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359. Logger Rate Limiter

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Design a logger system that receive stream of messages along with its timestamps, each message should be printed if and only if it is **not printed in the last 10 seconds**.

Given a message and a timestamp (in seconds granularity), return true if the message should be printed in the given timestamp, otherwise returns false.

It is possible that several messages arrive roughly at the same time.

Example:

```
Logger logger = new Logger();

// logging string "foo" at timestamp 1
logger.shouldPrintMessage(1, "foo"); returns true;

// logging string "bar" at timestamp 2
logger.shouldPrintMessage(2,"bar"); returns true;

// logging string "foo" at timestamp 3
logger.shouldPrintMessage(3,"foo"); returns false;

// logging string "bar" at timestamp 8
logger.shouldPrintMessage(8,"bar"); returns false;

// logging string "foo" at timestamp 10
logger.shouldPrintMessage(10,"foo"); returns false;

// logging string "foo" at timestamp 11
logger.shouldPrintMessage(11,"foo"); returns true;
```

Solution

Approach 1: Queue + Set

Intuition

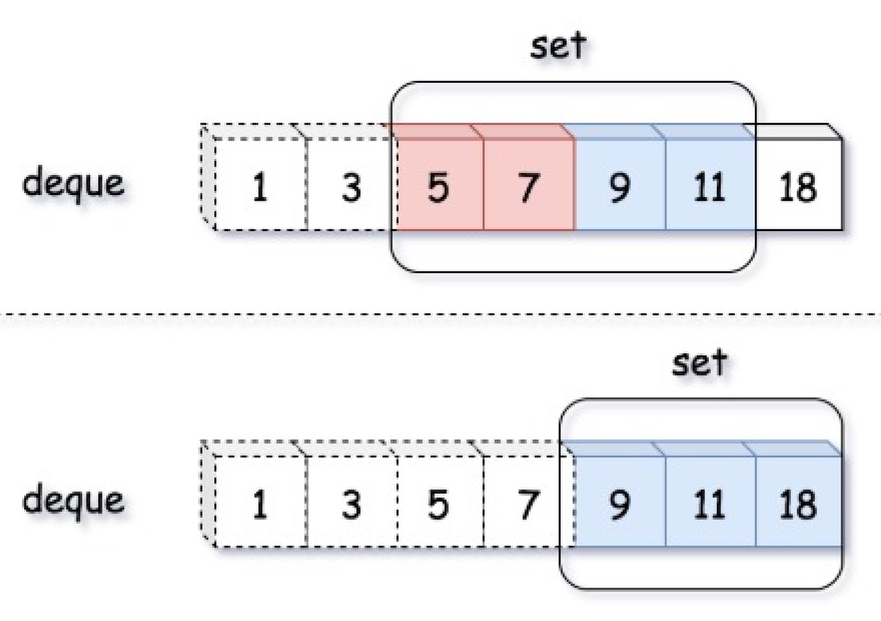
Before we tackle the problem, it is imperative to clarify the conditions of the problem, since it was not explicit in the problem description. Here is one important note:

> It is possible that several messages arrive roughly at the same time.

We could interpret that the input messages are in chronological order, *i.e.* the timestamps of the messages are monotonically increasing, though not *strictly*. This constraint is critical, since it would simplify the task, as one will see in the following solutions.

As a first solution, let us build a solution *intuitively* following the tasks described in the problem.

> We keep the incoming messages in a **queue**. In addition, to accelerate the check of duplicates, we use a **set** data structure to index the messages.



As one see can from the above example where the number indicates the timestamp of each message, the arrival of the message with the timestamp `18` would invalidate both the messages with the timestamp of `5` and `7` which go beyond the time window of 10 seconds.

Algorithm

- First of all, we use a queue as a sort of sliding window to keep all the printable messages in certain time frame (10 seconds).
- At the arrival of each incoming message, it comes with a `timestamp`. This timestamp implies the evolution of the sliding windows. Therefore, we should first invalidate those *expired* messages in our queue.
- Since the `queue` and `set` data structures should be in sync with each other, we would also remove those expired messages from our message set.
- After the updates of our message queue and set, we then simply check if there is any duplicate for the new incoming message. If not, we add the message to the queue as well as the set.

Java Python Copy

```python
from collections import deque

class Logger(object):

    def __init__(self):
        """
        Initialize your data structure here.
        """
        self._msg_set = set()
        self._msg_queue = deque()

    def shouldPrintMessage(self, timestamp, message):
        """
        Returns true if the message should be printed in the given timestamp, otherwise returns false.
        """
        while self._msg_queue:
            msg, ts = self._msg_queue[0]
            if timestamp - ts >= 10:
                self._msg_queue.popleft()
                self._msg_set.remove(msg)
            else:
                break

        if message not in self._msg_set:
            self._msg_set.add(message)
            self._msg_queue.append((message, timestamp))
            return True
```

As one can see, the usage of set data structure is not *absolutely* necessary. One could simply iterate the message queue to check if there is any duplicate.

Another important note is that if the messages are not chronologically ordered then we would have to iterate through the entire queue to remove the expired messages, rather than having *early stopping*. Or one could use some sorted queue such as **Priority Queue** to keep the messages.

Complexity Analysis

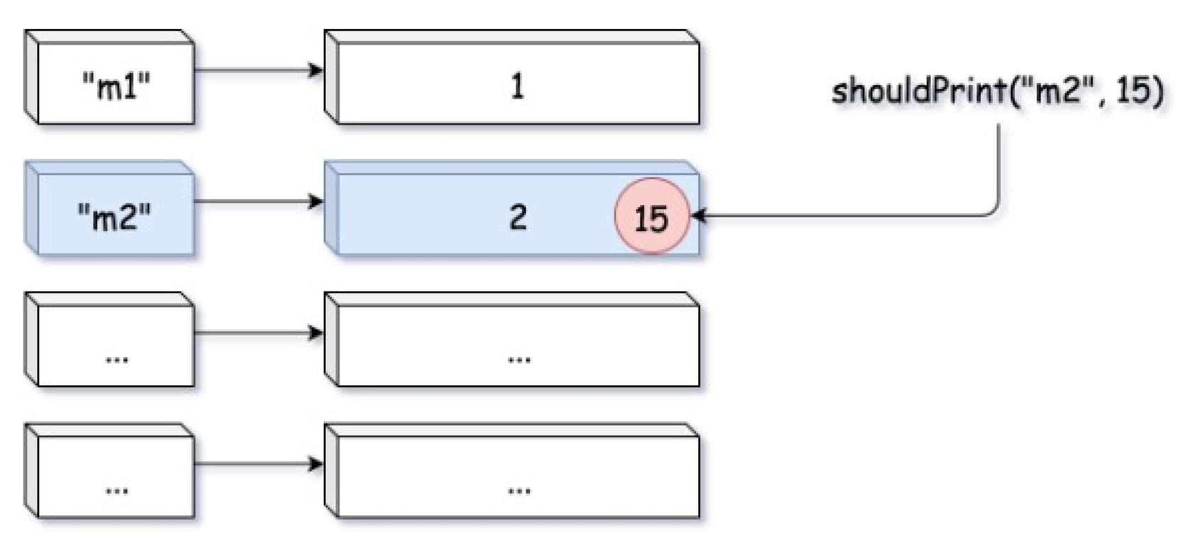
- Time Complexity: $\mathcal{O}(N)$ where N is the size of the queue. In the worst case, all the messages in the queue become obsolete. As a result, we need clean them up.
- Space Complexity: $\mathcal{O}(N)$ where N is the size of the queue. We keep the incoming messages in both the queue and set. The upper bound of the required space would be $2N$, if we have no duplicate at all.

Approach 2: Hashtable / Dictionary

Intuition

One could combine the queue and set data structure into a **hashtable** or **dictionary**, which gives us the capacity of keeping all unique messages as of queue as well as the capacity to quickly evaluate the duplication of messages as of set.

> The idea is that we keep a hashtable/dictionary with the message as key, and its timestamp as the value. The hashtable keeps all the unique messages along with the latest timestamp that the message was printed.



As one can see from the above example, there is an entry in the hashtable with the message `m2` and the timestamp `2`. Then there comes another message `m2` with the timestamp `15`. Since the message was printed 13 seconds before (*i.e.* beyond the buffer window), it is therefore eligible to print again the message. As a result, the timestamp of the message `m2` would be updated to `15`.

Algorithm

- We initialize a hashtable/dictionary to keep the messages along with the timestamp.
- At the arrival of a new message, the message is eligible to be printed with either of the two conditions as follows:
  - case 1). we have never seen the message before.
  - case 2). we have seen the message before, and it was printed more than 10 seconds ago.
- In both of the above cases, we would then update the entry that is associated with the message in the hashtable, with the latest timestamp.

Java Python Copy

```python
class Logger(object):

    def __init__(self):
        """
        Initialize your data structure here.
        """
        self._msg_dict = {}

    def shouldPrintMessage(self, timestamp, message):
        """
        Returns true if the message should be printed in the given timestamp, otherwise returns false.
        """
        if message not in self._msg_dict:
            # case 1). add the message to print
            self._msg_dict[message] = timestamp
            return True

        if timestamp - self._msg_dict[message] >= 10:
            # case 2). update the timestamp of the message
            self._msg_dict[message] = timestamp
            return True
        else:
            return False
```

Note: for clarity, we separate the two cases into two blocks. One could combine the two blocks together to have a more concise solution.

The main difference between this approach with hashtable and the previous approach with queue is that in previous approach we do *proactive* cleaning, *i.e.* at each invocation of function, we first remove those expired messages.

While in this approach, we keep all the messages even when they are expired. This characteristics might become problematic, since the usage of memory would keep on growing over the time. Sometimes it might be more desirable to have the *garbage collection* property of the previous approach.

Complexity Analysis

- Time Complexity: $\mathcal{O}(1)$. The lookup and update of the hashtable takes a constant time.
- Space Complexity: $\mathcal{O}(M)$ where M is the size of all incoming messages. Over the time, the hashtable would have an entry for each unique message that has appeared.

Analysis written by @liaison and @andvary

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nullPtr13 ★ 287 November 26, 2019 6:09 AM

Nice Article !! Thanks for posting it .

I've a suggestion for extending second solution further for more optimization and follow up question for interview.

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susumara ★ 7 February 8, 2020 11:30 AM

Here is a similar solution with memory usage less than 100% of submissions.
You just need to use LinkedHashMap instead of HashMap and maintain the map size to be max of 10.

class Logger {

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heroicVik ★ 4 February 2, 2020 8:31 AM

There is another bug in 1st approach. When the queue is at the max size & you add new message (which is a duplicate message), you deque the 1st element & the method returns false. In this scenario, you should not have dequeued in 1st place, isn't ?

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sahilwad ★ 1 April 2, 2020 1:18 PM

Runtime: 29 ms, faster than 64.20% of Java online submissions for Logger Rate Limiter.
Memory Usage: 48 MB, less than 100.00% of Java online submissions for Logger Rate Limiter.

class Logger {

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undefitied ★ 74 March 7, 2020 10:08 PM

Thank you for the article!
Can anybody explain to me the potential of the first solution?

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ohyeahfanfan ★ 1 January 8, 2020 8:36 PM

Amortized time complexity of solution 1 is O(1) and worst case is O(n)?

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henry26 ★ 44 November 26, 2019 6:22 AM

typo: `queue ans set`

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henry26 ★ 44 November 26, 2019 6:21 AM

thanks i learned from the article. The last paragraph i think can benefit to be repeated at the beginning of article: memory usage will prefer approach 1.

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Prashanth_123 ★ 0 April 30, 2020 11:10 PM

```
class Logger {
    private static final int MINIMUM_TIME_DIFFERENCE = 10;
    Map<String, Integer> map;
```

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box_of_donuts ★ 190 April 24, 2020 1:24 PM

The time complexity given for approach 1 is misleading. Sure, if we are only talking about a single call to the function, at some arbitrary point in time, we might have to remove a bunch of messages that are now obsolete from the queue.

But, consider this: each message in the queue is only ever touched twice, either to enqueue or dequeue.

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