PROJECT DESIGN AND DETAILS

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Algorithm

The algorithm used to extend the causal ordering established in Assignment 1 is based on the ISIS ABCAST [1] algorithm. The ISIS ABCAST [1] algorithm is a "BB" (broadcast-broadcast) variant [2] of fixed sequencer algorithms where the messages from any process are broadcast to all the processes in the system, following which the elected sequencer totally orders said message, and broadcasts the resulting order to all processes. The total order is broadcast using a sequence number assigned by the sequencer to every message it receives. Here is an abstract of the algorithm used:

I. Assumptions:

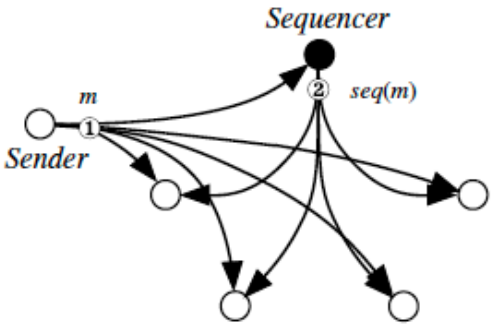


Figure 1: BB Sequencer Algorithm [2]

a. The system consists of N processes.
b. FIFO (First-In-First-Out) delivery and reliable channels.

II. Data Structures:
a. queue: A priority queue of pending messages at each process, sorted by (proposed, agreed) timestamps.
b. vectorClock[N]: A vector clock to track causal dependencies.
c. messageTimestamp: Tentative timestamp for each message.
d. sequenceNo: Agreed timestamp after sequencing.

III. Algorithm:
a. Sending a Message (Causal Broadcast)
i. Increment vector clock: vectorClock[self] += 1
ii. Attach vector timestamp to the message: msg = (content, vectorClock, senderID)
iii. Send message to all processes (including self).

b. Receiving a Message (Tentative Ordering)

i. Insert message into queue and tag them as messages received but not delivered.
ii. Order the messages based on the *messageTimestamp*. This will ensure that all messages in the priority queue will be causally ordered.

c. Sequencer (Total Order Assignment)
i. For each message in the priority queue, assign *sequenceNo* representing the total ordering of that message.
ii. Broadcast the *sequenceNo* of a message to all processes

d. Final Message Delivery
i. Update the corresponding messages with the received *sequenceNo*.
ii. Sort the queue based on the *sequenceNo*.
iii. Deliver messages based in increasing order of *sequenceNo.*
iv. Remove delivered messages from the queue.

The above algorithm modifies the ISIS ABCAST algorithm by removing the step of processes proposing an order to reduce the number of messages sent. Instead, the elected sequencer dictates the total ordering. To enhance fairness, this algorithm can easily be modified to have a moving sequencer.

Implementation Details

There are 3 main components, comDriver, ChannelManager and MessageBroker, that conduct the whole communication.

- The comDriver calls each phase – channel initialization, communication and channel termination.

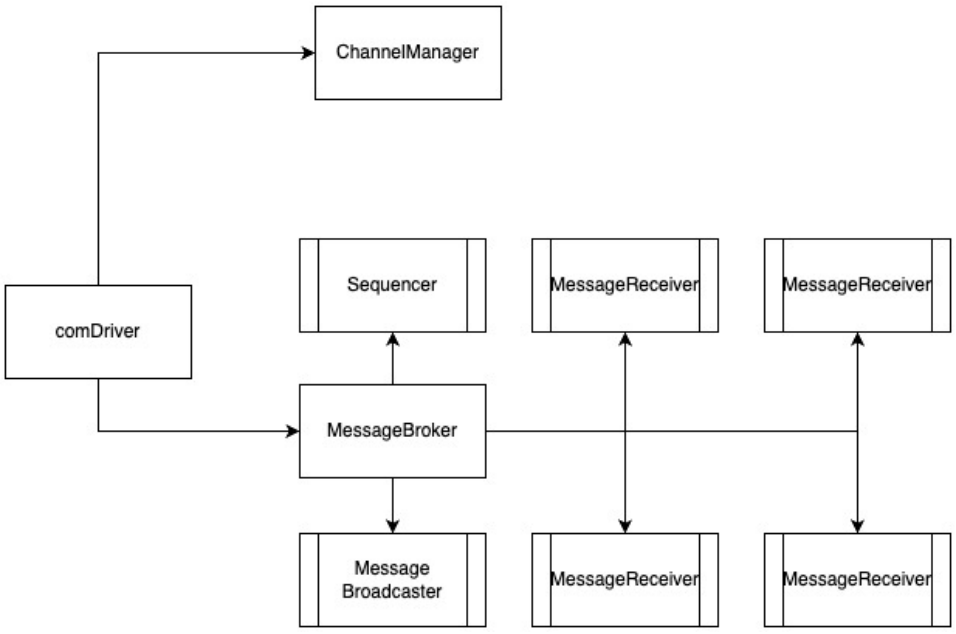


Figure 2: System Components

- Channel Initialization:
  The ChannelManager creates the channels between each process using the following two rules-
  - Each node accepts connections from all nodes with a smaller node number than its own.

    - Each node sends a connection request to all nodes with a larger node number than its own.

  Connections to oneself are not explicitly created. Rather, all communication with oneself is handled within the same process using flags.
- Communication:
    - The messageBroker initializes threads for the sequencer, 4 receivers, and a broadcaster.
    - Receivers accept messages and run the following two actions:
        - If they are application messages, directly place them in the undelivered priority queue.
        - If they are sequenced messages, they are placed in the sequencer priority queue to be evaluated by the sequencer.

      There is no receiver to receive messages from oneself. The broadcaster handles such types of messages.
    - The broadcaster broadcasts new application messages and sequenced messages from the sequencer to all processes in the system.
    - The sequencer thread does the following actions:
        - If it is on the sequencer node, it reads the application messages present in the sequenced queue, assigns a sequence number to the messages, and sends sequenced messages to the broadcaster to broadcast.
        - If on a non-sequencer node, it reads all received sequenced messages and delivers the messages according to the sequence order.

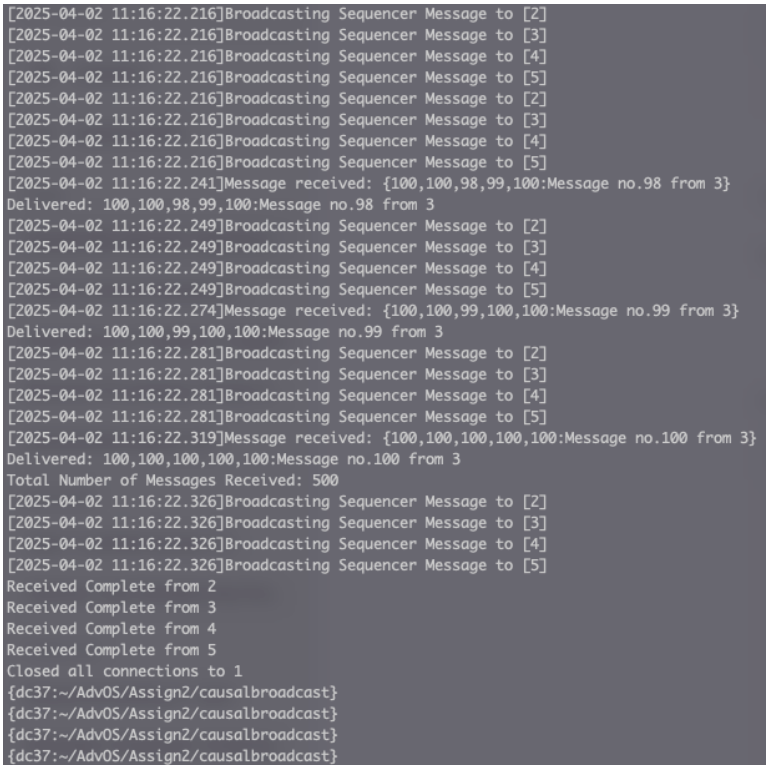
Citations

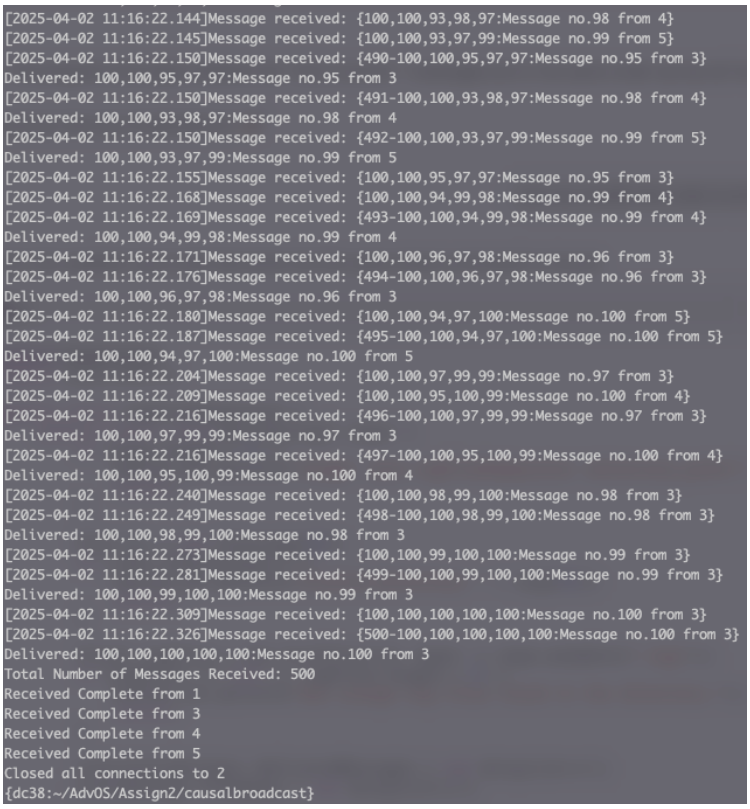
[1] **Ken P. Birman, André Schiper, and Pat Stephenson.** 1991. *Lightweight causal and atomic group multicast.* ACM Trans. Comput. Syst. **9**, 3 (Aug. 1991), 272–314. DOI:10.1145/128738.128742

[2] **Xavier Défago, André Schiper, and Péter Urbán.** 2004. *Total Order Broadcast and Multicast Algorithms: Taxonomy and Survey*. ACM Comput. Surv. **36**, 4 (Dec. 2004), 372–421. DOI:10.1145/1041680.1041682

Screenshots

Given in order of Nodes (1 to 5). Detailed logs are present in the logs folder.





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[2025-04-02 11:16:22.206]Message received: {494-100,100,96,97,98:Message no.96 from 3}
Delivered: 100,100,96,97,98:Message no.96 from 3
[2025-04-02 11:16:22.206]Message received: {495-100,100,94,97,100:Message no.100 from 5}
Delivered: 100,100,94,97,100:Message no.100 from 5
[2025-04-02 11:16:22.209]Message received: {100,100,95,100,99:Message no.100 from 4}
[2025-04-02 11:16:22.237]Broadcasting: 100,100,98,99,100:Message no.98 from 3
[2025-04-02 11:16:22.237]Broadcasting Message to [1]
[2025-04-02 11:16:22.237]Broadcasting Message to [2]
[2025-04-02 11:16:22.237]Broadcasting Message to [4]
[2025-04-02 11:16:22.237]Broadcasting Message to [5]
[2025-04-02 11:16:22.243]Message received: {496-100,100,97,99,99:Message no.97 from 3}
Delivered: 100,100,97,99,99:Message no.97 from 3
[2025-04-02 11:16:22.243]Message received: {497-100,100,95,100,99:Message no.100 from 4}
Delivered: 100,100,95,100,99:Message no.100 from 4
[2025-04-02 11:16:22.269]Broadcasting: 100,100,99,100,100:Message no.99 from 3
[2025-04-02 11:16:22.270]Broadcasting Message to [1]
[2025-04-02 11:16:22.270]Broadcasting Message to [2]
[2025-04-02 11:16:22.270]Broadcasting Message to [4]
[2025-04-02 11:16:22.270]Broadcasting Message to [5]
[2025-04-02 11:16:22.274]Message received: {498-100,100,98,99,100:Message no.98 from 3}
Delivered: 100,100,98,99,100:Message no.98 from 3
[2025-04-02 11:16:22.302]Broadcasting: 100,100,100,100,100:Message no.100 from 3
[2025-04-02 11:16:22.302]Broadcasting Message to [1]
[2025-04-02 11:16:22.302]Broadcasting Message to [2]
[2025-04-02 11:16:22.303]Broadcasting Message to [4]
[2025-04-02 11:16:22.303]Broadcasting Message to [5]
[2025-04-02 11:16:22.317]Message received: {499-100,100,99,100,100:Message no.99 from 3}
Delivered: 100,100,99,100,100:Message no.99 from 3
[2025-04-02 11:16:22.363]Message received: {500-100,100,100,100,100:Message no.100 from 3}
Delivered: 100,100,100,100,100:Message no.100 from 3
Total Number of Messages Received: 500
Received Complete from 1
Received Complete from 2
Received Complete from 4
Received Complete from 5
Closed all connections to 3
{dc39:~/AdvOS/Assign2/causalbroadcast}
{dc39:~/AdvOS/Assign2/causalbroadcast}
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[2025-04-02 11:16:22.203]Broadcasting: 100,100,95,100,99:Message no.100 from 4
[2025-04-02 11:16:22.203]Broadcasting Message to [1]
[2025-04-02 11:16:22.204]Broadcasting Message to [2]
[2025-04-02 11:16:22.204]Broadcasting Message to [3]
[2025-04-02 11:16:22.204]Broadcasting Message to [5]
[2025-04-02 11:16:22.208]Message received: {100,100,97,99,99:Message no.97 from 3}
[2025-04-02 11:16:22.215]Message received: {493-100,100,94,99,98:Message no.99 from 4}
Delivered: 100,100,94,99,98:Message no.99 from 4
[2025-04-02 11:16:22.215]Message received: {494-100,100,96,97,98:Message no.96 from 3}
Delivered: 100,100,96,97,98:Message no.96 from 3
[2025-04-02 11:16:22.215]Message received: {495-100,100,94,97,100:Message no.100 from 5
}
Delivered: 100,100,94,97,100:Message no.100 from 5
[2025-04-02 11:16:22.245]Message received: {100,100,98,99,100:Message no.98 from 3}
[2025-04-02 11:16:22.259]Message received: {496-100,100,97,99,99:Message no.97 from 3}
Delivered: 100,100,97,99,99:Message no.97 from 3
[2025-04-02 11:16:22.259]Message received: {497-100,100,95,100,99:Message no.100 from 4
}
Delivered: 100,100,95,100,99:Message no.100 from 4
[2025-04-02 11:16:22.259]Message received: {498-100,100,98,99,100:Message no.98 from 3}
Delivered: 100,100,98,99,100:Message no.98 from 3
[2025-04-02 11:16:22.284]Message received: {499-100,100,99,100,100:Message no.99 from 3
}
Delivered: 100,100,99,100,100:Message no.99 from 3
[2025-04-02 11:16:22.299]Message received: {100,100,99,100,100:Message no.99 from 3}
[2025-04-02 11:16:22.311]Message received: {100,100,100,100,100:Message no.100 from 3}
[2025-04-02 11:16:22.327]Message received: {500-100,100,100,100,100:Message no.100 from
 3}
Delivered: 100,100,100,100,100:Message no.100 from 3
Total Number of Messages Received: 500
Received Complete from 1
Received Complete from 2
Received Complete from 3
Received Complete from 5
Closed all connections to 4
{dc40:~/AdvOS/Assign2/causalbroadcast}
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[2025-04-02 11:16:22.174]Message received: {100,100,96,97,98:Message no.96 from 3}
[2025-04-02 11:16:22.176]Broadcasting: 100,100,94,97,100:Message no.100 from 5
[2025-04-02 11:16:22.176]Broadcasting Message to [1]
[2025-04-02 11:16:22.176]Broadcasting Message to [2]
[2025-04-02 11:16:22.176]Broadcasting Message to [3]
[2025-04-02 11:16:22.176]Broadcasting Message to [4]
[2025-04-02 11:16:22.186]Message received: {490-100,100,95,97,97:Message no.95 from 3}
Delivered: 100,100,95,97,97:Message no.95 from 3
[2025-04-02 11:16:22.186]Message received: {491-100,100,93,98,97:Message no.98 from 4}
Delivered: 100,100,93,98,97:Message no.98 from 4
[2025-04-02 11:16:22.186]Message received: {492-100,100,93,97,99:Message no.99 from 5}
Delivered: 100,100,93,97,99:Message no.99 from 5
[2025-04-02 11:16:22.186]Message received: {493-100,100,94,99,98:Message no.99 from 4}
Delivered: 100,100,94,99,98:Message no.99 from 4
[2025-04-02 11:16:22.186]Message received: {494-100,100,96,97,98:Message no.96 from 3}
Delivered: 100,100,96,97,98:Message no.96 from 3
[2025-04-02 11:16:22.207]Message received: {100,100,97,99,99:Message no.97 from 3}
[2025-04-02 11:16:22.210]Message received: {100,100,95,100,99:Message no.100 from 4}
[2025-04-02 11:16:22.230]Message received: {495-100,100,94,97,100:Message no.100 from 5}
Delivered: 100,100,94,97,100:Message no.100 from 5
[2025-04-02 11:16:22.231]Message received: {496-100,100,97,99,99:Message no.97 from 3}
Delivered: 100,100,97,99,99:Message no.97 from 3
[2025-04-02 11:16:22.231]Message received: {497-100,100,95,100,99:Message no.100 from 4}
Delivered: 100,100,95,100,99:Message no.100 from 4
[2025-04-02 11:16:22.248]Message received: {498-100,100,98,99,100:Message no.98 from 3}
Delivered: 100,100,98,99,100:Message no.98 from 3
[2025-04-02 11:16:22.251]Message received: {100,100,98,99,100:Message no.98 from 3}
[2025-04-02 11:16:22.275]Message received: {100,100,99,100,100:Message no.99 from 3}
[2025-04-02 11:16:22.282]Message received: {499-100,100,99,100,100:Message no.99 from 3}
Delivered: 100,100,99,100,100:Message no.99 from 3
[2025-04-02 11:16:22.310]Message received: {100,100,100,100,100:Message no.100 from 3}
[2025-04-02 11:16:22.326]Message received: {500-100,100,100,100,100:Message no.100 from 3}
Delivered: 100,100,100,100,100:Message no.100 from 3
Total Number of Messages Received: 500
Received Complete from 1
Received Complete from 2
Received Complete from 3
Received Complete from 4
Closed all connections to 5
{dc41:~/AdvOS/Assign2/causalbroadcast}
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