From Fragmented Logs to Unified Insights

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Engineering Manager, Storage Platform

- Master's from Carnegie Mellon University
- Prior experience: Big Switch Networks, VMware, Cisco
- Focus: Storage systems, scalable infrastructure, Telemetry
- Interested in AI/ML infrastructure challenges

Dropbox

- Founded in 2007
- 700+ million users
- 18+ million paying users
- 1 T+ pieces of content
- Billions of files uploaded per day

Unstructured Logs

- **Raw Data:** Logs without a defined schema.
- **Sources:** From first-party code & third-party debug files (e.g., /var/log/dropbox).
- **Contrast:** Unlike structured logs (e.g., Hive records, traces)
- **Use Case:** Real-time troubleshooting.

Problem Statement

- Unstructured logs stored in /var/logs/
- ssh individual box
- Host rotated in 7 days
- Migration from standalone hosts to containers
- Containers are ephemeral

High-Level Requirements

- Provide a secure, ergonomic interface for analyzing unstructured logs
- Replace manual, on-host SSH log analysis for production service owners
- Ingest the complete firehose of DBX production logs without modifying application code
- Lay the groundwork for future integration with logs from acquisitions and corporate assets

Requirements

Reliability	Security
Retention: 1-week log storage	**mTLS**: Deny-by-default enforcement
Throughput: 150TB/day	**Access Control**: Service-based segmentation
Latency: p99 ingestion <30s, queries <10s	**Encryption**: Secure storage with key management
Availability: 99% log durability & access	**PII Protection**: Detection, filtering & redaction

Non Goals

- **Log Format**: Don’t mandate changes
- **Observability**: Not going to replace structured logging/tracing/metrics
- **Analytics**: Not for batch or historical analysis
- **Enforcement**: No mandated logging practices

Evaluation Metrics

- **Cost:** Total cost of ownership (OpEx/CapEx, contract risks)
- **Performance:** Ingestion rates, query latency & scalability
- **UX & Query:** Rich query engine, familiar Grafana integration
- **Integration:** Ease of connecting with existing observability tools
- **Security:** Data protection, sensitive data exposure risk

Do Nothing (Status Quo)

- Overview: Continue existing SSH-based log analysis
- Pros: No additional investment
- Cons: Manual, non-scalable, inefficient troubleshooting
- Outcome: Inadequate for modern observability needs

Evaluation of Logging Services

Solution	Overview	Pros	Cons	Outcome
Externally Managed SaaS	Fully managed logging service by a third party	Reduces in-house management overhead	High annual cost; potential security risks	Rejected due to cost and security concerns
Managed Cloud Logging	Managed search and logging on a cloud framework	Mature, scalable technology	Higher operational costs; complex configuration affecting UX	Not cost-effective; UX challenges
Self-Hosted Enterprise	Enterprise-grade log management on-premise	Rich feature set; robust vendor support	Expensive licensing and infrastructure demands	Too costly and cumbersome for our scale
Build Your Own Logging	Custom-developed solution	Full control; tailored features	High engineering effort; slow time-to-value	Not viable given rapid open-source advances

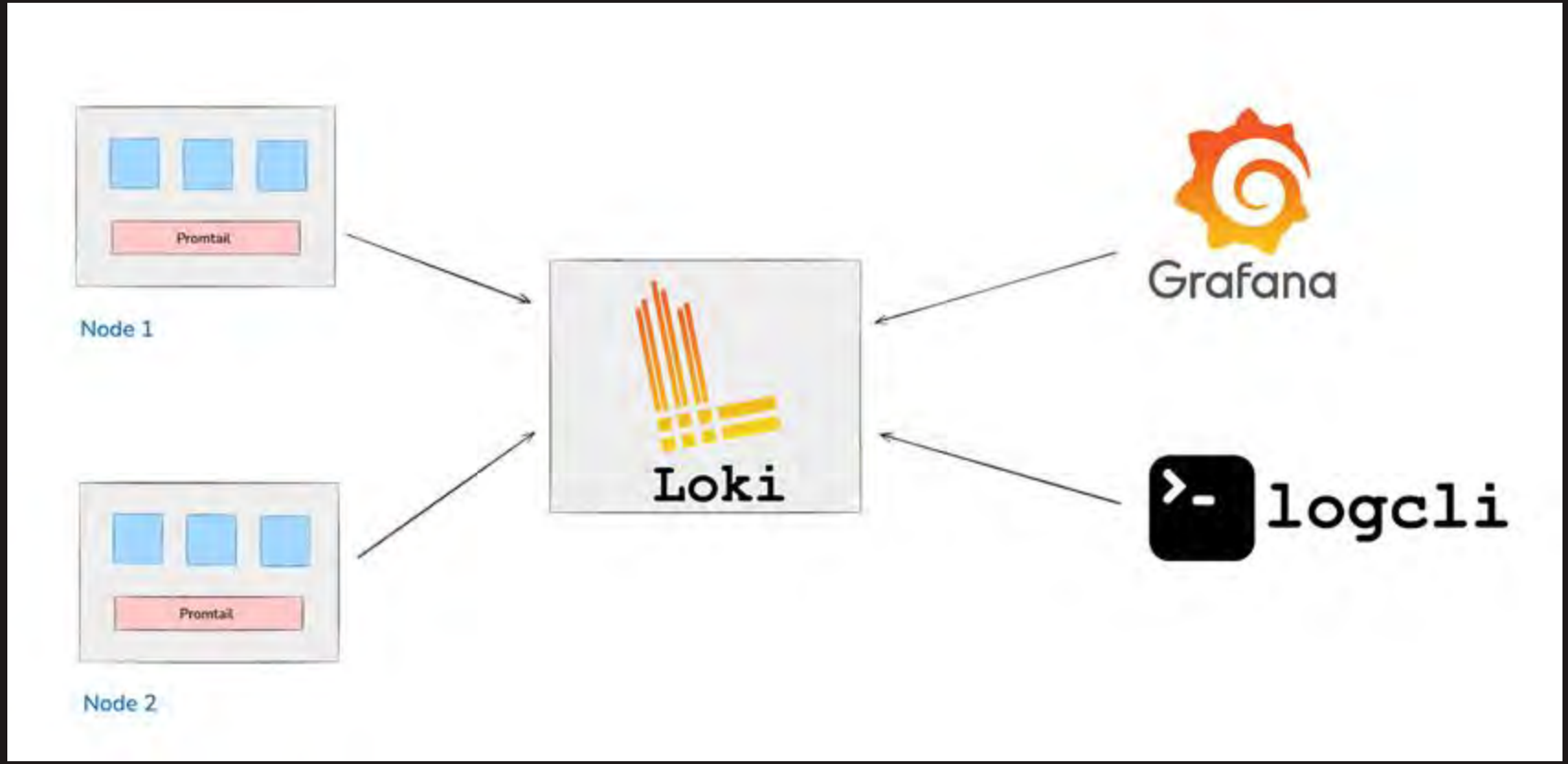
Grafana Loki

- **Cost-effective**: Open-source, low TCO
- **High-Performance**: Optimized for DBX-scale log ingestion and querying
- **Grafana Integration**: Native, unified observability interface
- **Scalable Architecture**: Distributed components

What is Loki?

- Open source
- Horizontally scalable
- Highly Available
- Multi tenant
- Prometheus inspired
- Log aggregation System

Architecture



Loki Scalability

- Does not indexes the text of the log
- Loki indexes metadata
- It groups log entries into streams and indexes labels
- Faster ingestion and queries with minimal infrastructure

Logs

2025-02-01T09:02:03.123456789Z {service=”dummy_service”, node_id=”ex_node_1”} GET /about

Timestamp
With nanosecond precision

Prometheus-style **Labels**
Key-value pairs

Content
Log line

Logs - Stream

A **log stream** is stream of log entries with **exact same label set**

```
2025-02-01T09:02:03.000Z  {service=”dummy_service”, node_id=”ex_node_1”}  GET /about
2025-02-01T09:02:04.000Z  {service=”dummy_service”, node_id=”ex_node_1”}  GET /
2025-02-01T09:02:06.000Z  {service=”dummy_service”, node_id=”ex_node_1”}  GET /help
```

```
2025-02-01T09:02:03.000Z  {service=”dummy_service”, node_id=”ex_node_2”}  GET /files/1
2025-02-01T09:02:03.000Z  {service=”dummy_service”, node_id=”ex_node_2”}  GET /files/2
2025-02-01T09:02:03.000Z  {service=”dummy_service”, node_id=”ex_node_2”}  GET /files/1
```

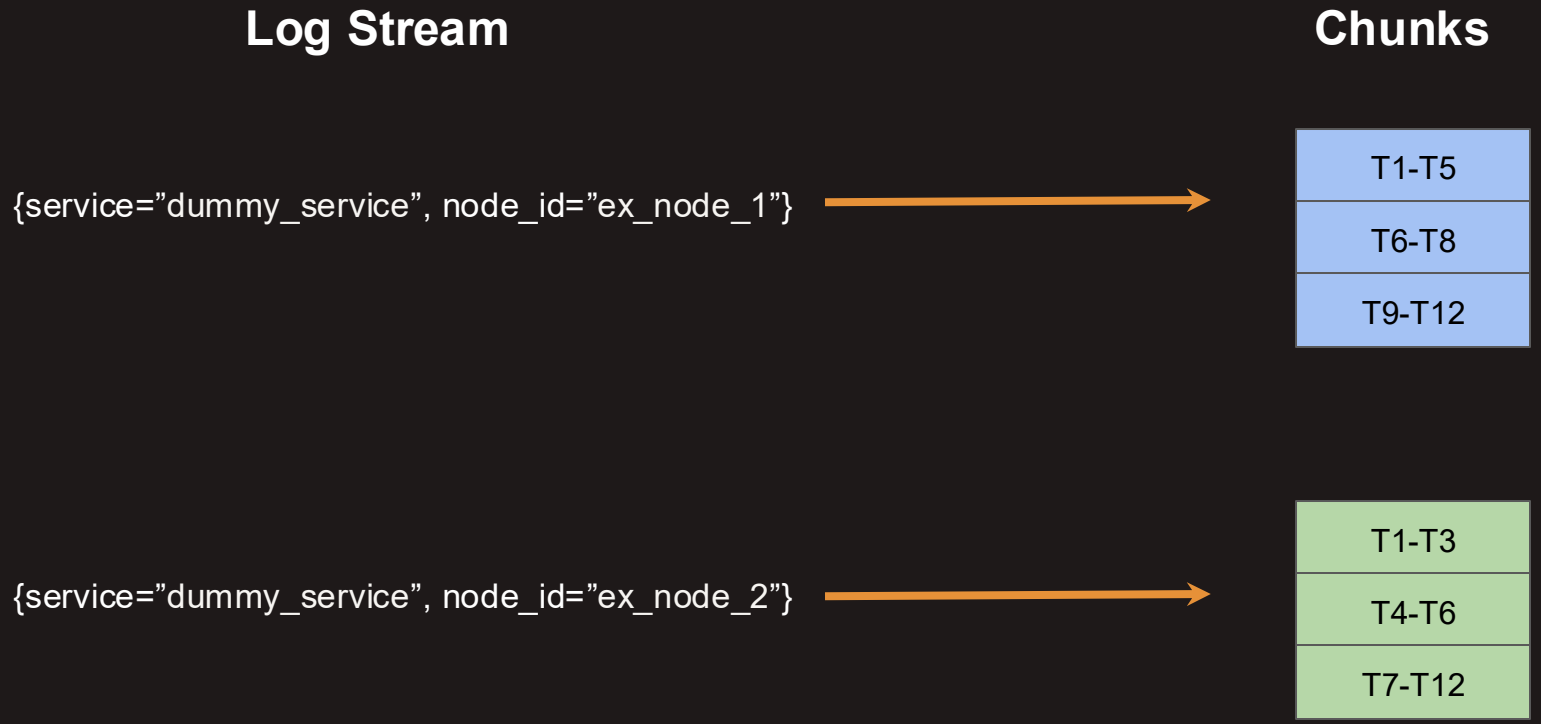
Logs Storage - Chunks

- Streams are stored in separate chunks
- Sorted in timestamp order
- Chunks are filled till they reach a target size or timeout
- Once full, they’re compressed and flushed to Object Store

chunk #1 {service=”dummy_service”, node_id=”ex_node_1”}

2025-02-01T09:02:03.000Z GET /about
2025-02-01T09:02:04.000Z GET /
2025-02-01T09:02:06.000Z GET /help

Logs - Query


Log Stream
Chunks
{service=”dummy_service”, node_id=”ex_node_1”}
T1-T5
T6-T8
T9-T12
{service=”dummy_service”, node_id=”ex_node_2”}
T1-T3
T4-T6
T7-T12

Logs - Query

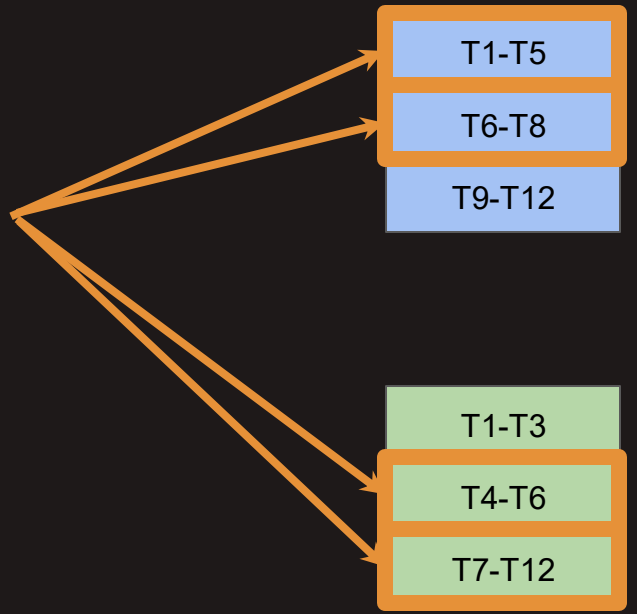
Log Stream

{service="dummy_service", node_id="ex_node_1"}

Query: {service="dummy_service"} start=T5 end=T7

{service="dummy_service", node_id="ex_node_2"}

Chunks

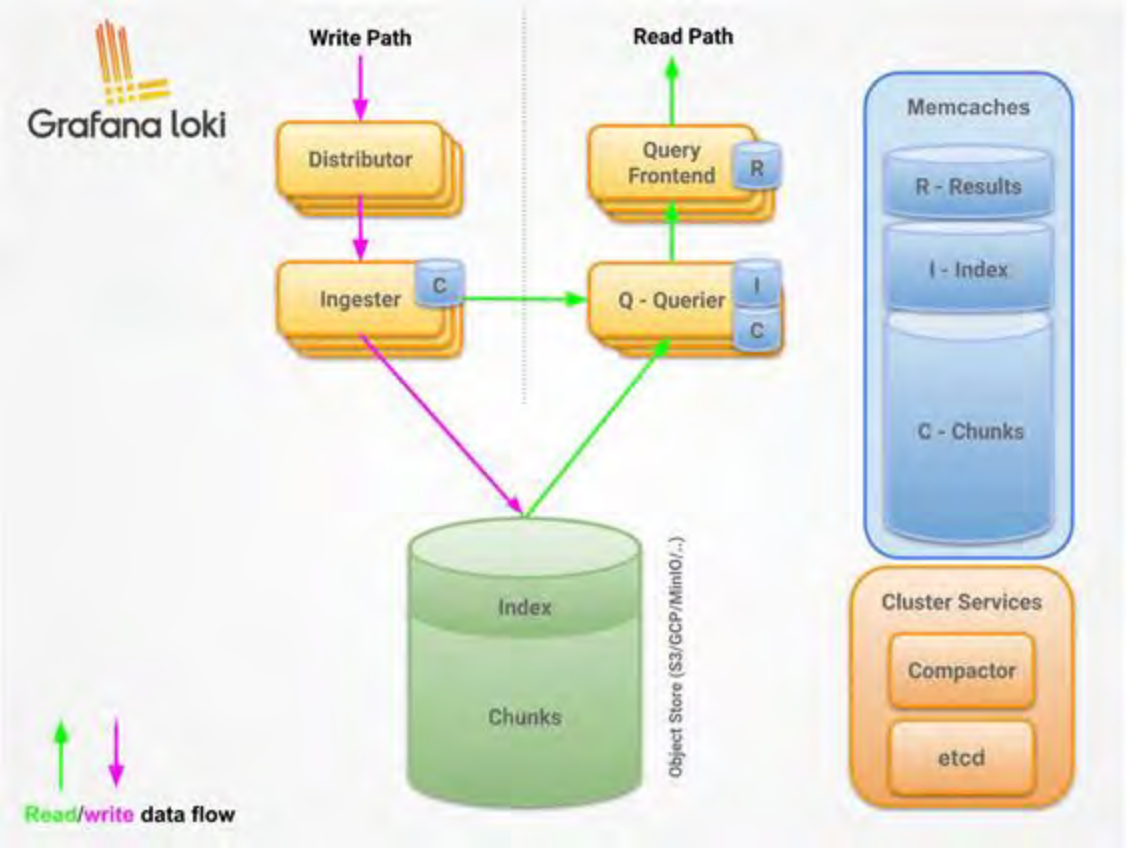


Label Cardinality

- Be mindful of label selection
- Avoid high-cardinality labels like trace_id, user_id, path, and status.
- Favor low-cardinality labels such as cluster, app, and filename for efficient indexing
- Using log level (4), status (3), and path (3) yields 36 unique streams

Dropbox-specific Loki

Loki Architecture



Loki at Dropbox: At a Glance

- ~10 GB/s logs processed
- 30 days of logs == ~10 petabytes stored in object storage
- ~1000 tenants
- <1 query per second

S3 Replacement

- Replaced S3 with internal storage to reduce costs (esp. data transfer)
- Lower costs → Increased log retention (1 week → 4 weeks)
- Performance differences:
  - S3 scales gradually; large queries cause timeouts
  - Internal storage has reserved capacity; avoids scaling issues
- Large index files still stored in S3

Multitenancy

- Loki isolates access/storage per tenant
- Dropbox: Tenant = service
- High-volume service split by project

Auth: What, Who & How?

- Previously: Production SSH access → log viewing
- Tenant (service) matches existing permission model
- Some global services are accessible by everyone
- Custom query auth proxy handles permissions (avoids Grafana RBAC complexity)

Auth: Sharing Challenges

- Team A wants to share access for their service's logs to Team B
- Team B must request permission to the service logs for their group
- Because the permission is owned by the logging team, only we can approve
- During an incident, this delay can be costly

Auth: Breakglass

- Breakglass allows a user with a justified reason to gain temporary access to any service’s logs
- Audit trail and safeguards in place

Multi-homing

- Run Loki in two data centers in separate geographic regions
- Same object storage is used in both regions
- Logs and queries are routed to the active region using DNS

Scaling Challenges

Ingester WAL

- Write Ahead Log stored on ingesters' disks
- Used to recover logs when ingester exits before flushing
- At Dropbox, disabled to prioritize availability over durability

Per-tenant Ingestion Rate Limits

- Conservative default limits set
- Alerts notify owners on breaches
- Tenants can override via config file
- Config distributed via KV store
- Loki reloads settings dynamically

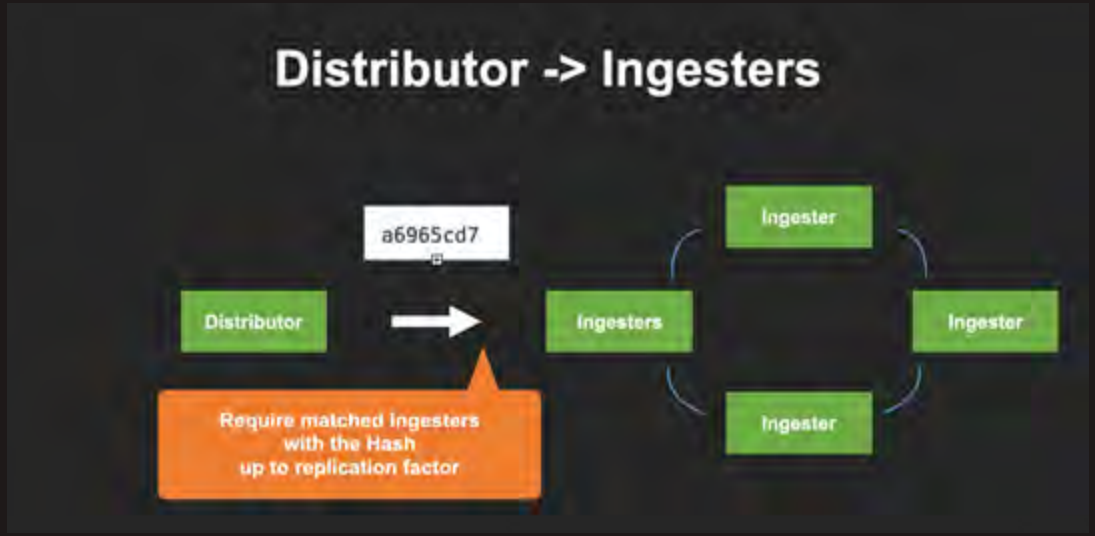
Hash Ring

- Ingesters shard log streams and own a range in the hash ring
- Ingester registers their range and health status in the ring stored in a distributed KV store
- Distributor uses ring to route log stream to ingester + replicate to other ingesters

Ingester Hash Ring Example

2025-02-01T09:02:03.000Z {service="dummy_service", node_id="ex_node_1"} GET /about

a6965cd7



Hash Ring: etcd

- We original used etcd as backing KV store for Loki hash ring
- etcd: distributed, consistent KV store
- Often used for coordination and configuration, default for k8s
- Now widely used at Dropbox

Hash Ring: etcd Write Contention

- Ingester sends heartbeat & updates ring every minute
- Ring updates occur on join/leave events
- etcd stores the ring as a single binary blob; updates use read + CAS
- RF=3 with 67 ingesters per factor = 201 total ingesters

Hash Ring: etcd Challenges

- Deployments take hours, ingesters are pushed sequentially
- Frequent availability alerts during ingester pushes
- Single point of failure: etcd outages cause disruptions

Hash Ring: etcd → memberlist

- Now default in Loki and other Grafana projects
- Peer-to-peer gossip protocol
- Each update is only the delta, not the entire ring
- Eventually consistent

Index: BoltDB → TSDB

- Log indexes determine query plan: how many log chunks to fetch
- Index format changed from BoltDB to TSDB
- TSDB based on Prometheus TSDB, ideal for labels
- Much better query performance after migration

Summary

- **Goal:** Scale and enhance observability at Dropbox
- **Challenges:** Manual SSH analysis of unstructured logs
- **Approach:** Evaluate multiple logging solutions
- **Solution:** Adopt Grafana Loki for cost-effective, high-performance logging
- **Result:** Improved retention, reduced costs, and efficient multi-tenant access

Thank You