Purgatory는 무엇인가?

강 한구

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Purgatory

가톨릭 교리에서 죽은 사람의 영혼이 살아있는 동안 지은 죄를 씻고 천국으로 가기 위해 일시적으로 머무른다고 믿는 장소이다.

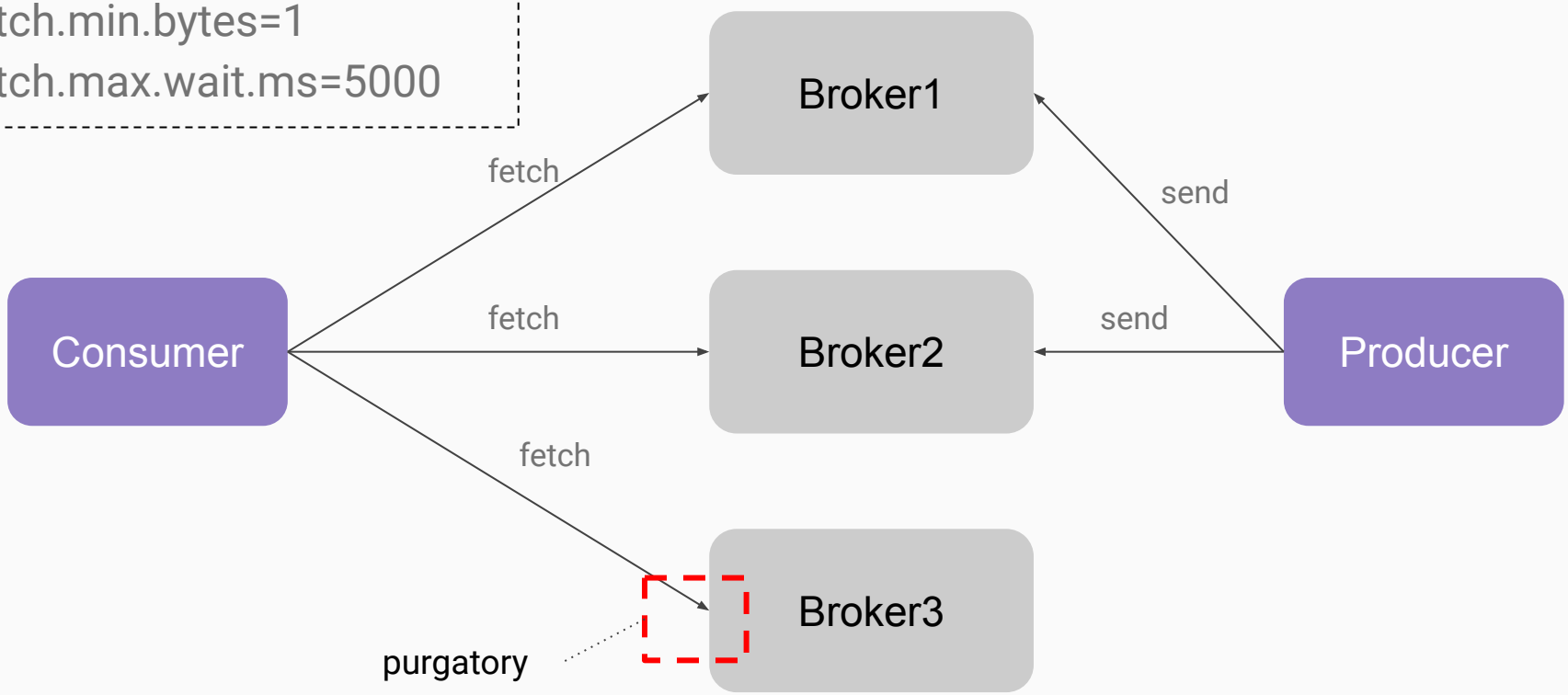
두산백과 두피디아 terms.naver.com

연옥 지식백과

- 요청 조건을 만족하지 않았거나 지정한 시간이 지나지 않은 대기 장소
- 조건을 만족하면 정상 응답, 지정한 시간이 지나면 **Expiry** 처리

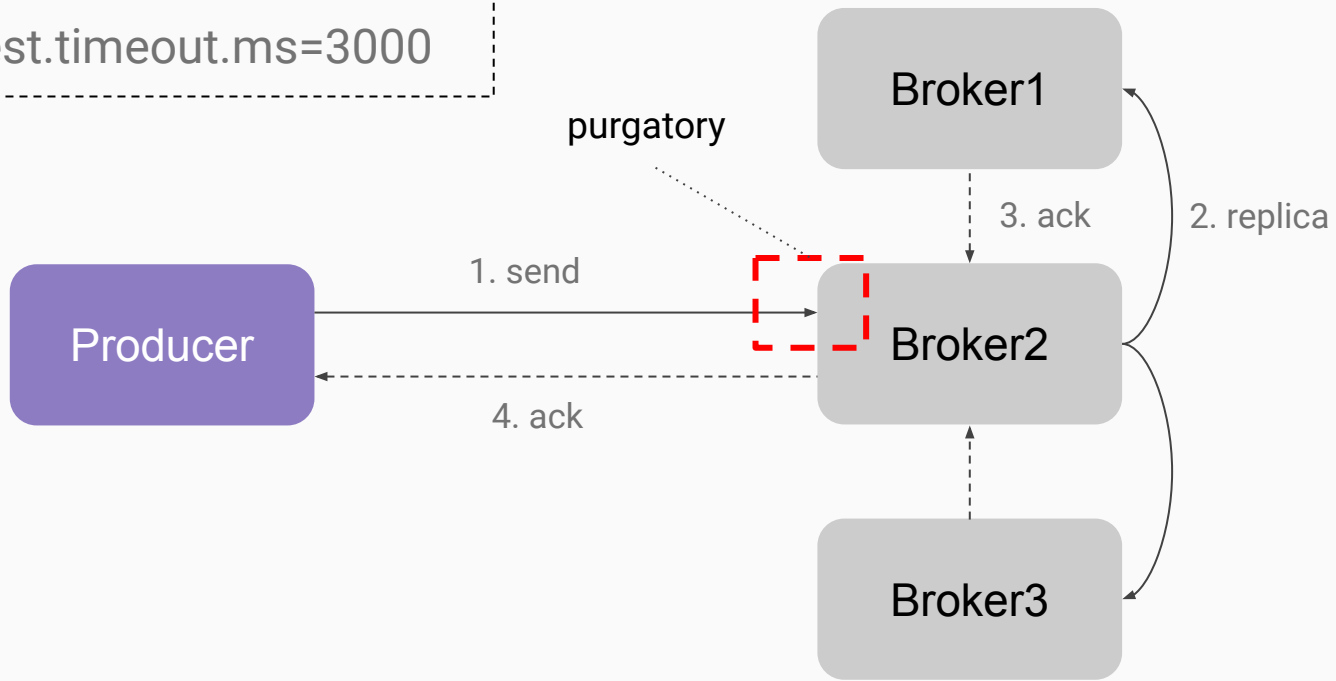
Purgatory

fetch.min.bytes=1
fetch.max.wait.ms=5000

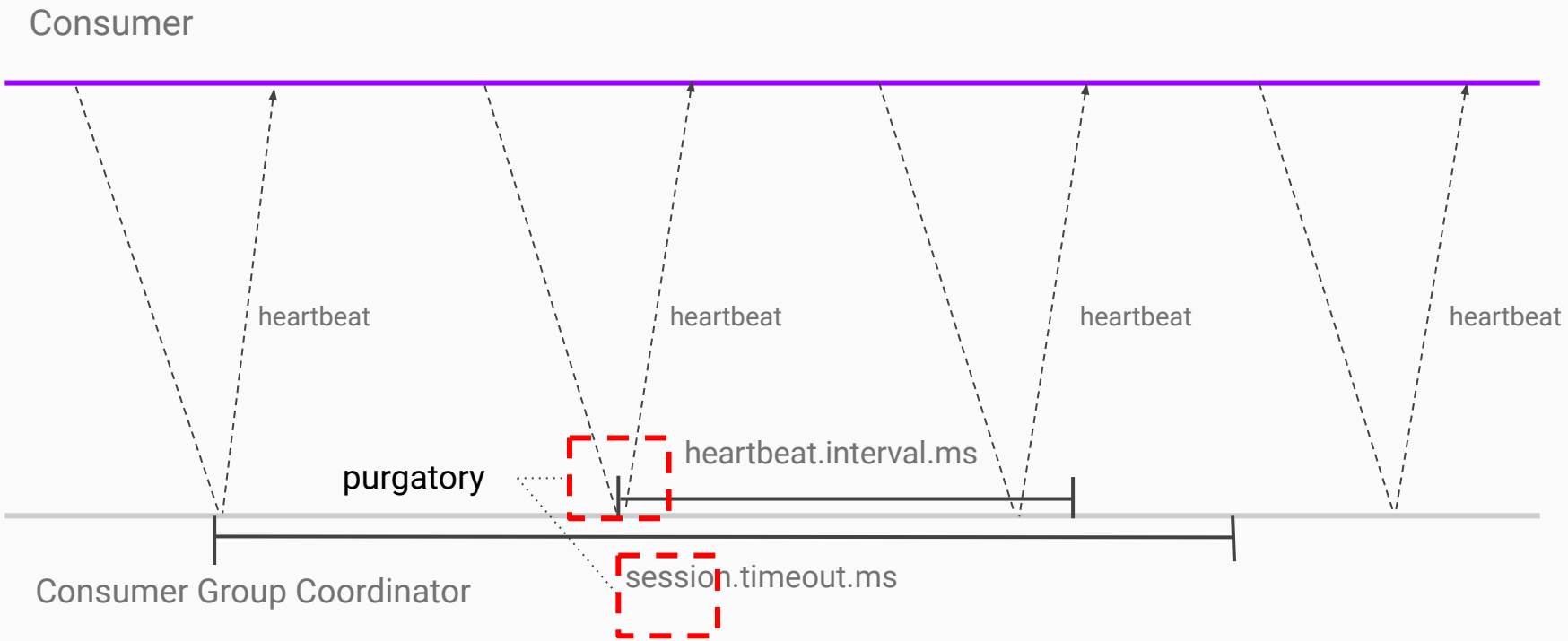


Purgatory

ack=all or ack=-1
request.timeout.ms=3000

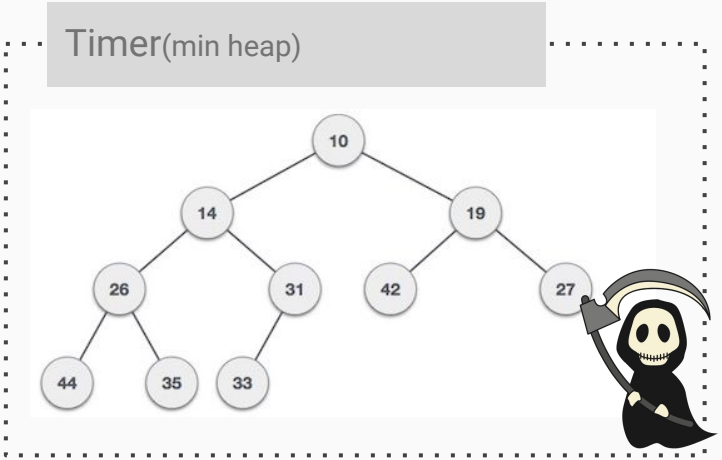


Purgatory


Consumer
heartbeat
heartbeat
heartbeat
heartbeat
heartbeat.interval.ms
purgatory
session.timeout.ms
Consumer Group Coordinator

기존 Purgatory in Kafka

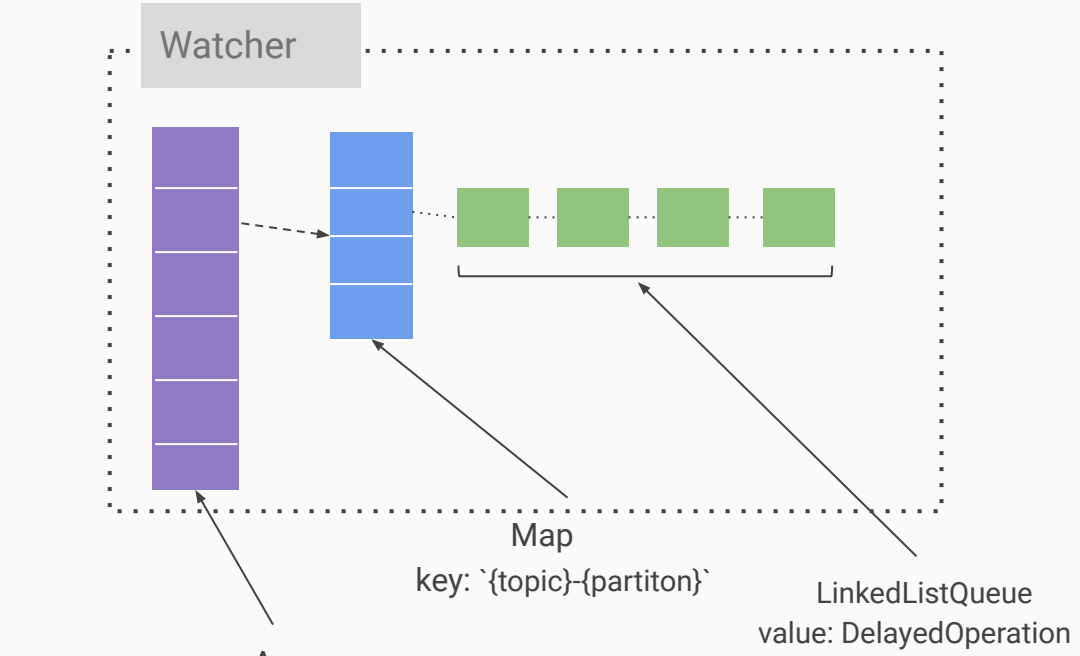
등록된 Expire task의 Expire 체크



완료 또는 Expire 된 task는 바로 삭제 하지 않고 Reaper thread가 주기적으로 Timer, Watcher를 돌면서 task 정리

. Timer task 등록, 삭제가 빈번한데 시간복잡도 O(log n)
. Reaper thread 주기를 짧게 하면 정리는 되지만 cpu cost 높음
주기를 길게 하면 cpu cost는 낮지만 정리 되지 않아 OOM 유발

등록된 Expire task의 조건 만족 판단



Timer 구현하는 7가지 방법

Client API

- Start: Expire task 등록
- Stop: 등록한 Expire task 삭제

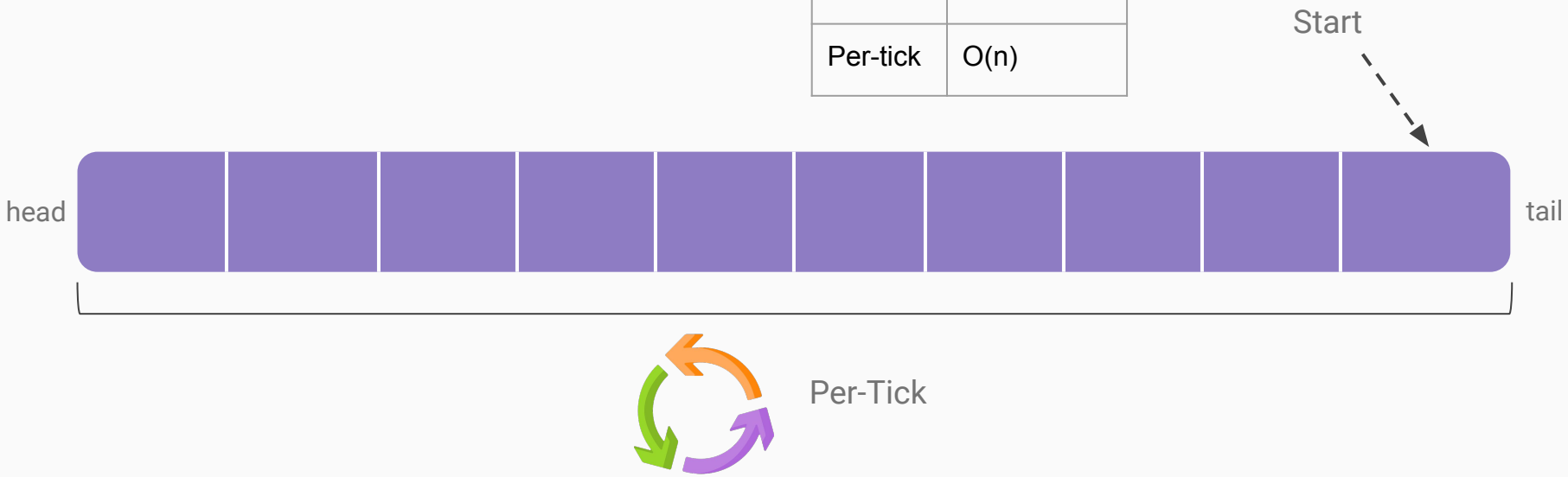
Timer

- Per-tick book-keeping: 매 Time-Unit마다 Expire 될 task 탐색
- Expiry processing: Expire 됐을 때 처리 로직

Timer 구현하는 7가지 방법

scheme 1: Unordered Timer List

	시간 복잡도
Start	O(1)
Per-tick	O(n)



Timer 구현하는 7가지 방법

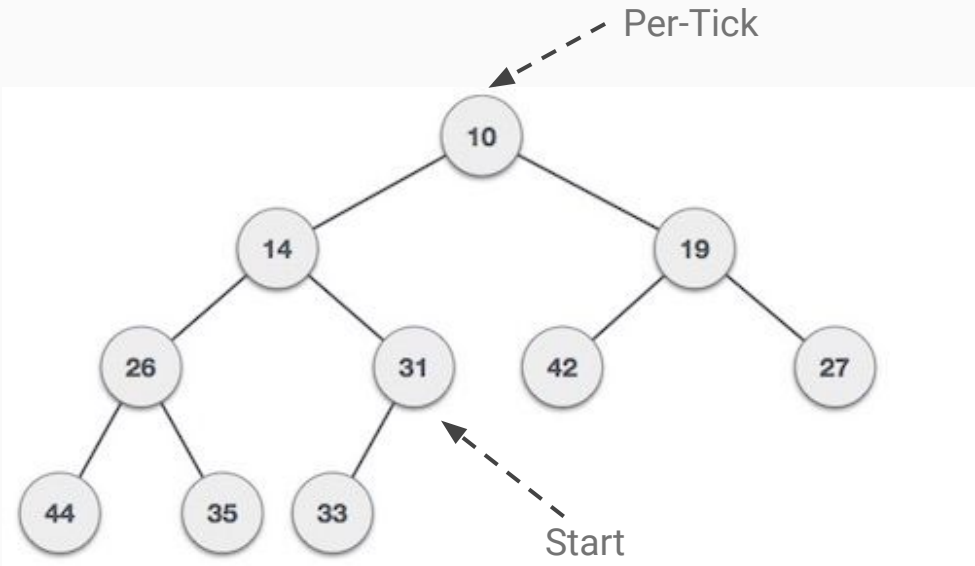
Scheme 2: Ordered List Timer List

	시간 복잡도
Start	O(n)
Per-tick	O(1)

Start ※ list가 expire 기준 정렬을 유지하는 위치 탐색 후 삽입

Timer 구현하는 7가지 방법

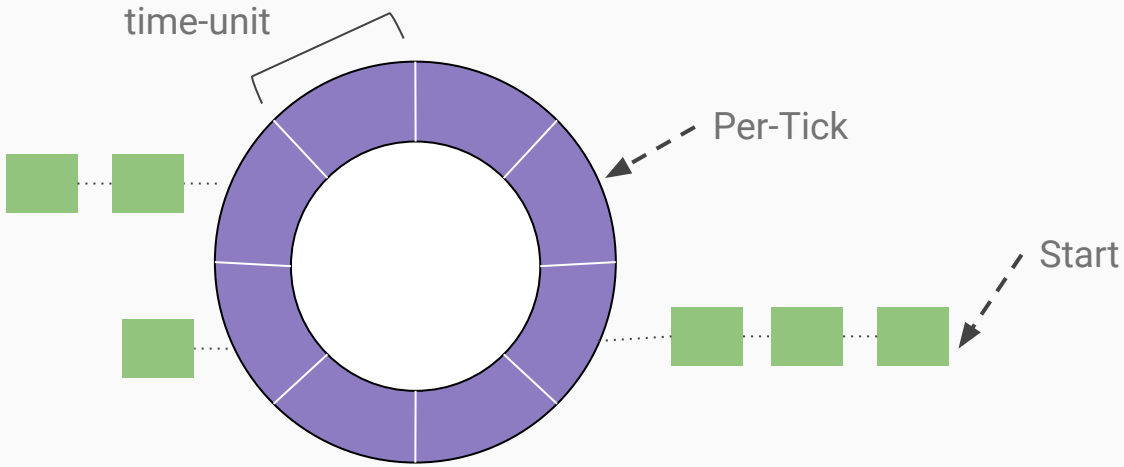
Scheme 3: Tree-based Timer (min heap)



	시간 복잡도
Start	O(log n)
Per-tick	O(1)

Timer 구현하는 7가지 방법

Scheme 4: Simple Timing Wheels



	시간 복잡도
Start	O(1)
Per-tick	O(1)

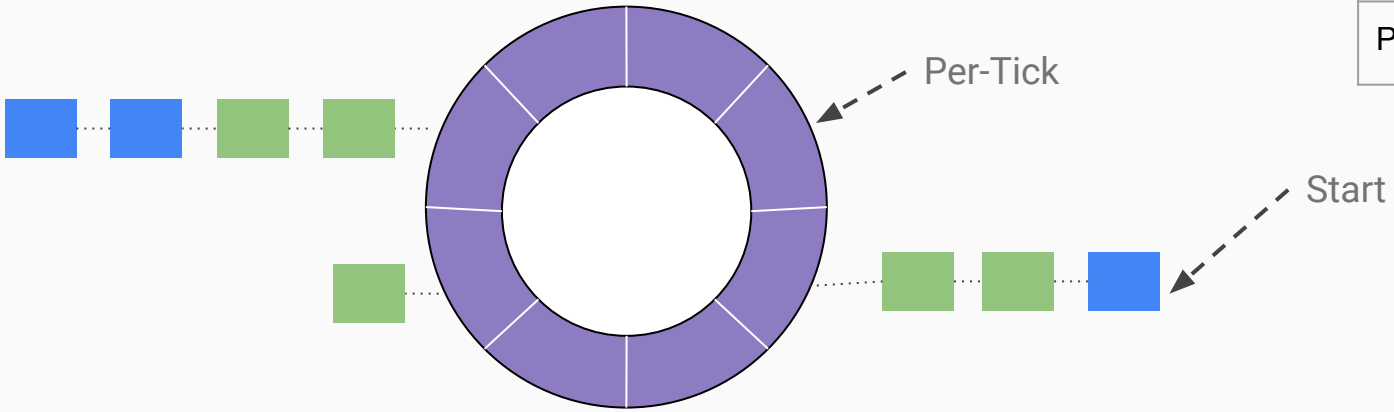
. time-unit이 1초라고 가정하면 위 Timing Wheel은 최대 8초 Expire 가능

. 8초 이상인 Expire task는 오류 발생, (Expire Time % 8) 값에 해당되는 bucket에 Expire task 추가

Timer 구현하는 7가지 방법

Scheme 5: Hashing Timing Wheel with Ordered Timer List

	시간 복잡도
Start	O(n)
Per-tick	O(1)



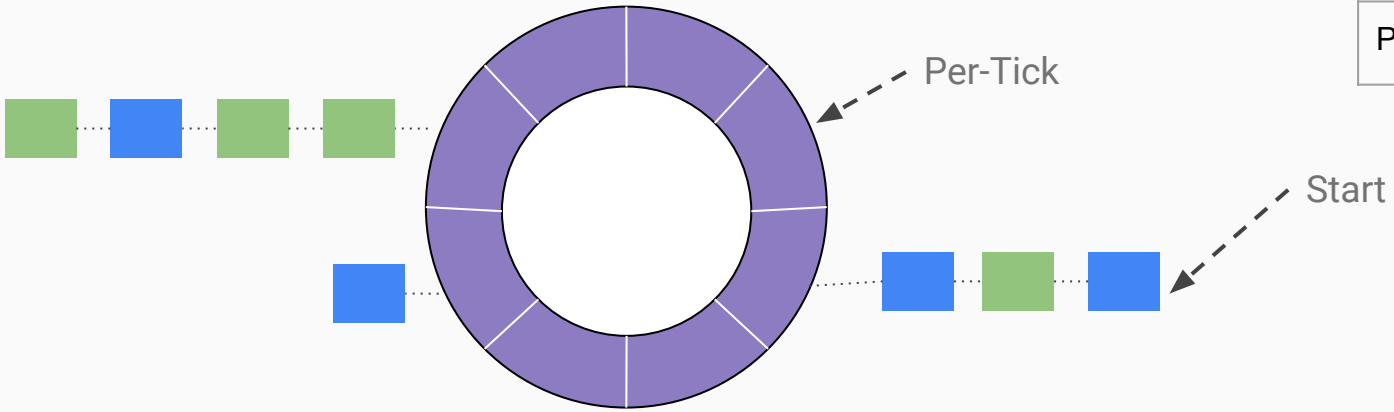
. 하나의 Timing wheel로 8초 이상의 Expire도 가능한 개념

. 8초 이상인 Expire task도 오류 발생 하지 않고, (Expire Time % 8) 값에 해당되는 bucket에 Expire task 추가

Timer 구현하는 7가지 방법

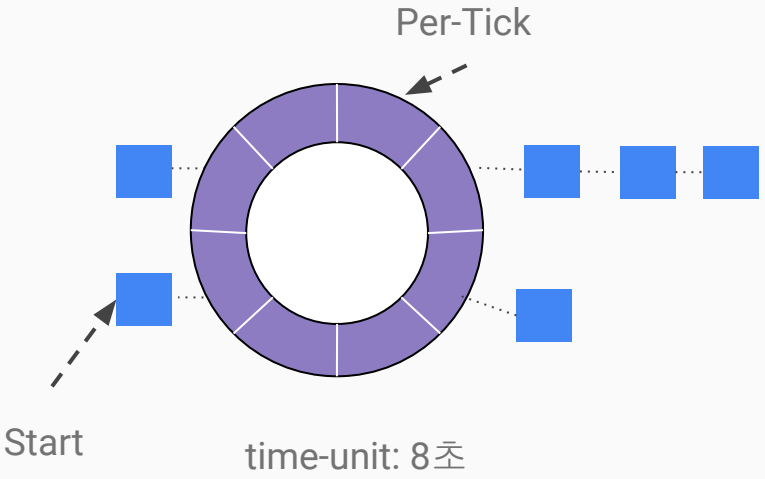
Scheme 6: Hashing Timing Wheel with UnOrdered Timer List

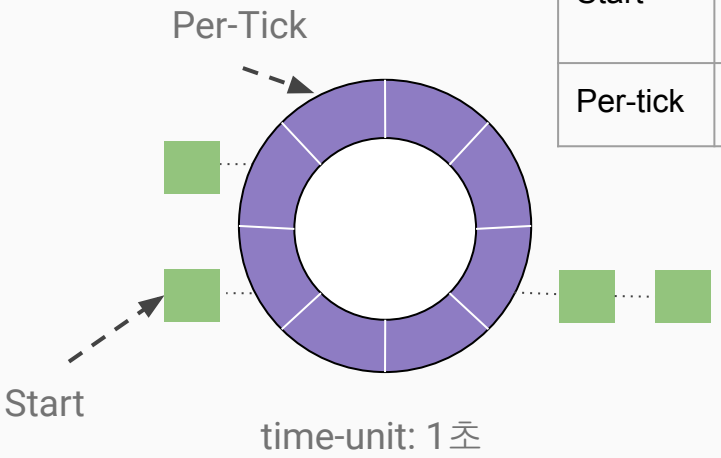
	시간 복잡도
Start	O(1)
Per-tick	O(n)



Timer 구현하는 7가지 방법

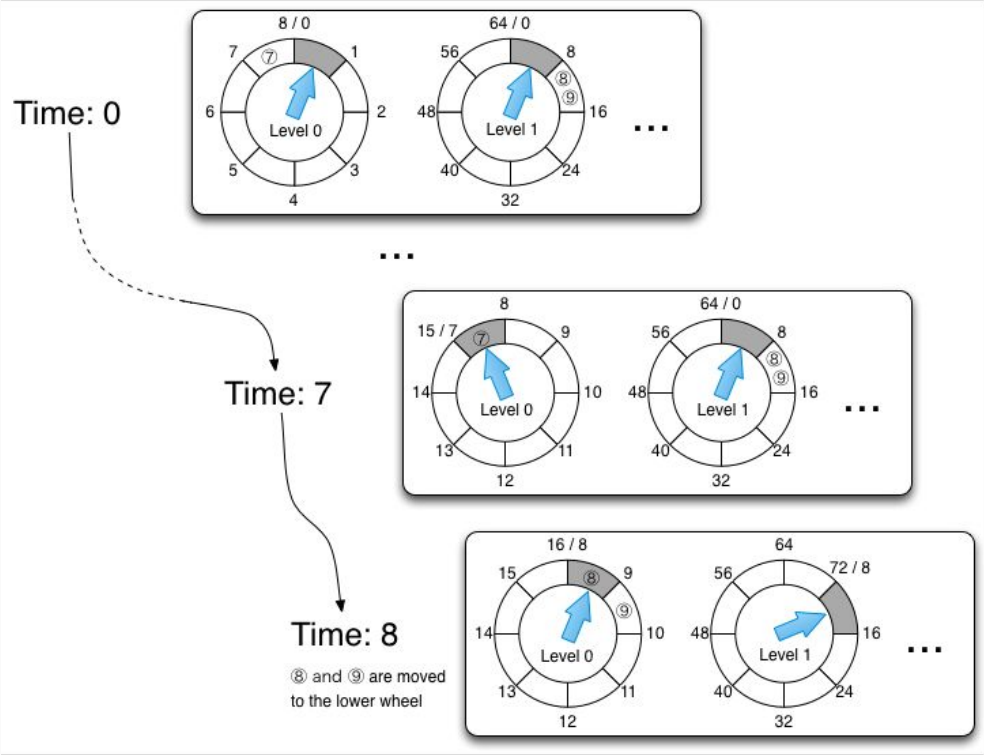
Scheme 7: Hierarchical Timing Wheel





	시간 복잡도
Start	O(m) m: wheel size
Per-tick	O(1)

Timer 구현하는 7가지 방법



time_unit 1초 Level 0 timing wheel
time_unit 8초 Level 1 timing wheel

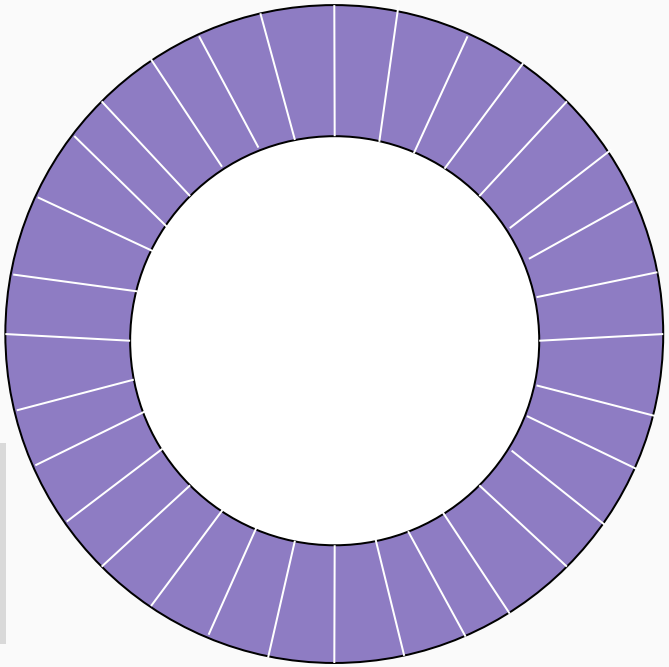
7초 Expire task 7번
8초 Expire task 8번
9초 Expire task 9번

Timer 구현하는 7가지 방법

Scheme	Name	Start	Per-Tick
1	UnOrdered Timer List	O(1)	O(n)
2	Ordered Timer List	O(n)	O(1)
3	Tree-based Timer	O(log(n))	O(1)
4	Simple Timing Wheel	O(1)	O(1)
5	Hashing Timing Wheel \w Ordered Timer List	O(n) worst O(1) average	O(1)
6	Hashing Timing Wheel \w UnOrdered Timer List	O(1)	O(n) worst O(1) average
7	Hierarchical Timing Wheel	O(m) m: number of wheels	O(1)

Timer 구현하는 7가지 방법

Scheme 4로 0 ~ 41 expire 가능한 timing wheel을 만든다면?



time-unit: 1초

bucket: 42개 (그림은 42개 아님)

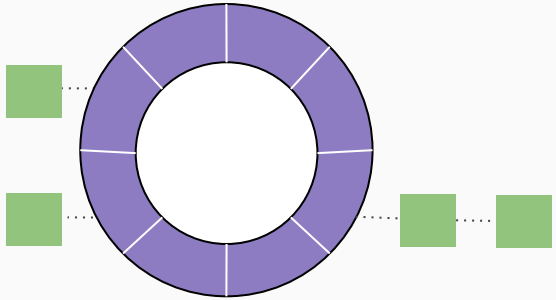
interval: 42초

bucket 갯수가 Expire 시간 만큼 증가한다는 단점은 있지만

Expire가 제한 적이고 max값이 크지 않은 서비스에선 scheme4로 충분하다고 생각

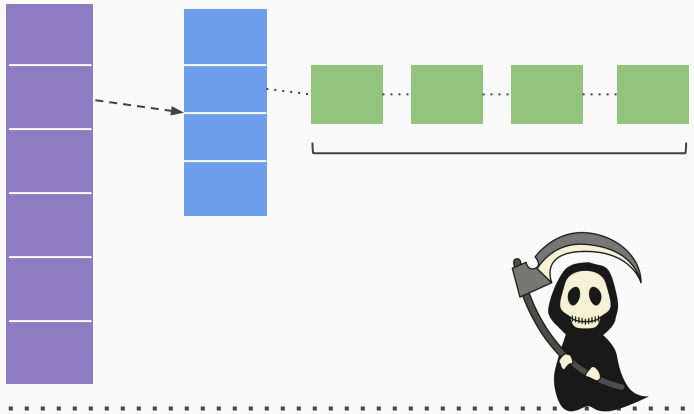
개선된 Purgatory in Kafka

Timer



time-unit: 1초, 최대 8초 expire 가능

Watcher



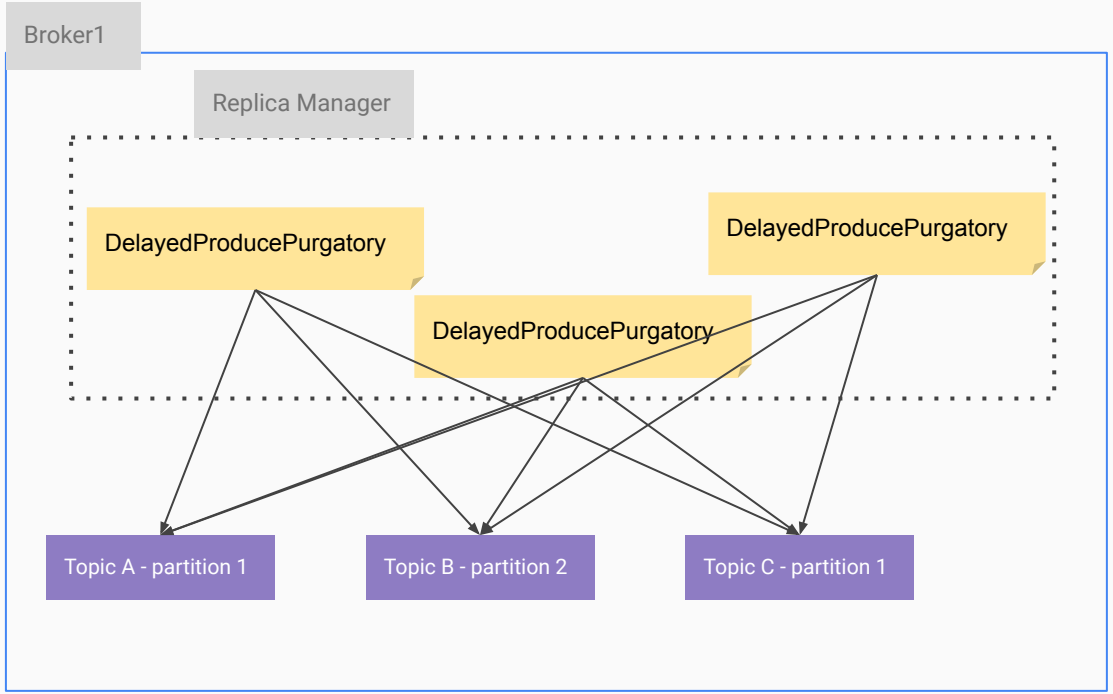
장점: 조건이 만족되면 Watcher와 Timer에서 바로 삭제가능하다. Reaper Thread가 탐색의 범위가 Watcher로 제한되어 부하 감소
Timer에 Expire task를 등록하고 삭제하는 시간 복잡도가 각각 O(m), O(1)

단점: Timer에서 계층별 migration 하는 추가 작업이 필요

개선된 Purgatory in Kafka

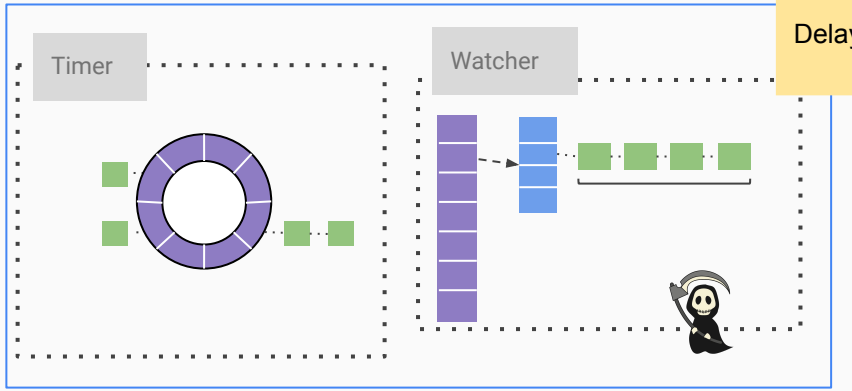
```
val delayedOperations = new DelayedOperations(
  topicPartition,
  replicaManager.delayedProducePurgatory,
  replicaManager.delayedFetchPurgatory,
  replicaManager.delayedDeleteRecordsPurgatory)

new Partition(topicPartition,
  replicaLagTimeMaxMs = replicaManager.config.replicaLa
  interBrokerProtocolVersion = replicaManager.config.in
  localBrokerId = replicaManager.config.brokerId,
  time = time,
  isrChangeListener = isrChangeListener,
  delayedOperations = delayedOperations,
  metadataCache = replicaManager.metadataCache,
  logManager = replicaManager.logManager,
  alterIsrManager = replicaManager.alterIsrManager)
```



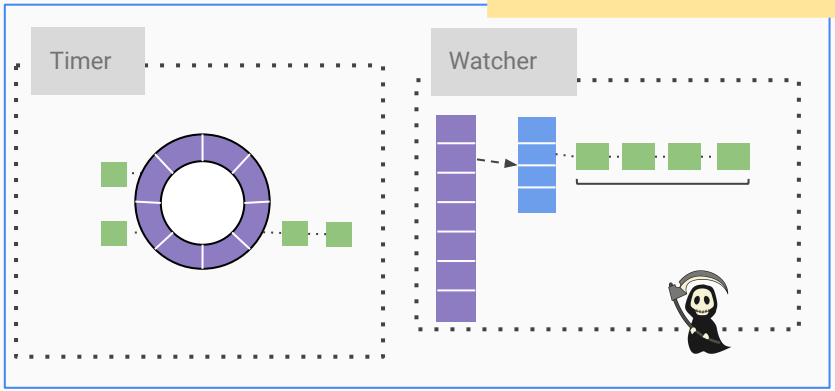
Broker마다 ReplicaManager 하나씩 존재.
그 안에 Purgatory가 생성되어있는데
Partition 생성될 때 주입합니다.

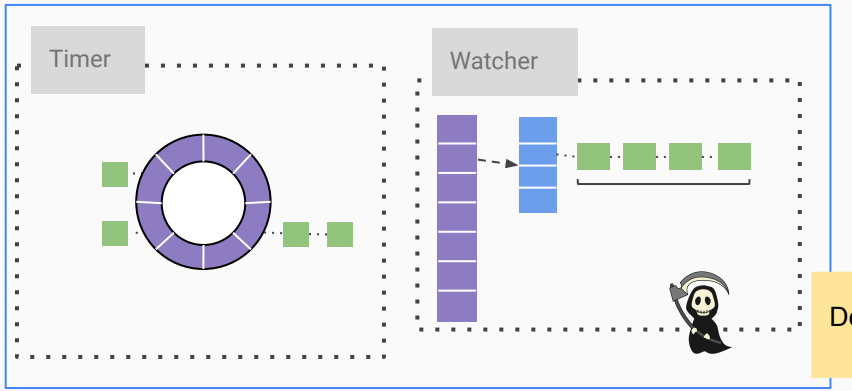
개선된 Purgatory in Kafka



DelayedProducePurgatory

DelayedDeleteRecordPurgatory

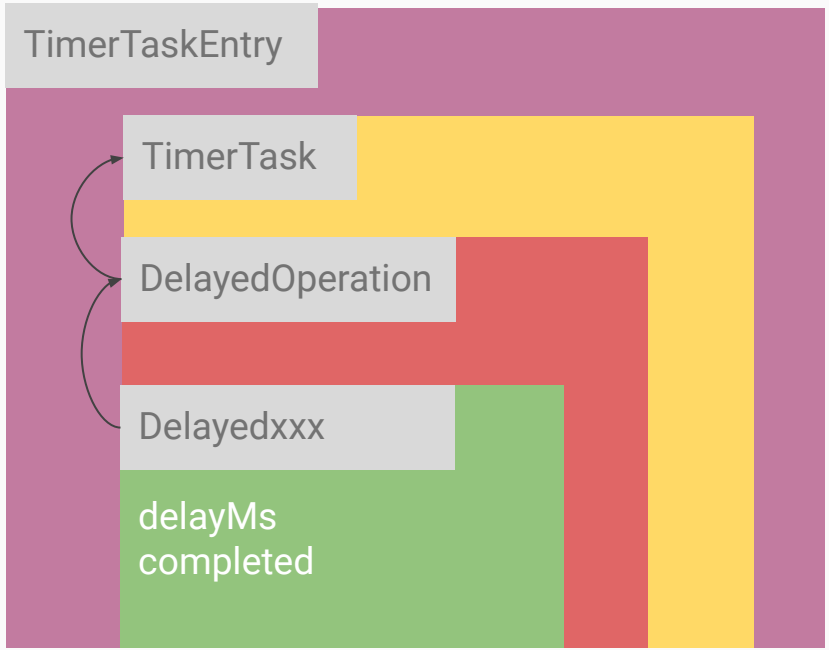




DelayedFetchPurgatory

개선된 Purgatory in Kafka

```
DelayedCreatePartitions (kafka.server)
DelayedDeleteRecords (kafka.server)
DelayedDeleteTopics (kafka.server)
DelayedElectLeader (kafka.server)
DelayedFetch (kafka.server)
DelayedFuture (kafka.server)
DelayedHeartbeat (kafka.coordinator.group)
DelayedJoin (kafka.coordinator.group)
DelayedProduce (kafka.server)
DelayedRebalance (kafka.coordinator.group)
DelayedSync (kafka.coordinator.group)
```

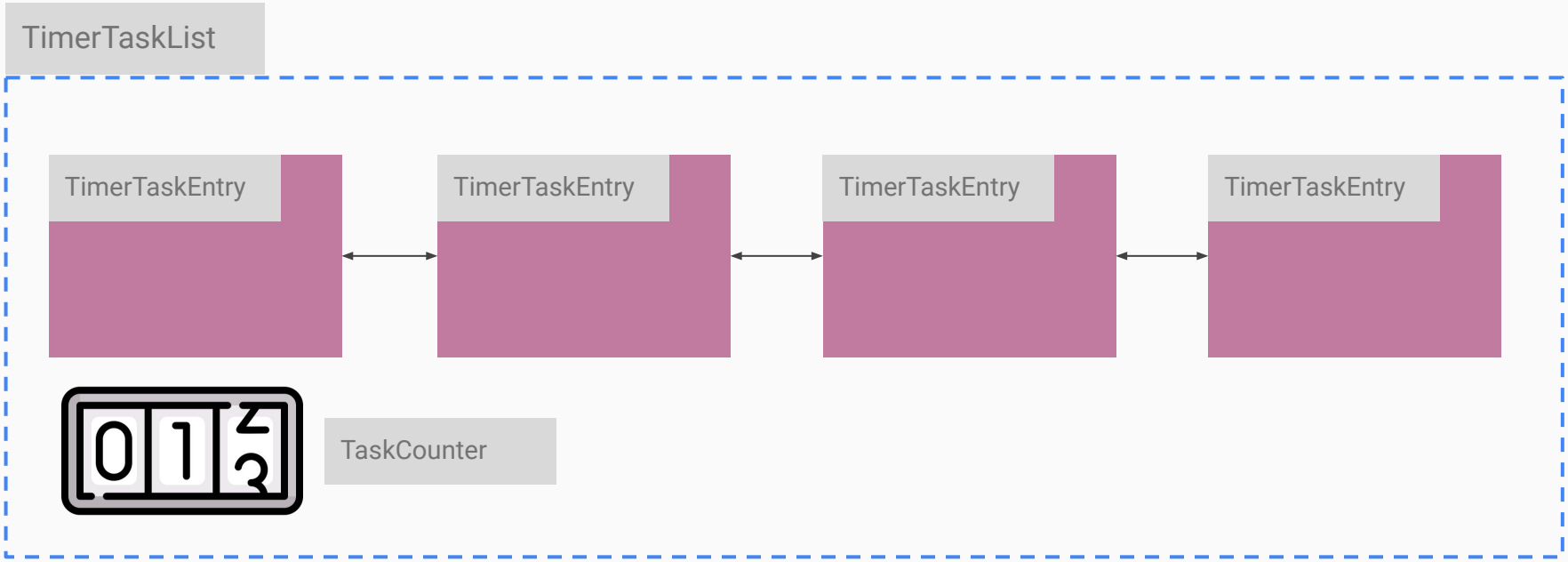



```
class TimerTaskEntry {
   TimerTask
    …
}
```

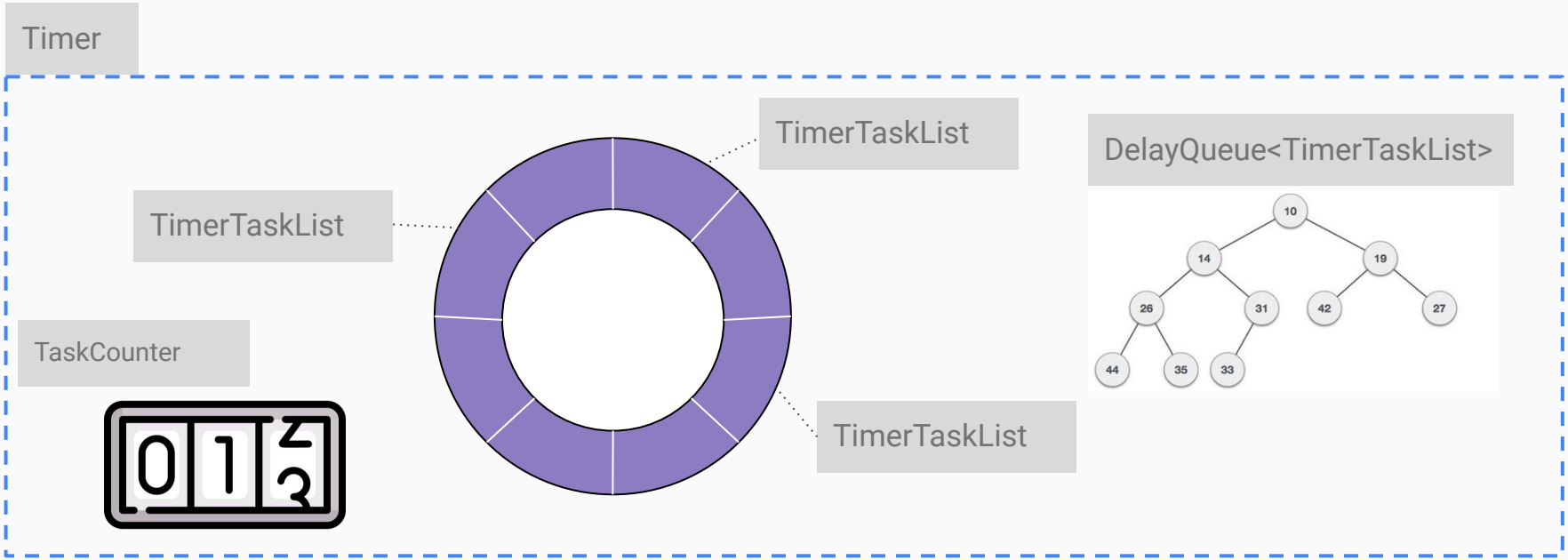
```
class DelayedOperation
extends TimerTask
```

```
class Delayedxxx
extends
DelayedOperation
```

개선된 Purgatory in Kafka

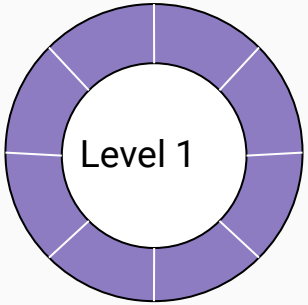


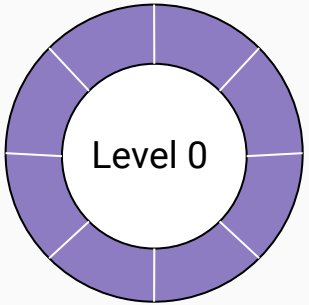
개선된 Purgatory in Kafka



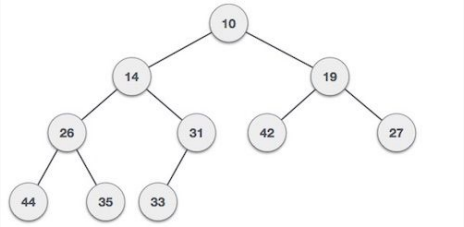
개선된 Purgatory in Kafka

Timer



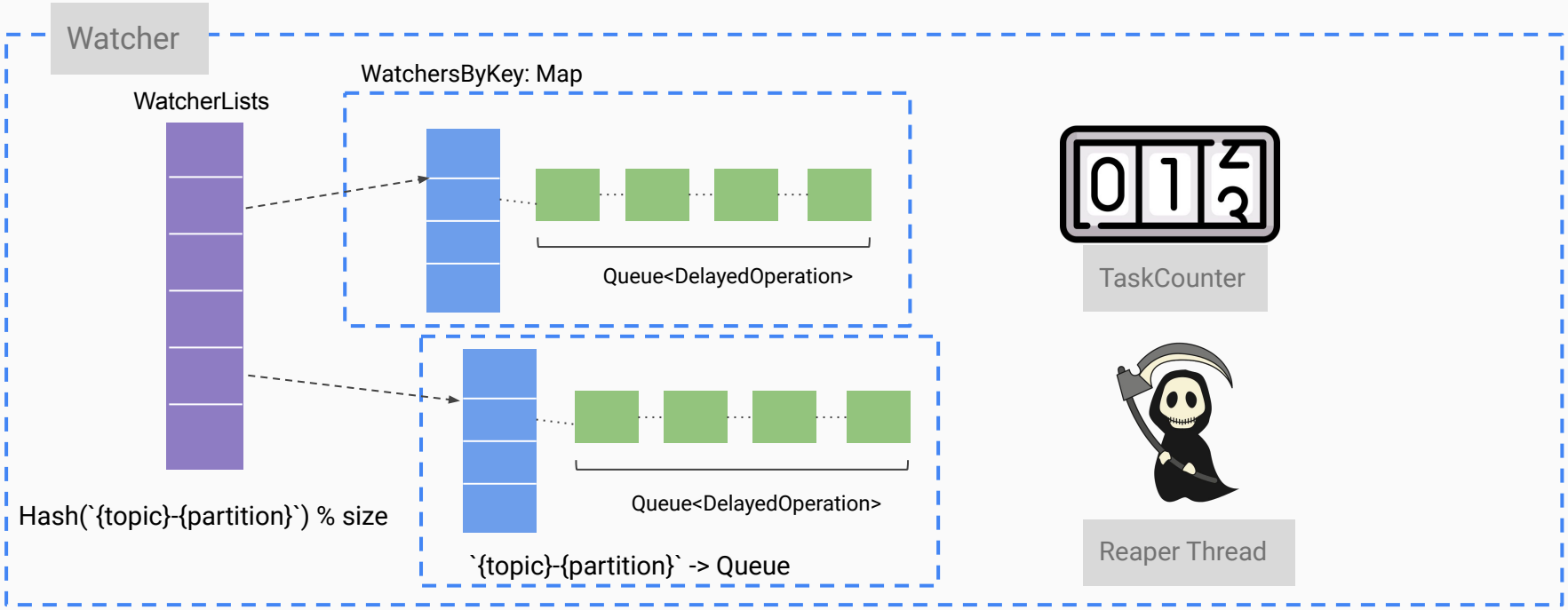


DelayQueue<TimerTaskList>

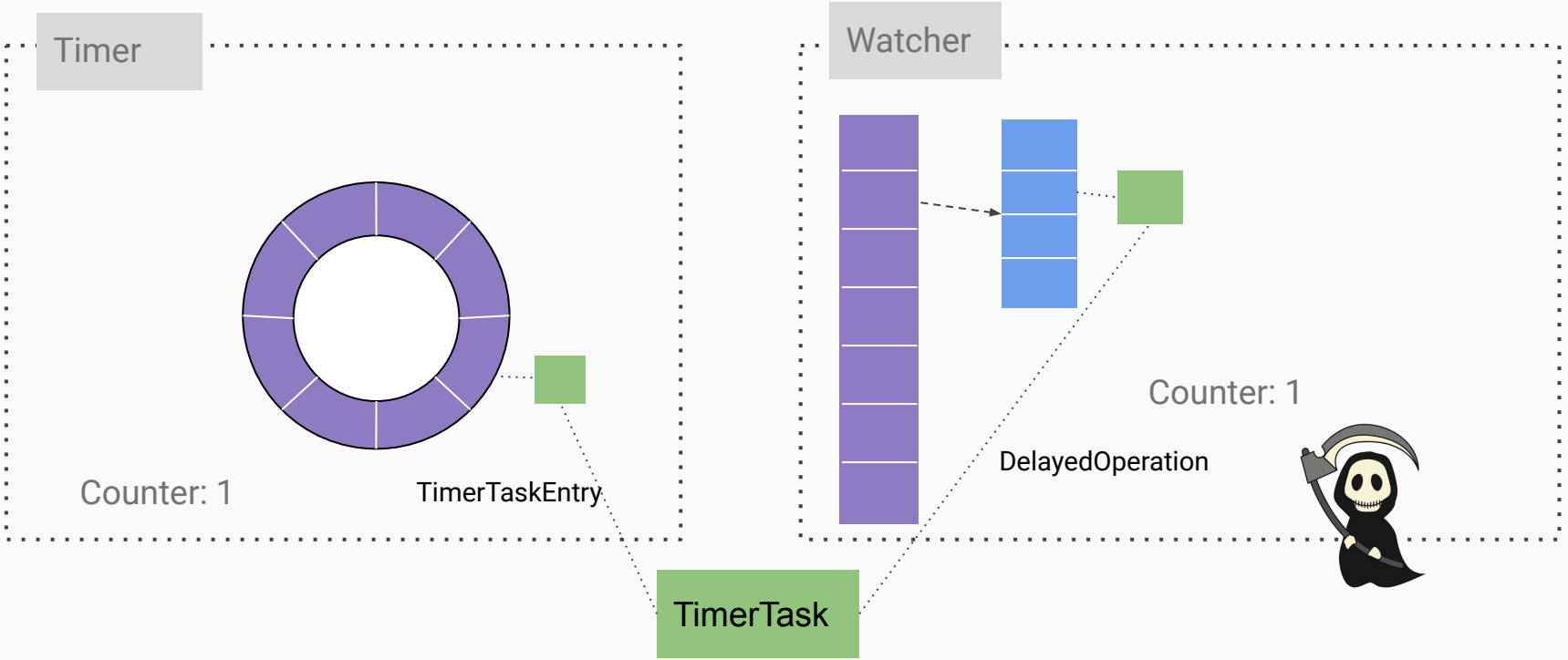


TaskCounter

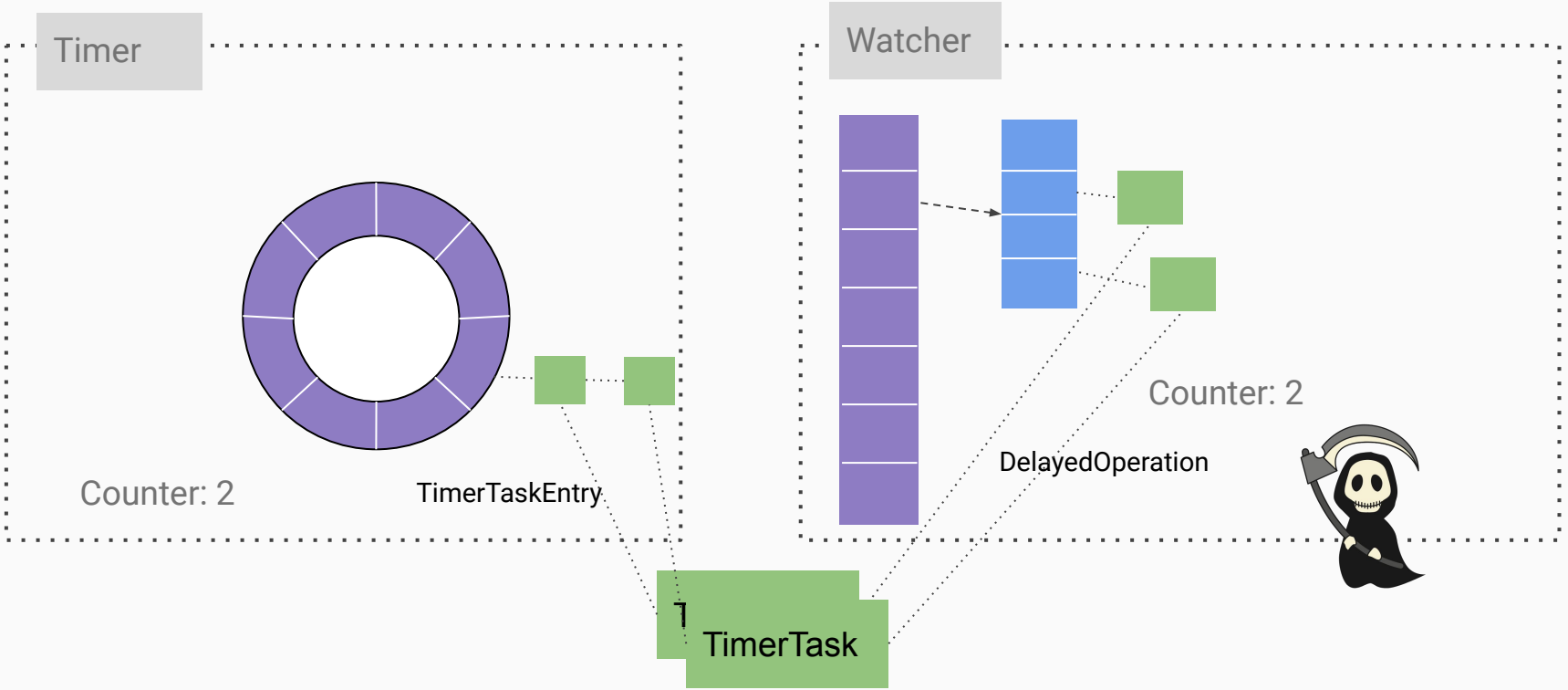
개선된 Purgatory in Kafka



개선된 Purgatory in Kafka

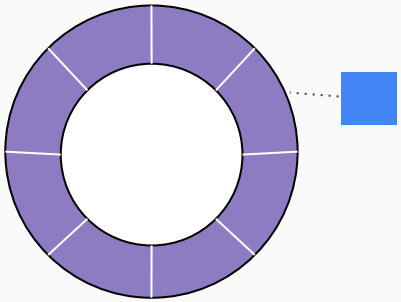


개선된 Purgatory in Kafka

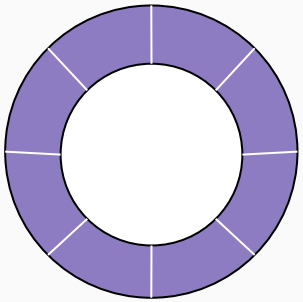


질문으로 알아보는 Purgatory

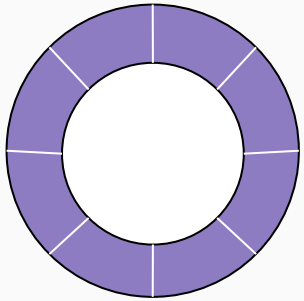
Q1. fetch.max.wait.ms = 92000ms로 했을 때 Timer 동작은 어떻게?



time-unit: 64초



time-unit: 8초



time-unit: 1초

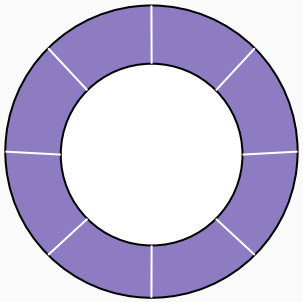
DelayQueue<TimerTaskList>

64

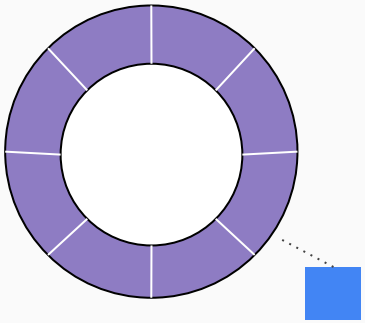
92초는 time-unit 1초 Timing Wheel에 추가되지 않아, time-unit 64초 Timing Wheel에 1(92 / 64) bucket에 Expire task추가
DelayQueue에는 64초 Expire로 추가

질문으로 알아보는 Purgatory

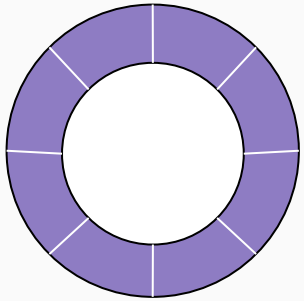
Q1. fetch.max.wait.ms = 92000ms로 했을 때 Timer 동작은 어떻게?



time-unit: 64초

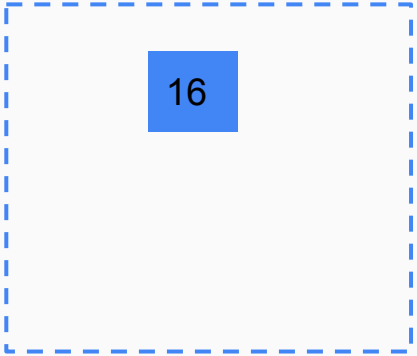


time-unit: 8초



time-unit: 1초

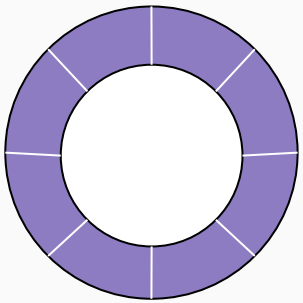
DelayQueue<TimerTaskList>



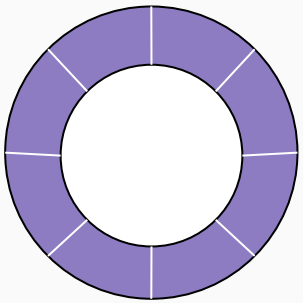
64초가 지나면 time-unit 64초 Timing Wheel에 있던 Expire task는
time-unit 8초 Timing Wheel로 migration 한다.
앞에 설명한 방식과 동일하게 Expire task 및 DelayQueue에 추가

질문으로 알아보는 Purgatory

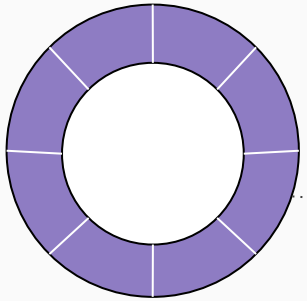
Q1. fetch.max.wait.ms = 92000ms로 했을 때 Timer 동작은 어떻게?



time-unit: 64초



time-unit: 8초



time-unit: 1초

DelayQueue<TimerTaskList>

2

질문으로 알아보는 Purgatory

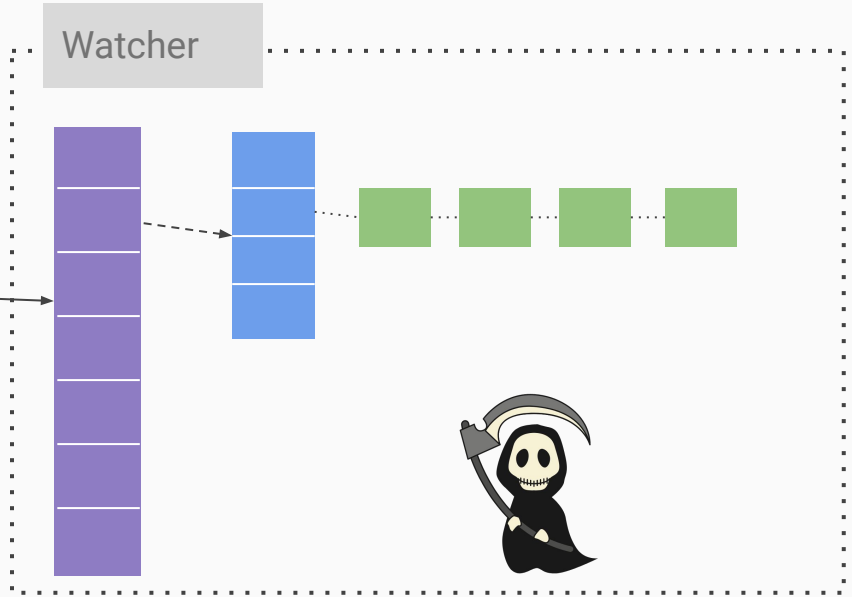
Q2. 조건을 만족했을 때 Purgatory에서는 어떤일이 일어나는가?

appendRecord

delayedProducerPurgatory.checkAndComplete

delayedFetchPurgatory.checkAndComplete

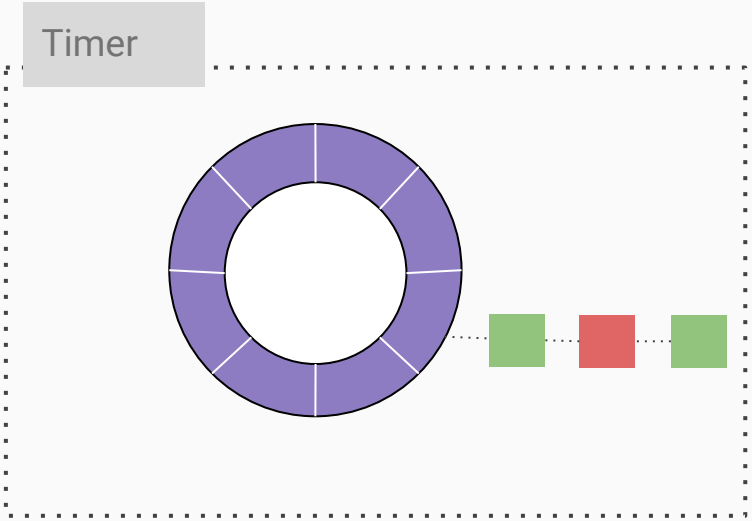
delayedDeleteRecordPurgatory.checkAndCompl
ete

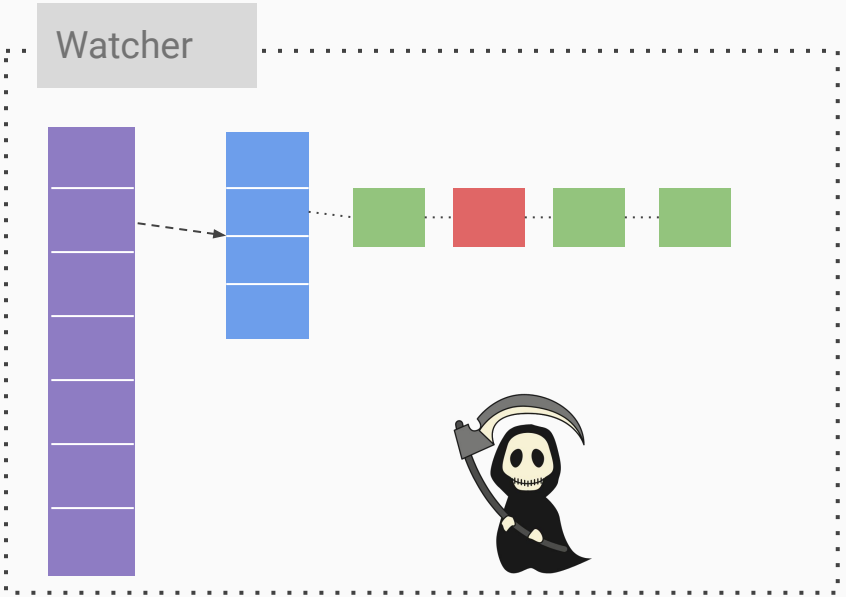


Leader 파티션에 메시지가 추가될 때마다 해당 파티션의 Purgatory 조건 만족 했는지 체크

질문으로 알아보는 Purgatory

Q2. 조건을 만족했을 때 Purgatory에서는 어떤일이 일어나는가?

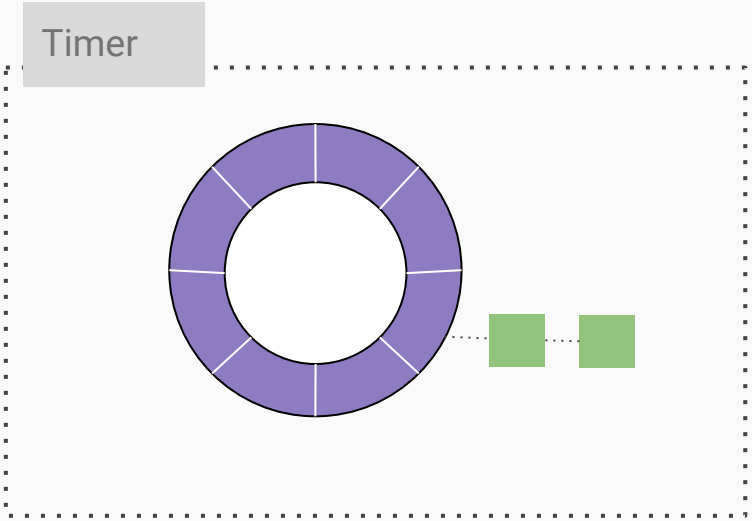


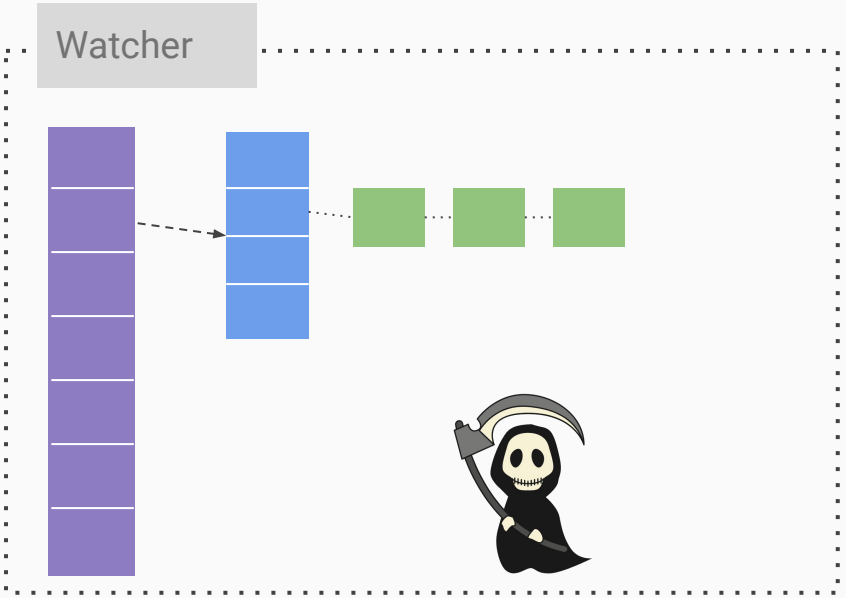


Watcher에서 조건을 만족한 Expire task를 찾았다면 Timer도 삭제 준비
DelayOperation(Watcher) -> TimerTask -> TimerTaskEntry(Timer)

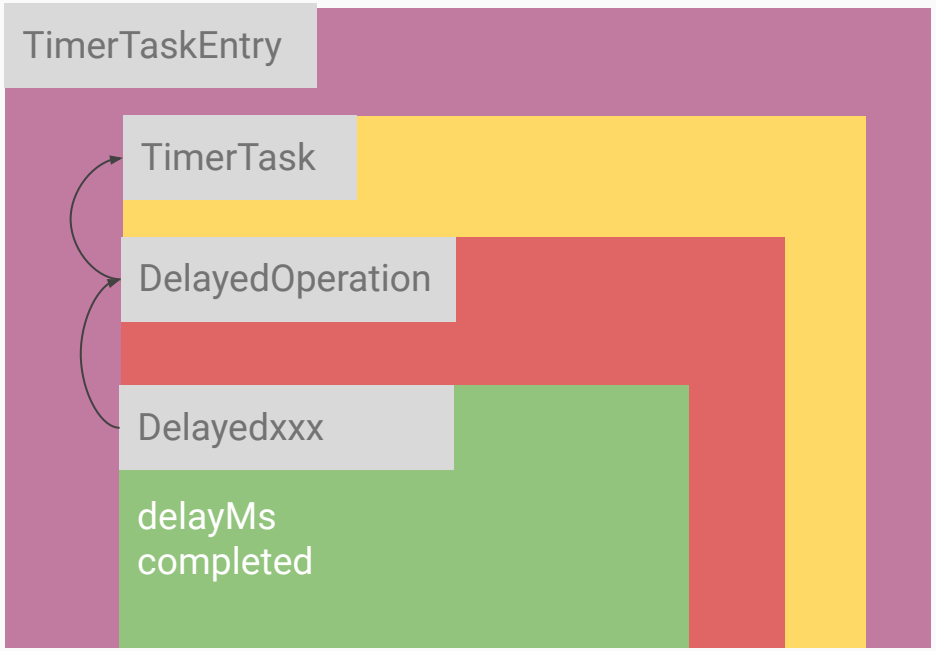
질문으로 알아보는 Purgatory

Q2. 조건을 만족했을 때 Purgatory에서는 어떤일이 일어나는가?

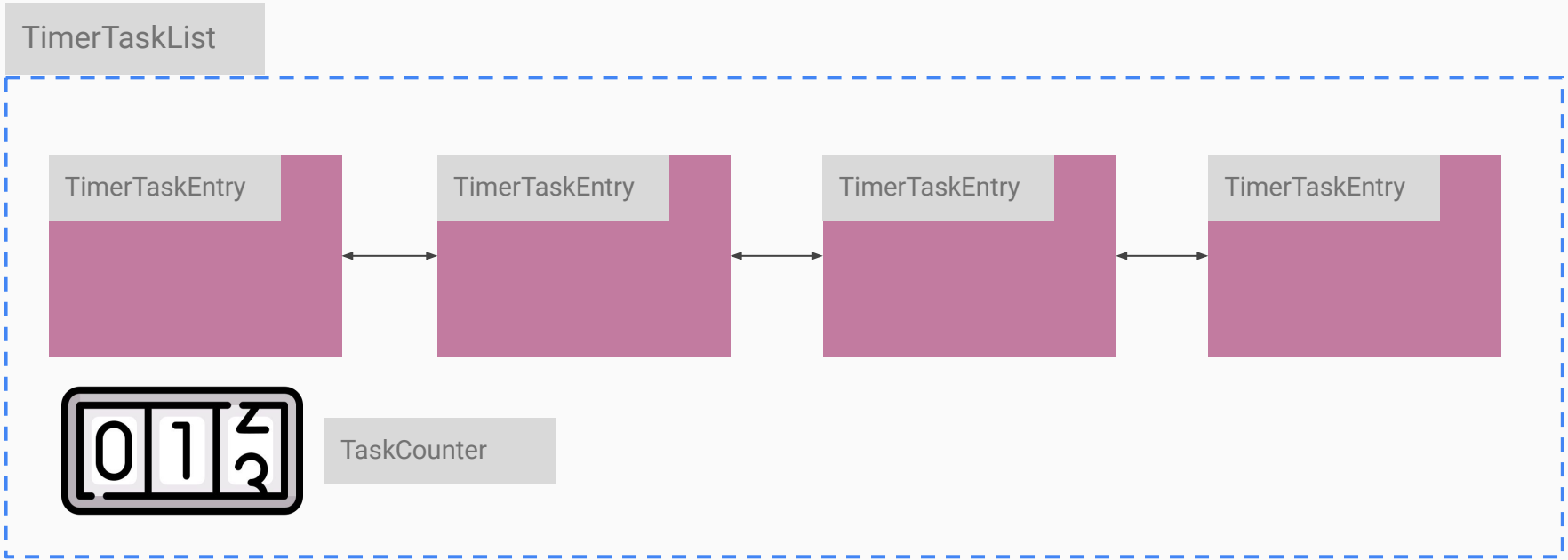




질문으로 알아보는 Purgatory

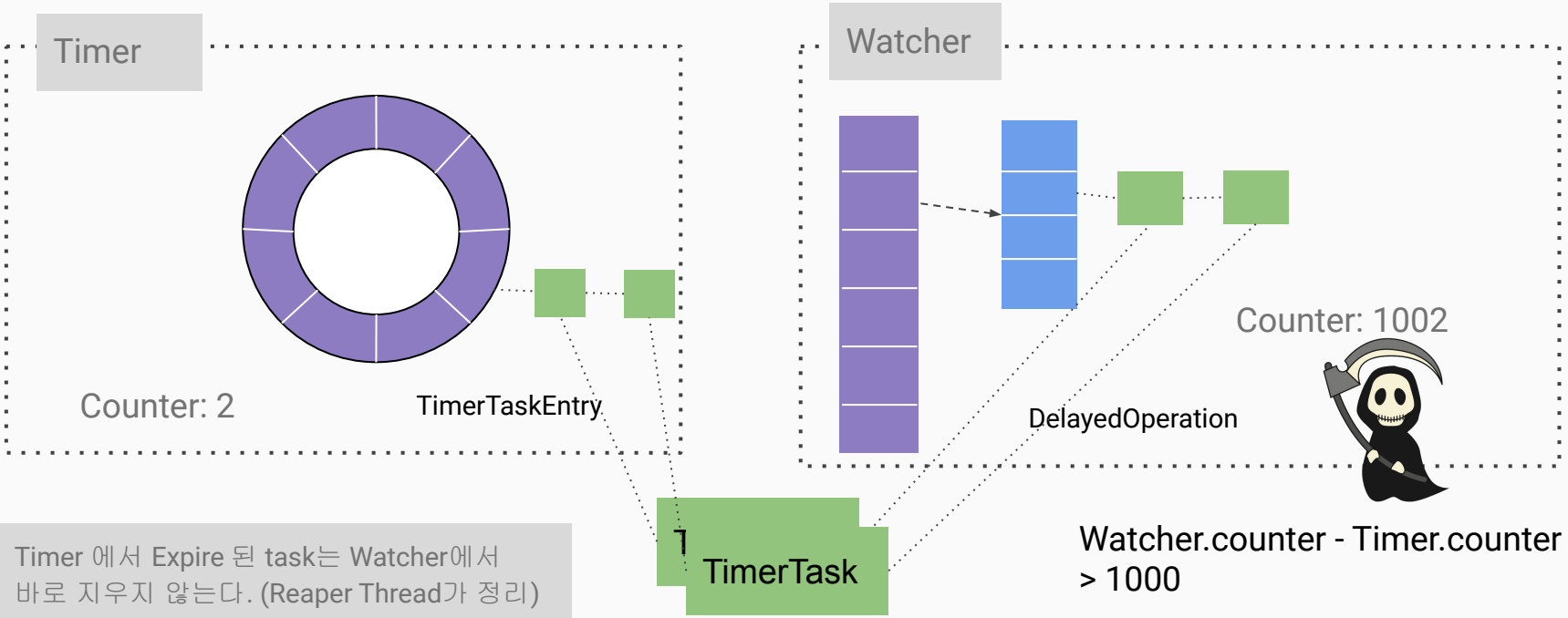


질문으로 알아보는 Purgatory



질문으로 알아보는 Purgatory

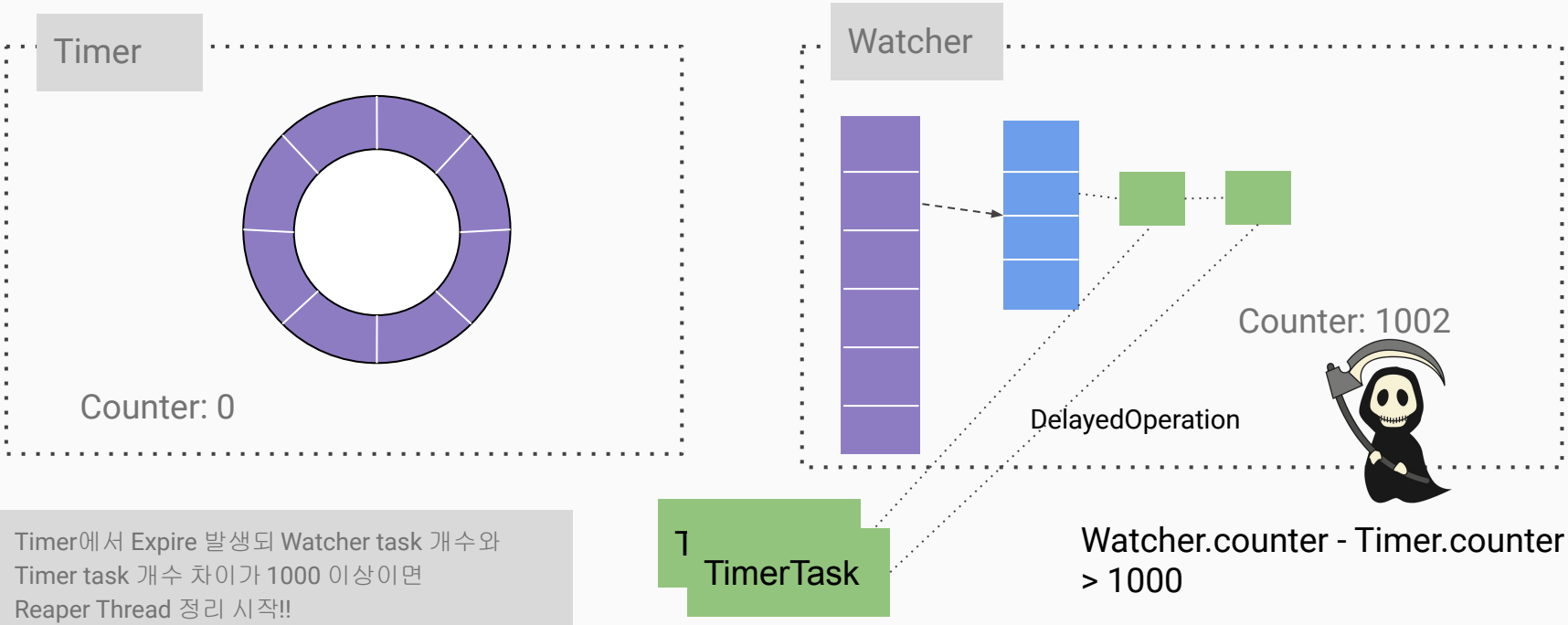
Q3. 조건을 만족하지 못하고 Expire 될 때 Purgatory에서는 어떤일이 일어나는가?



Timer 에서 Expire 된 task는 Watcher에서 바로 지우지 않는다. (Reaper Thread가 정리)

질문으로 알아보는 Purgatory

Q3. 조건을 만족하지 못하고 Expire 될 때 Purgatory에서는 어떤일이 일어나는가?



Timer에서 Expire 발생되 Watcher task 개수와
Timer task 개수 차이가 1000 이상이면
Reaper Thread 정리 시작!!

질문으로 알아보는 Purgatory

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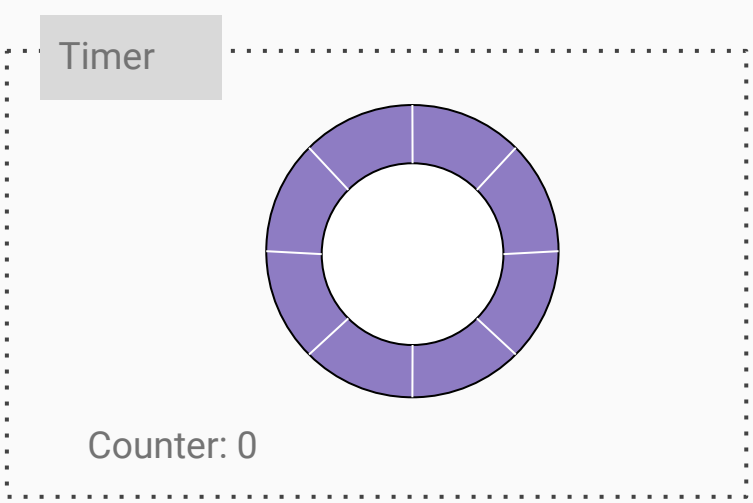
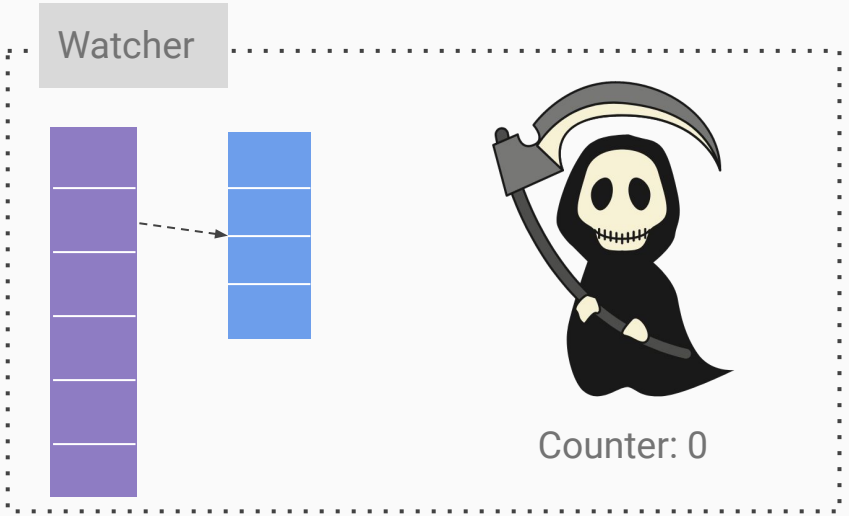
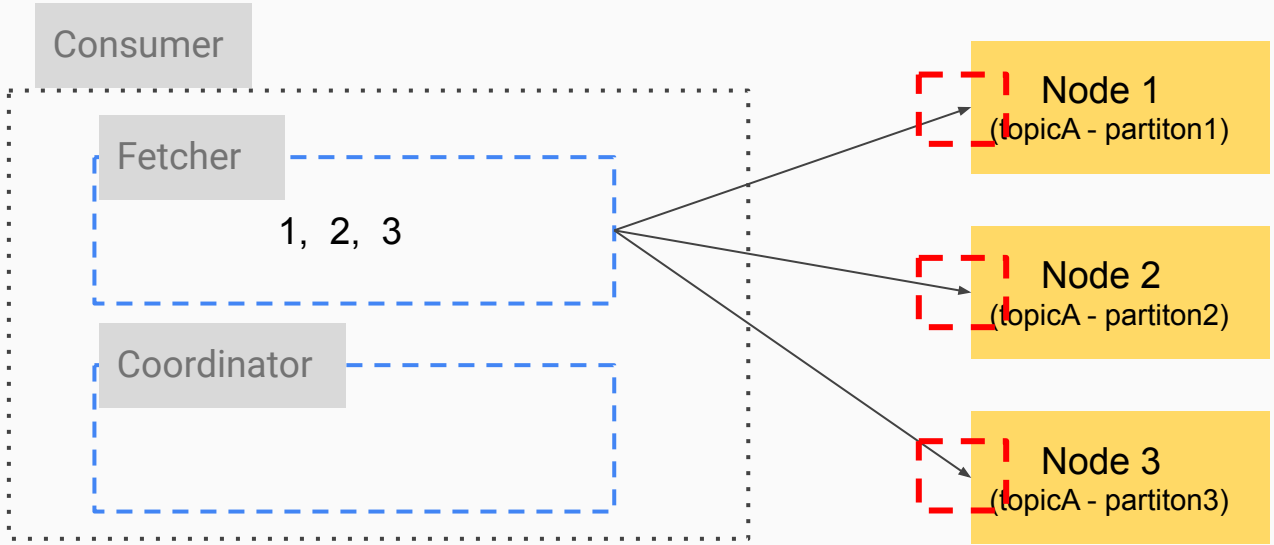




질문으로 알아보는 Purgatory

Q4. 3개 파티션을 fetch 중인 consumer가 2개는 조건을 만족해서 응답 받고 1개는 대기중 일 때 대기 중인 파티션에 또 fetch 요청 하면 안 될것 같다. 어떻게 동작할까?



질문으로 알아보는 Purgatory

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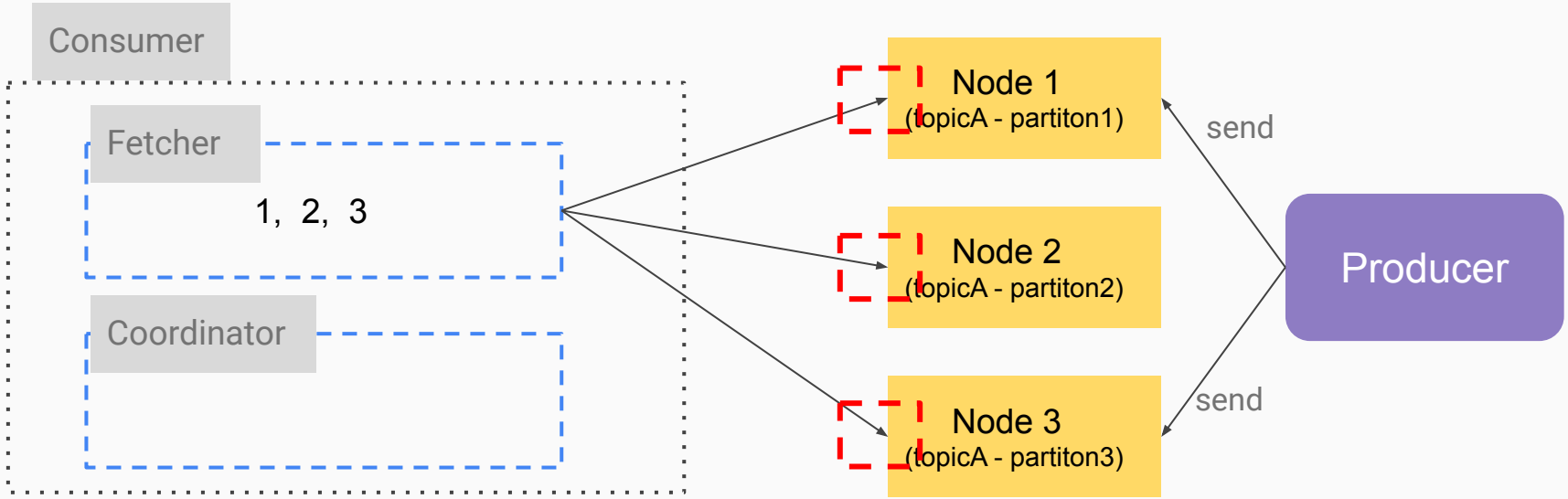

질문으로 알아보는 Purgatory

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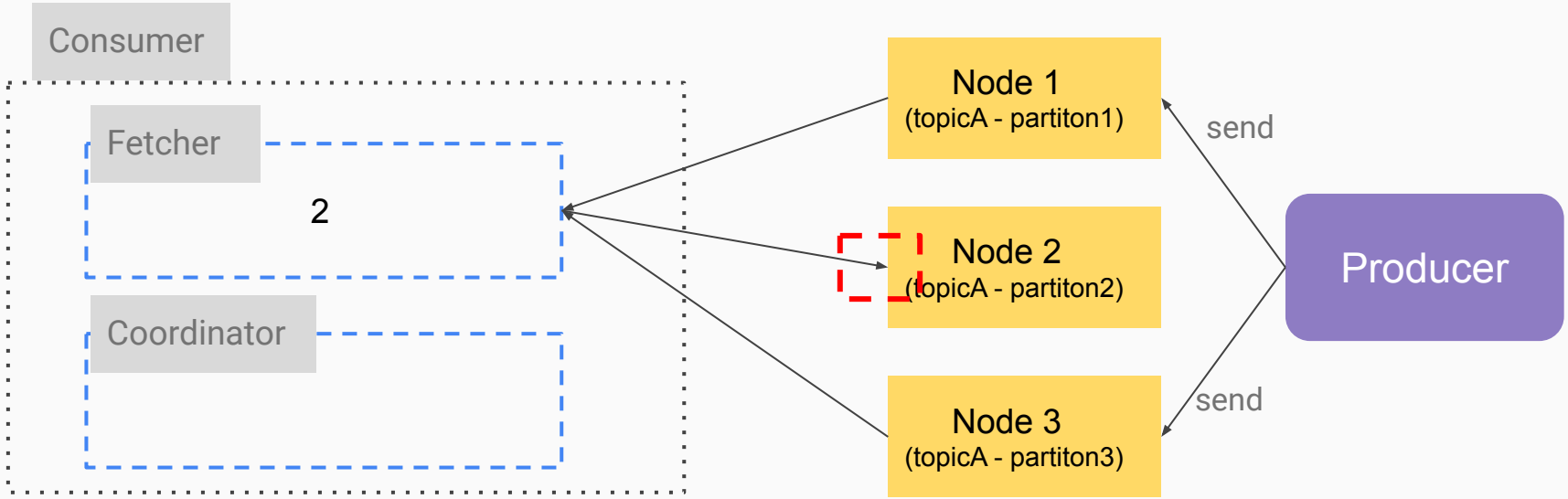

질문으로 알아보는 Purgatory

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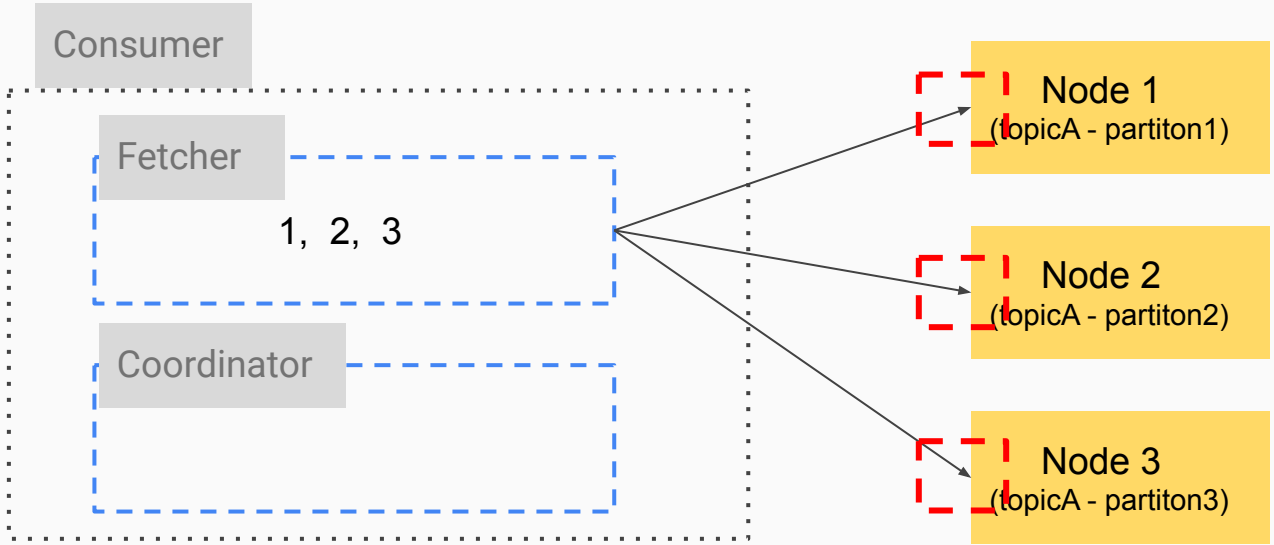

정리

. Expire task 추가 될때는 O(m)

. 조건을 만족하면 Watcher와 Timer에서 바로 삭제

. Expire되면 Timer에서 바로 삭제,
Watcher에선 바로 삭제 하지 않고 Reaper Thread가 정리

. Purgatory 기능을 활용하기 위해서 Client에 추가 로직

Q & A

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