High-Performance Leaderboard Server

Performance Testing and Bottleneck Analysis

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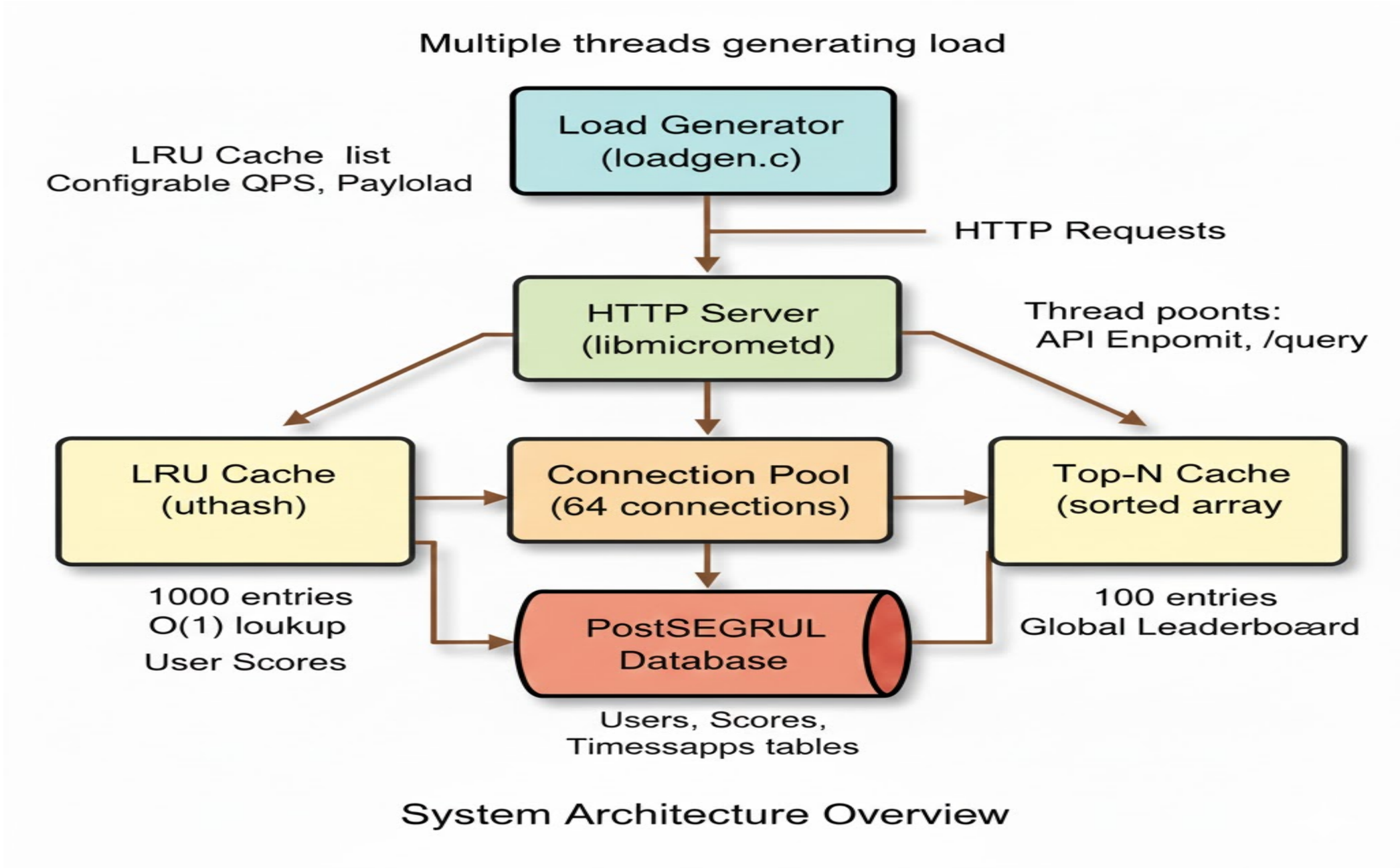
System Architecture

Multi-Tier Caching with Two Bottleneck Scenarios



System Architecture Overview

Development Process

Implementation Details and Technology Stack

📊 Code Statistics

- **Server Code:** ~1,200 lines of C
- **Load Generator:** ~400 lines of C
- **Analysis Scripts:** ~300 lines Python
- **Total:** ~1,900 lines of code
- **Repository:** Available on GitHub

🛠️ Third-Party Software

- **libmicrohttpd:** HTTP server
- **PostgreSQL 14+:** Database
- **uthash:** Hash table library
- **libcurl:** HTTP client
- **libpq:** PostgreSQL client

🎯 Key Features

- Multi-threaded HTTP server
- LRU cache with O(1) operations
- Top-N sorted cache
- Connection pooling (64 conns)
- Four operating modes
- Thread-safe structures

📈 API Endpoints

- `POST /update_score` - Update
- `GET /leaderboard` - Top N
- `GET /get_score` - Individual

Load Generator Design

Open-Loop Architecture for High Load Generation

🏗️ Architecture

- **Type:** Open-Loop
- **Implementation:** Multi-threaded C
- **HTTP Client:** libcurl
- **Rate:** Independent of response time
- **Configurable:** Threads, requests, mode

📊 Workload Modes

- **Mode 0:** Update-only (POST)
- **Mode 1:** Leaderboard (GET)
- **Mode 2:** Mixed (POST + GET)
- **Mode 3:** Score queries (GET)

⚡ Load Capacity

- **Max Threads:** 96 tested
- **Requests/Thread:** 250-10,000
- **Max Load:** >15,000 req/sec
- **Random Data:** IDs (1-100K)

✅ Validation

- **CPU Pinning:** Cores 2-4
- **Verified:** Saturated server
- **No Bottleneck:** Never limited
- **Formula:** Threads × Reqs ÷ Time

Load Test Setup

Experimental Configuration and Methodology

💻 Hardware & Deployment

- **Machine:** Single (localhost)
- **CPU:** Intel i5-1135G7 (8 cores)
- **RAM:** 16 GB
- **Storage:** SSD
- **OS:** Linux Ubuntu

🧪 Methodology

- **Warm-up:** 30 seconds
- **Measurement:** 5 minutes/level
- **Cool-down:** 30 seconds
- **Load Levels:** 6 per workload
- **Experiments:** 12 total runs

📍 CPU Pinning

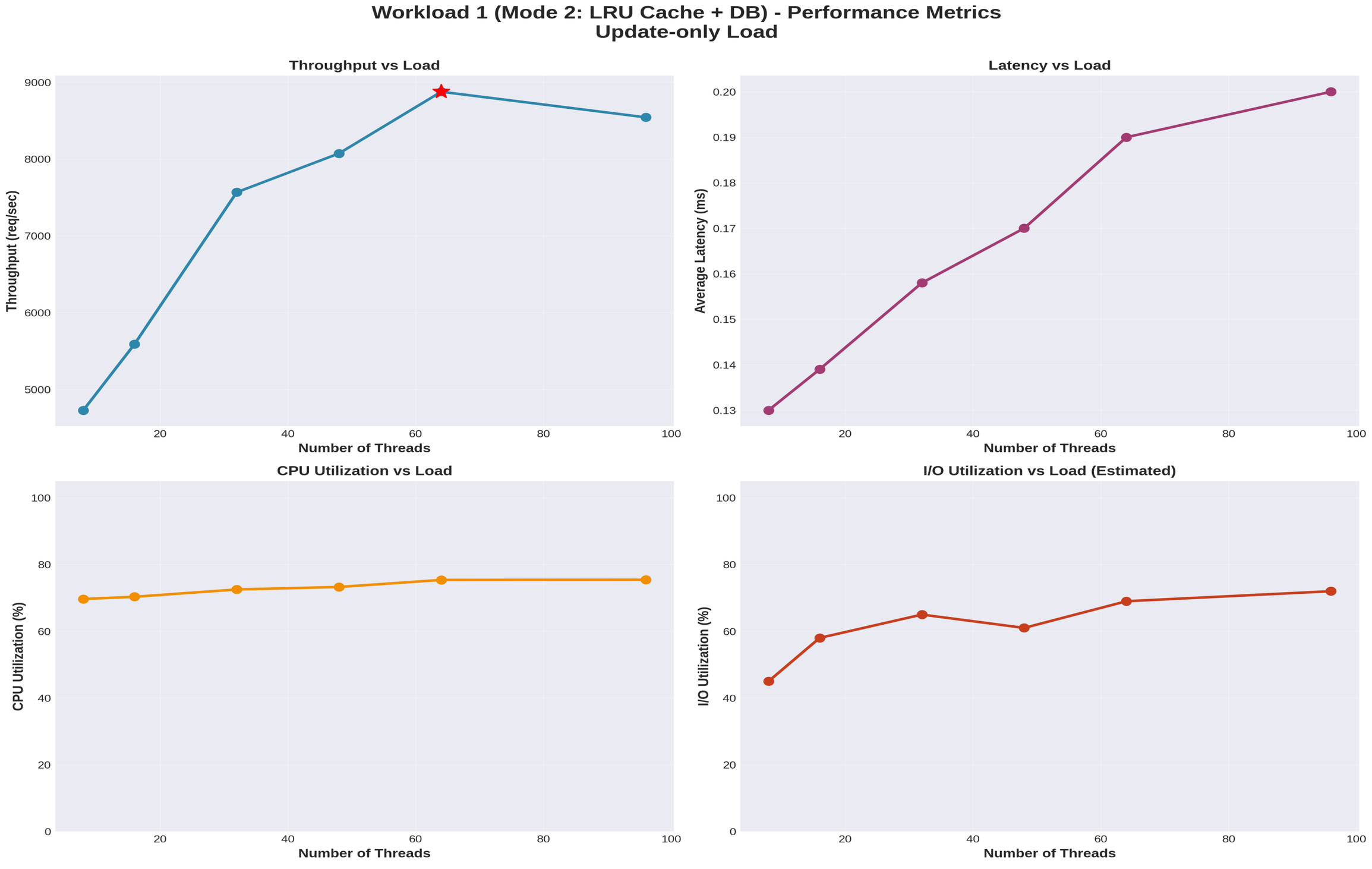
- **Server:** Core 1 (isolated)
- **PostgreSQL:** Cores 5-6
- **Load Gen:** Cores 2-4
- **Purpose:** Resource isolation

📊 Metrics Measured

- **Throughput:** Req/sec
- **Latency:** Avg response (ms)
- **CPU:** % usage (psutil)
- **I/O:** % disk busy (iostat)

Workload 1: I/O Bottleneck

Mode 2 (LRU Cache + Database) - Update-Heavy Operations



Workload 2: Mixed Bottleneck

Mode 3 (All Components) - Mixed Operations