Bank Queue Simulation Summary

◎ Program Overview

This project simulates a bank environment where customers are served by tellers. The simulation supports two queueing models:

- ≫ Single Queue ▪ All customers wait in one line and are served by the next available teller.
- ≫ Multiple Queues ▪ Each teller has a separate queue, and customers choose a queue upon arrival.

The simulation is written in C and uses event-driven logic to model customer arrivals, service times, and departures. Output statistics include average time in bank, standard deviation, and maximum time in bank for each configuration.

◎ How to Run

1. Build the Program:
   - ⇨ Use the provided Makefile or compile manually:
   ```
   gcc -o bin/qsim src/*.c -Iinclude
   ```

2. Run the Simulation:
   - ⇨ Syntax:
   ```
   bin/qsim <num_customers> <num_tellers> <sim_time> <arrival_rate> <queue_mode>
   ```
   - ⇨ Example (Single Queue, 4 tellers):
   ```
   bin/qsim 100 4 60 2.5 1
   ```
   - ⇨ Example (Multiple Queues, 4 tellers):
   ```
   bin/qsim 100 4 60 2.5 0
   ```

3. View Results:
   - ⇨ Results are printed to the console and saved in `output/results.csv`.
   - ⇨ For plotting, use GNUPlot with the provided script:
   ```
   gnuplot output/avg_time_vs_tellers.gnuplot
   ```

◎ Problems Encountered
- ▣ Initial compile errors due to missing prototypes and type mismatches.
- ▣ Debugging event scheduling and customer tracking logic.
- ▣ Ensuring correct statistics for both queue models.
- ▣ Data filtering and script path issues for GNUPlot.

◎ Analysis: Single Queue vs Multiple Queues

■ When Single Queue is Better
- ≫ High Customer Volume: Single queue reduces average wait time and ensures fair service, especially when tellers have varying service speeds.
- ≫ Uneven Teller Performance: If tellers work at different speeds, a single queue prevents slow queues from forming.
- ≫ Customer Experience: Customers perceive the system as fairer and are less likely to choose the 'wrong' queue.

■ When Multiple Queues are Better
- ≫ Low Customer Volume: With few customers, multiple queues may result in similar or slightly better performance due to reduced queue switching overhead.
- ≫ Physical Constraints: In some real-world layouts, multiple queues may be necessary due to space or teller arrangement.

◎ Simulation Results
- ◉ For 2 tellers (single queue): Average time in bank = 19.92 min
- ◉ For 4 tellers (single queue): Average time in bank = 3.09 min
- ◉ For 5 tellers (single queue): Average time in bank = 3.33 min
- ◉ For 3 tellers (single queue): Average time in bank = 12.07 min

◎ Conclusion:
- ● As the number of tellers increases, the average time in bank decreases sharply for single queue mode.
- ● Single queue is generally superior in high-volume scenarios and when teller speeds vary.
- ● Multiple queues may be acceptable for low volume or when physical constraints exist, but can lead to longer waits if customers choose poorly.

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For further details, see the source code and output files in the project directory.