클라우드 환경 기반 실시간 데이터 처리의 유실 없는 Geo-Replication 구축

김영진, 이모원, 신수인

Data Insight Center, Log Data

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CONTENTS

NAVER
DEVIEW
2023

NAVER
DEVIEW
2023

1. IDC 장애의 심각성
그리고 Geo Replication

1.1 10/15 사태가 주는 교훈

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IDC 장애 그리고 대응

- 10/15 화재가 주는 교훈

- 빠른 장애 대응력이 곧 기업의 경쟁력
  - 기업의 기술 경쟁력에 대한 재고
  - 대응 방식에 따라 Brand 가치의 상승 or 하락

- IT 빅테크 기업이 갖춘 고도화된 장애 대응 시스템
  - 국내 여러 데이터 센터 분산 구조
  - 구글은 1년에 2번 이상 재해 복구 훈련 진행

과기정통부, 모레 '민간 데이터센터 안정성' 긴급 점검

https://m.yna.co.kr/view/AKR20210180807000 17

[IT 줌인] 국내 데이터센터 '외연 확장' 치중, 재해복구 능력 제한

국내 데이터센터 60% 수도권 집중, 이원화 미비
해외 빅테크 재해복구 대책 기반 '회복력' 강조
데이터센터 규제 입법 소위원회 통과, 향방 주목

https://biz.newdaily.co.kr/site/data/html/2022/11/29/2022112900095.html

〈 재난·재해 사고에 대비한 글로벌 빅테크 기업의 데이터센터 관리 운영 〉

기업	대응 현황
amazon	• 물리적으로 분리된 데이터센터 여러 개를 '가용영역'으로 관리 • 인접 가용영역들은 지역별 리전으로 묶어 서비스 연속성 보장 • 서울에 가용영역 4개를 갖추고 서로 연동
Microsoft	• 세계 140개 국가에 데이터센터 분산, 총 60개 리전 운영 • 국내에서는 서울·부산 두 곳의 데이터센터가 상호 백업역할 담당 • 데이터센터 내부 온도 유지에 도움이 되는 스코틀랜드 인근 해저에 데이터센터 구축
Google	• 정확한 데이터센터 위치와 수를 보안 이유로 미공개 • 지난 5년간 미국에서만 370억 달러 투자해 데이터센터 증설(2022년 테네시, 버지니아, 오클라호마 등에 데이터센터 추가 건립) • 1년에 두 차례 이상 재해 복구 훈련

자료 : 한겨레, 2022.10.19. / 한국경제, 2022.10.17

https://now.k2base.re.kr/portal/trend/mainTrend/view.do?poliTrndId=TRND0000000000048121&menuNo=2000&pageUnit=10&pageIndex=4

1.2 Geo Replication의 기능

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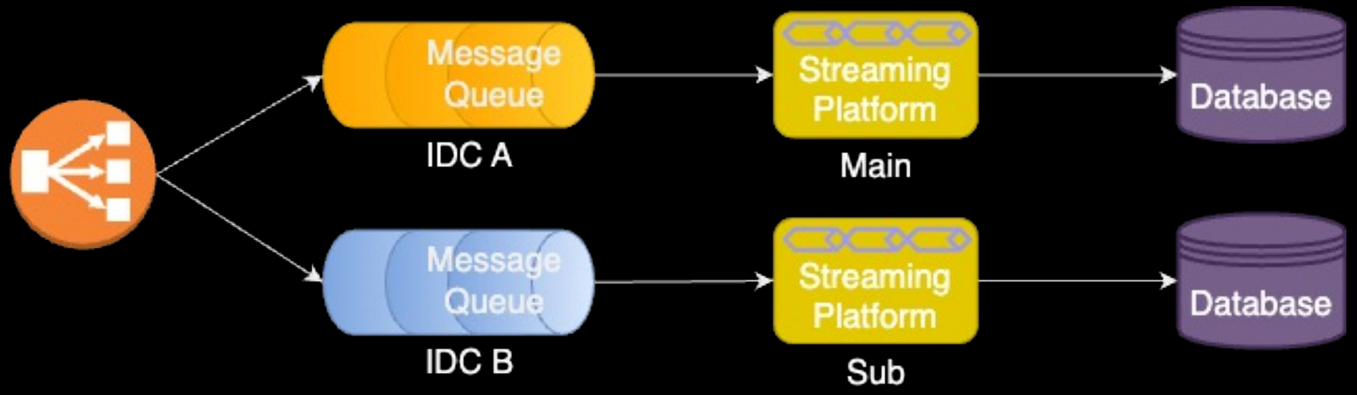
Geo-Replication의 여러 기능들

- Disaster Recovery
  - RTO (Recovery Time Objective)
- Compliance
  - GDPR, HIPPA and SEC
- Data Migration
  - Copy of Data
- Data Distribution
  - Read Only copy of data
- Data co-location
  - for latency sensitive workload



1.3 Geo Replication의 현황

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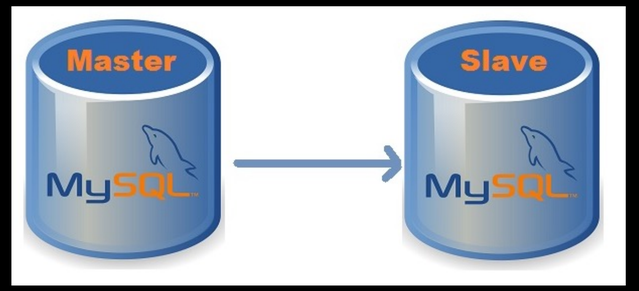
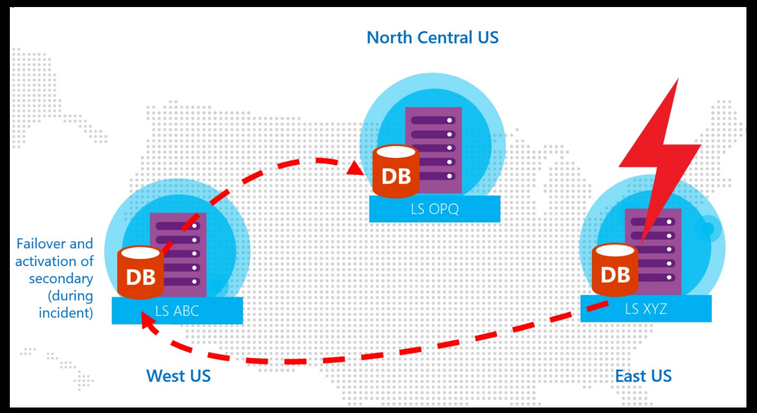
Geo Replication 인식

- 다양한 Platform 에서 이미 지원
  - 자연재해가 많은 국가에서는 보편적
  - 국토의 면적이 넓은 기업에게도 보편적
- 우리는 "Geo Replication" 이라는 단어 조차 익숙하지 않은 실정

Mysql의 GeoReplication



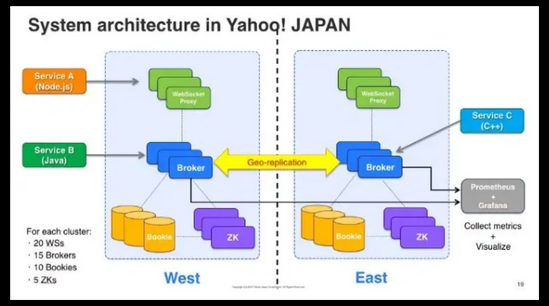
https://thecustomizewindows.com/2019/10/mysql-configuration-to-set-up-master-slave-replication/



https://mscloud.be/azure/configuring-azure-sql-db-active-geo-replication/

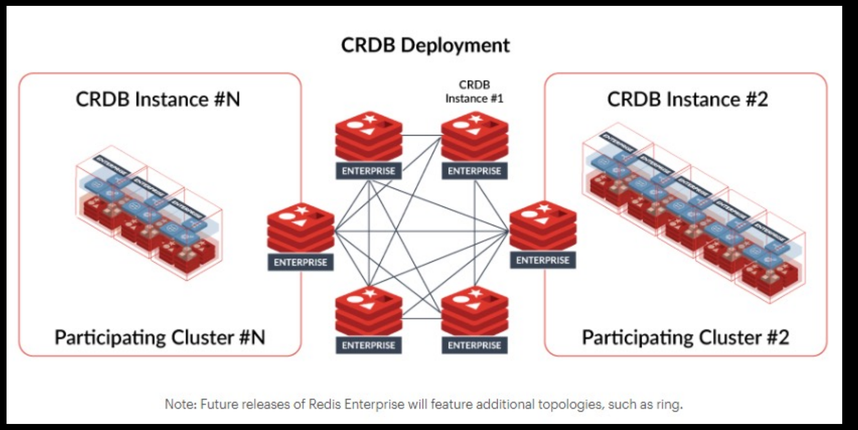
왜? Geo Replication 이 생소할까?

- Multi-IDC Deployment 를 수반
  - 비용증가
  - 관리 Point 증가
- 자연 재해에 대한 경험 부족



https://medium.com/streamnative/apache-pulsar-at-yahoo-japan-b7765bb7b58c

Redis의 GeoReplication



https://redis.com/redis-enterprise/technology/active-active-geo-distribution/

1.4 Geo Replication의 구성

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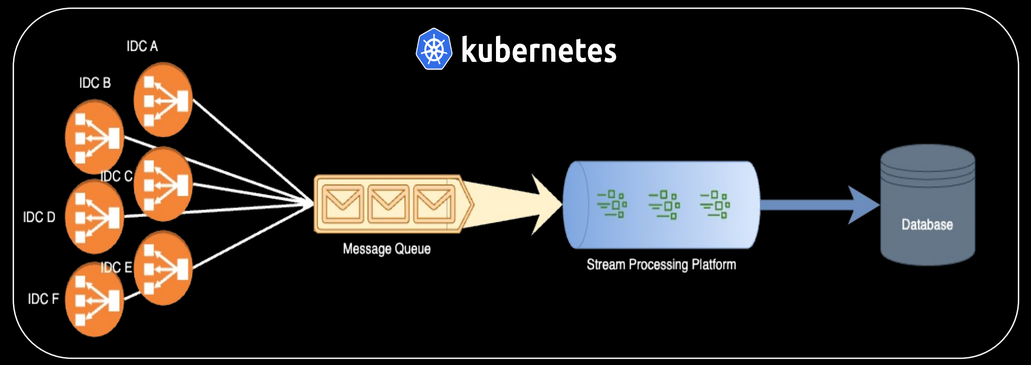
완벽하고 효율적인 Geo Replication을 위해서

- End-to-End 에 걸친 섬세한 설계가 필요
  - End-to-end Transaction
  - Message Delivery Guarantees
  - Exactly Once by Post Processing (eg. Deduplication)

- Trade Off 에 대한 면밀한 분석이 필요
  - Loss-Tolerant <-> Lossless Data Guarantee
  - Automatic <-> Manual Cluster 전환
  - Active-Active <-> Active-Standby 등



Cloud를 기반으로 Source 에서 Database 까지 이르는 전체 Pipeline 에 대한 Geo Replication 이 필요

1.5 Geo Replication의 분류

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Geo Replication 적용의 3가지 분류

Performance

- Local Read를 통한 Low Latency

Scalability

- 여러 사이트에 걸친 Load Balance

Availability

- 중단 없는 서비스 유지

※참조 문헌: Fine-grained consistency for geo-replicated systems, Cheng Li, Nuno Preguica, Rodrigo Rodrigues

Availability 중점의 Cost Efficient Geo Replication

- Eventual consistency 모델에 가까운 실용적인 Geo Replication

Cost

Recovery Speed

Data Loss

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2. Message Queue in Geo Replication

2.1 Message Queue in Geo-Replication

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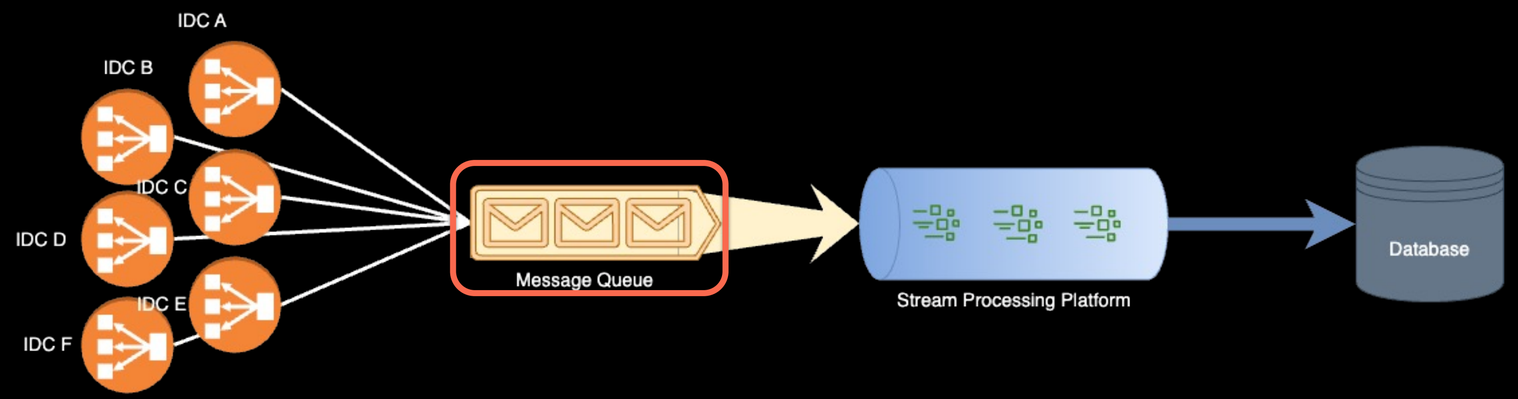
Key roles of Message Queue in Realtime Data Pipeline

- 1st Level Data Aggregation
- Sequential I/O with High TPS
- 찰나의 장애도 Critical



Revisiting Kafka in terms of Geo Replication

- Out-of-the-box: Native & built-in feature
- A/Synchronous Replication Support
- Various Metrics Visibility
- Automatic Cluster Switching API

2.2 Message Queue Geo Replication Key Elements

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Key Element 1 : Out-of-the-box feature

- 개발 난이도와 관리 측면에서 중요한 포인트

Key Element 2: Synchronous & Asynchronous Replication

- Synchronous Replication은 데이터 정합성에 강점
- Asynchronous Replication은 Dynamic Scalability 적용 가능

Key Element 3 : Visible/Measurable Metrics

- Asynchronous Replication 의 Replication Lag 측정
- Subscription offset 정보 등의 확인 가능 여부

2.3 Kafka Stretch Cluster

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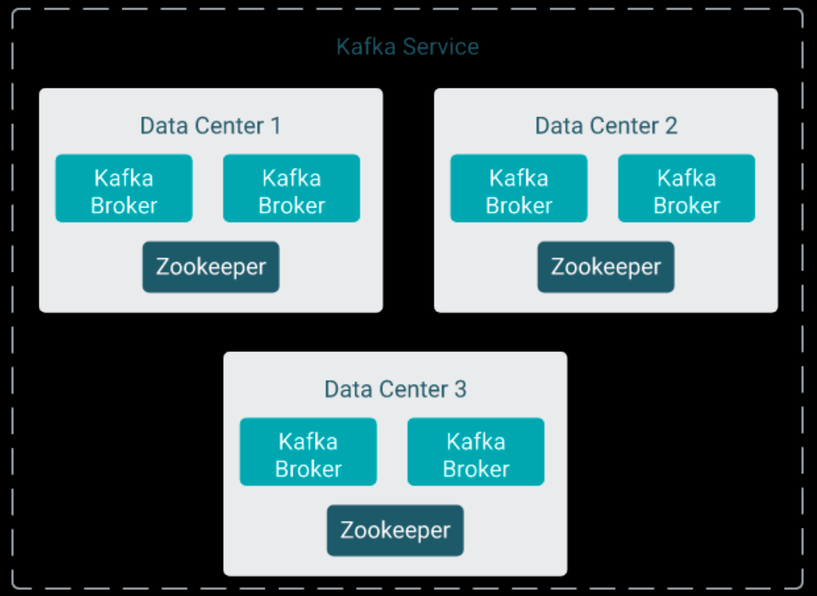
Synchronous Replication on Kafka

- Single Kafka Cluster on Multiple IDC
- Zookeeper Majority Quorums
- Inter Cluster Transfer Latency
- Static Resources



https://docs.cloudera.com/runtime/latest/kafka-overview/topics/kafka-overview-stretch-overview.html

Nominal Write $T_{(client \rightarrow broker)} + (T_{(broker \rightarrow broker)} * min.insync.replicas-1)$

Stretched Write $T_{(client \rightarrow broker)} + (T_{(broker \rightarrow broker)} * min.insync.replicas-1)$

IDC 간 Network Latency 가 추가

2.4 Kafka MirrorMaker

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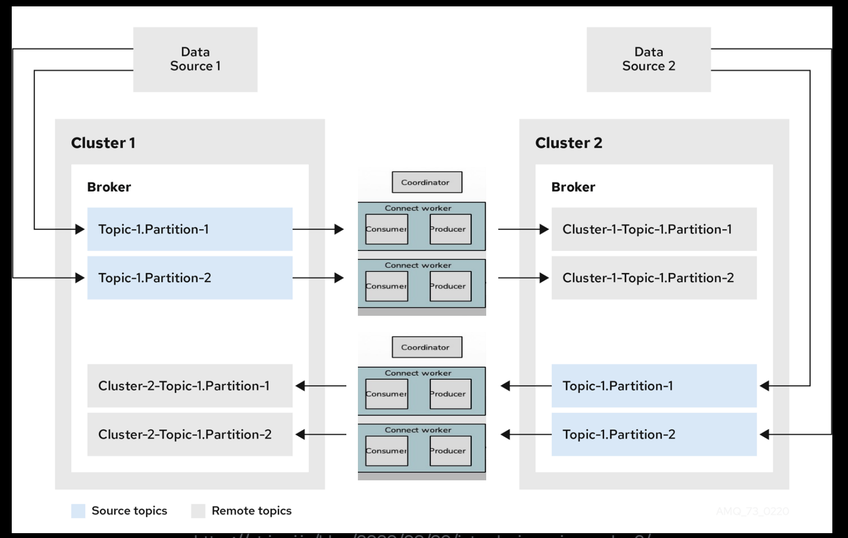
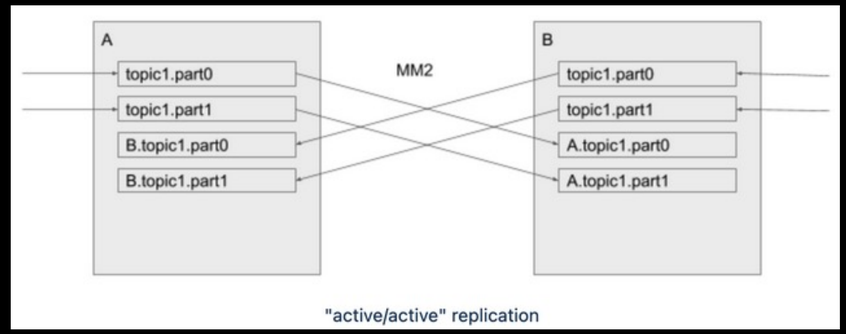
- Asynchronous Replication on Kafka
- MirrorMaker2 features
  - Auto topic discovery & replication
  - Offset replication
  - At least once guarantee
  - Active-Active cluster support
  - Cycle detection

- Limitation of external feature
  - Active–Active 구성 시,
    동일 토픽 간 Multi-named Topic Consuming 필요



https://strimzi.io/blog/2020/03/30/introducing-mirrormaker2/



https://cwiki.apache.org/confluence/display/KAFKA/KIP-382%3A+MirrorMaker+2.0#KIP382:MirrorMaker2.0-Cycledetection

2.5 Alternative Platform Research

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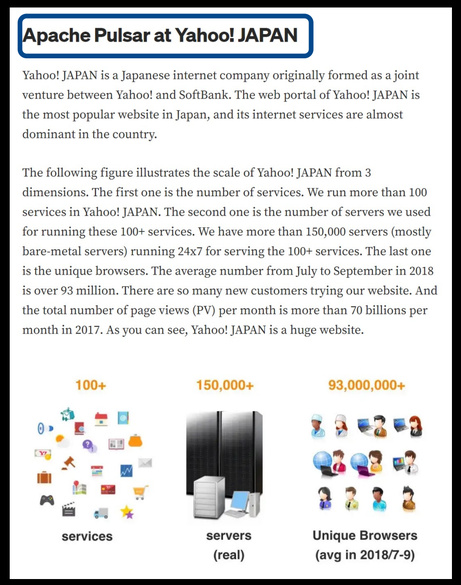
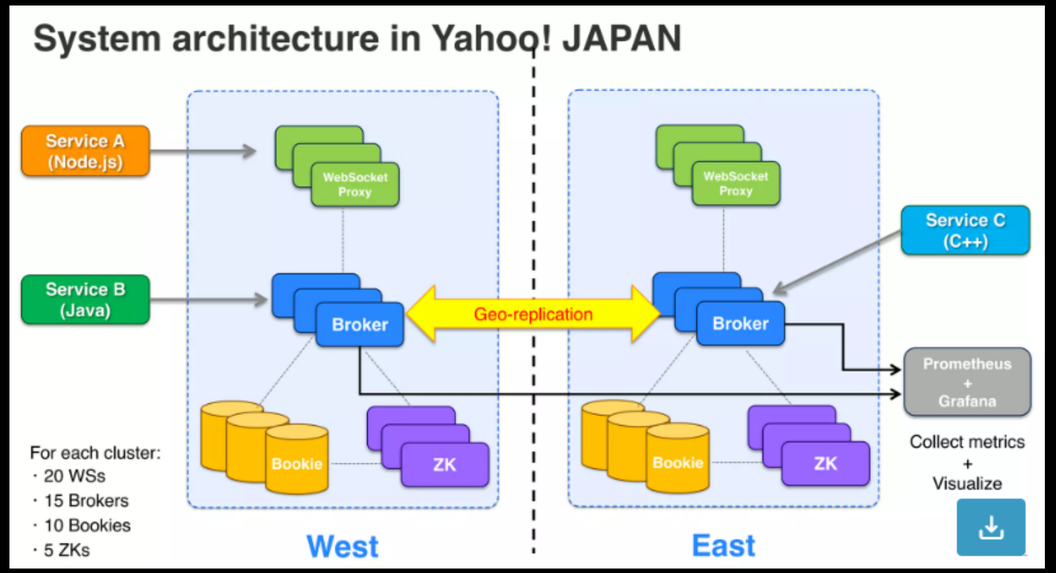
Geo Replication in Yahoo! Japan

- Yahoo! Japan 에서의 Geo Replication Story에 주목
  - 미국, 중국의 Replication 기법 보다는 일본이 우리에게 상대적으로 Realistic
    - 자연재해가 비교적 우리보다 많아 경험 풍부
- Verified Geo Replication functionalities on Production Level





https://medium.com/streamnative/apache-pulsar-at-yahoo-japan-b7765bb7b58c

https://www.google.co.kr/url?sa=i&url=https%3A%2F%2Fwww.docswell.com%2Fs%2Fydnjp%2FK46YJZ-2021-10-05-150329&psig=AOvVaw100tMeJ3XqYsMpluvQoVAw&ust=1673946176443000&source=images&cd=vfe&ved=2ahUKEwig5YPL3cv8AhVJFYgKHWc8D8sQr4kDegUIARDQAQ

2.6 Pulsar Geo Replication

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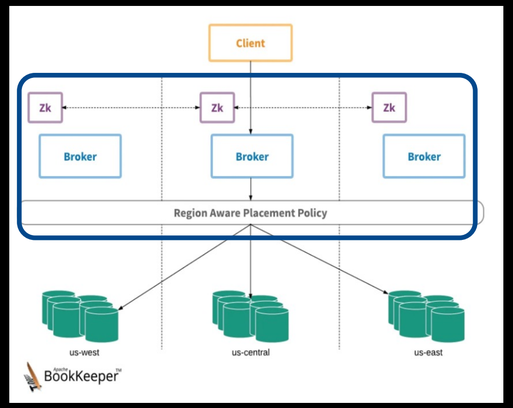
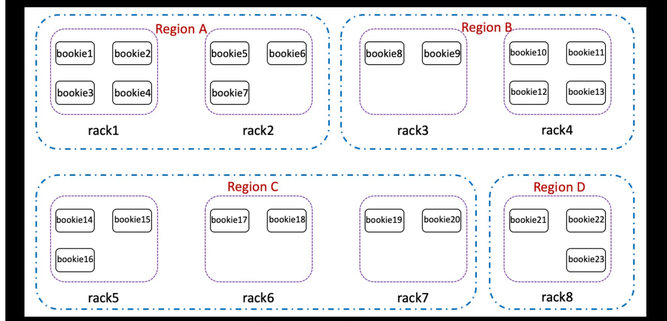
Synchronous Replication

- Region Aware Placement Policy
- Muti-Cluster + 단일 Zookeeper ensemble
- Multi IDC Data Write Ack



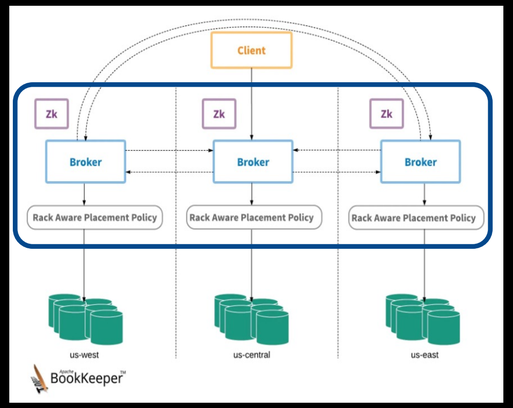
Synchronous Replication



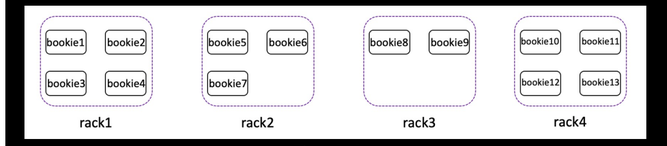
RegionAware

Asynchronous Replication

- Rack Aware Placement Policy
- Write Ack 없이 동작
- Replication Lag 발생 가능



Asynchronous Replication (Full Mesh)



RackAware

https://www.splunk.com/en_us/blog/it/geo-replication-in-apache-pulsar-part-1-concepts-and-features.html

2.7 Pulsar Asynchronous Replication 적용

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Geo-Replication Command Example

- Asynchronous Replication across multiple cluster

Geo Replication (3 types of commands)

1. 다음과 같은 명령어를 사용하여 2개의 Cluster 를 서로 연결

```
[irteam@command1.server pulsar]$ cat connect_to_cluster_2.sh
#!/bin/sh

bin/pulsar-admin clusters create \
        --broker-url pulsar://command2.server:8080 \
        --url http://command2.server:6650/ \
        pulsar-nds
```

```
[irteam@command2.server pulsar]$ cat connect_to_cluster_1.sh
#!/bin/sh

bin/pulsar-admin clusters create \
        --broker-url pulsar://command1.server:8080 \
        --url http://command1.server:6650/ \
        pulsar-nlog
```

2. 복제 하려고하는 tenants 에 대해서 다음과 같은 명령어 입력

- 데이터를 Push 하려고 하는 cluster 에서 실행할 명령어 (원본 cluster)

```
bin/pulsar-admin tenants update nlog --admin-roles my-admin-role --allowed-clusters pulsar-nlog,pulsar-nds
```

- 데이터를 Pull 하려고 하는 cluster 에서 실행할 명령어 (복사본 cluster)

```
bin/pulsar-admin tenants create nlog --admin-roles my-admin-role --allowed-clusters pulsar-nlog,pulsar-nds
```

3. 복제 하려고 하는 namespace 에 대해서 다음과 같은 명령어 입력

- 데이터를 Push 하려고 하는 cluster 에서 실행할 명령어 (원본 cluster)

```
bin/pulsar-admin namespaces set-clusters nlog/nlog --clusters pulsar-nds,pulsar-nlog
bin/pulsar-admin namespaces set-clusters nlog/source --clusters pulsar-nds,pulsar-nlog
bin/pulsar-admin namespaces set-clusters nlog/refined --clusters pulsar-nds,pulsar-nlog
```

- 데이터를 Pull 하려고 하는 cluster 에서 실행할 명령어 (복사본 cluster)

```
bin/pulsar-admin namespaces create nlog/nlog
bin/pulsar-admin namespaces set-clusters nlog/nlog --clusters pulsar-nds,pulsar-nlog
bin/pulsar-admin namespaces create nlog/source
bin/pulsar-admin namespaces set-clusters nlog/source --clusters pulsar-nds,pulsar-nlog
bin/pulsar-admin namespaces create nlog/refined
bin/pulsar-admin namespaces set-clusters nlog/refined --clusters pulsar-nds,pulsar-nlog
```

Visibility of Replication Status

Search Tenants | + New Tenant

Tenant	Namespaces	Allowed Clusters	Admin Roles	In Rate	Out Rate	In Throughput	Out Throughput	Storage Size	Actions
nlog	2	pulsar-nlog pulsar-nds	my-admin-role	↓ 10.48	↑ 7.63	↓ 20K	↑ 14K	2.2G	Edit Delete
public	2	pulsar-nlog		↓ 0.08	↑ 0.00	↓ 59	↑ 0	49.2M	Edit Delete
pulsar	1	pulsar-nlog		↓ 0.00	↑ 0.00	↓ 0 Bytes	↑ 0 Bytes	0 Bytes	Edit Delete

Search Tenants | + New Tenant

Tenant	Namespaces	Allowed Clusters	Admin Roles	In Rate	Out Rate	In Throughput	Out Throughput	Storage Size	Actions
nds	4	pulsar-nds		↓ 161.1K	↑ 80.45K	↓ 143M	↑ 76M	83.94G	Edit Delete
nlog	2	pulsar-nlog pulsar-nds	my-admin-role	↓ 10.12	↑ 7.63	↓ 19K	↑ 14K	2.2G	Edit Delete
public	2	pulsar-nds		↓ 0.05	↑ 0.00	↓ 56	↑ 0	49.2M	Edit Delete
pulsar	1	pulsar-nds		↓ 0.00	↑ 0.00	↓ 0 Bytes	↑ 0 Bytes	0 Bytes	Edit

2.8 Pulsar Important Features

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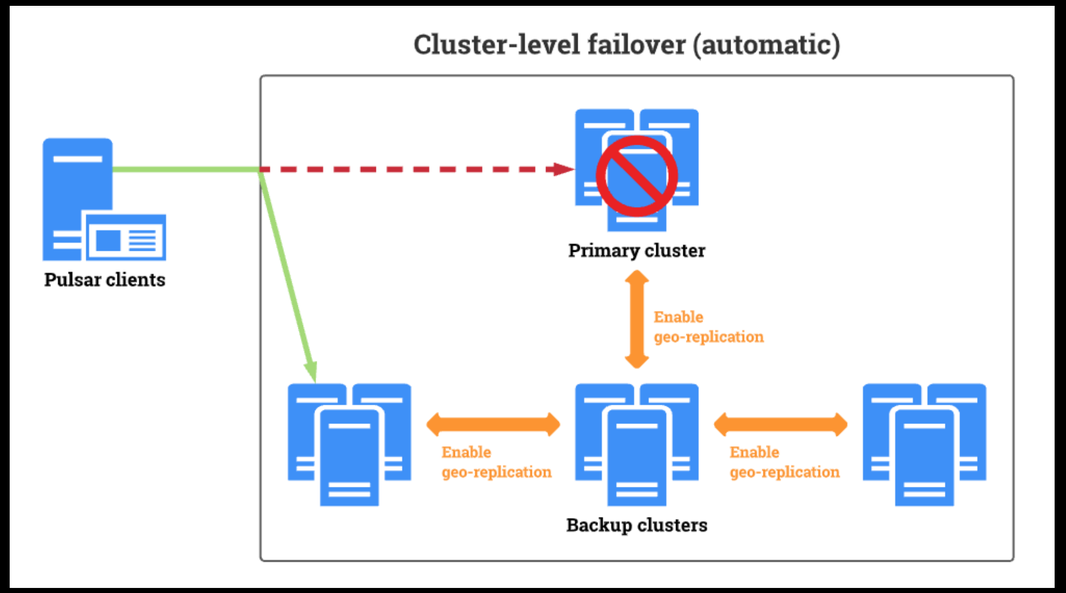
Pulsar Automatic Cluster Failover API

- 데이터 수집 서버에서 Pulsar Client를 활용하여 Message Produce
- 버전 2.10 부터 Native API 로 Secondary Cluster를 지정하여 활용 가능
- Primary Cluster의 장애 탐지 시 Secondary Cluster로 자동 전환



https://pulsar.apache.org/docs/2.11.x/concepts-cluster-level-failover/

Failover Trigger 조건

- Network failure
- Power failure
- Service error
- Crashed storage space

```
1
2   private PulsarClient getAutoFailoverClient() throws PulsarClientException {
3
4         ServiceUrlProvider failover = AutoClusterFailover.builder()
5                .primary("pulsar://localhost:6650")
6                .secondary(Collections.singletonList("pulsar://other1:6650","pulsar://other2:6650"))
7                .failoverDelay(30, TimeUnit.SECONDS)
8                .switchBackDelay(60, TimeUnit.SECONDS)
9                .checkInterval(1000, TimeUnit.MILLISECONDS)
10               .secondaryTlsTrustCertsFilePath("/path/to/ca.cert.pem")
11     .secondaryAuthentication("org.apache.pulsar.client.impl.auth.AuthenticationTls",
12 "tlsCertFile:/path/to/my-role.cert.pem,tlsKeyFile:/path/to/my-role.key-pk8.pem")
```

2.9 Message Queue 관점의 Pulsar vs Kafka

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PULSAR

Pros

- Out of the box feature
- Asynchronous Replication 의 경우 간단히 구축 가능
- A/A 구성 시 동일 Topic Name 이슈 없음
- 2.10 버전부터는 Automatic Cluster Failover API 활용 가능

Cons

- Synchronous Replication 은 Topology 적으로 복잡한 구조
- Subscription Offset 에 대한 Exactly Once 지원 계획 없음
- 문서화, 사례 정보 부족

Apache Kafka

Pros

- 다양한 구축 사례 등의 많은 정보
- Subscription offset 에 대한 Exactly Once (PIP-656) 진행중

Cons

- MirrorMaker2는 별도의 설치 및 Cluster 구축 필요
- A/A 구성에서 동일 Topic-Name 구성 불가
- Static Resource 기반의 Replication 구조

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3. Realtime Data Processing in Geo Replication

3.1 Realtime Data Processing in Geo-Replication

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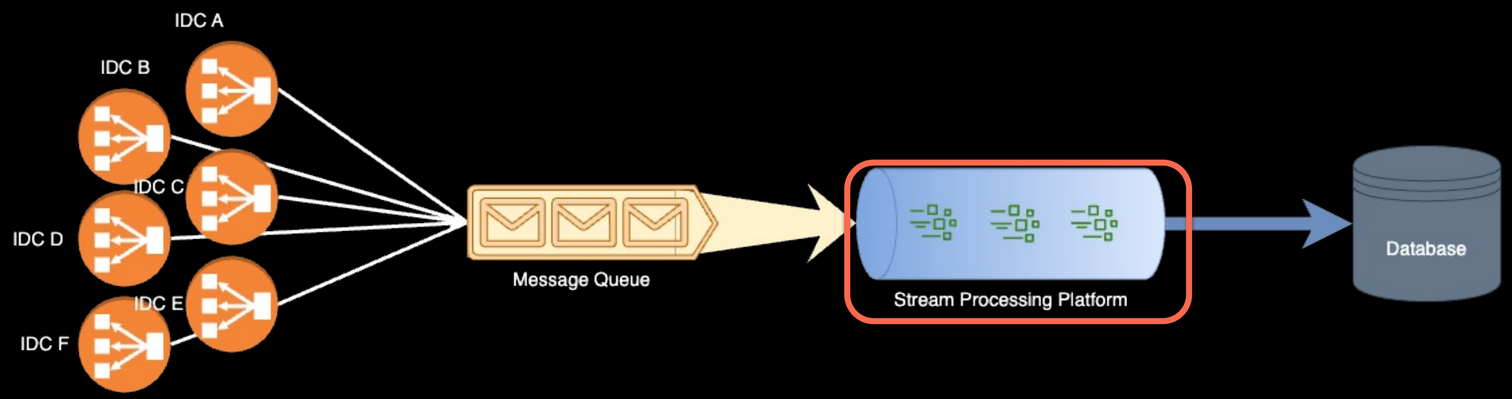
Realtime Streaming Data Enrichment

- Geo Replication 의 관점에서 관리 포인트
  - Network Endpoints
  - Offset Management



Revisiting Stream Processing Platforms in terms of Geo Replication

- Message Queue 시스템과 얼마나 단순하게, 효율적으로 동작하는가?
- Dynamic scale in/out 이 가능한지?
- 얼마나 Data Reusability가 높은가?

3.2 Realtime Data Processing Geo Replication Key Elements

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Key Element 1 : Cloud Friendliness

- 장애시 Catch-up reads와 평상시의 Tailing reads 사이의 탄력적 Resource Scaling
- Cost Efficient 관점에서 중요한 Feature

Key Element 2: Reduced Management with Integrated Processing

- Message Queue System 과 연결 point를 최소화
- Fewer Platforms Pipeline이 Geo Replication에 보다 유리

Key Element 3: Data Reusability

- Data Enrichment 결과 데이터를 얼마나 효과적으로 재사용할 수 있는가?
- 장애 복구 시 효과적인 리소스 사용

3.3 Revisiting Typical Realtime Processing

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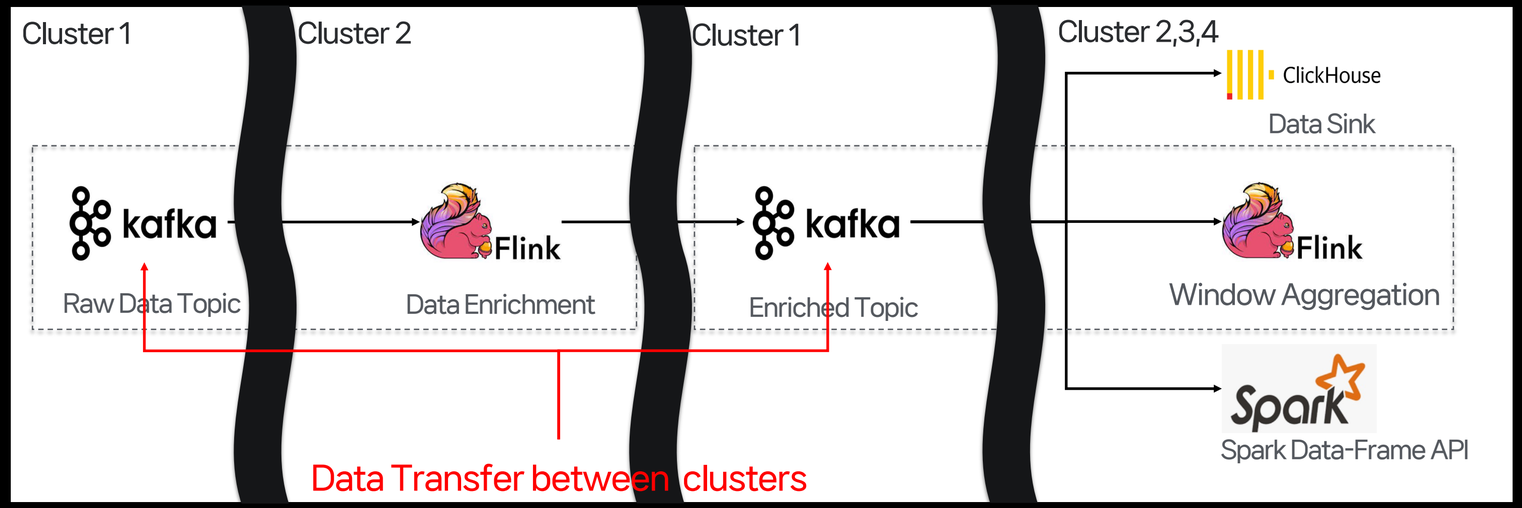
Low Data Reusability Problem

- Kafka -> Flink 의 Chain은 Cluster to Cluster 통신을 통해서 동작
  -> 높은 네트워크 비용
  -> API를 통한 데이터 전송 코드 개발 및 최적화 필요
- Cluster 간 통신을 줄이고 Data Reusability 가 높은 Platform 에 대해서 Research



3.4 Alternative Platform Research

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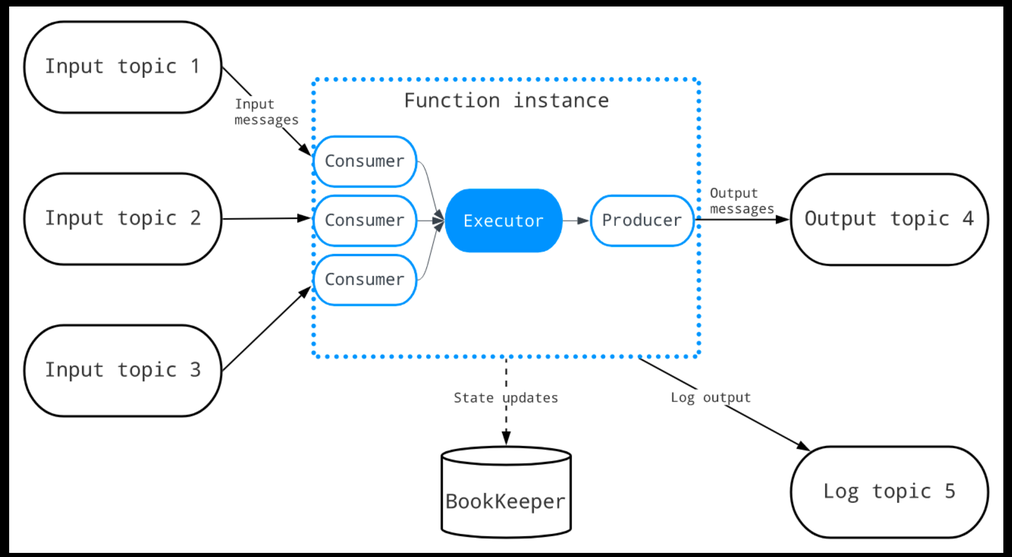
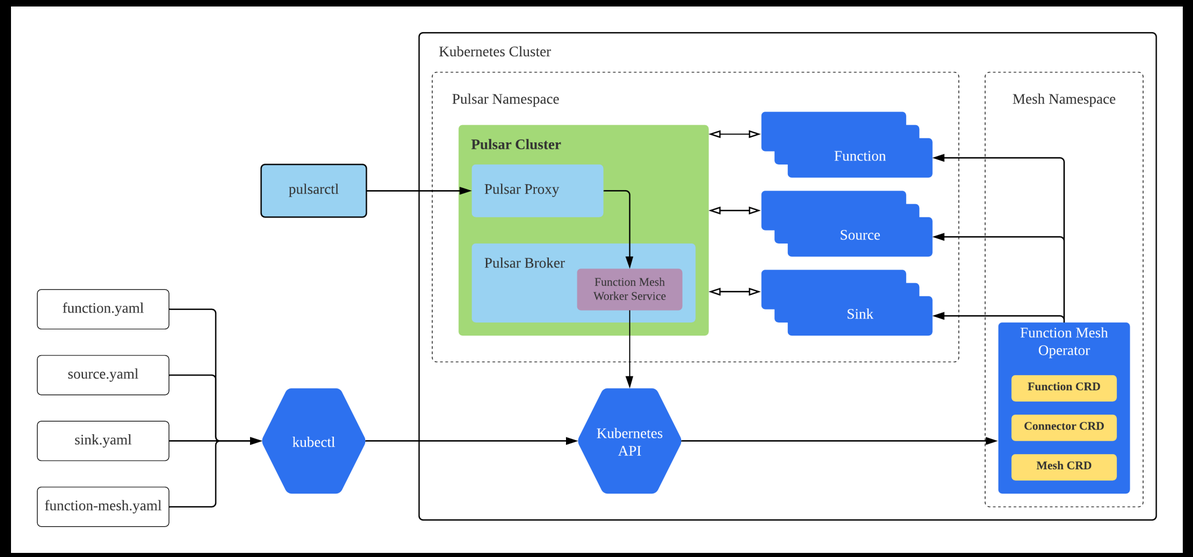
Function and FunctionMesh in Pulsar

- Function: Dynamically Scalable Lambda Like Light-weight processing with Chaining
- Output Topic 을 통한 간편한 In-Cluster 데이터 이동
- Resource Utilization, Prometheus Metrics 연동해 HPA 구성이 가능
- Source, Functions, Sink로 나눠 단계적인 데이터 처리가 가능한 FunctionMesh 적용



https://pulsar.apache.org/docs/2.11.x/functions-concepts/



https://functionmesh.io/docs/

3.5 Streaming Engines Comparison

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Summarized Comparison of Streaming Engines

	Flink	Spark	Pulsar
API Set	Rich (WindowJoin, SessionWindow...)	Rich (Spark Structured Streaming...)	Relatively Compact (복잡한 Window 연산 불가)
Realtime/ MicroBatch	Realtime	MicroBatch	Realtime
Productability	Need to build complete Application	Leverage Spark's dataframe API	Fast and easy

3.6 Messaging and Processing with Pulsar

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Pulsar를 통한 Window Aggregation

- Key_Shared Subscription을 활용하여 기존 keyBy()연산을 대체
- 자체 Window Function 활용

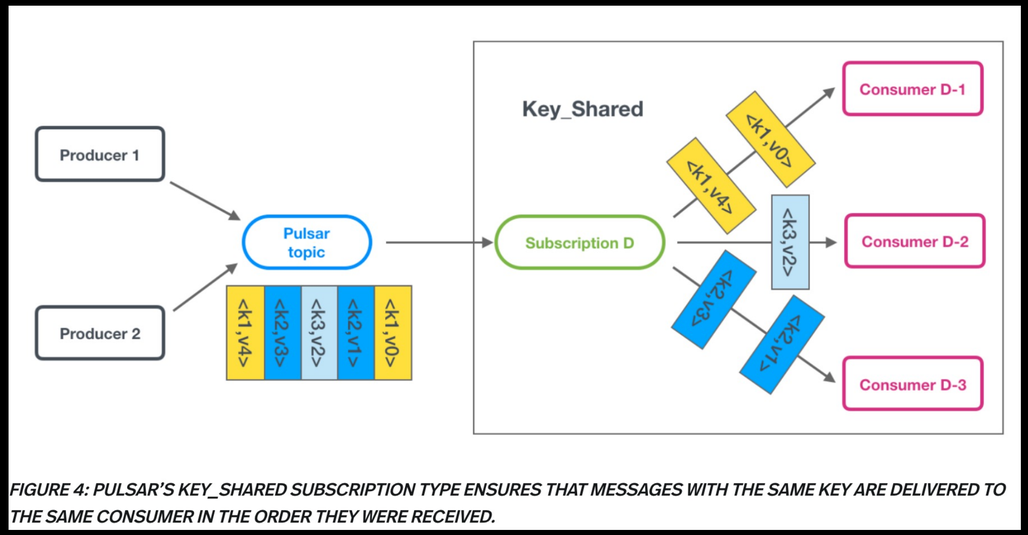

FIGURE 4: PULSAR'S KEY_SHARED SUBSCRIPTION TYPE ENSURES THAT MESSAGES WITH THE SAME KEY ARE DELIVERED TO THE SAME CONSUMER IN THE ORDER THEY WERE RECEIVED.

https://streamnative.io/blog/scalable-stream-processing-pulsars-key-shared-subscription

∴ Messaging + Processing + Sinking을 Pulsar FunctionMesh 하나로 대체

- Data Reusability 향상
- In Cluster 연산을 통한 Network 관리포인트 감소

3.7 Drawback of using HPA on Consumer

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HPA로 인한 Window Split

1) HPA로 인해서 Consumer 구성 변경 발생
2) Consumer 구성 변경 → KeyBy() 결과에 변화 발생
3) Window Split 현상 발생

2022-01-05	12:03:10	12:03:20	네이버 블로그	30-40	F	Android	Browser	4	사용자 A, 사용자 B 사용자 C, 사용자 D

2022-01-05	12:03:10	12:03:20	네이버 블로그	30-40	F	Android	Browser	2	사용자 A, 사용자 B	s1
2022-01-05	12:03:10	12:03:20	네이버 블로그	30-40	F	Android	Browser	2	사용자 C, 사용자 D	s2

- 따라서 Window Aggregation 함수가 다음의 수식을 만족하지 않는다면 문제 발생

$$F(s1\ UNION\ ALL\ s2)\ =\ F(F(s1)\ UNION\ ALL\ F(s2))$$

- 해결 방법 예시: Rolled up Cube 구성 시 Group By 필요

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4. Cloud Friendliness in Geo Replication

4.1 Geo Replication in Cloud

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Platforms with Geo Replication

- Cloud 환경에 적합한 Data Processing Platform 이 필요
  - Storage Architecture에 Dependent 할 수록 Dynamic Scalability 저하
  - Cost Efficient Geo Replication 을 위해선 Cloud Friendly Platform 이 필요
    - 예시) 1. Repartition 없이 Scaling 될 수 있는 Messaging Platform
    - 2. 장애 시 HPA 를 통해 빠르게 Catch-up Read 가능한 Processing Platform
    - 3. Standby 시 Resource 사용을 최소화 할 수 있는 Messaging Platform

Apache Kafka

kubernetes

PULSAR

APACHE Spark™

Flink

4.2 Geo Replication in Cloud Key Elements

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Key Element 1: HPA 기반의 Dynamic Resource 할당

- HPA를 기반으로 한 탄력적 Resource Scaling 을 통해서 빠르게 장애 대응
- Active/Active, Active/Standby 와 같은 다양한 Resource 구성에 효과적으로 대응
- Cost Efficient Geo Replication을 위한 필수적 특징

Key Element 2: Modularly Designed Sub-system

- Monolithic Design 의 경우 Resource 를 효과적으로 Scaling 하기에 불리한 구조
- Micro Service Architecture 에 유리한 Modular design

Key Element 3: No Penalty after Scaling In/Out

- Resource Scaling 으로 성능 저하/기능 제약이 있는 경우 Cloud의 Resource 환경에 부적합

4.3 Dynamic Scalability of Kafka

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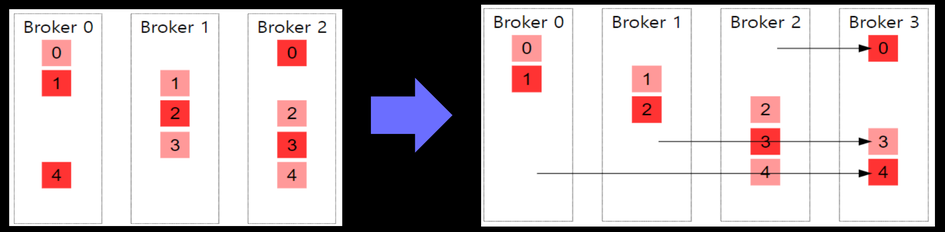
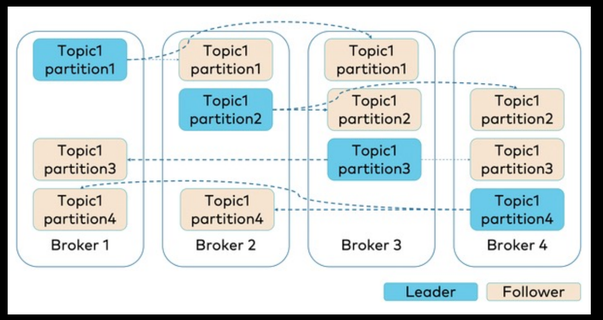
Kafka's architecture and Dynamic Scalability

- Strongly combined broker and partitions
- 증설 시 새로운 노드에 온전한 Partition을 위해 Data Migration 필요
  - 매 증설마다 Performance Degradation 이 발생 (Disk, Network, Computation cost)



https://teke42.wordpress.com/2018/08/29/scaling-kafka/

- Storage and Broker 가 결합되어 있는 구조
  - Message Broker와 Storage 를 독립적으로 Scale 할 수 없는 구조



4.4 Dynamic Scalability of Pulsar

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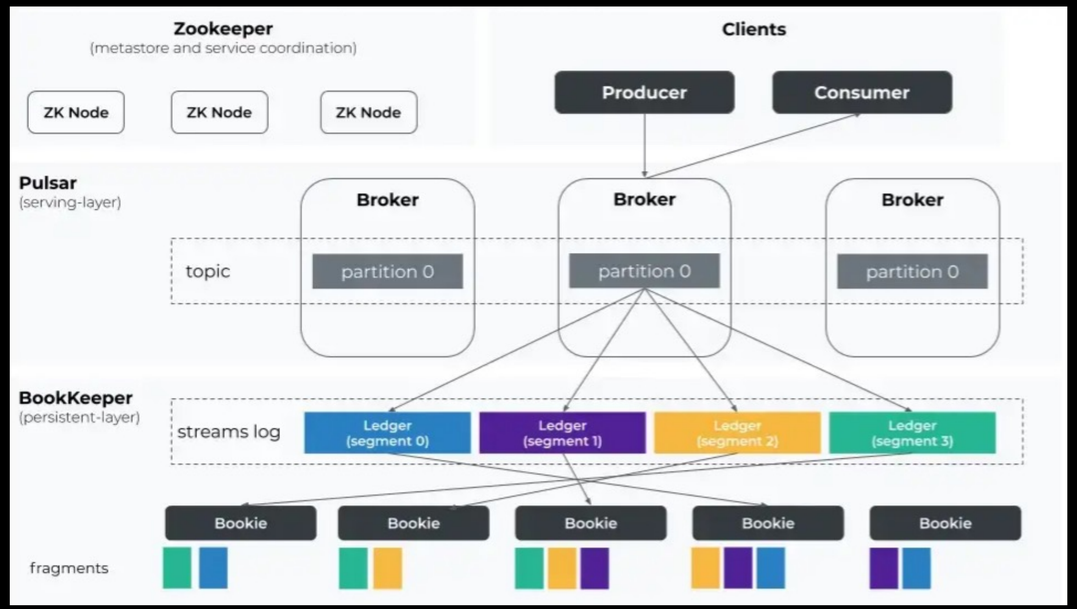
Pulsar's architecture and Dynamic Scalability

- Layered Architecture and Independent Storage Sub-system
  - Node 추가 시 Partition 구조 없이 새로운 Bookie 로 저장되는 구조
  - Bookie 추가 시 Data Migration 으로 인한 성능 저하가 없음
  - 새 데이터는 새 Bookie 로 저장되는 구조

- Broker 의 Independent Scalability
  - 독립적으로 동작
  - Stateless
  - Auto-Scaling in/out 가능



https://medium.com/streamthoughts/introduction-to-apache-pulsar-concepts-architecture-java-clients-71f1a30b75d6

4.5 Comparison of Cloud Friendliness

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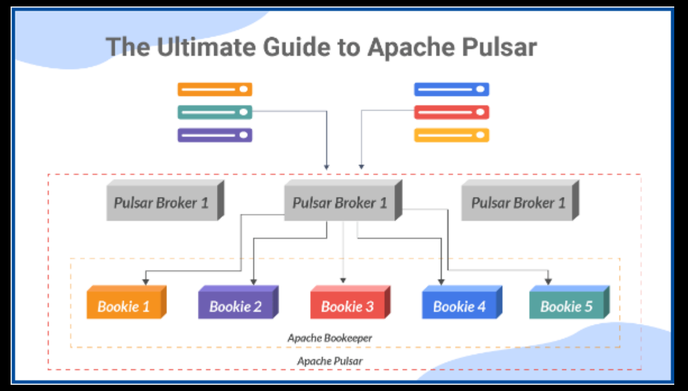
Pulsar vs Kafka

- Monolithic architecture vs Multi-layered architecture
  - Kafka : Broker와 Storage 가 결합된 구조
  - Pulsar : Broker와 Storage (BookKeeper)와의 완전한 분리

https://www.splunk.com/en_us/blog/it/apache-pulsar-architecture-designing-for-streaming-performance-and-scalability.html

- Broker
  - Kafka : Storage 와 결합되어 있어 Stateless 함에도 불구, Dynamic Scaling 불가
  - Pulsar : Storage 와 분리되어 있어 Storage와 별개로 독립적 Dynamic Scaling 가능

- Storage
  - Kafka : 특정 Topic의 특정 Partition을 특정 노드에 할당
  - Pulsar(BookKeeper) : 데이터를 Segment화 하고 Stripping하여 분산 저장



https://medium.com/streamthoughts/introduction-to-apache-pulsar-concepts-architecture-java-clients-71f1a30b75d6

4.6 Pulsar's feature summary

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Pulsar's Pros

- "Cloud Native" : Modularity design 과 Cloud Friendly
- "Out-of-box Geo replication" : MM2 와 같은 외부 툴 없이 Geo Replication 을 자체 제공
- "Function" : In Cluster Processing Runtime 을 제공
    - 외부 Connector 의 지원이 부족한 Pulsar 의 단점을 대부분 Cover
    - 자체 Lambda Processing Platform 제공
    - 데이터를 외부로 꺼내지 않더라도 자체적으로 처리 하는 것이 가능
    - Out-of-box feature
- "Multi-Tenant" : Topic Hierarchy가 Kafka 에는 없음

4.7 Integrated Package Manager

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Package Manager 를 통한 Application/배포 관리

- 장애시에 배포 시스템이 문제가 있다면?
  - Git 를 통한 Version Control -> Pulsar Package Manager

- Pulsar Package manager 를 통한 Version 관리 장점
  - 외부에 배포 시스템으로 부터 독립적
  - Out of the box feature

내장된 Package Manger

```
enablePackagesManagement=true
packagesManagementStorageProvider=org.apache.pulsar.packages.management.storage.bookkeeper.BookKeeperPackagesStorageProvider
packagesReplicas=1
packagesManagementLedgerRootPath=/ledgers
```

```
sink://public/default/mysql-sink@1.0
function://my-tenant/my-ns/my-function@0.1
source://my-tenant/my-ns/mysql-cdc-source@2.3
```

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5. Geo Replication in Practice

5.1 Standard Synchronous Geo-Replication (Type 0)

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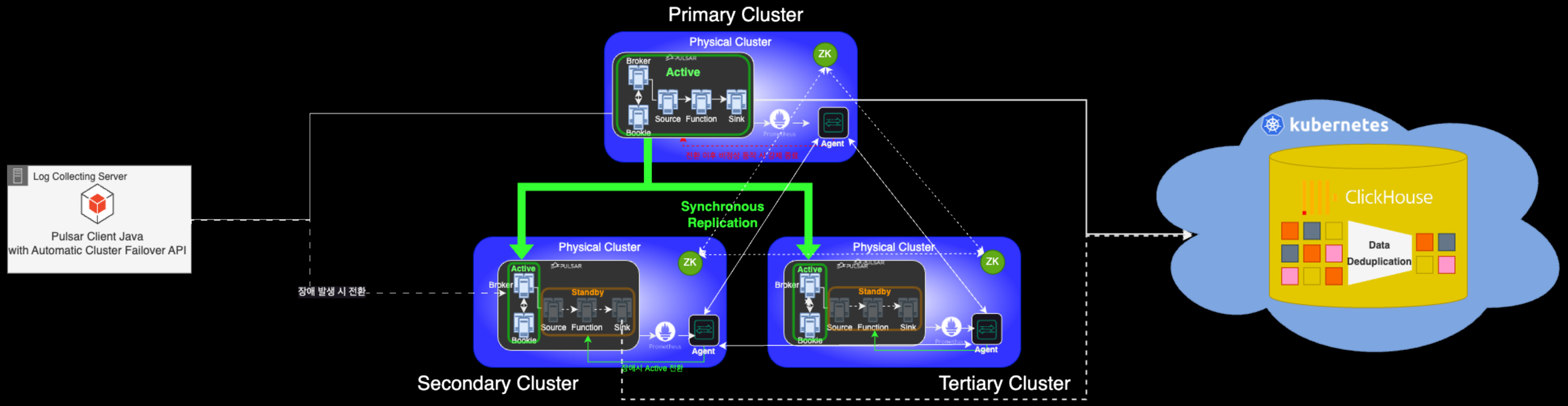

Features

- Full 3 IDC Cluster
- Region-Aware Ensemble Placement Policy
- Automatic Cluster Failover API

Pros

- 높은 Fault Tolerant

Cons

- High Resource
- Inter-Cluster Transfer Latency
- Non Dynamic Scalable

Inter-Cluster Latency

단위: ms

	A	B	C
A	0.02	0.48	2.52
B	0.46	0.01	1.6
C	2.6	1.5	0.03

5.2 Two-point-Five Cluster Synchronous Geo-Replication (Type 1)

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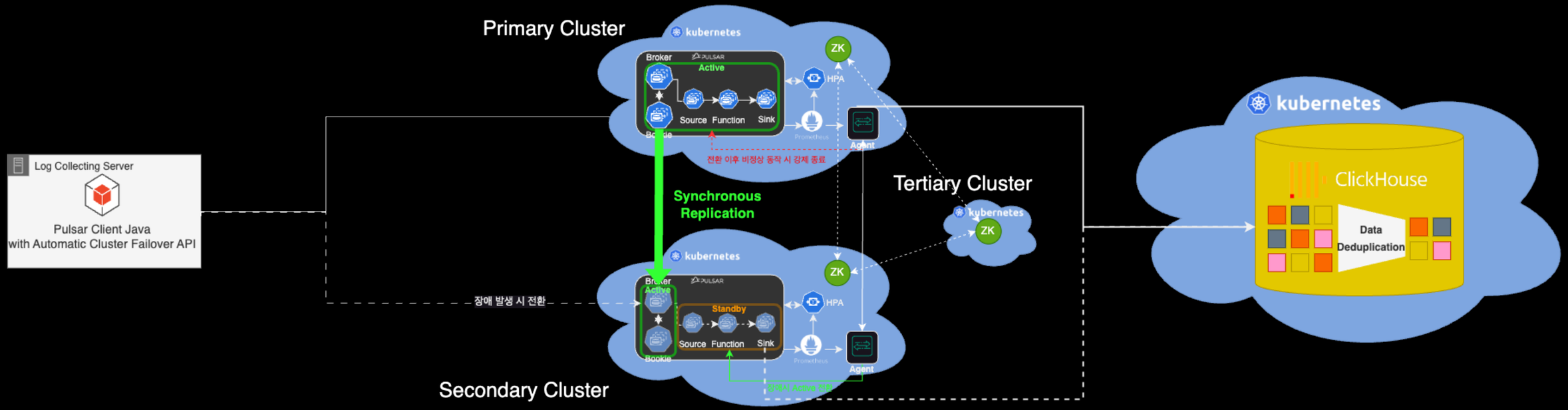

Features

- 3 IDC Stretched Zookeeper
- Region-Aware Ensemble Placement Policy
- Active-Active Topic Data
- Active-Standby Processing Function
- Data deduplication on DB side

Pros

- Lossless Geo Replication
- Dynamic Scalable on Pulsar Cluster

Cons

- Due to Zookeeper Ensemble & Quorum, at least 3 Cluster needed
- Inter-Cluster Transfer Latency

5-3. Agent의 Secondary Pulsar Function Trigger 조건, 처리

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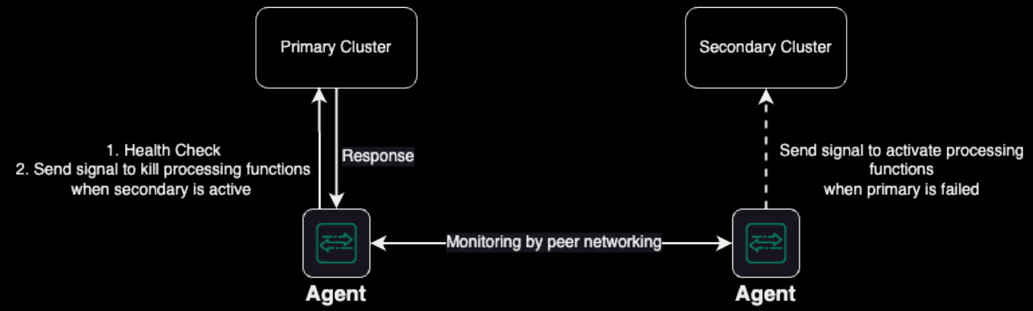
Secondary Pulsar Function이 시작하는 조건

- Trigger Condition
  - 1초마다 Service Ping Check
  - Storage Fail Check
  - Clickhouse Insert rate Outlier detection



- What is triggered
  - 단일 YAML로 실시간 Processing Pipeline 전체 배포
  - Replicated Application using Pulsar Package manager
  - Cluster 전환 시 Circuit Break 로
    기존 Pulsar Function Instance 삭제

```yaml
functions:
  - name: function-lcs
    namespace: pulsar-nds
    className: refine_lcs.RefineFunctionLCS
    forwardSourceMessageProperty: true
    replicas: 40
    maxReplicas: 80
    input:
      topics:
      - persistent://nds/source/lcs-topic
    output:
      topic: persistent://nds/refined/lcs-refined-topic
    resources:
      requests:
        cpu: "0.8"
        memory: 524M
      limits:
        cpu: "0.8"
        memory: 524M
    pod:
      autoScalingMetrics:
      - type: Resource
        resource:
          name: memory
          target:
            type: Utilization
            averageUtilization: 60
      - type: Pods
        pods:
          metric:
            name: pulsar_function_received_total_1min_total
            selector:
              matchLabels:
                name: functionmesh-nds-realtime-function-lcs
                namespace: pulsar-nds
          target:
            type: AverageValue
            averageValue: "40000"
    pulsar:
      pulsarConfig: "pulsar-nds"
    python:
      pyLocation: function://public/functions/lcs-refine-function@0.1
```

```yaml
sinks:
  - name: sink-lcs
    className: com.riferrei.pulsar.sink.custom.CustomSinkConnector
    replicas: 40
    maxReplicas: 40
    input:
      topics:
      - persistent://nds/refined/lcs-refined-topic
      typeClassName: java.lang.String
    sinkConfig:
      columnList: "sp,url,os_type,br_type,br,age,gender,idno,bc"
      tableName: "secret"
      clickhouseJDBCUrl: "secret"
      clickhouseUser: "secret"
      clickhousePassword: "secret"
    resources:
      requests:
        cpu: "0.8"
        memory: 1G
      limits:
        cpu: "0.8"
        memory: 1G
    pod:
      autoScalingMetrics:
      - type: Resource
        resource:
          name: memory
          target:
            type: Utilization
            averageUtilization: 60
      - type: Pods
        pods:
          metric:
            name: pulsar_sink_received_total_1min
            selector:
              matchLabels:
                name: functionmesh-nds-realtime-sink-lcs
                namespace: pulsar-nds
          target:
            type: AverageValue
            averageValue: "40000"
    pulsar:
      pulsarConfig: "pulsar-nds"
    java:
      jarLocation: function://public/functions/nds-sink@0.1
      jar: custom-sink-connector-0.0.1.jar
    clusterName: pulsar-nds
    autoAck: true
```

5.4 Client-Side Synchronous Geo Replication (Type 2)

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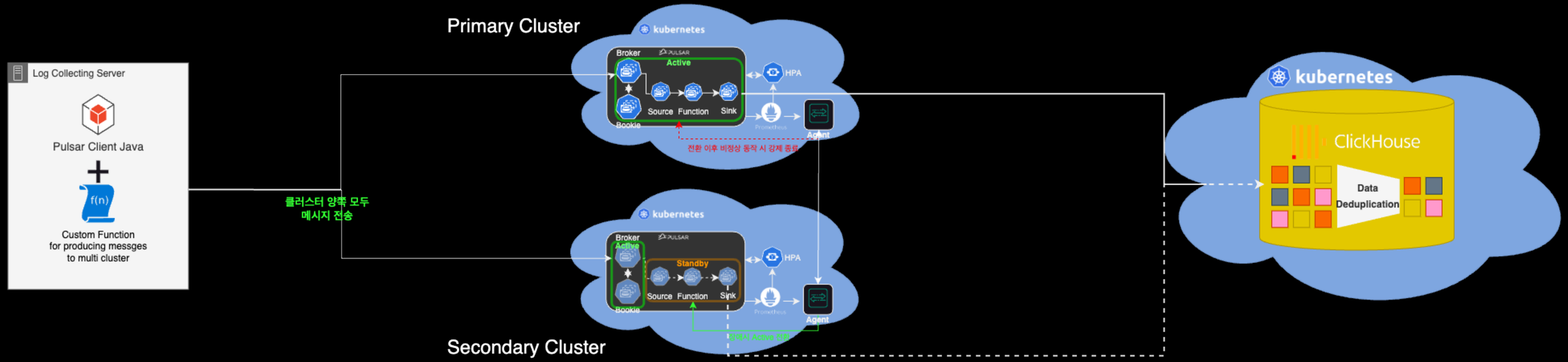

Features

- Transaction API on Client Side
- Active-Active Topic Data
- Active-Standby Processing Function
- Data deduplication on DB side

Pros

- 2 IDC Synchronous Data Replication

Cons

- Client Side High Resource & Latency
- Not using Automatic Cluster Failover API

5.5 Lossless Asynchronous Geo Replication (Type 3)

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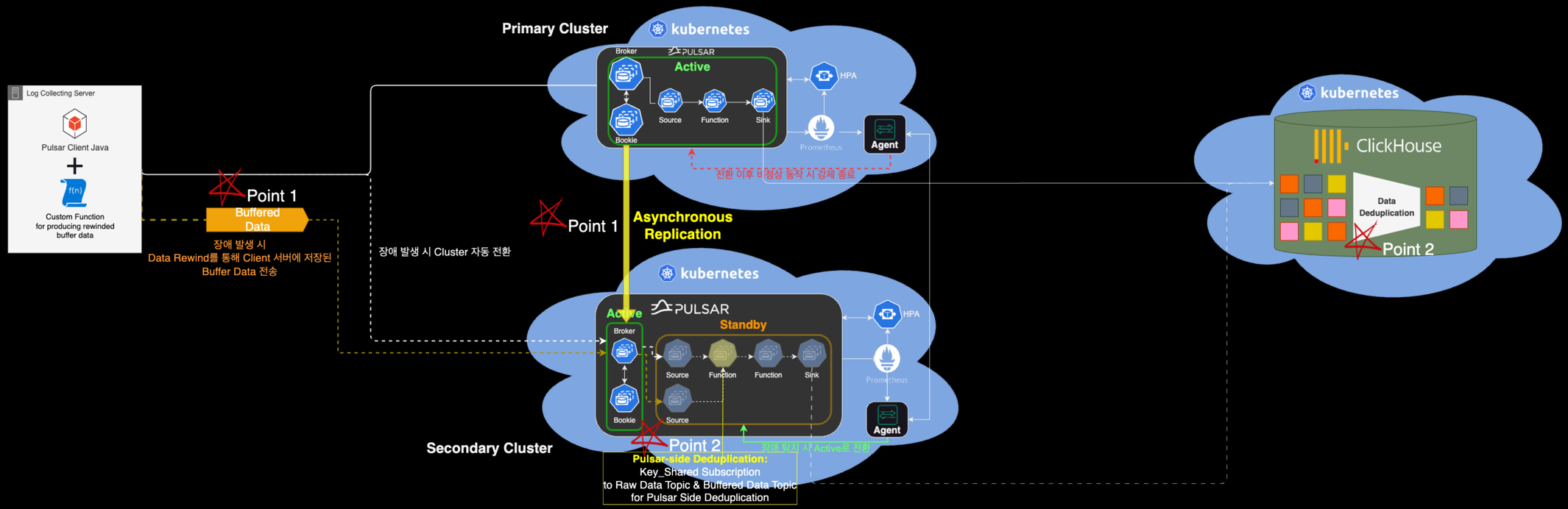

Features

- Automatic Cluster Failover API
- Active-Active Topic Data
- Active-Standby Processing Function
- Data deduplication on Pulsar & DB side
- Client Side Buffer 활용 Data Rewind

Pros

- Easy to develop and manage
- Low Resources
- No Inter-Cluster latency

Cons

- Need to manage the Client Buffer Size

5.6 Point 1: Replication Lag & Data Rewind

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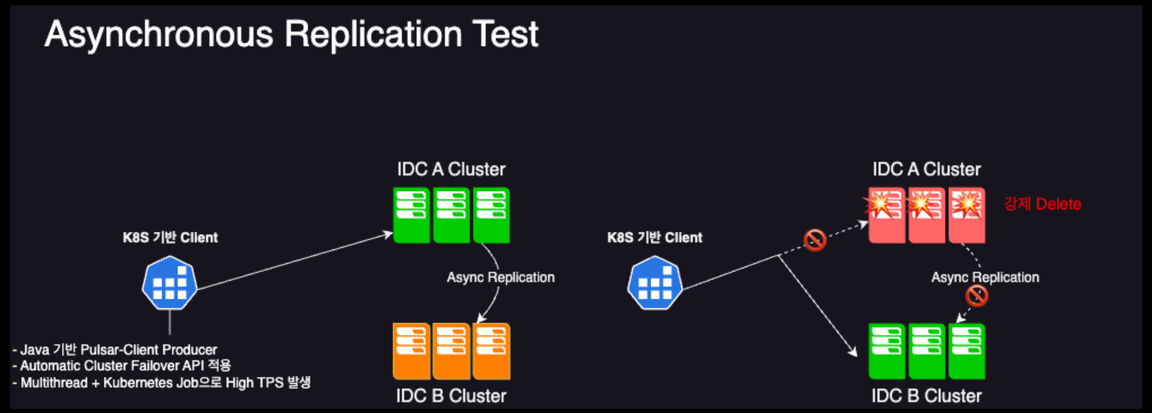
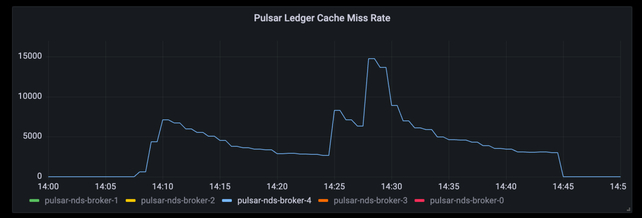
Replication Lag



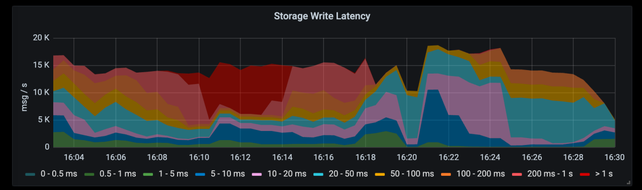
TPS	총 유입 시간	유실 비율
1k	2분	0%
10k	2분	0%
10k	30분	0.1%
30k	30분	1%
50k	30분	3%

TPS	Replication Lag
10k	
30k	
50k	

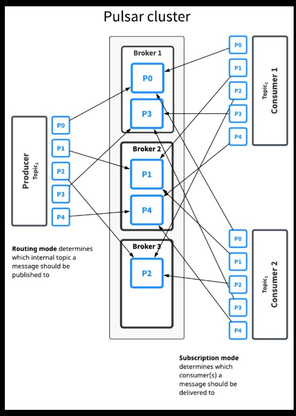
➢ Factors which affect the Replication Lags on Pulsar



- Data Journaling and Ledger



- Storage I/O Performance



- Pulsar Message Routing Mode

5.6 Point 1: Replication Lag & Data Rewind

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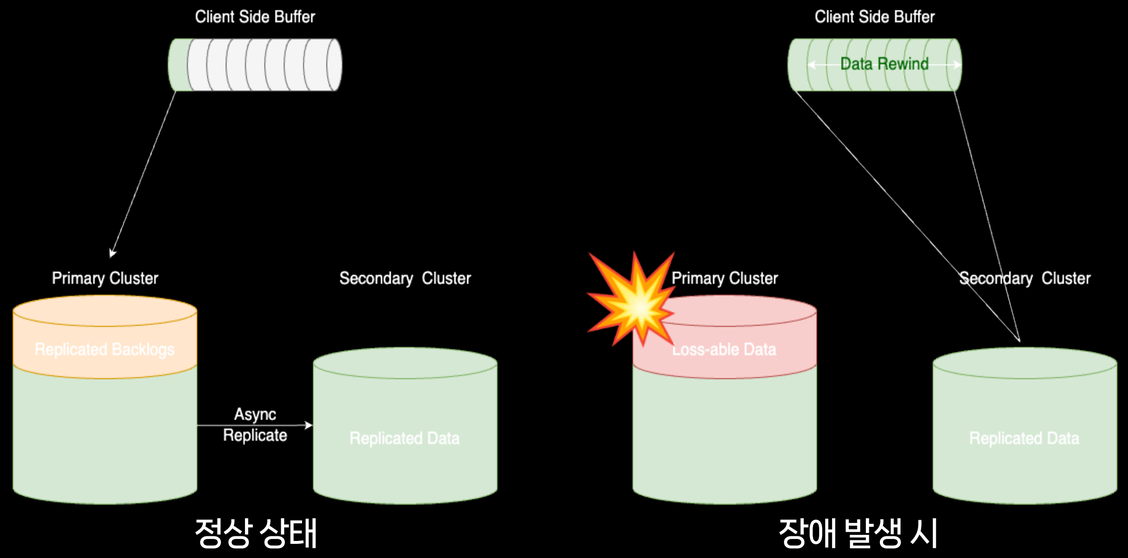
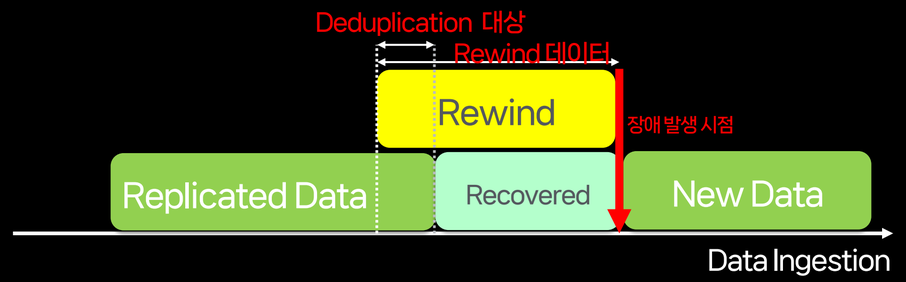
Data Rewind on Producers

- Client Side Buffering을 이용한 Data Rewind 적용
  - Fixed-size buffering
  - Adaptive buffering
  - Cluster Switch 시 File Offset 변경을 통해서 데이터 Rewind



- Side Effects
  - Data Deduplication 필요
  - Windows 연산에 대한 시간 경계와 이로 인한 Row Split
  - Rollup Style Database는 일부 산술 연산 시 잘못된 결과 발생 가능
  - Message Ordering Guarantee 가 필요한 경우 추가 작업이 필요



5.7 Point 2: Data Deduplication

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2 Way Data Deduplication

DB-Side Deduplication

- Data Deduplication on Append Only Database (OLAP)
  - Clickhouse의 Replacing Merge Tree 를 이용한 DB-Side Deduplication

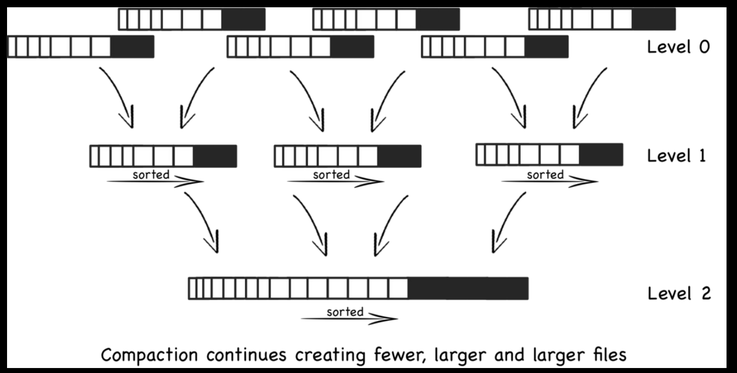
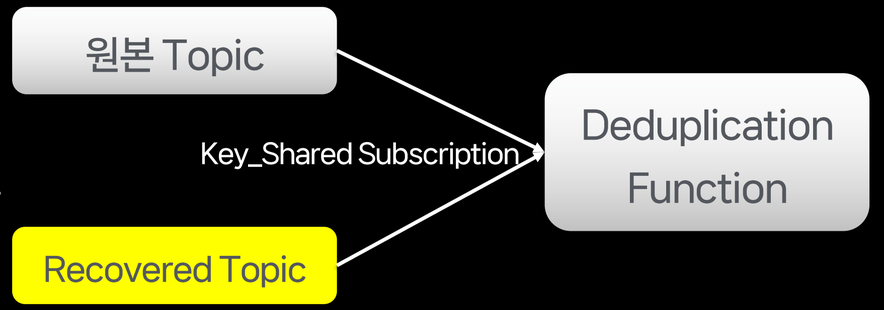


Diagram illustrating compaction of data in a log-structured merge tree

Pulsar-Side Deduplication

- Rewind 된 데이터를 별도의 Topic 에 저장
- 별도의 Platform 없이 Deduplication 을 위해서 Pulsar Function 을 이용
- Key_Shared Subscription + Sequence ID 로 구현
- Replication Lag으로 삭제된 데이터를 찾는 것이 가능



Sequence ID Each Pulsar message belongs to an ordered sequence on its topic. A message's sequence ID is its ordering in that sequence.

5.8 Comparison of 4 Types

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	Main Features	Development	Resource Cost	Scalability	Replicated Data Consistency	Performance
Type 0		Easy	$$$	Low	High	Low
Type 1		Middle	$$	Middle	High	Middle
Type 2		Middle	$$	Middle	Middle	Middle
Type 3		Hard	$	High	Low	High

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6. Efficiently Lossless Realtime Processing in Log-data

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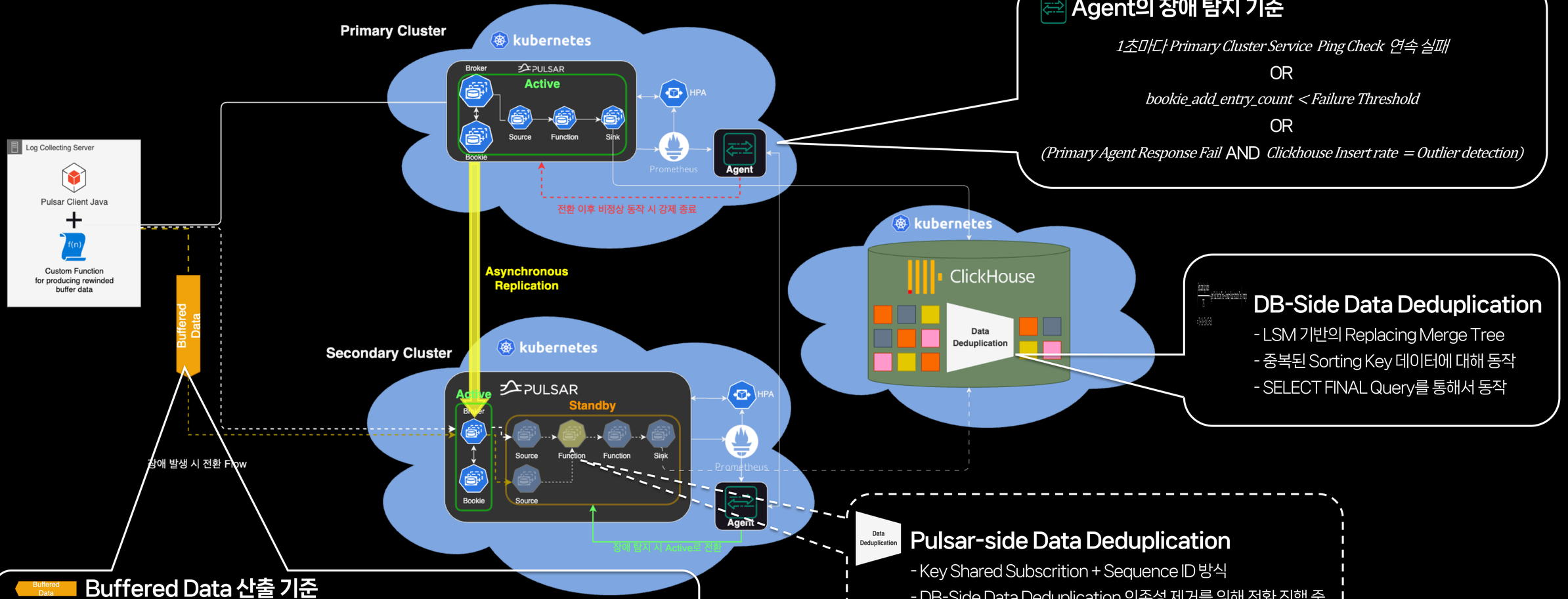
6. Efficiently Lossless Realtime Processing in Log-data

Async Type + Cost Efficient + Lossless Features



Agent의 장애 탐지 기준

1초마다 Primary Cluster Service Ping Check 연속 실패

OR

bookie_add_entry_count < Failure Threshold

OR

(Primary Agent Response Fail AND *Clickhouse Insert rate = Outlier detection)*

DB-Side Data Deduplication

- LSM 기반의 Replacing Merge Tree
- 중복된 Sorting Key 데이터에 대해 동작
- SELECT FINAL Query를 통해서 동작

Pulsar-side Data Deduplication

- Key Shared Subscription + Sequence ID 방식
- DB-Side Data Deduplication 의존성 제거를 위해 전환 진행 중

Buffered Data 산출 기준

Buffered Data

$$\left(\frac{Replication\ Lag\ volume}{TPS} + Agent\ \ Fault\ Detection\ Time + Secondary\ Pulsar\ Activation\ Time\right) \times margin$$

$$= (7s + 10s + 5s) \times 1.5 = 33s$$

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7. Wrap up

7.1 Keys of Geo Replication #1

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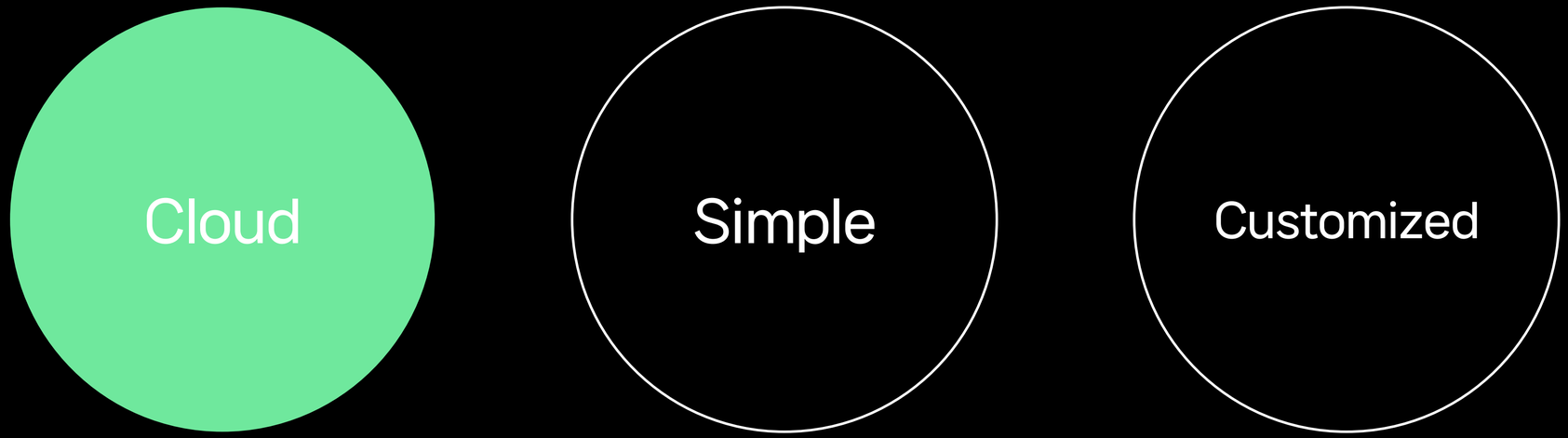
Cloud

- Cloud 의 유연한 환경에 기반을 둔 비용 효과적인 Resource 사용
- HPA에 기반한 시스템 인프라 구축



7.2 Keys of Geo Replication #2

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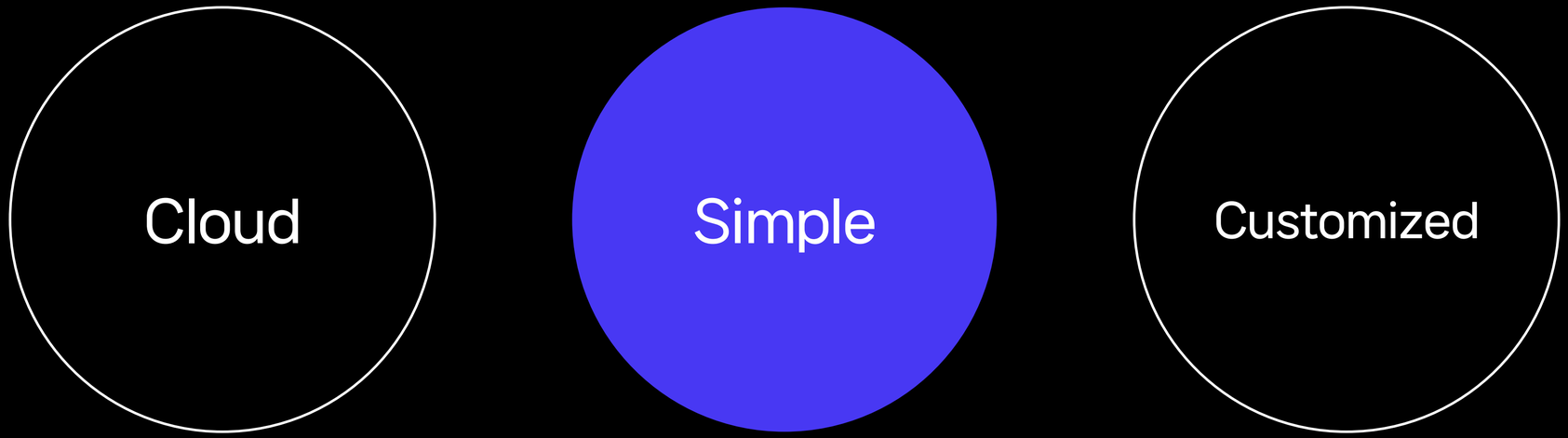
Simple

- 불필요한 데이터 흐름을 최소화한 Platform 구조
- Single Cluster 내에서의 데이터 처리



7.3 Keys of Geo Replication #3

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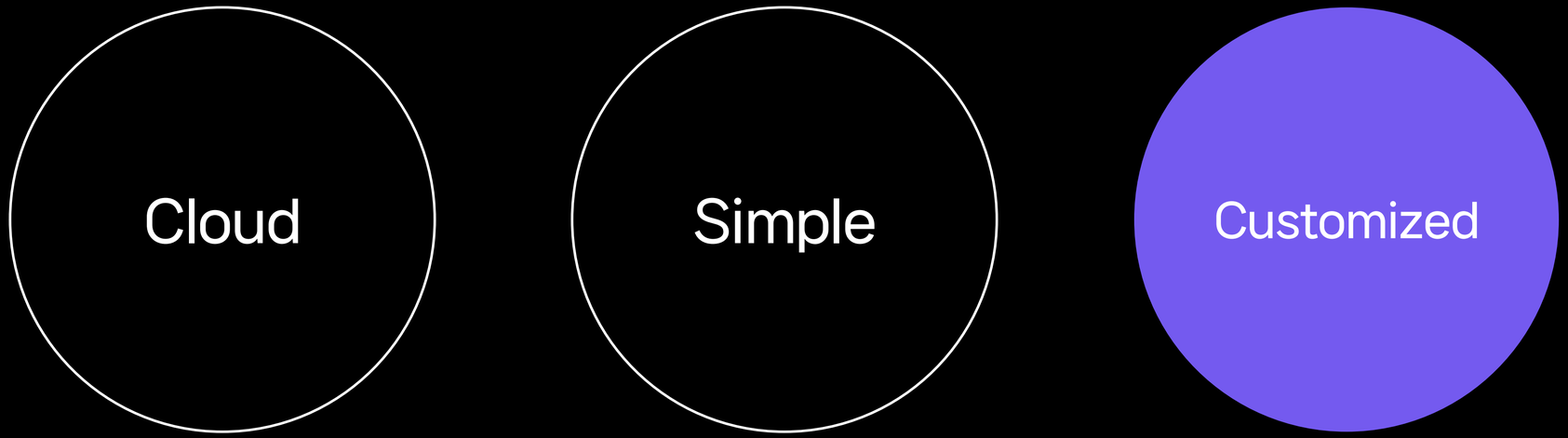
Customized

- Business Model에 맞는 Tolerant Control
- Client Level Data Rewind, DB side Deduplication 등 다양한 기술 활용



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Thank You / Q&A

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