Distributed Data Collection for the Next Generation ATLAS EventIndex project

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on behalf of the ATLAS Collaboration
Outline

1) ATLAS EventIndex project
   - Objective and use cases
2) Distributed Production and Data Collection Architecture
3) Performance and results
4) Evolution guidelines for Next Generation EventIndex
   - Testing Kudu as a new Backend Storage.
5) Summary
1. ATLAS EventIndex: an event catalog

- **A catalog of data** (all events in all processing stages) is needed to meet multiple use cases and search criteria. A small quantity of data per event is indexed.

  Events stored in files (identified by GUID)
  Files are grouped into DATASETS
  Wanted Event Index information ~ 300 bytes to 1K byte per event:
  - Event identifiers (run / event numbers, trigger stream, luminosity block)
  - Online trigger pattern (l1, l2, ef)
  - References (pointers) to the events at each processing step (RAW, ESD, AOD, DAOD) in all permanent files on storage

- We are indexing **Billions of Events**, stored in **Millions of files** replicated at CERN and **hundreds of grid-sites worldwide**, adding **100 Petabytes of data** → A complex big data distributed system.
Use Cases

1) Event picking: users able to select single events depending on constraints. Order of hundreds of concurrent users, with requests ranging from 1 event (common case) to 30k events (occasional).

2) Production consistency checks
   - Duplicate event checkings: events with same Id appearing in same or different files/datasets.
   - Overlap detection in derivation framework: construct the overlap matrix identifying common events across the different files.

3) Trigger checks and event skimming: Count or give an event list based on trigger selection.
   - Trigger Overlap detection: number of events in a real data Run/Stream satisfying trigger X which also satisfies trigger Y.

Requirement: Storing and accessing thousands of files and millions of events in reasonable time.
2. EventIndex Architecture

**Data Production** task to ensure all event index grid production performs correctly.

**Data Collection** task: a distributed producer/consumer architecture to collect all indexed data and ingest it to the Data Storage services.
2015 - mid 2017: Pure Messaging Based architecture (ActiveMQ brokers / Stomp protocol). Json data encoding. (production peaks showed bottlenecks on messaging brokers)

mid 2017 onwards: ObjectStore (CEPH / S3 interface) as intermediary storage. Google protobuf data encoding (compressed)

Producer: Athena Python transformation, running at Tier-0 and grid-sites. Indexes AOD data and produces an \textbf{eventindex file}, stored in \textbf{ObjectStore}

Supervisor: Controls all the process, receives processing information and validates data by dataset. Signals valid unique data for ingestion to Consumers. Operated with a web interface

Consumers: Retrieves ObjectStore data, groups by dataset and ingest it into \textbf{HDFS (Hadoop distributed Filesystem)}
3. Performance: Event processing rates

EventIndex data production:
- Tier0 @ CERN: ~60 M events/day
- Grid Sites: ~280 M events/day

Total (Tier0 + Grid)
Peaks of 3500 M events indexed per day
105 Billion events indexed during last year (350 days) with ObjectStore approach
Object Store rates

Object creation rates:
- Mean of 5600 objects created/day with peaks of 44K objects.
- A total of 2M objects residing on CERN Ceph Object Store.

Size creation rates:
- Mean of 15 GiB stored/day, with peaks of 100GiB.
- A total of ~5 TiB stored on CERN Ceph Object Store.

Objects Size:
- Mean object size: 2.6 MiB (99% of objects are less than 15 MiB)
- Some bigger object, biggest one is 670 MiB
- Factor 10 compressed with respect to original eventindex data.

CHEP2018 Distributed Data Collection for the Next Generation ATLAS EventIndex Project
Data Ingestion to Hadoop HDFS

- Consumers retrieve the eventindex files from ObjectStore and write it in HDFS Hadoop
  - Granularity at the dataset(tid) level
    - 40% contained in a single object.
    - Most of the datasets < 75 MiB
    - Biggest one: 8000 objects (~7GiB)
  - Single Consumer event throughput performance improved from 1K events/s (Messaging only), to 15K events/s (ObjectStore).
  - Overcoming messaging brokers bottleneck, we can also now scale horizontally.
  - Stored in a single HDFS file per dataset (tid) in a directory named after the container. Reduced the number of HDFS files compared with previous approach with a HDFS file per indexed GUID.

- Current (all years) EventIndex Data in Hadoop:
  - 37 TiB of indexed events data (167 TiB before compression): 31 TiB real data, 6 TiB MonteCarlo simulated data

![Single Consumer Throughput Histogram](image)

![Hadoop (HDFS)](image)
4. Evolution guidelines for Next Generation EventIndex

- **An evolution of the EventIndex concepts**
  - **Currently**: the same event across each processing step (RAW, ESD, AOD, DAOD, NTUP) is physically stored at different HADOOP HDFS files.
  - **Future**: One and only one logical record per event (Event Identification, Immutable information (trigger, lumiblock, ...), and for each processing step:
    - Link to algorithm (processing task configuration)
    - Pointer(s) to output(s)
    - Flags for offline selections (derivations)

- **Support Virtual Datasets:**
  - A logical collection of events
    - Created either explicitly (giving a collection of Event Ids) or implicitly (selection based on some other collection or event attributes)
    - Labelling individual events by a process or a user with attributes (key:value)

- **Evolve EventIndex technologies to future demanding rates:**
  - **Currently**: ALL ATLAS processes: ~30billion events/day (up to 350Hz on average) → update rate throughout the whole system (all years, real and simulated data). Read 8 M files/day and produce 3 M files
  - **Future**: due to expected trigger rates, need to scale for next ATLAS runs: at least half an order of magnitude for Run3 (2021-2023): 35 B new real events/year and 100 B new MC event/year. For run4: 100 B new real events and 300 B new MC events per year. Then sum up replicas and reprocessing
Exploring new backend storage solutions

Optimization and unification of data storage for the EventIndex

**Apache Kudu**: new columnar-based storage that allows fast insertions and retrieval.

- Tables with defined schema, primary keys and partitions. No foreign keys
- Ingestion and query scanning are distributed among the servers holding the partitions (tablets)
- Partition pruning and projection/predicate pushdown

**Benefits for EventIndex**:

- Unify data for all use cases (random access + analytics)
- Related data (reprocessings) sit close to each other on disc. Reduce redundancies and improve navigation.

- See poster in this conference for more information: “A PROTOTYPE FOR THE EVOLUTION OF ATLAS EVENTINDEX BASED ON APACHE KUDU STORAGE”
### Kudu events table schema

| KEY columns |  |
|-------------|---|
| `<epoch, project, streamname, prodstep, datatype, version, runnumber, eventnumber>` | - Event uniqueness is forced among all tids and files  
- Key keeps events that belong to same dataset close  
- Scans for events in the same dataset are concentrated  
- Horizontal Partitions by HASH(eventnumber) and RANGE(epoch) on Key columns. |

| Trigger columns -binary- |  |
|--------------------------|---|
| **L1**: 24 columns x int64 = 1536 bits  
8x(before prescaler), 8x(after prescaler), 8x(after veto)  
**HLT**: 192 columns x int64 = 12288 bits  
64x(physics), 64x(Passthrough), 64x Resurrected | - To allow selection on individual triggers  
- Directly mapped to IMPALA bitwise operations (limited to 64bit operands)  
- Projection and predicate: push-down omitting unnecessary fields from table scan. |

| Trigger columns -text- |  |
|------------------------|---|
| **L1mask**: string (JSON)  
**EFmask**: string (JSON) | - JSON encoded trigger bits to allow versatile operations. Less columns than binary approach, but without the possibility of bitwise IMPALA operations. |

| Event location |  |
|----------------|---|
| db, oid1, oid2 | - GUID of the file where to find this event, and object id inside that file |

| Event info |  |
|------------|---|
| Lumiblockn, bunchid, eventtime, eventtimens, lvl1id, hltpsk, l1psk | - Event info specific data. Information shared by dataset would go in another table. |
Kudu Test setup

• Current setup at IFIC
  – Kudu 1.7 + Impala 2.11 +Spark 1.6 (cdh5.14.2)

• 5 machines with:
  – 2x Intel(R) Xeon(R) CPU E5-2690 v4 @ 2.60GHz (14 cores/CPU)
  – 16x 16 GB RAM DDR4 @ 2400 MHz (256 GB)
  – 8x data disks SATA SEAGATE ST6000NM0034 (6TB)
  – 1x os disk SSD SAMSUNG MZ7KM240 (240GB)
  – 1x Intel SSD DC P3700 (1.5 TB) pci nvme
  – 2x 10Gpbs ethernet controller

• Current configuration:
  – 1 master, 4 tablet servers
  – 1 big data disk (RAID10) to store tablets (22TB per machine)
  – WAL on Intel SSD
Trigger encoding test

- **Data in KUDU**
  - **L1**: 8x(before prescaler), 8x(after prescaler), 8x(after veto)  
    - 24 columns x int64 = 1536 bits
  - **HLT**: 64x(physics), 64x(Passthrough), 64x Resurrected  
    - 192 columns x int64 = 12288 bits
  - **L1mask**: string (JSON)
  - **EFmask**: string (JSON)

|          | Columns total size in Bytes/event |
|----------|-----------------------------------|
| trig     | BIT_SHUFFLE                        |
|          | LZ4                               |
|          | 0 as null                         |
|          | PLAIN_ENCODING                     |
|          | LZ4                               |
|          | 0 as null                         |
|          | PLAIN_ENCODING                     |
|          | LZ4                               |
|          | 0 as 0                            |
| L1       | 59.96                             |
| HLT      | 14.97                             |
| mask     | DICT                              |
|          | NO_COMPRESSION                     |
| L1Mask   | 697.55                            |
| EFMask   | 680.86                            |
Kudu ingestion test results

- 1 consumer per table performance

- Input data: datasets from May 2018 (mainly tier0)
- Tested different tables/configuration:

Base-t1: HASH(eventnumber)=8 RANGE(runnumber)
-all May’18 ds in same range(runnumber)

Base-t2: same as Base-t1 with key ending
<...,runnumber, eventnumber>

Epoch: HASH(eventnumber)=4 RANGE(epoch)=4

Epoch-t2: HASH(eventnumber)=8 RANGE(epoch)=4

Ingestion mean rate: ~5K events/s

Consumer Ingestion Stages:

Wait: for data valid (1%)
Parse: data conversion (4%)
Insert: into Kudu client buffers (23%)
Flush: buffers to Kudu (72%)
Summary

- EventIndex Distributed Data Collection is running in production indexing and collecting billions of events worldwide. During last year we have indexed 300 M events per day.

- Object Store based improved previous messaging-only approach:
  - Producer payload encoded in a single object.
  - More compact binary data encoding using protocol buffers. Compression reduces a factor 10 the data.
  - Supervisor selects unique validated data, without consuming duplicate data into HDFS.
  - Consumer improved performance. No blockings detected, we can scale horizontally adding new instances when needed.

- Future challenges regarding new production rates, and EventIndex use cases evolution:
  - Current work on new Storage Technologies to support faster insertion, and random access (low latency) and analytics use cases unification.
  - First Ingestion tests on Kudu shows a promising backend for the EventIndex project.
  - See poster in this conference for more information: “A PROTOTYPE FOR THE EVOLUTION OF ATLAS EVENTINDEX BASED ON APACHE KUDU STORAGE”