the corresponding callback (e.g. updates the state of sockets)



PgBouncer Architecture: Event Execution

4. Event Loop continues: monitors all events and triggers callbacks for whichever socket ready first



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In PgBouncer, Everything is an Event!

- **Timed events**
  - Stats
  - Full maintenance
- **Signal events**
  - SIGUSR1 reload
  - SIGINT / SIGTERM handling…
- **Dynamic events**
  - New connections
  - Connected sockets (Connection handled as a state machine driven by events)

Why Event-Driven Design Matters

- **No busy-waiting**

- One thread can handle **thousands of sockets**, because it only wakes up when real work exists

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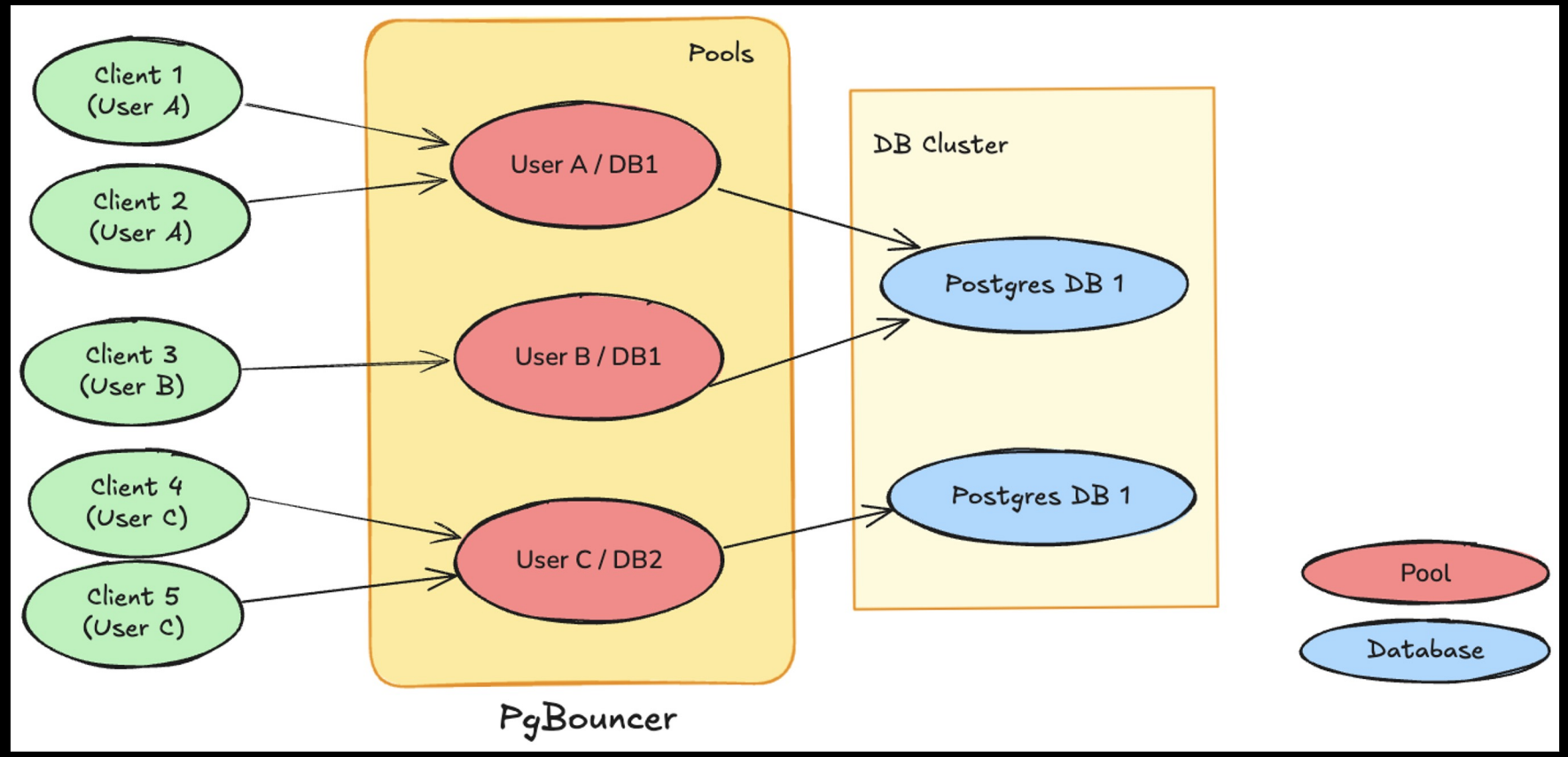
Client-Pool-Server Architecture

- Each pool maintains its client and server sockets (active / idle)



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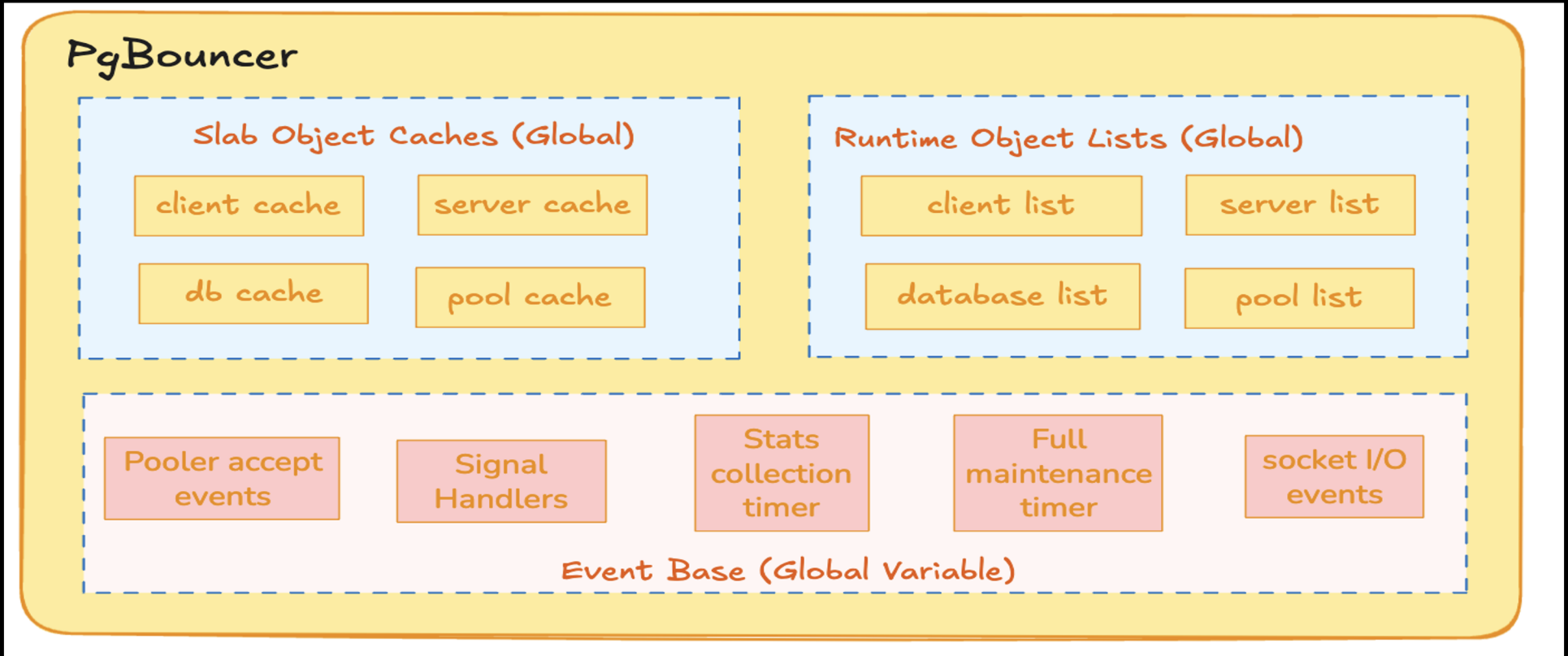
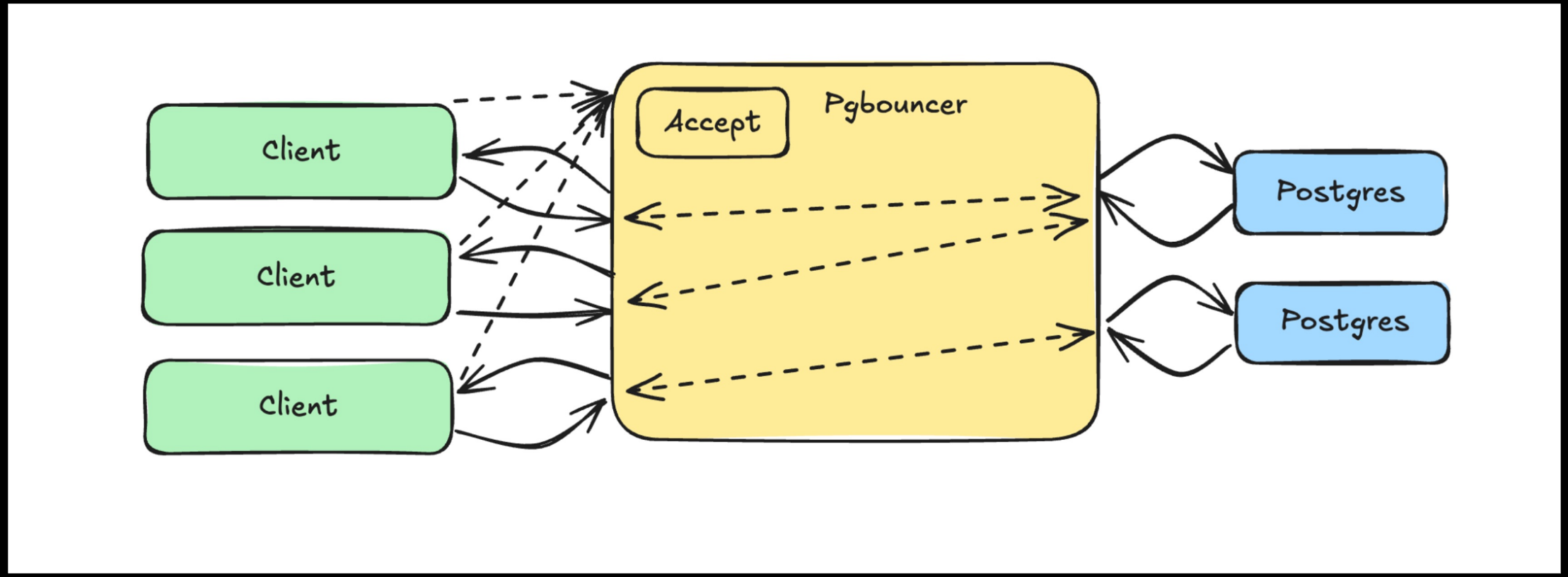
PgBouncer Memory Management



- **List:** Collections of live objects, implemented as linked lists. PgBouncer periodically needs to scan all objects
- **Cache:** Provide memory pool for objects

How Single Thread Pgbouncer handle connections



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How Admin Works in PgBouncer

- Users connect to **PgBouncer's admin console** via the special "pgbouncer" database
- Allows users to query **PgBouncer's internal status** and execute Admin commands
- Admin requests are handled like normal requests
- Admin connections do **not** establish a back-end connection to PostgreSQL

Why do we multithread PgBouncer?

- Performance
- Desired feature by the community

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Multi-Threaded PgBouncer is Coming!

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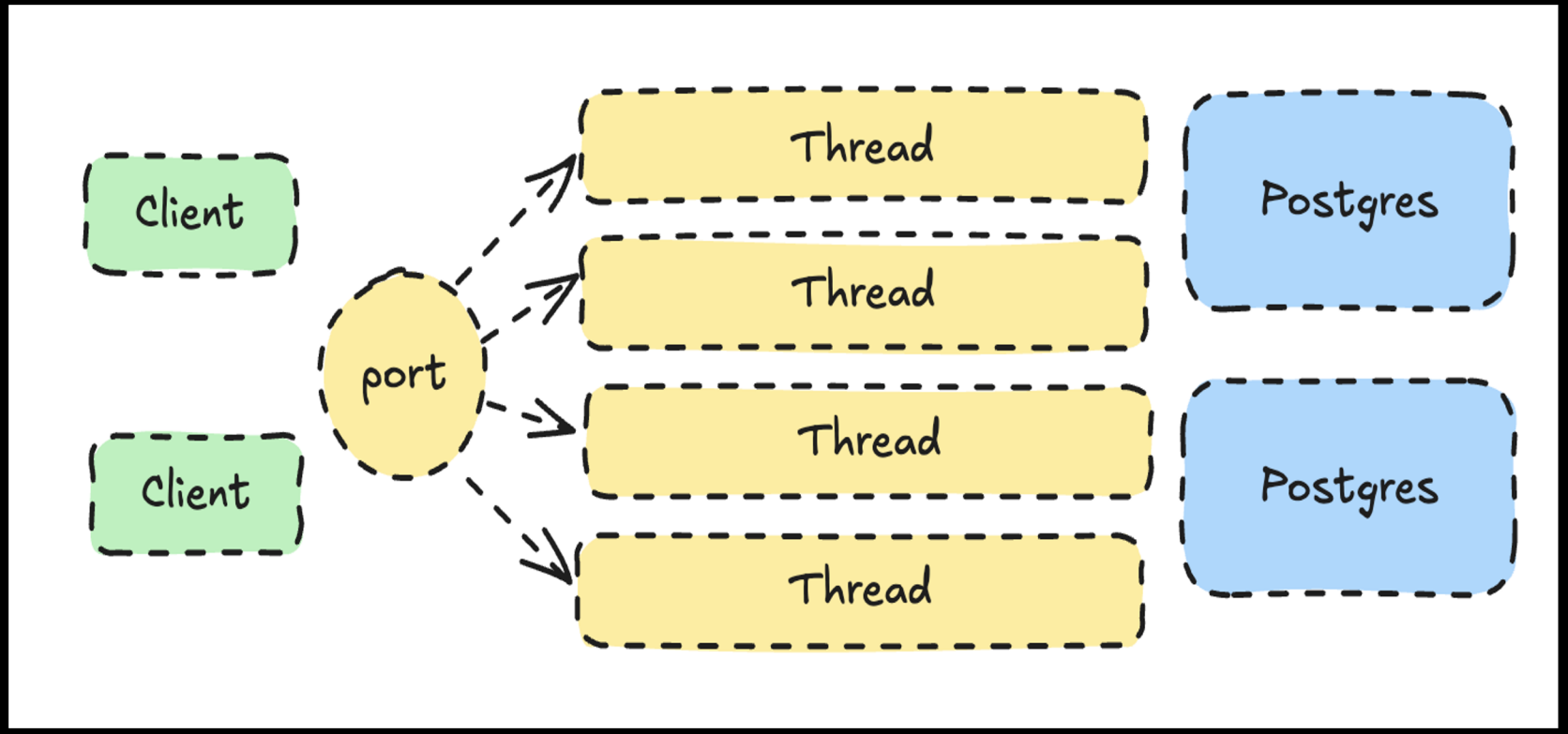
Worker Threads Listen on the Port (peer with shared memory)



- Kernel distributes the connections
- SO_REUSEPORT on different platforms

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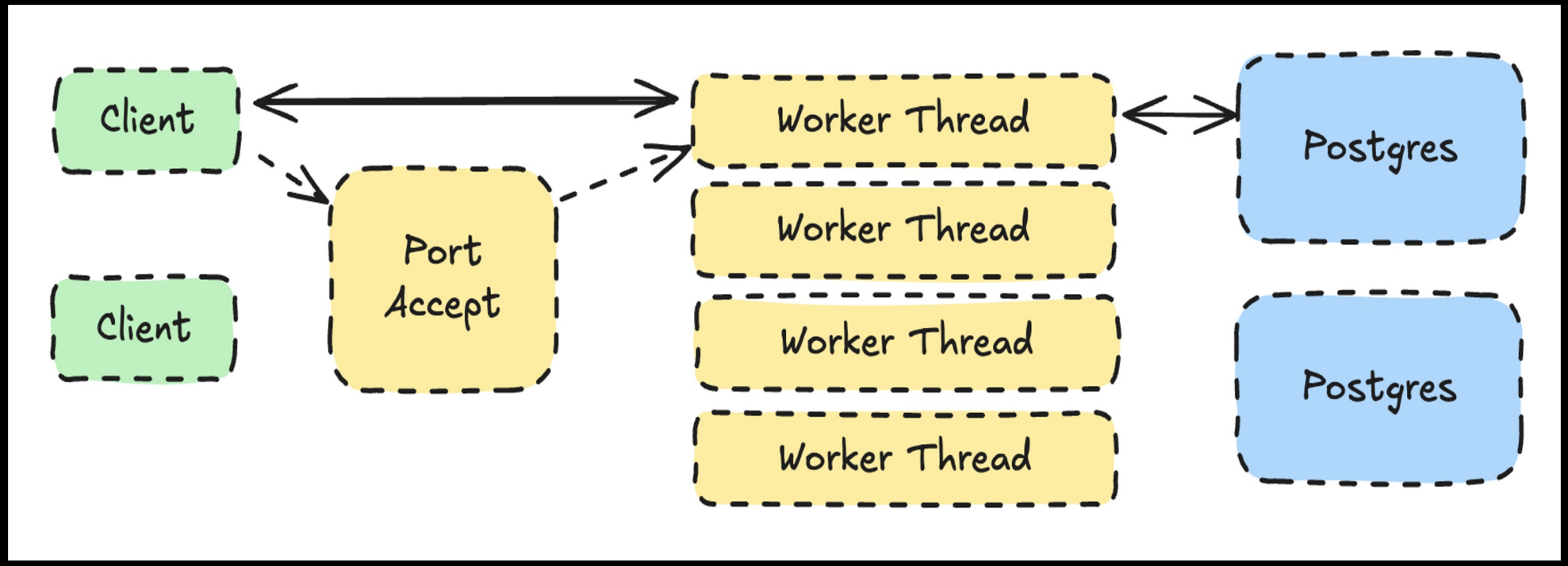
Connection-Thread Affinity

- Each connection’s requests are always handled by a single thread
- Each thread dispatches its own event base



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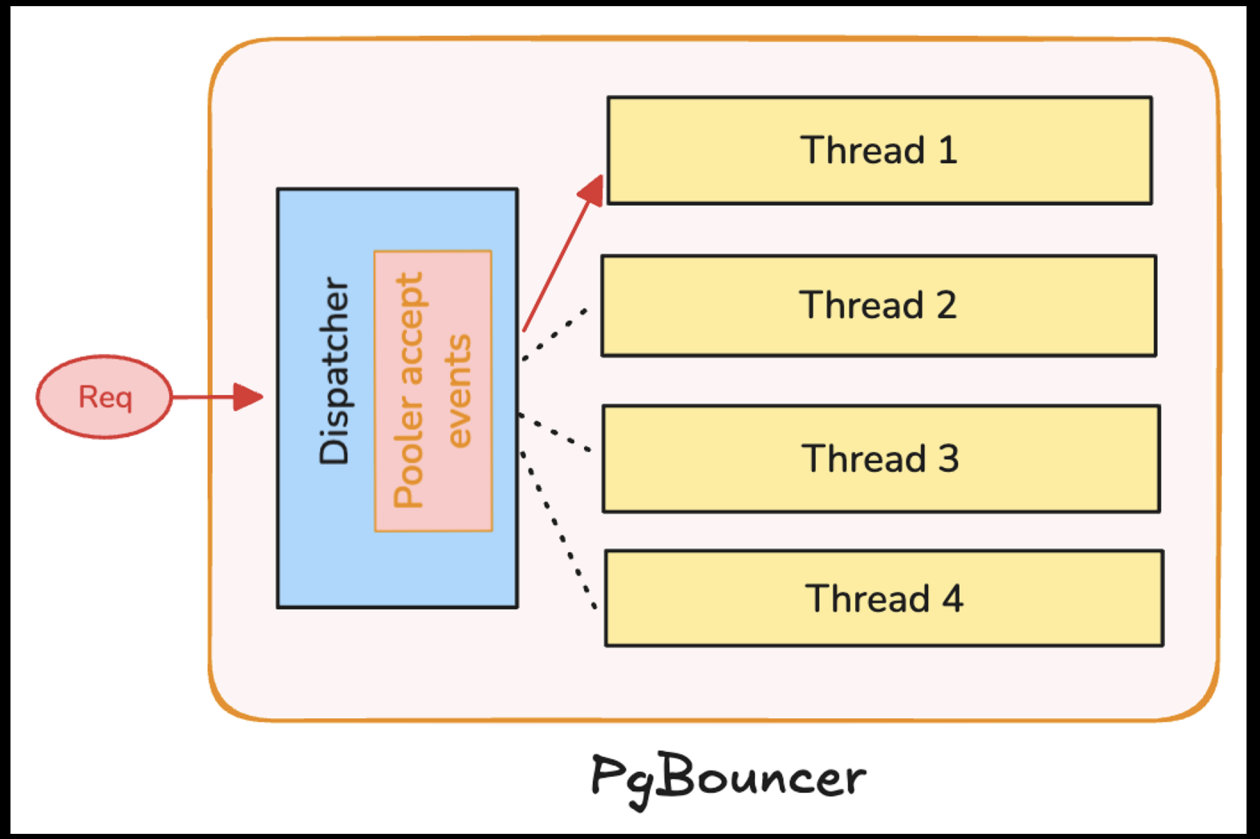
Multi-Threaded PgBouncer: Thread Model

Main thread:

- Accepts new client connections from TCP/Unix sockets
- *Dispatches* file descriptors to worker threads



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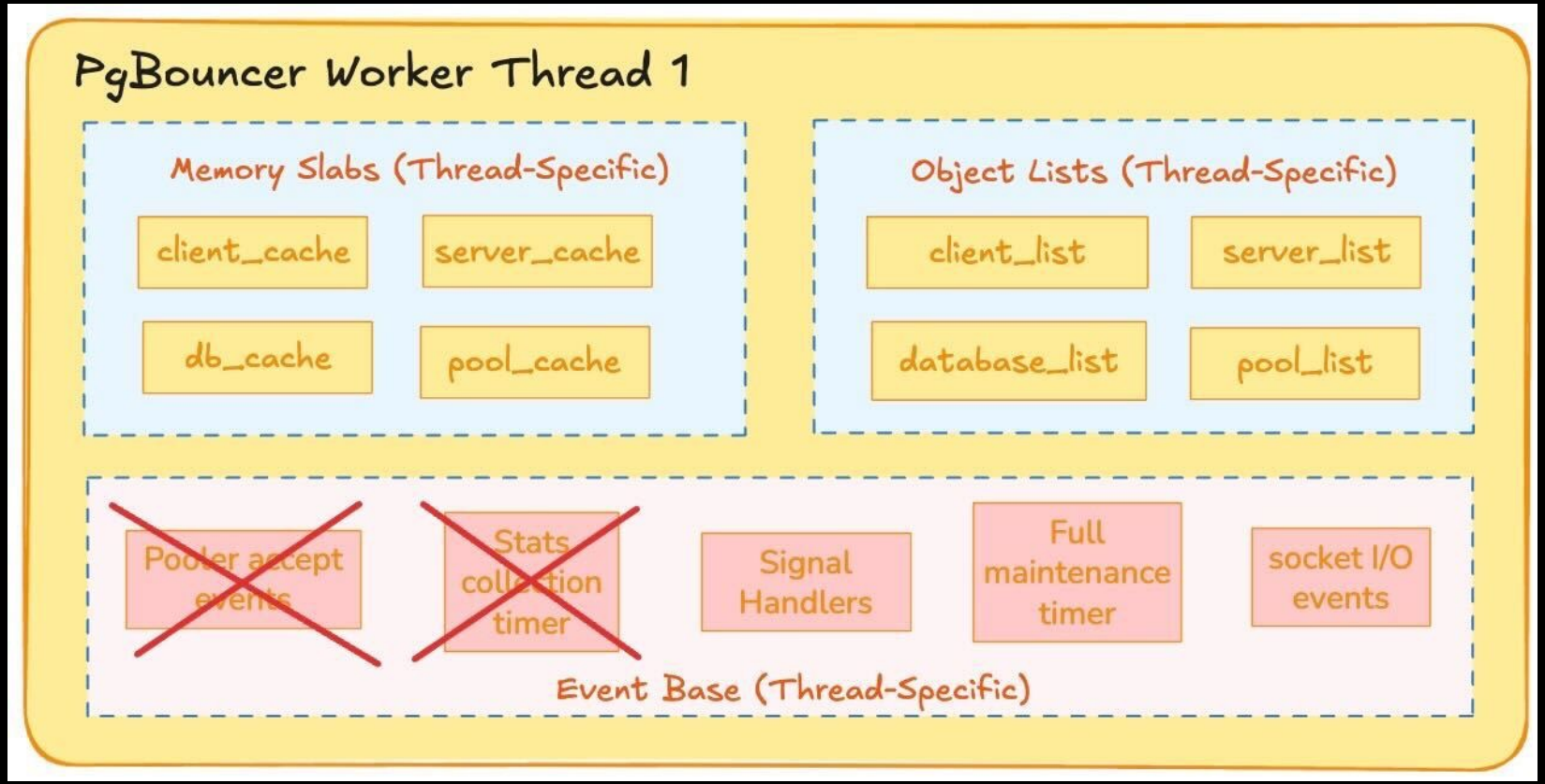
Multi-Threaded PgBouncer: Thread Model

Worker thread:

- Each worker maintains its own event loop, connection pools, and memory slabs



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Implementation Challenges

1. Short Critical Sections

2. Deadlocks

3. Cross-thread operations

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How Close to Lock-Free?

- Stats
- Admin (KILL Client, KILL db …)
- Limits (max_db_connections …)
- Prepared Statements

Thread Safety

- Locking
- Thread Pausing

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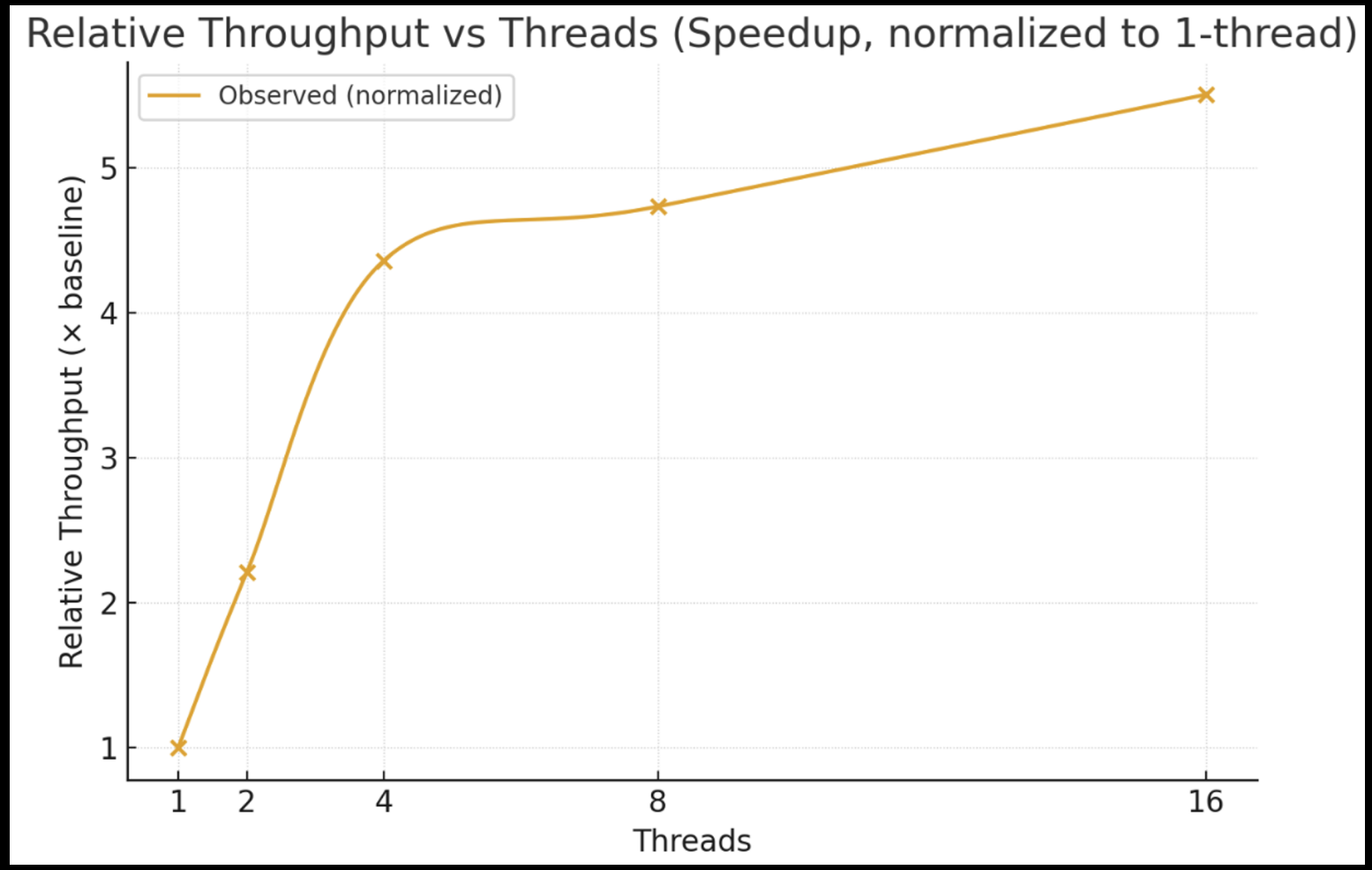
Benchmarking - PgBouncer on a dedicated server



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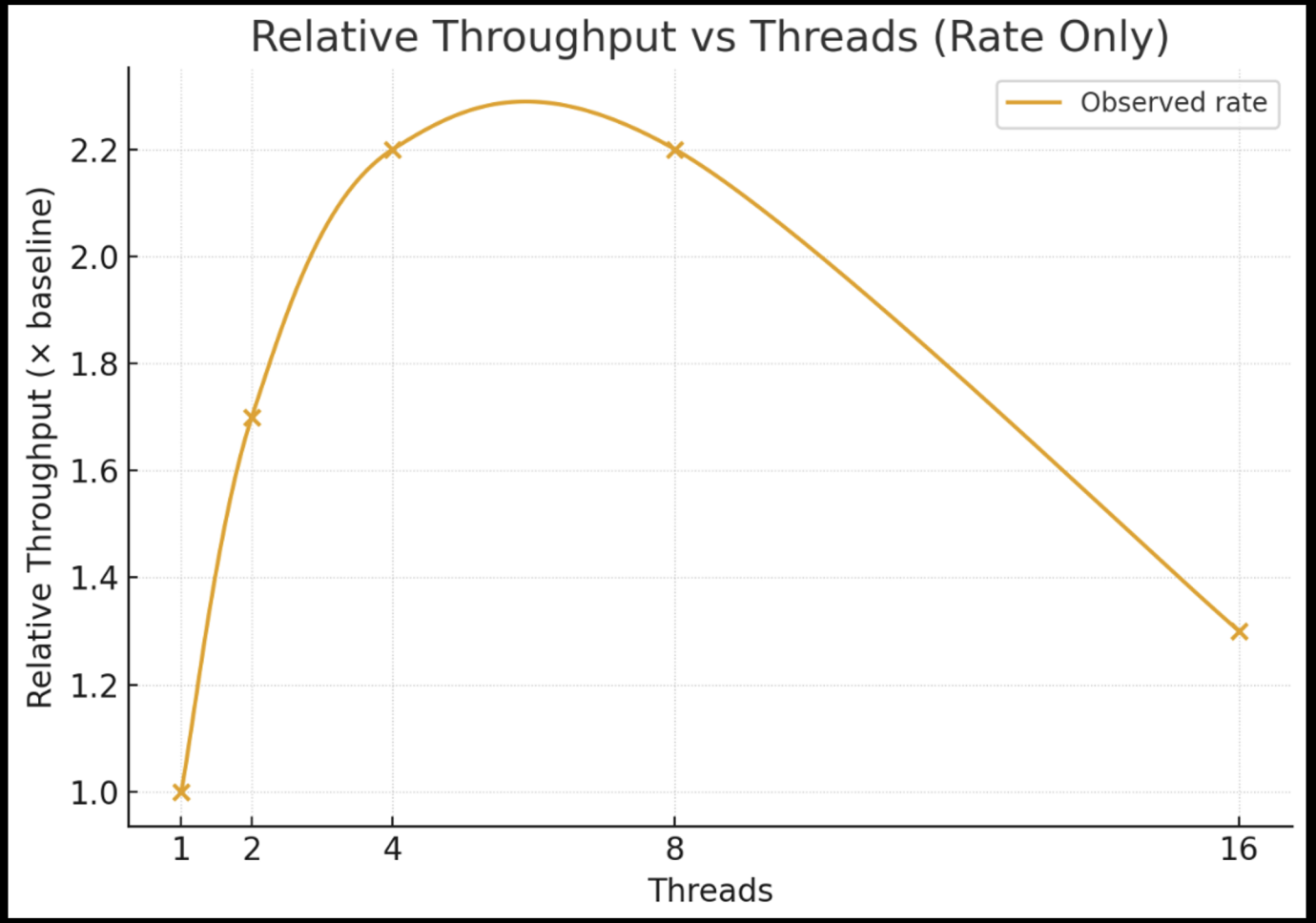
Benchmarking - PgBouncer on a Postgres server



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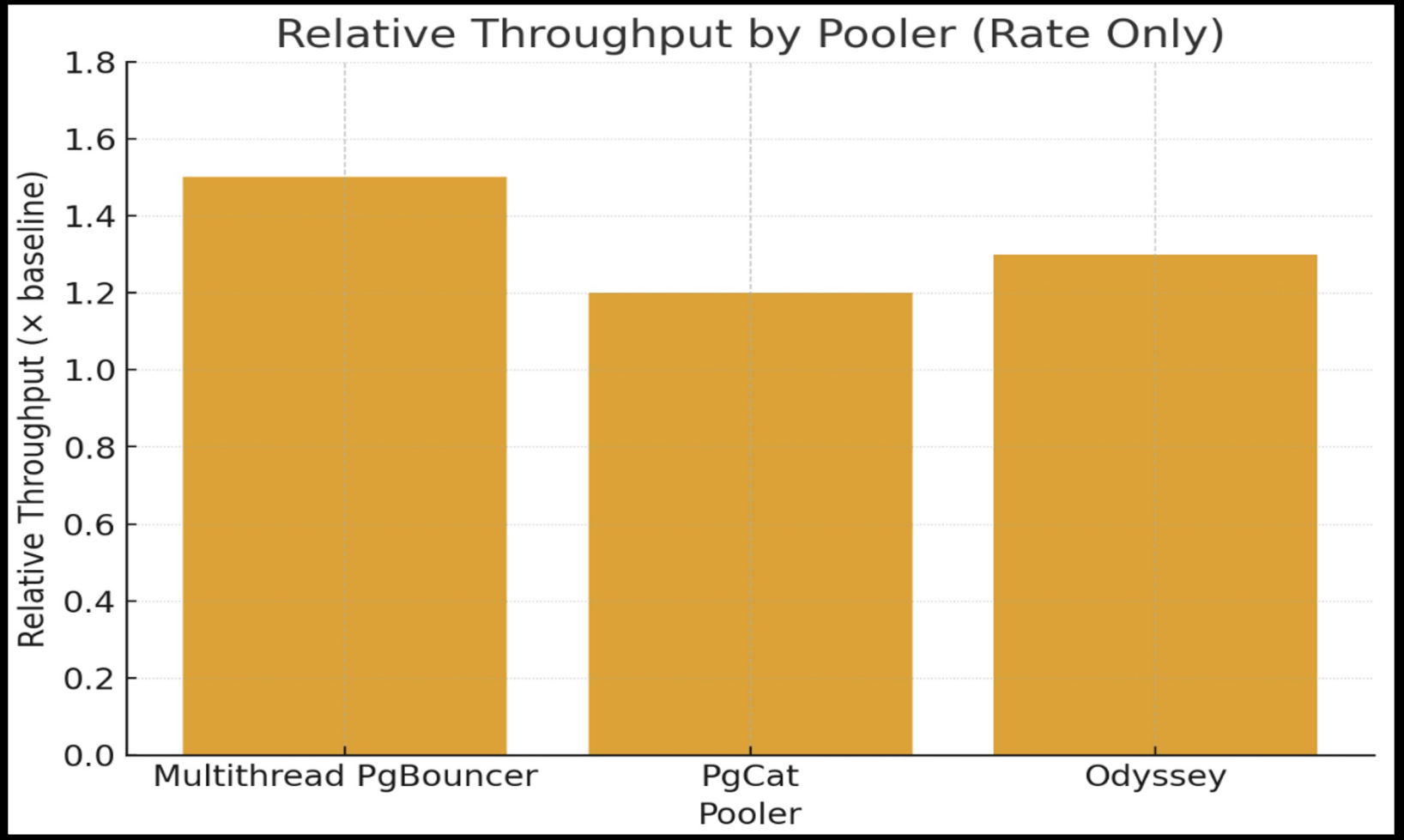
Benchmarking - Poolers on a Postgres server



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Squeeze More from Threads

- Avoid frequent stats collection; longer stat period
- Avoid frequent automated admin actions
- Finding the Right PgBouncer Settings

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What’s Different: Connection Limits in Multithreaded Mode

- **Less strict accuracy:** Limits are not as precise as in single-threaded mode
- **Bounded deviation:** Actual connections may exceed the limit slightly, but never more than *limit* + *thread count*

Rollout Plan!

PR: https://github.com/pgbouncer/pgbouncer/pull/1386

How to Use

- **No changes:** If you don’t change anything, PgBouncer behaves exactly as before (single-threaded)
- **Opt-in multithread:** Enable by thread_number in config
- **Dual mode during rollout:** We’ll keep the single-threaded mode until bugs and performance issues are fully resolved
- **Same binary:** Use the **same binary** to benchmark and test both modes

Acknowledgement

Bloomberg’s Databases Guild ❤️ Open Source Software!

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Thank you!

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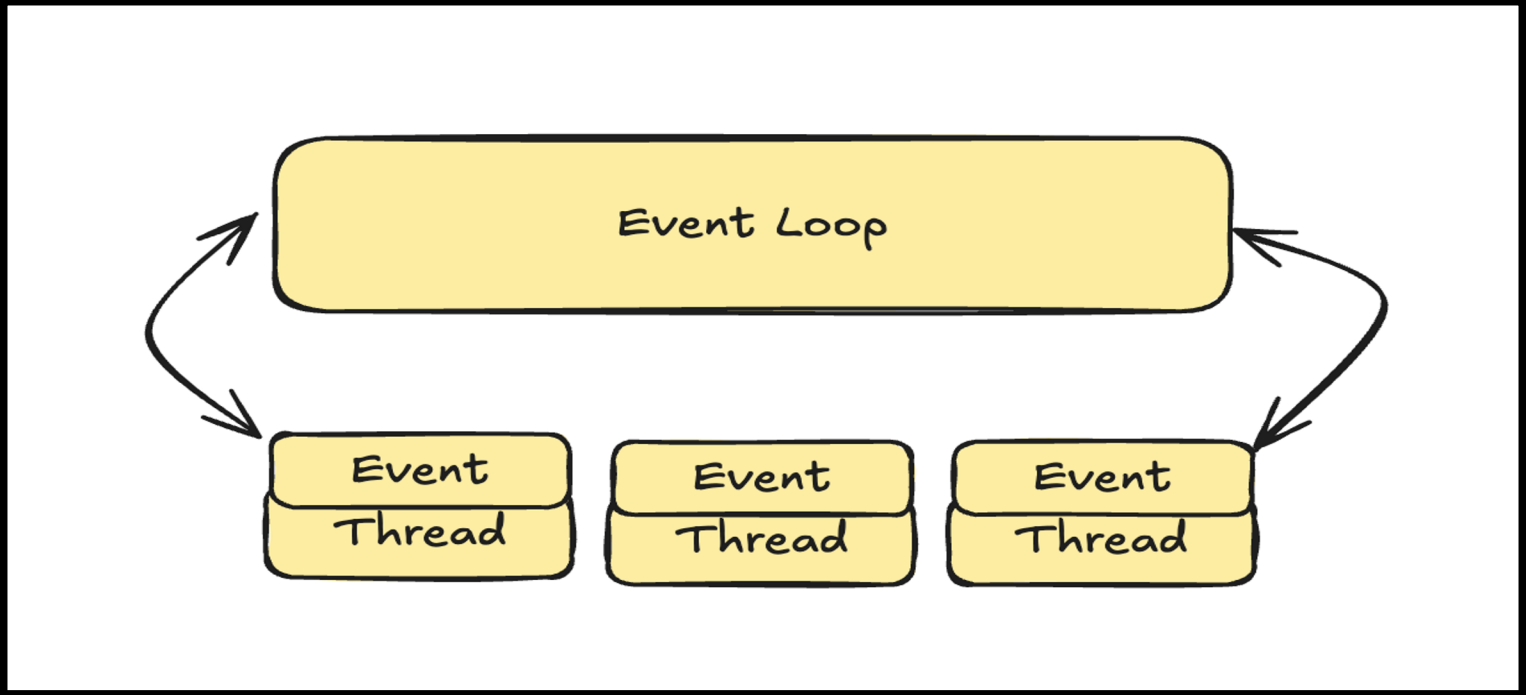
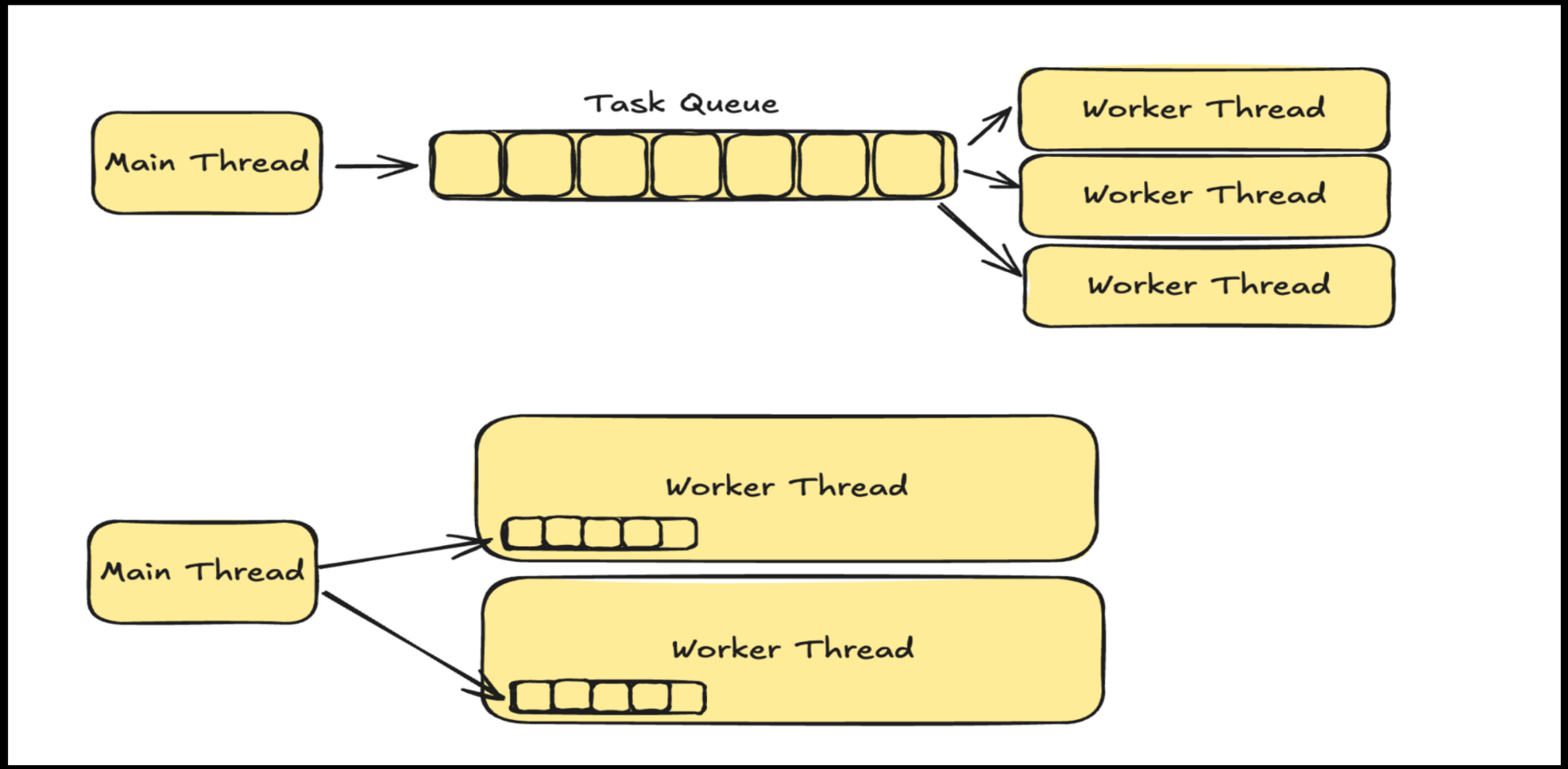
Single Event Loop vs. Multiple Event Loops

- Multiple threads dispatch a single event base, but this would force all threads to share all data structures, requiring excessive locking



Pull vs. Push



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Tuning the Accept/Consume Ratio

- Ratio is difficult to tune, influenced by many factors
- Current implementation shows no obvious backlog
- A switch to **limit accept rate** was considered