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# Grokking Modern System Design Interview for Engineers & Managers

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# Considerations of a Distributed Messaging Queue's Design

Learn about the factors that affect the design of a messaging queue.

### We'll cover the following

- Ordering of messages
  - Best-effort ordering
  - Strict ordering
    - Sorting
- Effect on performance
  - Managing concurrency

Before embarking on our journey to design a distributed messaging queue, let's discuss some major factors that could significantly affect the design. These include the order of messages, the effect of the ordering on performance, and the management of concurrent access to the queue. We discuss each of these factors in detail below.

## Ordering of messages#

A messaging queue is used to receive messages from producers. These messages are consumed by the consumers at their own pace. Some operations are critical in that they require strict ordering of the execution of the tasks, driven by the messages in the queue.

For example, while chatting over a messenger application with a friend, the messages should be delivered in order; otherwise, such communication can be confusing, to say the least. Similarly, emails received by a user from different users may not require strict ordering. Therefore, in some cases, the strict order of incoming messages in the queue is essential, while many use cases can tolerate some reordering.

Let's discuss the following two categories of messages ordering in a queue:

- *Best-effort ordering*
- *Strict ordering*

**How is the order associated with messages?**

## Best-effort ordering#

With the **best-effort ordering** approach, the system puts the messages in a specified queue in the same order that they're received.

For example, as shown in the following figure, the producer sends four messages, A, B, C, and D, in the same order as illustrated. Due to network congestion or some other issue, message B is received after message D. Hence, the order of messages is A, C, D, and B at the receiving end. Therefore, in this approach, the messages will be put in the queue in the same order they were received instead of the order in which they were produced on the client side.

Best-effort ordering: Messages are placed in a queue in the same order that they're received and not in the

order they were sent

## Strict ordering#

The strict ordering technique preserves the ordering of messages more rigorously. Through this approach, messages are placed in a queue in the order that they’re produced.

Before putting messages in a queue in the correct sequence, it’s crucial to have a mechanism to identify the order in which the messages were produced on the client side. Often, a unique identifier or time-stamp is used to mark a message when it’s produced.

Point to Ponder

Question

Who’ll be responsible for providing the sequence numbers?

Show Answer

One of the following three approaches can be used for ordering incoming messages:

1. **Monotonically increasing numbers:** One way to order incoming messages is to assign monotonically increasing numbers to messages on the server side. When the first message arrives, the system assigns it a number, such as 1. It then assigns the number 2 to the second message, and so on.

However, there are potential drawbacks to this approach. First, when a burst of requests is received, it acts as a bottleneck that affects the system’s performance because the system has to assign an ID in a specified sequence to a message while

the other messages wait for their turn.

Second, it still doesn't tackle the problem that arises when a message is received before the one that's produced earlier at the client side. Because of this, it doesn't guarantee that it will generate the correct order for the messages produced at the client side.

2. **Causality-based sorting at the server side:** Keeping in view the drawbacks of using monotonically increasing numbers, another approach that can be used for time-stamping and ordering of incoming messages is causality-based sorting. In this approach, messages are sorted based on the time stamp that was produced at the client side and are put in a queue accordingly. The major drawback of this approach is that for multiple client sessions, the service can't determine the order in terms of wall-clock time.
3. **Using time stamps based on synchronized clocks:** To tackle the potential issues that arise with both of the approaches described above, we can use another appropriate method to assign time stamps to messages that's based on synchronized clocks. In this approach, the time stamp (ID) provided to each message through a synchronized clock is unique and in the correct sequence of production of messages. We can tag a unique process identifier with the time stamp to make the overall message identifier unique and tackle the situation when two concurrent sessions ask for a time stamp at the exact same time. Moreover, with this approach, the server can easily identify delayed messages based on the time stamp and wait for the delayed messages.

As we discussed in the section on the sequencer building block, we can get sequence numbers that fulfill double duty as sequence numbers and globally synchronized wall clock time stamps. Using this approach, our service can globally order messages across client sessions as well.

To conclude, the most appropriate mechanism to provide a unique ID or time stamp to incoming messages, from among the three approaches described above, involves the use of synchronized clocks.



## Sorting#

Once messages are received at the server side, we need to sort them based on their time stamps. Therefore, we use an appropriate online sorting algorithm for this purpose.

Point to Ponder

### Question

Suppose that a message sent earlier arrives late due to a network delay. What would be the proper approach to handle such a situation?

Show Answer

## Effect on performance#

Primarily, a queue is designed for first-in, **first-out (FIFO) operations**; First-in, first-out operations suggest that the first message that enters a queue is always handed out first. However, it isn't easy to maintain this strict order in distributed systems. Since message A was produced before message B, it's still uncertain that message A will be consumed before message B. Using monotonically increasing message identifiers or causality-bearing identifiers provide high throughput while putting messages in a queue. Though the need for the online sorting to provide a strict order takes some time before messages are ready for extraction. To minimize latency caused by the online sorting, we use a time-window approach.

Similarly, for strict ordering at the receiving end, we need to serialize all the requests to give out messages one by one. If that's not required, we have better throughput and lower

latency at the receiving end.

Due to the reasons mentioned above, many distributed messaging queue solutions either don't guarantee a strict order or have limitations around throughput. As we saw previously, the queues have to perform many additional validations and coordination operations to maintain the order.

## Managing concurrency#

Concurrent queue access needs proper management. Concurrency can take place at the following stages:

- When multiple messages arrive at the same time.
- When multiple consumers request concurrently for a message.

The first solution is to use the locking mechanism. When a process or thread requests a message, it should acquire a lock for placing or consuming messages from the queue. However, as was discussed earlier, this approach has several drawbacks. It's neither scalable nor performant.

Another solution is to serialize the requests using the system's buffer at both ends of the queue so that incoming messages are placed in an order and consumer processes also receive messages in their arrival sequence. This is a more viable solution because it can help us avoid the occurrence of race conditions.

Applications might use multiple queues with dedicated producers and consumers to keep the ordering cost per queue under check, although this comes at the cost of more complicated application logic.

Avoiding race conditions: Producers and consumers are serialized at both ends of the queue

In this lesson, we discussed some key considerations and challenges in the design process of a messaging queue and answered the following questions:

- Why is the order of messages important, and how do we enforce that order?
- How does ordering affect performance? How do we handle concurrency while accessing a queue?

Now, we are ready to start designing a distributed messaging queue.

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Design of a Distributed Messaging Qu...

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