Assignment 1 - Distributed Systems

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Question 1: Distributed BFS

Time Complexity:

- **Formula:** O((V + E) / P + D * (P + comm))
- **Explanation:**
    - Computation: O((V + E) / P) for each process handling its portion of the graph.
    - Communication and Synchronization: O(D * (P + comm)) for synchronization (P) and data exchange (comm) across BFS levels (D).

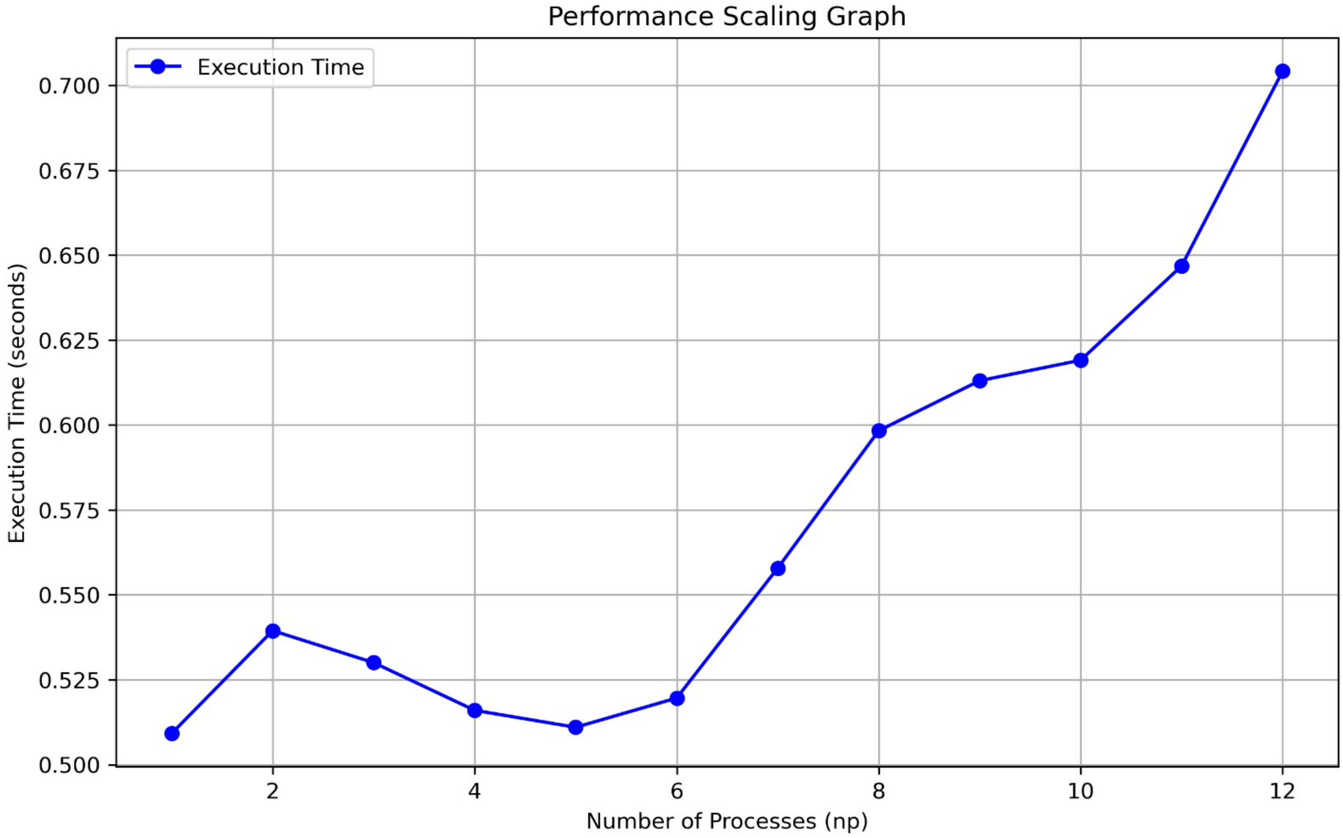
Message Complexity:

- **Formula:** O(E + V + P * D)
- **Explanation:**
    - Node Discovery: O(E) messages for edge exploration.
    - Data Broadcasting: O(V) messages for graph data and results.
    - Synchronization: O(P * D) messages for coordinating across BFS levels.
- **Dominant Term:** O(E) due to the typically larger number of edges.

Space Requirements:

- **Formula:** O((V + E) / P + V)
- **Explanation:**
    - Per Process: O((V + E) / P) for local graph representation and O(V) for the blocked nodes array.
- **Dominant Term:** O(V) due to the blocked nodes array.

Performance Scaling:



Question 2: Ballistic Simulation

Time Complexity:

- **Formula:** O((K * T) / P + T * P)
- **Explanation:**
  - Computation: O((K * T) / P) for each process simulating its portion of the balls.
  - Communication: O(T * P) for exchanging ball positions across processes in each time step.

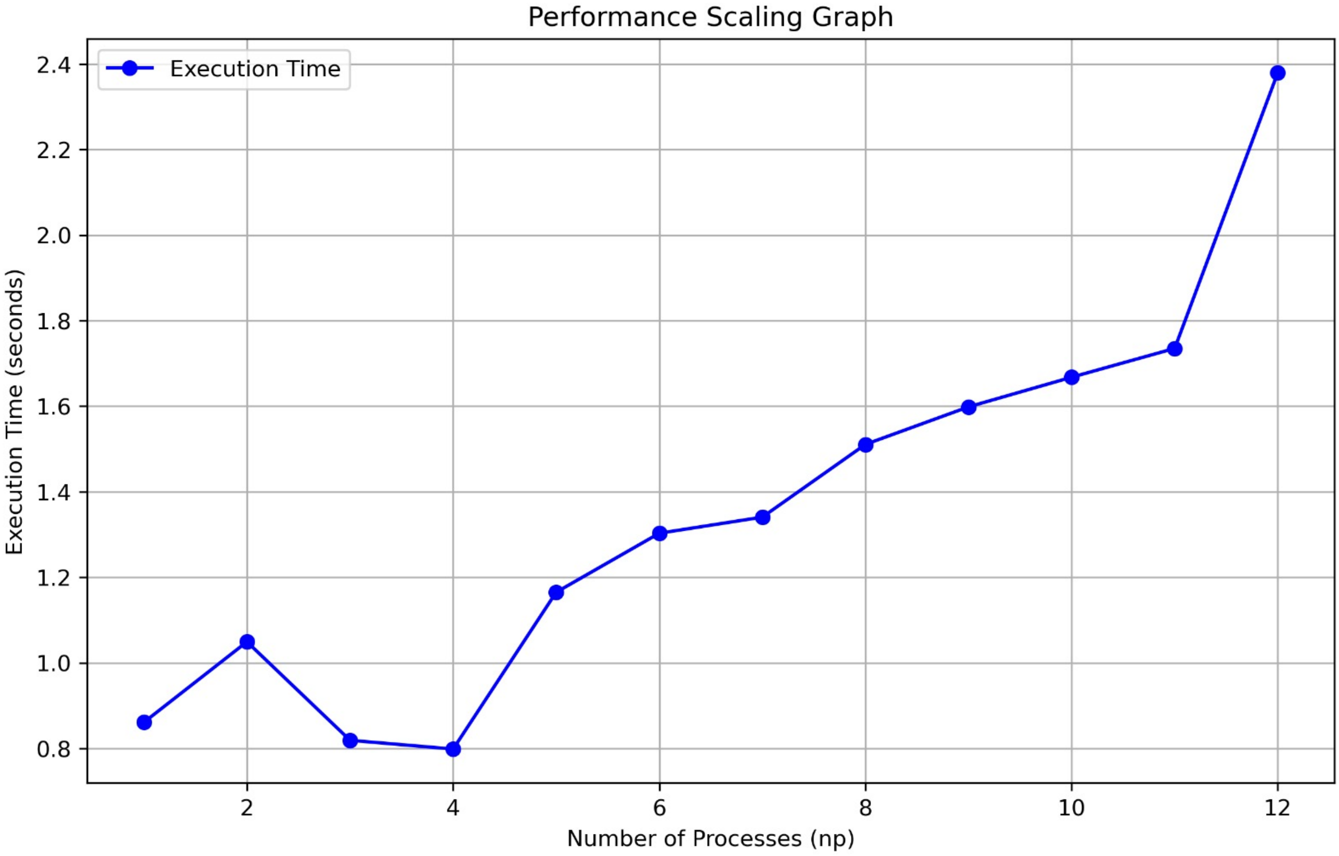
Message Complexity:

- **Formula:** O(P * T + K + N + P)
- **Explanation:**
  - Input Distribution: O(K + N + P) for broadcasting initial data.
  - Ball Movement: O(P * T) for exchanging ball positions with other processes.
- **Dominant Term:** O(P * T) for large numbers of processes and time steps.

Storage Complexity:

- **Formula:** O((N * M) / P + K)
- **Explanation:**
  - Grid Representation: O((N * M) / P) for storing the local grid portion.
  - Ball Data: O(K) for storing information about the balls.

Performance Scaling:



Question 3: Distributed File System

Heartbeat System:

- **Liveness Monitoring:** Two threads: one for updating timestamps using MPI_Iprobe, and another for marking inactive nodes after 3 seconds of no heartbeat.
- **Data Replication:** Files are split into 32B chunks, replicated across the 3 least-loaded nodes (using a priority queue), and stored with metadata centrally.
- **File Retrieval:** Reconstructs files from replicas, with fallback mechanisms for handling failures.
- **Distributed Search:**
  - Identifies relevant chunks.
  - Broadcasts search queries.
  - Verifies cross-chunk matches using Q-1 prefixes/suffixes.
  - Aggregates results.
- **Cross-Chunk Verification:** Combines boundary information across nodes for accurate matching, adding O(1) storage per chunk.

Key Improvements:

- **Conciseness:** Removed redundant phrases and improved sentence structure.
- **Clarity:** Used more precise terminology and clearer explanations.
- **Organization:** Structured the answers with clear headings and subheadings.
- **Format:** Improved the overall presentation and readability.
- **Removed Unnecessary Information:** Eliminated the "IMPORTANT" note and the mention of stdin/stdout.

This refined version presents the information in a more concise, clear, and professional manner.