StorageTapper

Real-time MySQL Change Data Streaming @ Uber

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UBER

Overview

What we will cover today

- Background & Motivation
- High Level Features
- System Architecture
- System Components
- Implementation
- Using StorageTapper
- Current Status & Future Work

Background & Motivation

Background

MySQL @ Uber

- MySQL stores majority of the operational data
- Schemaless is a scalable and highly available datastore on top of MySQL clusters
  - Schemaless storage system powers some of the biggest services at Uber
  - Many Schemaless instances consisting of more than 3,000 clusters
- MySQL-as-a-Service: full featured MySQL available to services in raw form
  - More than 500 services using it for their storage needs
- Currently running MySQL 5.6
  - Have our own fork uber/percona-server
  - Migrating to MySQL 5.7 soon

Capturing Data Changes

The traditional way

- Export the entire dataset and import it to your analytics platform every 24 hours
- Doesn’t scale
  - With growth in size of dataset you can’t export and import quickly enough for your business needs
- Data is no longer fresh
  - 24 hours is way too long!
  - Competitive pressure demands up-to-the-minute information
- Inefficient to read and write the same data over and over again
- Performance penalty on the source

Change Data Capture

Motivation and use-cases

- How Wikipedia defines it?
  - In databases, change data capture (CDC) is a set of software design patterns used to determine (and track) the data that has changed so that action can be taken using the changed data
- Deal with data changes incrementally
  - Only dealing with data that has changed
  - Possible to make changes available close to real-time
- Use cases at Uber
  - Data ingestion into analytics platform
  - Logical incremental backups

High Level Features

Key Features

What does StorageTapper provide?

- Real-time change data streaming
- Multiple output formats (Avro, JSON, MessagePack)
- Multiple publishing destination (Kafka, File, S3, HDFS, SQL)
- REST API for automated operations
- Source performance-aware design
- Horizontally scalable

Guarantees & Limitations

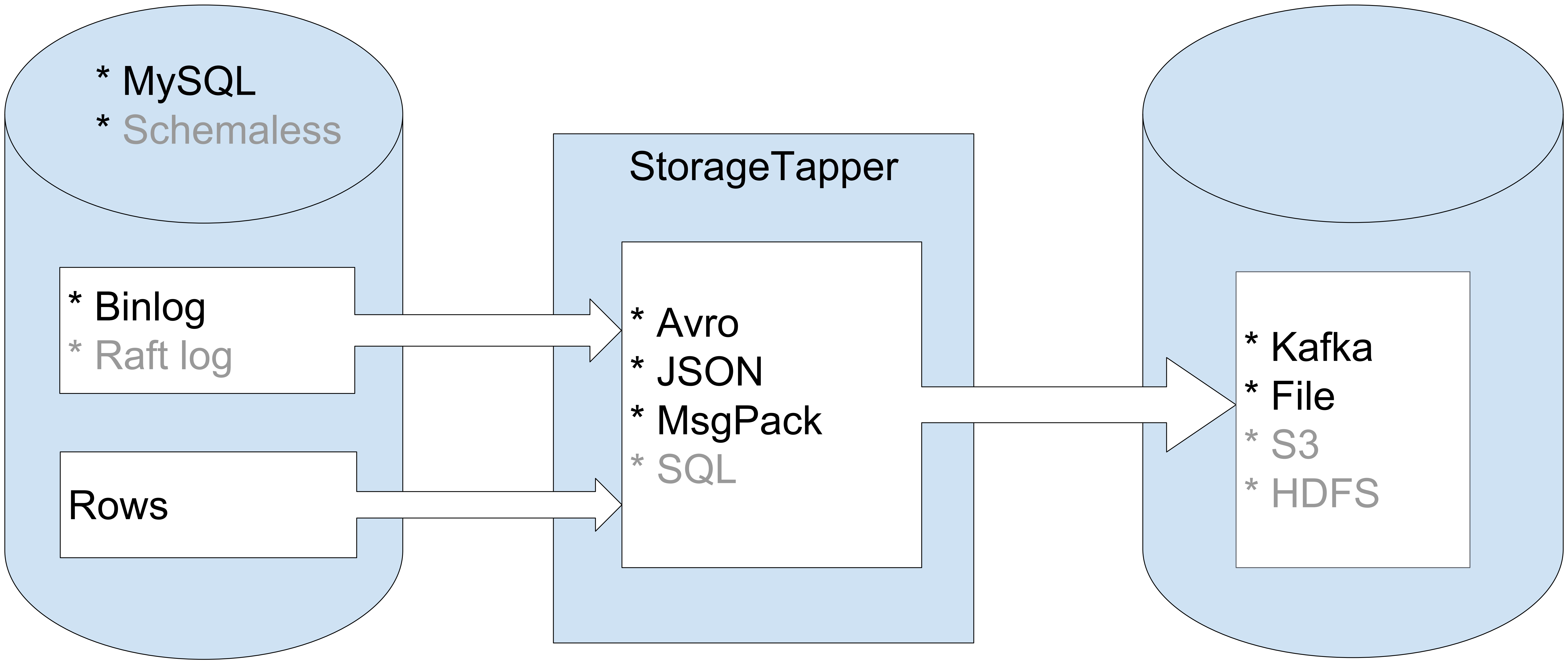
What are the assurances & requirements?

- Guarantees
  - Data changes on the database consistent with what is published
  - Events guaranteed to be published at-least-once
  - Events guaranteed to be published with a pre-defined format
  - Events corresponding to **the same row** guaranteed to be published in commit order
- Restrictions & Limitations
  - Every table being ingested must have a Primary Key defined
  - Incompatible schema changes will break ingestion
  - MySQL binary log must be enabled with the RBR format

System Architecture

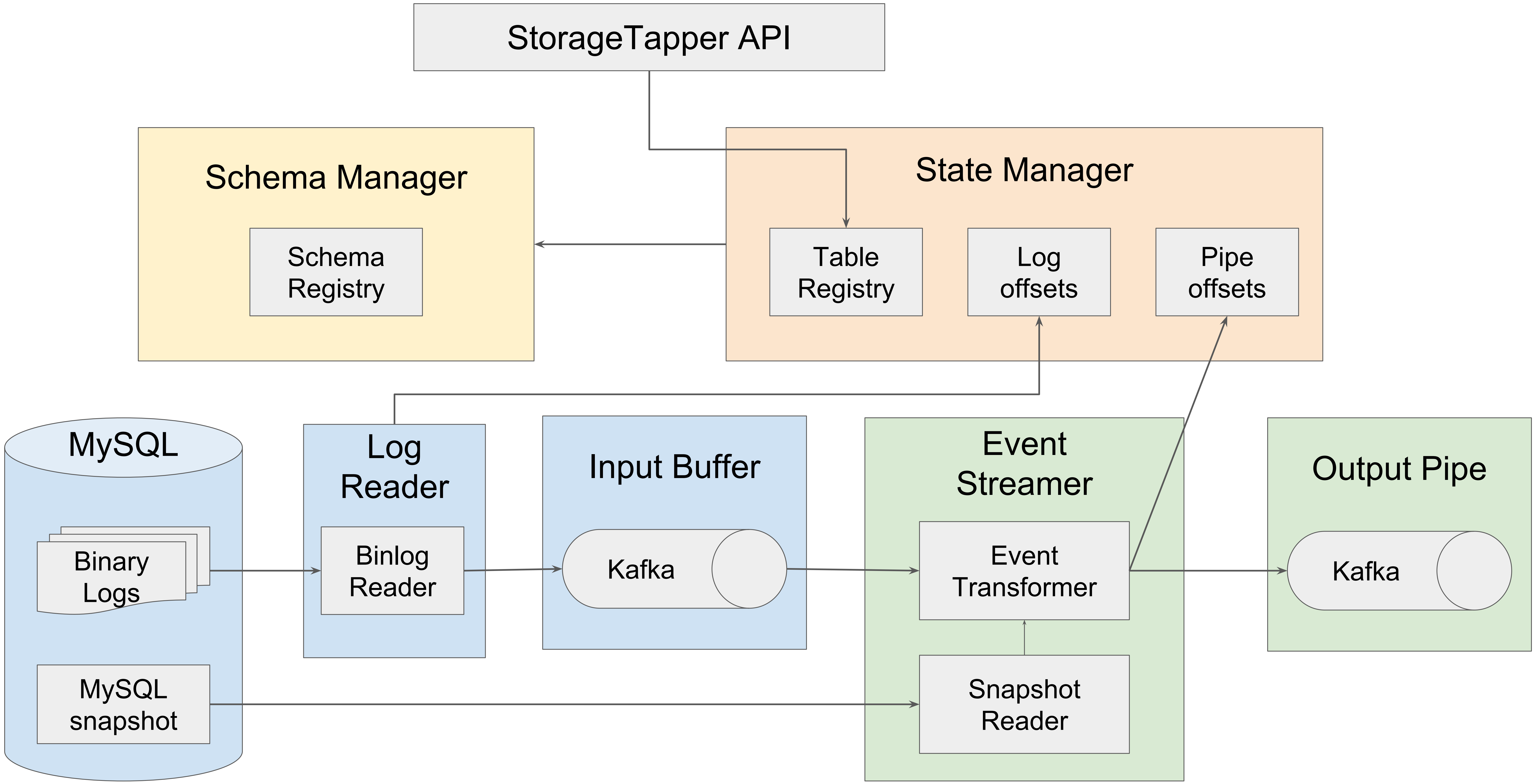
High Level Design

Bird’s-eye View



High Level Design

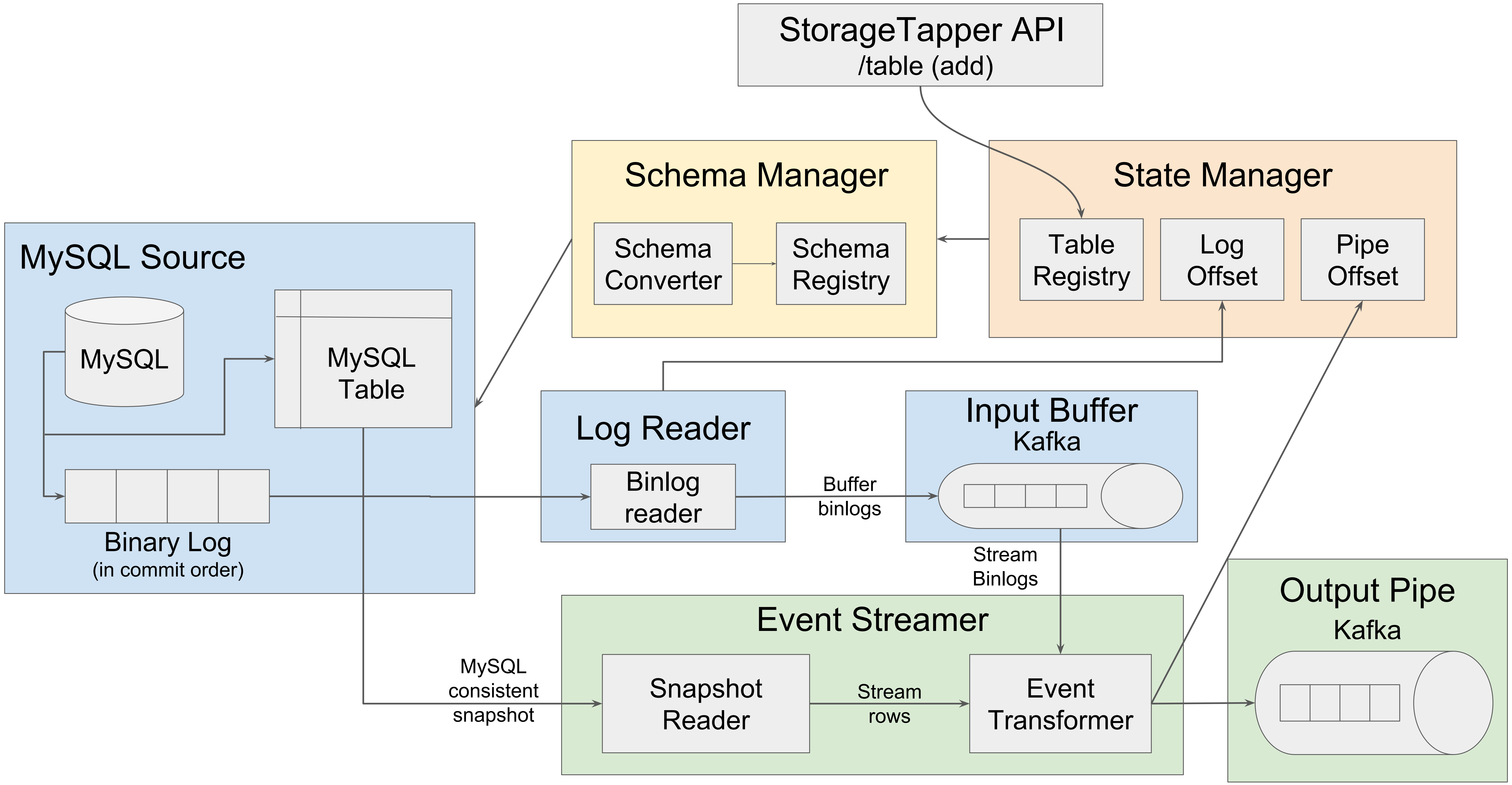
System components and their interaction



System Components

High Level Design

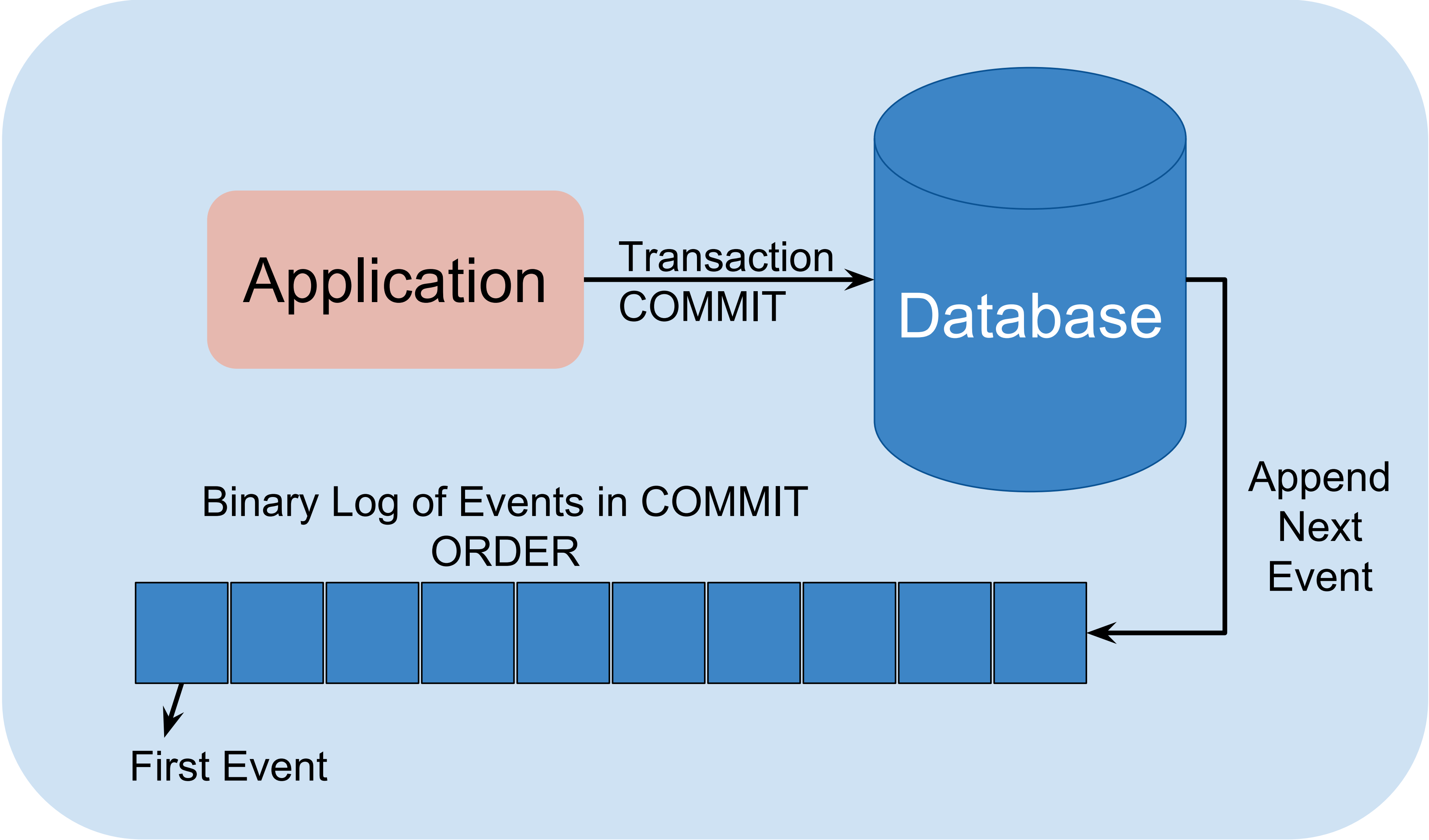
System Flow



Log Reader

MySQL binlog events reader

- Fetches binary log events from master
- Appears as a regular slave, no additional config
- Update master connection info on master failover via API
- Publishes binary log events to Kafka input buffer topic
    - Input topic acts as a persistent buffer
    - Binary log events buffered until consumed and transformed by Event Streamer



Event Streamer

Snapshot reader

- Snapshot Reader: a special type of event reader that reads rows from the table
- Takes transactionally consistent snapshot of the table together with corresponding GTID
- Typically used when bootstrapping a table with existing data
- Allows all the existing rows to be transformed into the required format and published

Event Streamer

Events transformation

- Events are transformed into messages according to the latest schema
  - Row Key: generated from the primary key column values in an event
  - Sequence Number: used by the consumer to read events for the same Row Key in order
  - Is Deleted flag: signals whether the row was deleted

Event	**Transformation**
DDL	Avro Schema
Row INSERT	Message encoded with Avro schema. Additional fields are row_key, ref_key & is_deleted set to FALSE.
Row UPDATE	Additional fields as in INSERT. Update converted to DELETE + INSERT.
Row DELETE	Message encoded with Avro schema. All fields set to NULL, except row_key, ref_key. is_deleted set to 1

Event Streamer

Publishing events to Kafka

- The events are published to Kafka as keyed messages
- The Row Key is used as the key of the message
  - Ensures that all events corresponding to the same row go to the same partition
  - Kafka provides ordering guarantees within a partition
- All messages written to Kafka correspond to a complete Row in MySQL

Schema Manager

Managing the schema

- StorageTapper doesn’t control MySQL schema creation or changes
- Converts MySQL schema to output schema, publishes to external or integrated schema service
- Schema changes validated for backward compatibility
- Need for schema to be validated and registered before publishing events
- Maintains versioned history of MySQL and corresponding output schema

State Manager

Managing and persisting state

- Tracks the state of ingestion for every table that is being published
- State tracking involves:
  - tracking the latest GTID up to which binlog events have been consumed
  - tracking the Kafka input buffer offset
- Ensures stop/restart of StorageTapper without losing the current state
- Persistence
  - State updated after publishing a batch of binary log events
  - Ensures that we don’t impede the performance

Implementation

Overview

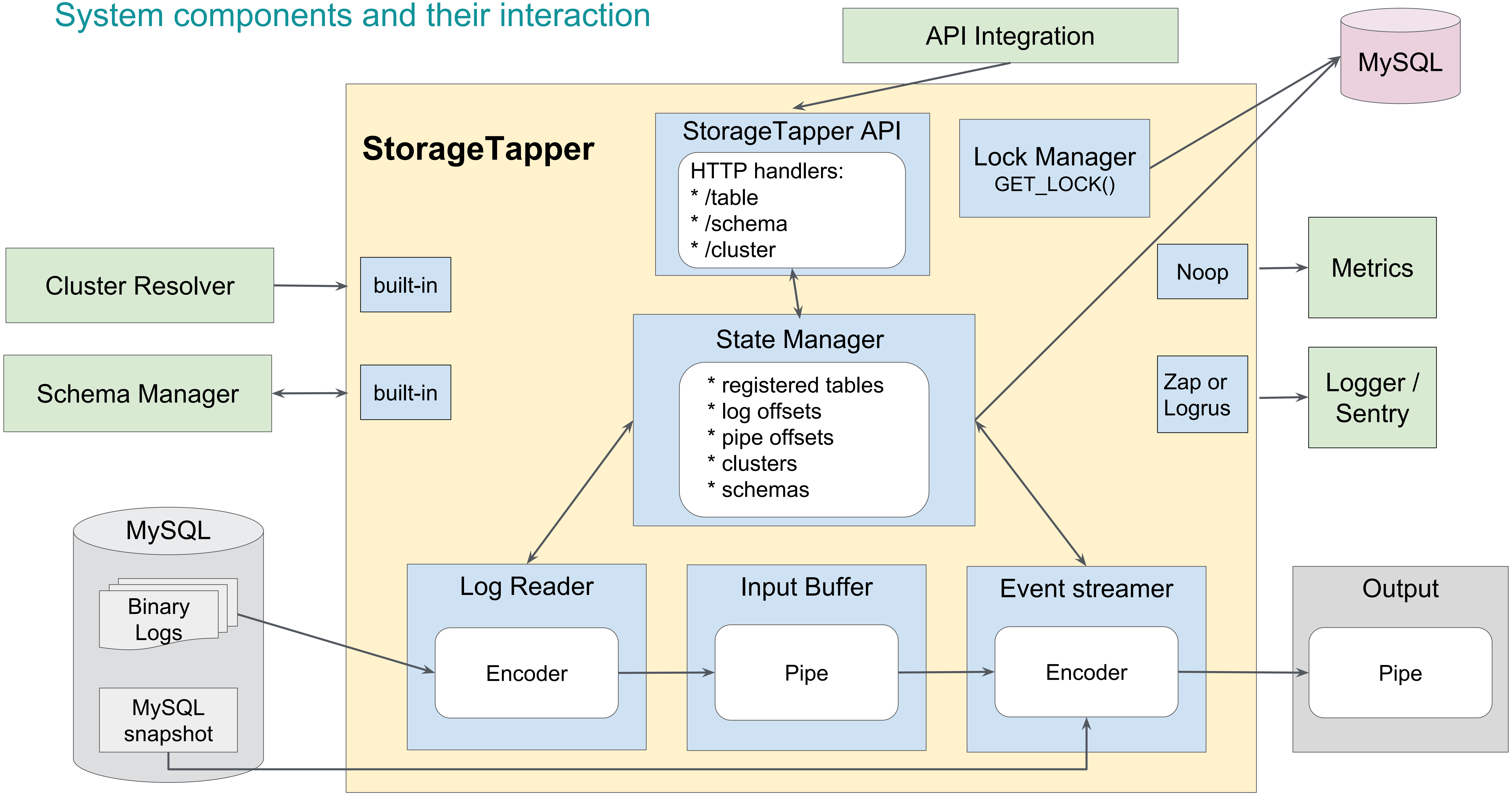
Implementation overview

- Written in Go
- TravisCI integration
- Builds and tests with Go 1.6-1.8
- Score A+ at Go Report Card
- 9000 lines of code
- Overall code coverage is 62%

- Pluggable components
  - Schema services
  - Cluster resolvers
  - Metric reporters
  - Loggers

Zoom In

System components and their interaction



Event Format

Representation of the event in Go and JSON

```
{
  "Type": "insert",  // Event type: “insert”, “delete”, “schema”
  "Key" : [ 1, 2 ],  // Row key of the event
  "SeqNo": 1,        // Monotonically increasing logical time
  "Timestamp" : 1506816319,  // Wall clock time of the event creation
  "Fields": [                               // Array of all row fields
      { "Name" : "pk_field1", "Value" : 1 },
      { "Name" : "pk_field2", "Value" : 2 },
      { "Name" : "field3",  "Value" : "value3" },
       ...
   ]
}
```

Interfaces

Encoder abstraction

- Encoders transform event to specific format
- Implemented encoders
  - JSON
  - Avro
  - MessagePack
- Implementation in progress
  - SQL

```go
type Encoder interface {
   Row(typ int, row []interface{}, seqNo uint64) ([]byte, error)
   Event(cf *types.Event) ([]byte, error)

   UpdateCodec() error

   Schema() *types.TableSchema
   Type() string

   EncodeSchema(seqNo uint64) ([]byte, error)
   DecodeEvent(b []byte) (*types.Event, error)
}
```

Interfaces

Streaming abstraction

- Pipes implement different event transports
- Implemented pipes
  - Kafka
  - Go channel
  - File
- Implementation in progress
  - HDFS
  - S3

```go
type Pipe interface {
   RegisterConsumer(topic string) (Consumer, error)
   RegisterProducer(topic string) (Producer, error)
   CloseConsumer(p Consumer, graceful bool) error
   CloseProducer(p Producer) error
   Type() string
}
```

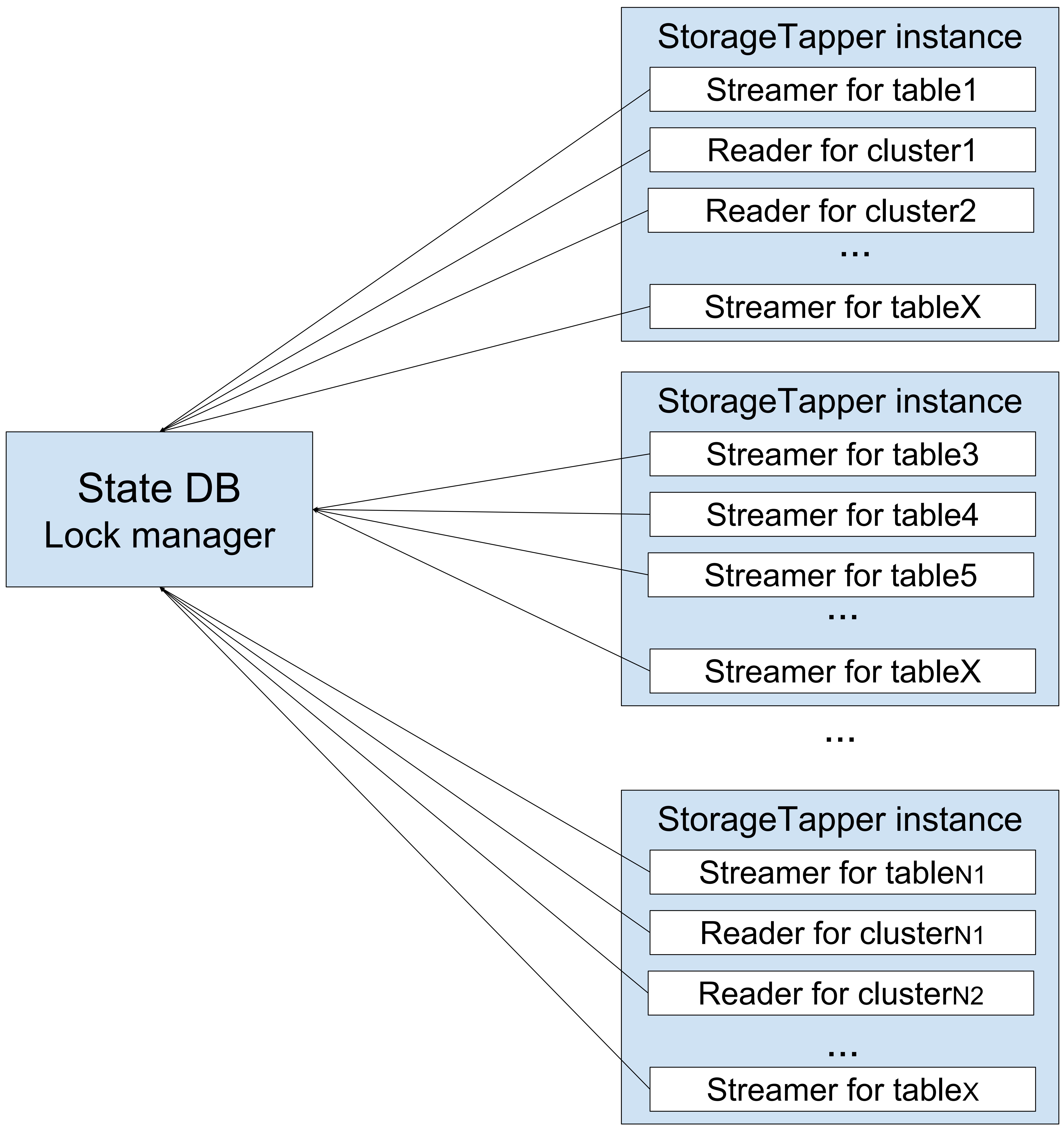
```go
type Consumer interface {
   FetchNext() bool
   Pop() (interface{}, error)

   SaveOffset() error

   Close() error
}
```

```go
type Producer interface {
   Push(key string, data interface{}) error

   PushBatch(key string, data interface{}) error
   PushBatchCommit() error

   PushSchema(key string, data []byte) error
   Close() error
}
```

Work Distribution

Who does what?

- Configurable number of workers per instance
- Dynamic work distribution
- Worker (goroutine) per streamer/reader
- Kafka topic per table



Using StorageTapper

Try It Out

Setup and Installation

- Dependencies: glide, gometalinter, local MySQL and Kafka.
  - Use **scripts/install_deps.sh** for installing all dependencies in **TESTING** environment
- Get the source, compile and install:

```
$ mkdir -p $GOPATH/src/github.com/uber && cd $GOPATH/src/github.com/uber

$ git clone https://github.com/uber/storagetapper.git

$ cd storagetapper

$ DEB_BUILD_OPTIONS=nocheck make deb && sudo dpkg -i ../storagetapper_1.0_amd64.deb
```

Try It Out

Configuration

- Edit configuration file

```
$ sudo vim /etc/storagetapper/production.yaml
```

- Replace the content with:

```
state_connect_url: "root@localhost"
kafka_addresses:
    - "localhost:9092"
output_format: json
```

- Restart the service

```
$ sudo service storagetapper restart
```

Try It Out

Create test data

- Create test database and table:

```
$ echo 'create database oow_test_db1' | sudo mysql

$ echo 'create table oow_test_t1(f1 int primary key, f2 bigint)' | sudo mysql oow_test_db1
```

- Insert some rows, which will be snapshotted by bootstrap process:

```
$ echo 'insert into oow_test_t1 values (1, 1), (2, 2), (3, 3)' | sudo mysql oow_test_db1
```

Try It Out

Register table for ingestion

- Add cluster connection information to built-in cluster resolver:

```
$ curl --data \
    '{"cmd":"add", "name":"cluster1", "host":"localhost", "port":3306, "user":"root", "pw":""}' \
    http://localhost:7836/cluster
```

- Publish current table schema to built-in schema service (for Avro output format only):

```
$ curl --data \
    '{"cmd":"register", "service":"svc1", "db":"oow_test_db1", "table":"oow_test_t1"}' \
    http://localhost:7836/schema
```

- Register table for ingestion:

```
$ curl --data \
    '{"cmd":"add", "cluster":"cluster1", "service":"svc1", "db":"oow_test_db1", "table":"oow_test_t1"}' \
    http://localhost:7836/table
```

Try It Out

Run various DMLs to test binlog reader and test Kafka output

- Table is bootstrapped, time to test ingestion of binlog events

```
$ echo 'insert into oow_test_t1 values (10, 10)' | sudo mysql oow_test_db1
$ echo 'delete from oow_test_t1 where f1=2' | sudo mysql oow_test_db1
$ echo 'update oow_test_t1 set f2=555 where f1=1' | sudo mysql oow_test_db1
```

- Tail the topic and see published events stream:

```
$ /home/kafka/bin/kafka-console-consumer.sh --zookeeper localhost --from-beginning \
     --topic hp-svc1-oow_test_db1-oow_test_t1 --from-beginning
```


1. {"Type":"insert","Key":[1],"SeqNo":0,"Timestamp":1506839585,"Fields":[{"Name":"f1","Value":1},{"Name":"f2","Value":1}]}
2. {"Type":"delete","Key":[1],"SeqNo":1000003,"Timestamp":1506839750}
3. {"Type":"insert","Key":[1],"SeqNo":1000004,"Timestamp":1506839750,"Fields":[{"Name":"f1","Value":1},{"Name":"f2","Value":555}]}
4. {"Type":"insert","Key":[2],"SeqNo":0,"Timestamp":1506839585,"Fields":[{"Name":"f1","Value":2},{"Name":"f2","Value":2}]}
5. {"Type":"delete","Key":[2],"SeqNo":1000002,"Timestamp":1506839738}
6. {"Type":"insert","Key":[3],"SeqNo":0,"Timestamp":1506839585,"Fields":[{"Name":"f1","Value":3},{"Name":"f2","Value":3}]}

....

Current Status & Future Work

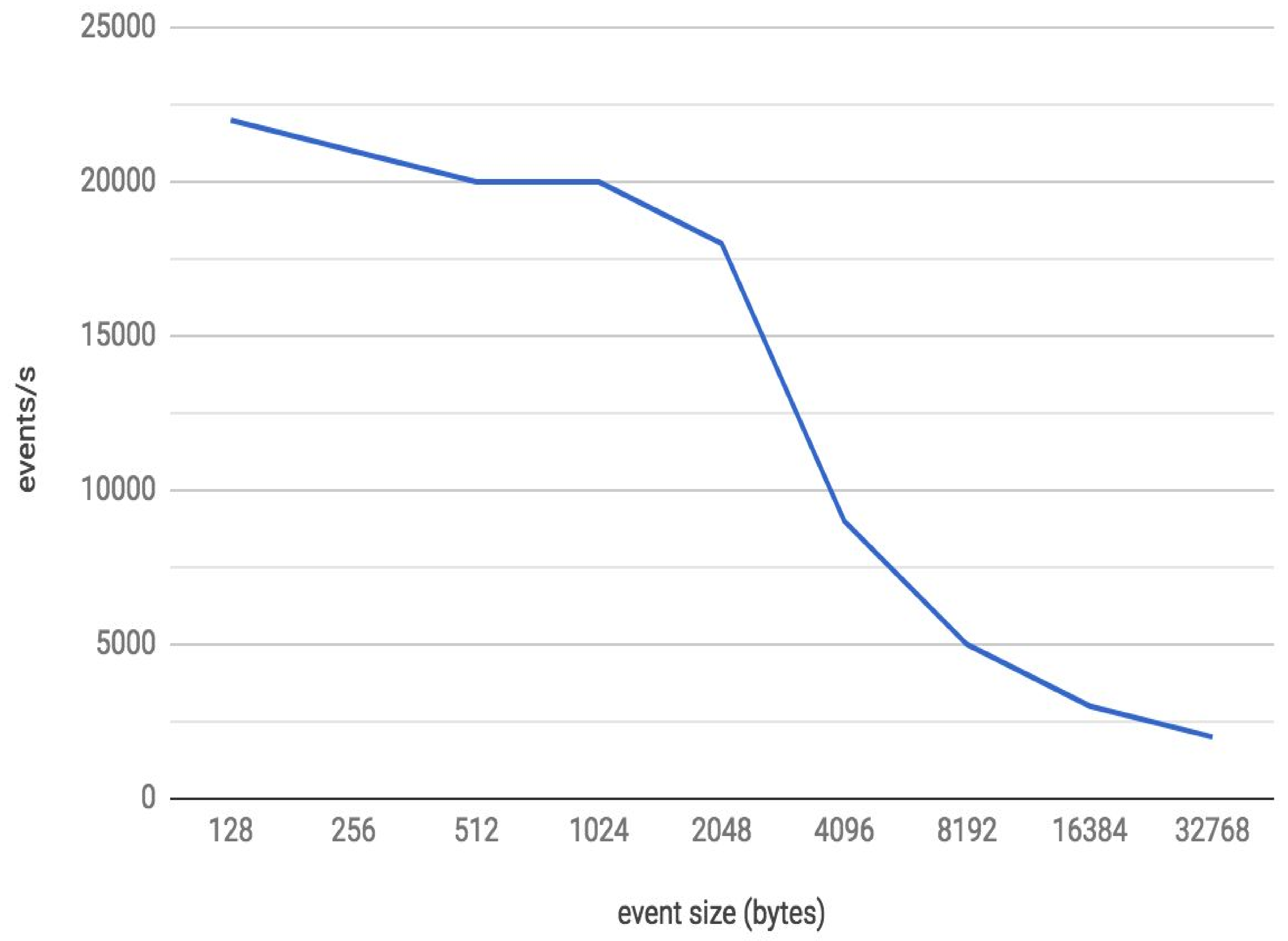
Current Status

Where we are right now?

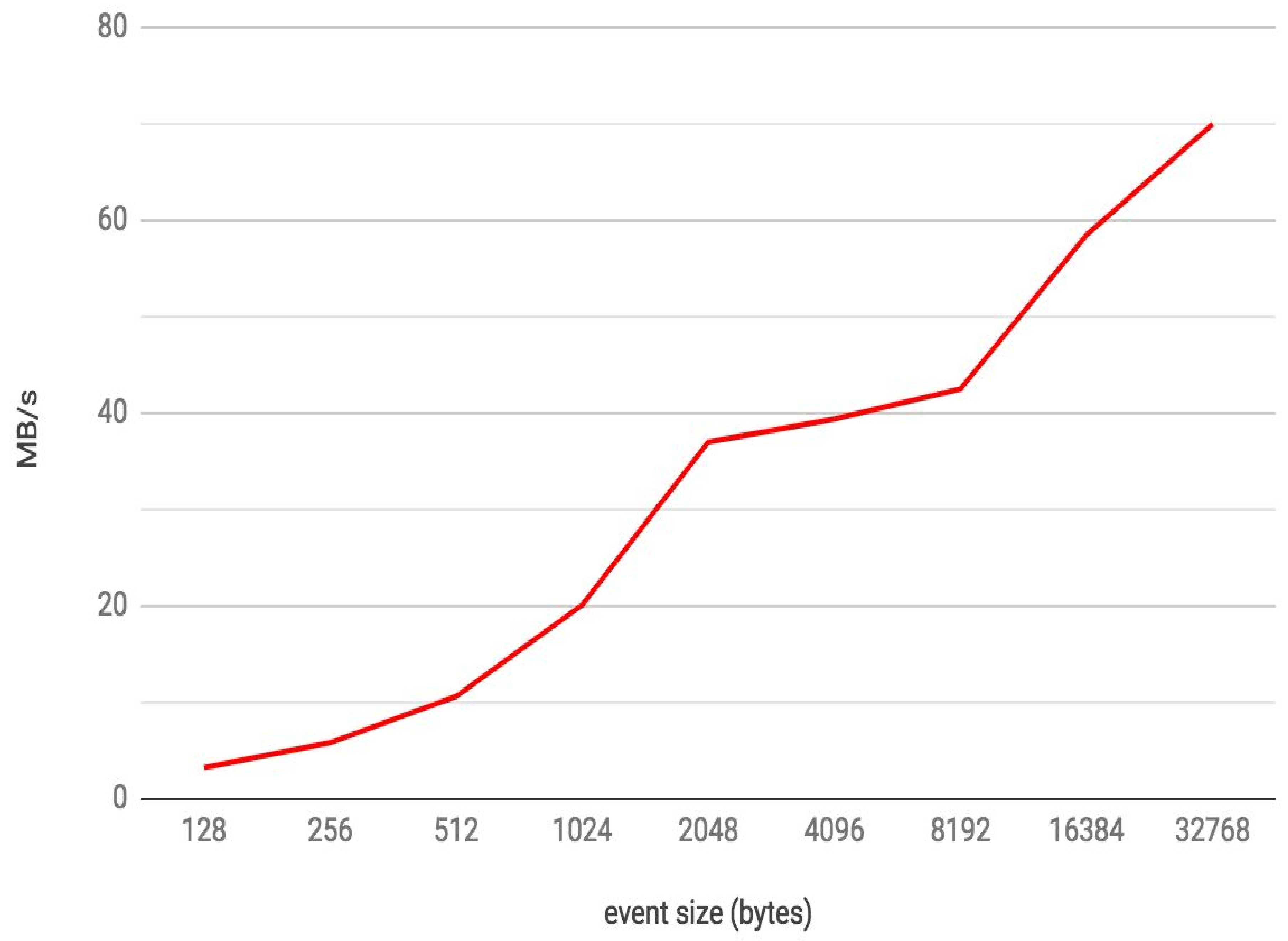
- Currently in use at Uber for data ingestion into analytics platform
  - Primarily used by MySQL-as-a-Service internal customers
  - 50% rollout complete
  - Targeting 100% rollout by the end of 2017
- Open sourced on Github github.com/uber/storagetapper

Current Status

Per worker performance numbers



Peak of 22K events/sec/worker with 128b record size



Peak of 70 MB/sec/worker with 32KB record size

These are initial numbers without any performance optimization.

In The Works

What to expect next?

- Logical incremental backup use-case at Uber
  - Implementing RAFT log reader
  - HDFS output pipe
  - SQL encoder
- Automated validation
  - Continuously running validation
  - Being implemented inside StorageTapper
- Performance optimization

Thank You

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Contact us

Explore further and contribute:
github.com/uber/storagetapper

Reach out to us directly:

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