Joining Dynamic Tables

Flink SQL Training

https://github.com/ververica/sql-training

Joining Static Tables Is Well-Understood

- Join Types
  - INNER JOIN, [LEFT, RIGHT, FULL] OUTER JOIN, CROSS JOIN
- Join Predicates
  - Equality Predicates & Non-Equality Predicates
- Join Algorithms
  - Nested-Loops, Index-Nested-Loops, Sort-Merge, Hybrid-Hash, …
- Static tables are completely available when a join is processed

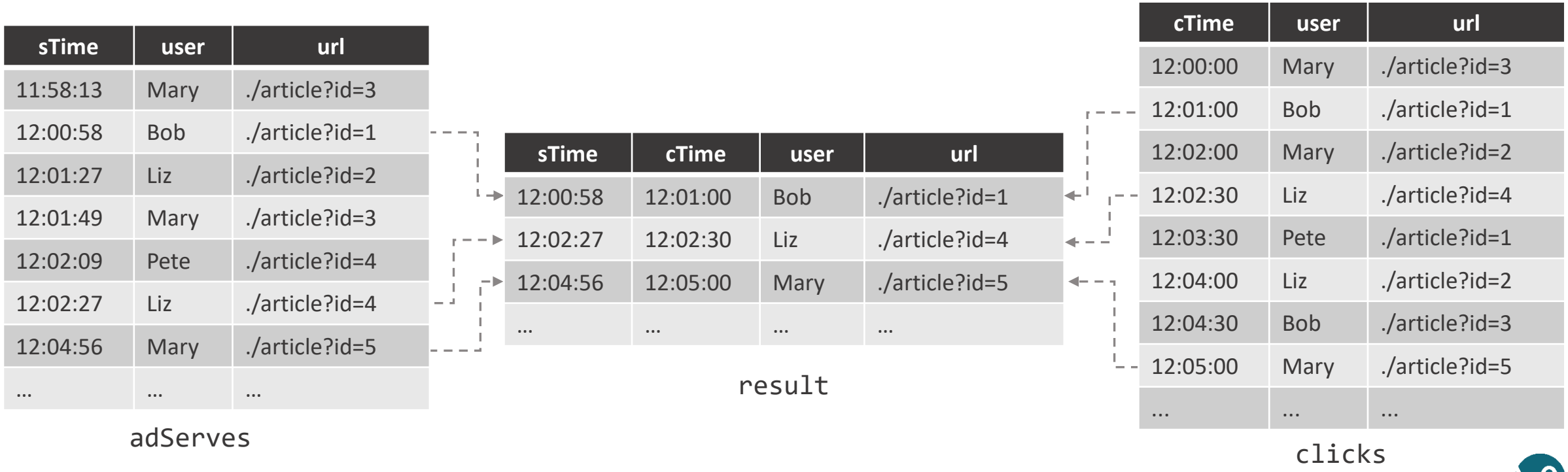
Joining Dynamic Streaming Tables Is Considered a Challenge

- Dynamic tables are constantly changing
  - Append-only tables can only be joined with time-constraining conditions
  - Updating tables need to be fully materialized
- Different requirements & terminology
  - People have different semantics in mind when talking about joining streams
  - There are different use cases for joining streams
- Flink SQL supports three common ways to join dynamic tables
  - Interval joins
  - Joins with temporal tables
  - Regular / default joins

Interval Joins

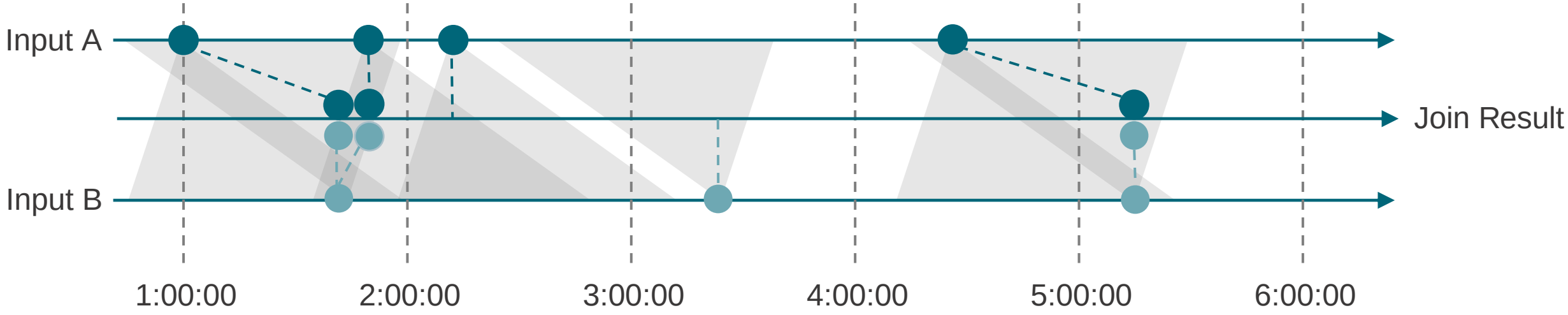
Interval Join: Use Case

- Given
  - A table adServes with served ads events: [servingTime, userId, URL]
  - A table `clicks` with click events: `[clickTime, userId, URL]`
- Find URLs that were clicked less than 5 seconds after being served as an ad



Interval Join

An interval join joins records of ***two append-only tables***
such that the ***time attributes*** *of joined records*
are not more than a specified window interval apart from each other*.*



Every record of Input A is joined with all records of Input B that arrived at most 15 minutes earlier or 1 hour later.
Every record of Input B is joined with all records of Input B that arrived at most 1 hour earlier or 15 minutes later.

Interval Join: Requirements and Syntax

- Tables A and B are append-only (records are never updated!)
- The join condition includes
  - An equality predicate
  - A predicate defining a closed window around A's and B's time attributes

```
SELECT *
FROM A, B
WHERE A.id = B.id AND
      A.t BETWEEN B.t - INTERVAL '15' MINUTE AND
                  B.t + INTERVAL '1' HOUR
```

Every record of A is joined with all records of B that arrived at most 15 minutes earlier or 1 hour later.
Every record of B is joined with all records of A that arrived at most 1 hour earlier or 15 minutes later.

Interval Join: Use Case

- Find URLs that were clicked less than 5 seconds after being served as an ad

```
SELECT url
FROM clicks c, serves s
WHERE s.url = c.url AND
      s.user = c.user AND
      c.cTime BETWEEN s.sTime AND
                      s.sTime + INTERVAL ‘5’ SECOND
```

Interval Join: Execution

- The tails of both append-only tables that correspond to their active join-window are kept in state
- Rows are immediately removed from state once they cannot be joined anymore
- Event-time skew between tables increases state size

Joins with Temporal Tables

Join with Temporal Table: Use Case

- Given
  - A table `clicks` with click events: `[URL, userId, clickTime]`
  - A table `userHistory` with user information `[id, subscription, versionTime]` that is continuously updated and stores the history of changes
- Enrich every click with the most recent version of the user information

user	cTime	url
Mary	12:00:00	./article?id=3
Bob	12:00:00	./article?id=1
Mary	15:00:00	./article?id=2
…	…	…

`clicks`

user	cTime	url	subscription
Mary	12:00:00	./article?id=3	free
Bob	12:00:00	./article?id=1	free
Mary	15:00:00	./article?id=2	paid
…	…	…	

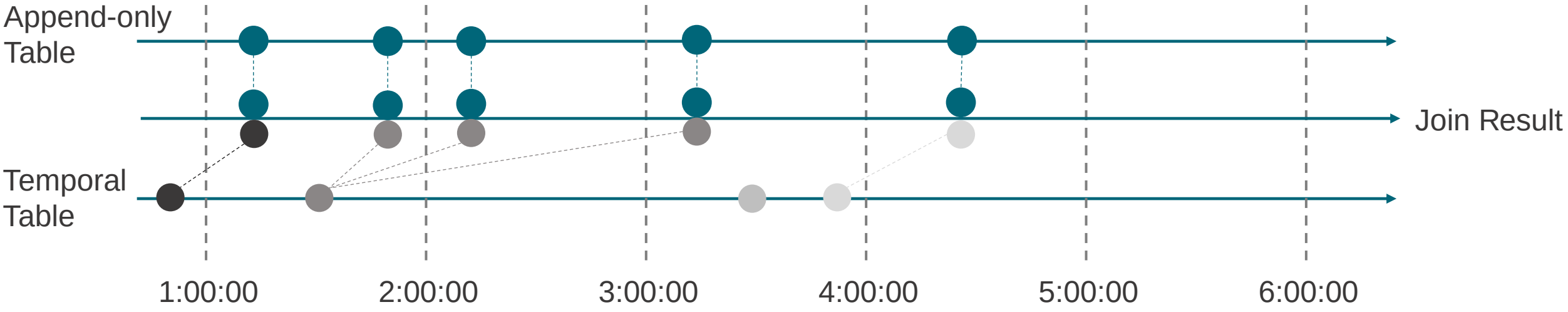
`result`

id	subscription	versionTime
Mary	free	10:00:00
Liz	paid	10:30:00
Bob	free	11:00:00
Mary	paid	14:00:00

`UserHistory`

Join with Temporal Table

A temporal table gives access to the history of a dynamic table.
By joining with a temporal table, records of an append-only table can be joined with the version of the dynamic table that corresponds to their timestamp.



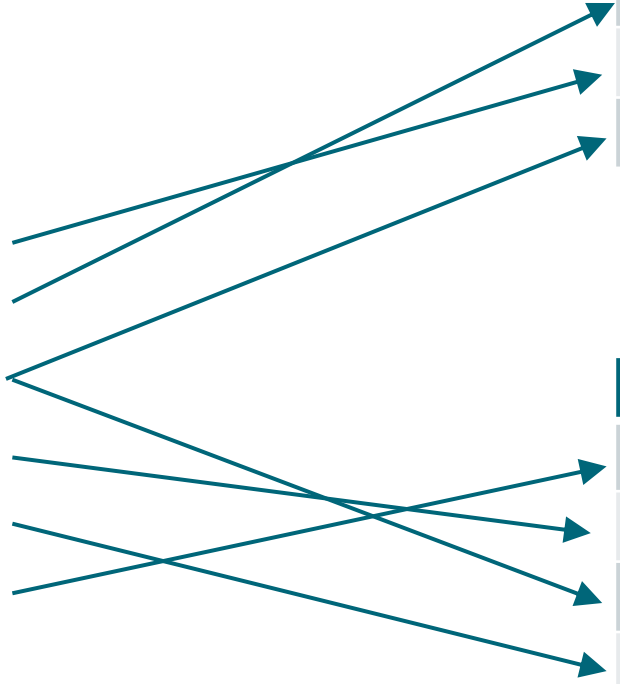
Every record of the append-only table is joined with the latest version in the temporal table.

Temporal Tables

- A temporal table gives access to a version of an append-only history table.
  - Temporal table has a unique key
  - Updates are versioned by timestamp

Key	VersionTime	Value
A	12:00:00	1
B	12:00:00	1
A	12:01:00	2
C	12:02:00	1
B	12:04:00	2
D	12:04:00	1
A	12:05:00	3
C	12:07:00	2
E	12:08:00	1

Append-only History Table



Key	VersionTime	Value
A	12:01:00	2
B	12:00:00	1
C	12:02:00	1

Temporal Table at 12:03:00

Key	VersionTime	Value
A	12:05:00	3
B	12:04:00	2
C	12:02:00	1
D	12:04:00	1

Temporal Table at 12:06:00

Temporal Tables

- Temporal tables are defined as a built-in table-valued function in Flink SQL
- Defining the table-valued function requires:
  - Append-only history table
  - Declaration of unique key attribute
  - Declaration of time attribute (event or processing time) as version time

See documentation for details:

https://ci.apache.org/projects/flink/flink-docs-release-1.10/dev/table/streaming/temporal_tables.html

Join with Temporal Table: Requirements and Syntax

- Table A is append-only (records cannot be updated!)
- Table B is a Temporal Table function and takes the time attribute of A as parameter
- An mandatory equality predicate on B's unique key.

```
SELECT *
FROM A, LATERAL TABLE(B(A.t))
WHERE A.id = B.id
```

For each row of table A, temporal table B returns the version that corresponds to the timestamp of the A row. The row of A is joined with the rows returned by B according to the join condition.

Join with Temporal Table: Use Case

Enrich click data with the current version of user information.
Users is a Temporal Table defined on UserHistory.

```
SELECT c.url, c.cTime, u.id, u.subscription
FROM
  clicks c,
  LATERAL TABLE(users(c.cTime)) u
WHERE c.user = u.id
```

Time attribute

Proper event-time support:

Correct semantics during failure recovery, backfill, etc!

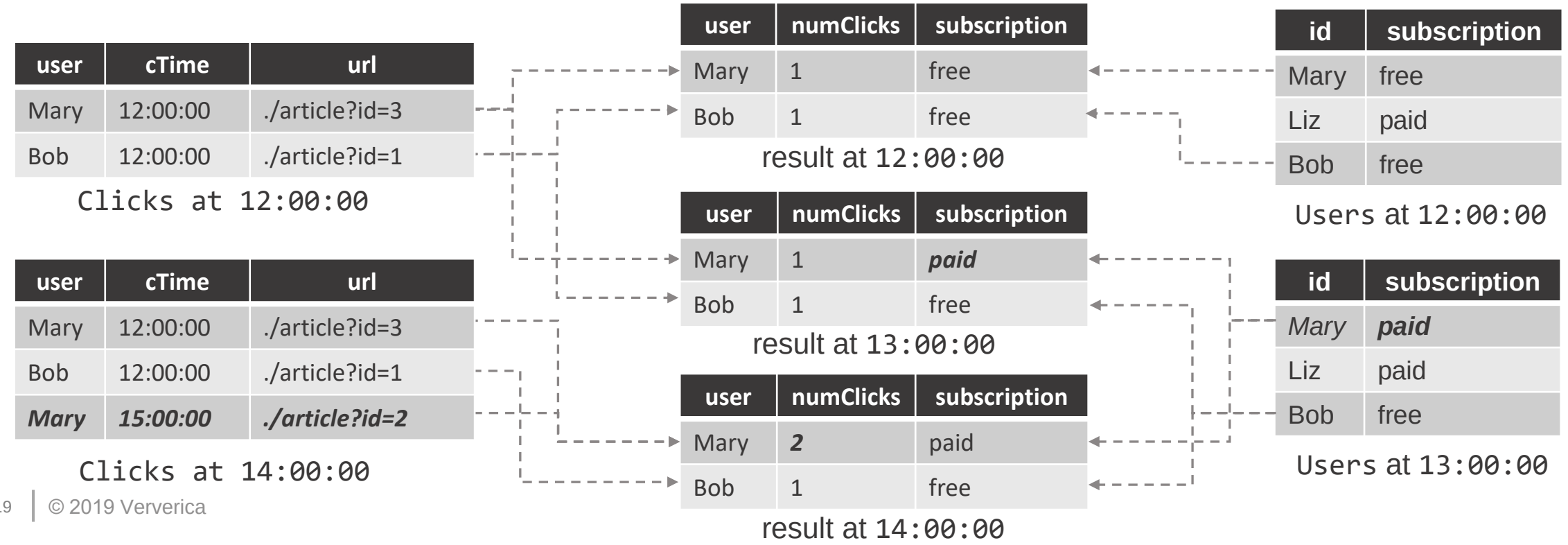
Join with Temporal Table: Execution

- Event time:
  - Temporal table:
    - For each unique key at least one row with the latest version is kept in state
    - Possibly more versions depending on event time skew
  - Append-only table:
    - Rows with timestamps later than the current event-time are temporarily buffered in state
- Processing time:
  - Temporal table:
    - For each unique key exactly one row with the latest version is kept in state
  - Append-only table:
    - All rows are immediately joined and not buffered
- Event-time skew between tables increases state size

Regular / Default Joins

Regular Join: Use Case

- Given
  - A table `clicks` with click events: `[URL, userId, clickTime]`
  - A table `users` with user information `[id, subscription]` that is continuously updated. The table does not store the history of changes.
- Keep track the number of clicks and the subscription status of all users



Regular / Default Join

Joins without a temporal join condition
(i.e., joins that are neither time-windowed nor temporal table joins)
are handled as regular joins. Input tables can be updating.

The join result is updated as records of either input table are inserted, deleted, or updated.

Regular Join: Requirements and Syntax

- Tables A and B should be updating (but can be append-only as well)
- The join condition includes at least one equality predicate

```
SELECT *
FROM A, B
WHERE A.id = B.id
```

All pairs of records of A and B that satisfy the join condition are joined.
Records can be inserted into, deleted from, or updated in A and B.

Regular Join: Use Case

- Keep track the number of clicks and the subscription status of all users

```
SELECT user, numClicks, subscription
FROM (SELECT user, COUNT(*) AS numClicks
      FROM clicks
      GROUP BY user) c,
     Users u
WHERE c.user = u.id
```

GROUP BY subquery produces updating table

Users table is updating

Regular Join: Execution

- The join operator fully materializes both input tables in state
  - A new record can joins with any other record of the other table
- Regular joins only work well if both input tables are not growing too large
  - Table is only slowly growing (or not growing at all)
- Flink can be configured to remove rows that have not been used for x time.
  - Query result becomes inconsistent if state is discarded too early

Attention!

- Regular joins cannot forward time attributes
  - The order in which result rows are emitted is not defined
  - Time attributes lose their orderness / watermark alignment property

- Time attributes must be either projected out or casted to regular TIMESTAMP

- If you mess up the join condition for a time-windowed join,
  the query will be planned with a regular join.
  - You will get an exception about the time attribute in your result.

Hands On Exercises

Joining Dynamic Tables

Continue with the hands-on exercises in
“Joining Dynamic Tables”

https://github.com/ververica/sql-training/wiki/Joining-Dynamic-Tables

We are here to help!

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