03

Continuous Query Language

Notice

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Bibliography

- **Many examples are extracted and adapted from:**
  - Arvind Arasu, Shivnath Babu, Jennifer Widom: The CQL continuous query language: semantic foundations and query execution. VLDB J. 15(2): 121-142 (2006)

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CQL Basic Concepts

Continuous Query Language

- **CQL is a declarative query language for DSMS**
  - It was developed in 2006 for STREAM, the **St**anford St**re**am Dat**a** **M**anagement System
  - It is an extension of SQL, tailored to deal with streams, besides dealing with relations
  - It is part of Oracle's system since version 11g (in Oracle CEP)
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- **This is done with an algebra that has 3 kinds of operators**
  - ***stream-to-relation***, ***relation-to-relation***, ***relation-to-stream***
- **There are no *stream-to-stream* operators, and this makes things closer to SQL**
  - Can be obtained by combining *stream-to-relation - relation-to-relation - relation-to-stream*

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- **The system computes tolls in real-time, and continuously outputs a stream with the prices to pay by each car, upon their exit**

Simplified Linear Road (details)

- The road is **divided into 100 segments** (of 1 Mile each), possibly with an entrance at the beginning of each segment, and/or an exit at the end.

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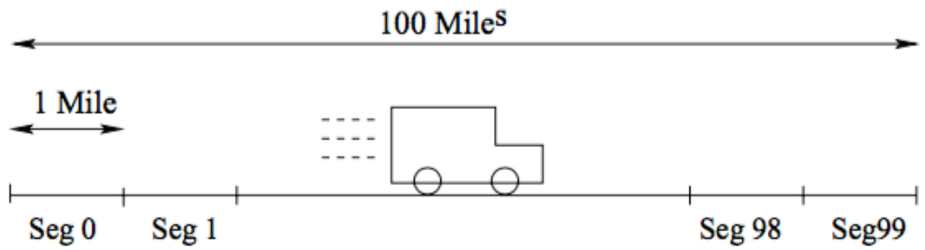

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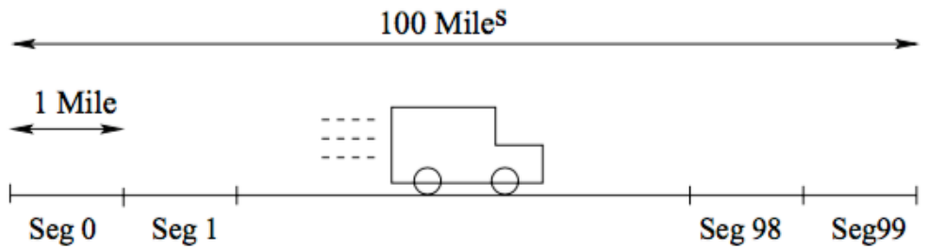

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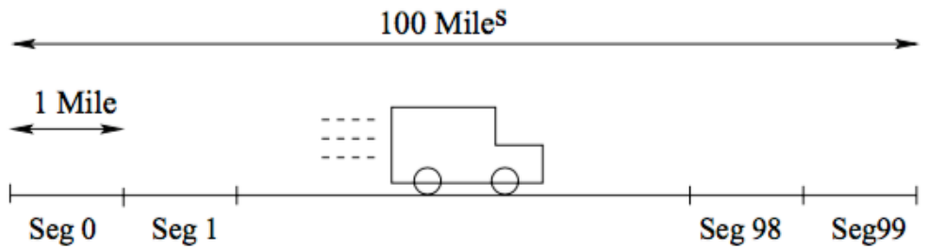

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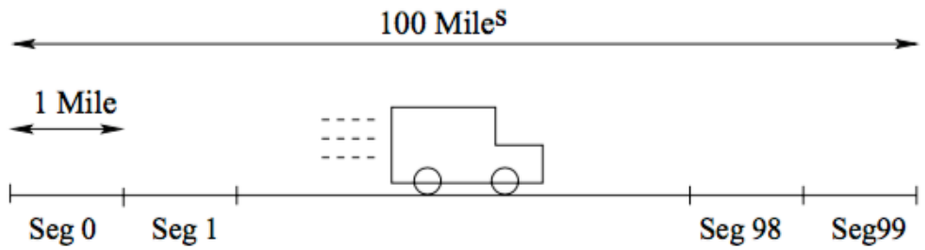

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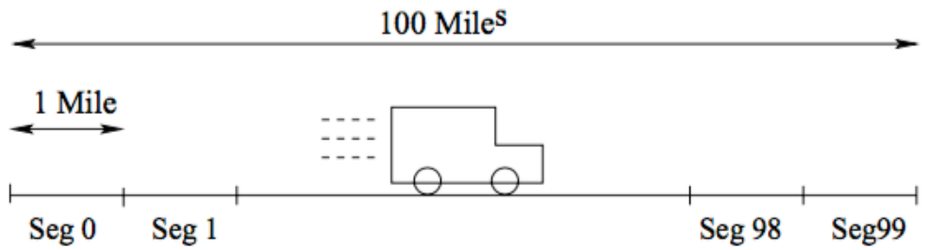

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- Note that all of this changes dynamically, and the **continuous query must compute the tolls at all times**

Streams and Relations

- There is a notion of **schemas**, which is exactly as in relational DBs (**a set of named attributes**)
- There is also a notion of **timestamps** (or time instants) which is simply a **discrete totally ordered set** T (e.g. nonnegative integers, or datetime)

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- **A relation *R* is a mapping from each time instant in T to a finite bag of tuples in the schema of *R***

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- **A Relation is a set of Instantaneous relation *R(t)***

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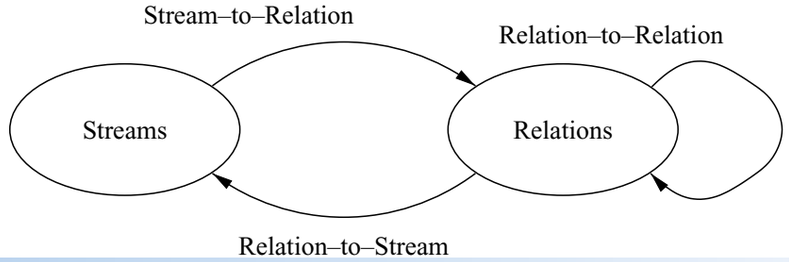
- At time *t*, `SegVolRel(t)` contains the count of vehicles (`numVehicles`) in each highway segment (`segNo`) as of time t.

It seems more natural to model "the current number of vehicles in a segment" as a **time-varying relation**, rather than as a stream of the latest values.

Abstract operators



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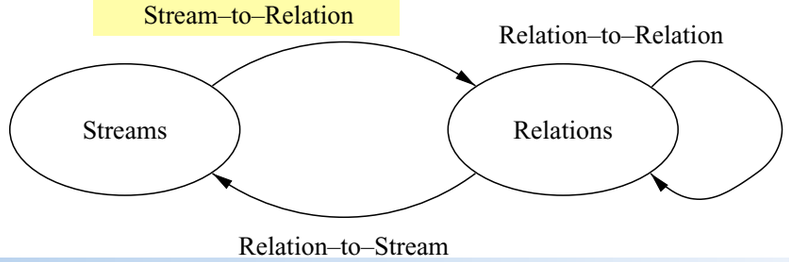

- **Stream-to-relation (s2r) operators**
  - Receive a stream *S* and produce a relation *R* with the same schema of *S*
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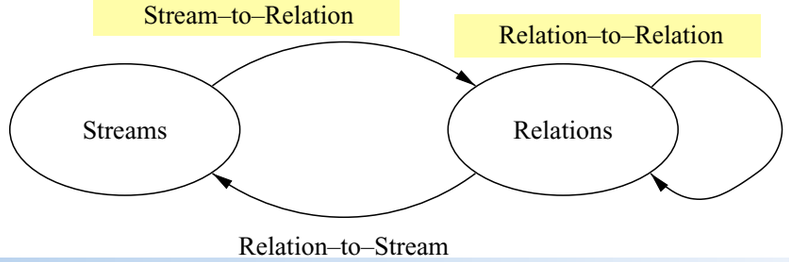

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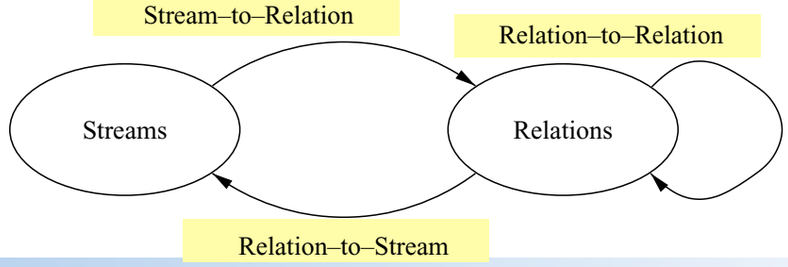

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  - Receive one relation *R* and produce a stream *S*
  - At any instant *t*, *S at t* must be computable from *R(t)*
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- The **result of continuous query Q at a time t** , which denotes the result of Q once all inputs up to *t* are “available”. There are two cases:
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  - If the query produces a **relation** *R*, it **updates the relation from *R(t-1)* to *R(t)***

Continuous Semantics Example

- Query: `Istream(Filter(LastRow(S))`
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`SegVolRel (segNo, numVehicles)`

Requirements for processing a query

- In the Linear Road application the sequence of operators producing derived relation **`SegVolRel`** conceptually produces, **at every time instant *t*,** the instantaneous relation **`SegVolRel(t)`** containing the current number of vehicles in each segment.

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- Furthermore, once they have been received, **there may be additional lag before the relation is actually updated** due to query processing time.

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- **General Idea**

  - Support a **large class** of relation-to-relation operators that **perform the bulk of data manipulation** in a typical CQL query, along with a **small set** of stream-to-relation and relation-to-stream operators that **convert streams to relations and back**.

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  - The primary advantage of this approach is the ability to **reuse** the formal foundations and **huge body of implementation techniques for relation-to-relation languages** such as relational algebra and SQL !

CQL language

- **CQL is obtained by a precise instantiation of the abstract operators**
- **r2r operators are those of relational algebra**
  - Formally, they have to be adapted to time-varying relations, but that is easy:
  - If $\oplus_r$ is a traditional operator (e.g. $\bowtie$, Π, σ, …) over $R_1, \ldots, R_n$ then $\oplus$ in CQL produces a time-varying relations R, such that at each t, $R(t) = \oplus(R_1(t), \ldots, R_n(t))$

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- **For writing the queries, CQL uses an extension of SQL syntax**
  - By now, it should be more than clear to you how to switch from SQL syntax to relational algebra, and back!
- **Incorporating user-defined** procedures, aggregates, and windows, is **straightforward in CQL**, at least from the semantics perspective.

CQL's **s2r** operators

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- **They are all based on the concept of sliding window over a stream**
  - at any point *t* **a window is an instantaneous relation *R(t)* that contains a historical snapshot** of a finite portion of the stream
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- **4 types of sliding window s2r operators**
  - **time-based** (e.g. last minute)
  - **tuple-based** (e.g. last five tuples)
  - **partitioned** (similar to `group by` in SQL)
  - **with slide parameter** (e.g. last minute, picked every minute)

Time-based windows

- **`S [Range T]` takes a stream *S* and a time-interval *T*, and produces the relation *R* such that**

$$R(t) = \{s | \langle s, t' \rangle \in S \wedge max(t - T, 0) \leq t' \leq t\}$$

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  - Produces a relation with all tuples of stream *S* with timestamps in the last *T* time
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- **Special cases:**

  - *T=0* (write `S [Now]`)
    - at any time *t*, *R(t)* has the tuples that appeared in the stream at *t*, possibly empty
  - *T=∞* (write `S [Range Unbounded]`)
    - at any time *R*, has all the tuples that ever appeared in *S*, so far

Example

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- **In SQL-like syntax:**

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select *
from PosSpeedStr [Range 30s]
where speed ≥ 60;
```

- **The ids of cars that were ever detected with a speed higher than 200**

```
select distinct carID
from PosSpeedStr [Range Unbounded]
where speed ≥ 200;
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- A **time-based window** over stream S with **window size** T and **slide parameter** L is denoted as
  - S [Range T Slide L]

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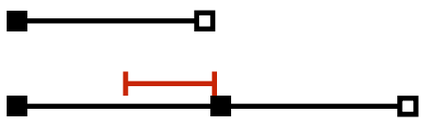

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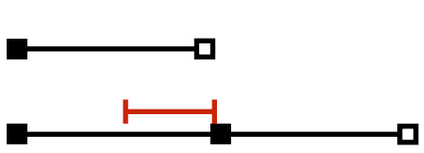

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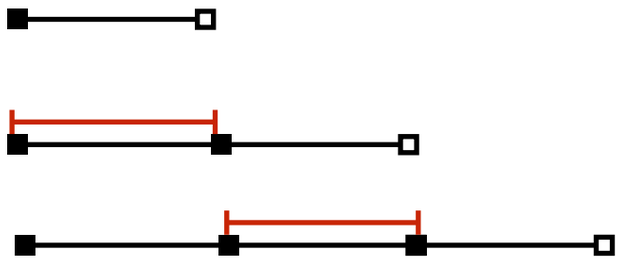

Windows with a slide parameter

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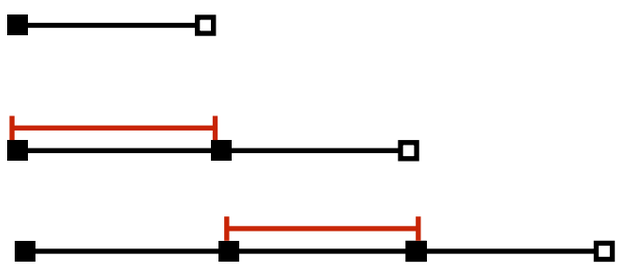

- **Tuple-based** and **partitioned windows** with a **slide parameter** are defined analogously.

CQL's **r2s** operators

- **They take a varying-time relation *R*, and build a stream *S* based on the changes that occur in *R* over the time**
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  - **Istream** (*insert stream*): the stream "registers" the **insertions** made in the relation
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  - **Rstream** (*relation stream*): at each instant, outputs to the stream **all the tuples** that are in the relation

Insert stream

$$\texttt{Istream}(R) = \bigcup_{t \geq 0} ((R(t) - R(t-1)) \times \{t\})$$

- I.e. S has <*s,t*> whenever *s* is in *R(t)* and was not in *R(t-1)*

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- **Example: Output in a stream the id and position of a car whenever that car is detected with a speed greater than 150**

```
select Istream(carID, position)
from PosSpeedStr [Range Unbounded]
where speed ≥ 150;
```

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- Note that, this query has as **input a stream** and as **output another stream**, and continuously produces the output upon what it receives from the input - i.e., it is a continuous query

Delete stream

$$\texttt{Dstream}(R) = \bigcup_{t \geq 0} ((R(t-1) - R(t)) \times \{t\})$$

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- **Example: Output in a stream the ids of cars that exit the highway**

```
select Dstream(carID)
from PosSpeedStr [Range 30s];
```

- An id of a car is output in the stream whenever the car reported its position and speed before 30 seconds ago, and in the last 30 seconds did not send anything

Relation stream

$$\texttt{Rstream}(R) = \bigcup_{t \geq 0} (R(t) \times \{t\})$$

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- **Example: What does this query compute?**

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select Rstream(carID, position)
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- **Example: What does this query compute?**

```
select Rstream(carID, position)
from PosSpeedStr [Now]
where speed ≥ 150;
```

- **Exactly the same as this other one!**

```
select Istream(carID, position)
from PosSpeedStr [Range Unbounded]
where speed ≥ 150;
```

- **We will see that this is a general equivalence result. This is the general form of a stream filter**

Shortcuts

- **To makes things easier to write, there are some shortcut and default assumptions (though this is not usual in SQL-like languages)**

  1. When a stream is referred in a place where a relation is expected (e.g. in the from clause) assume an unbounded range
  2. If one has a monotonic query based on streams, assume that the result should be a stream, and use the Istream operator

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  1. When a stream is referred in a place where a relation is expected (e.g. in the from clause) assume an unbounded range
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- **Example: With this, one can simply write**

```
select carID, position
from PosSpeedStr
where speed ≥ 150;
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  - to denote

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select Istream(carID, position)
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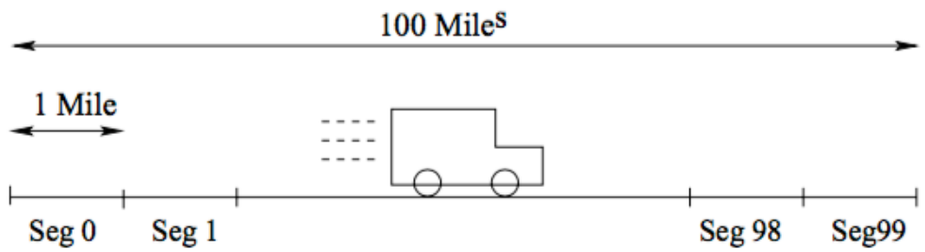
Simplified Linear Road (details)



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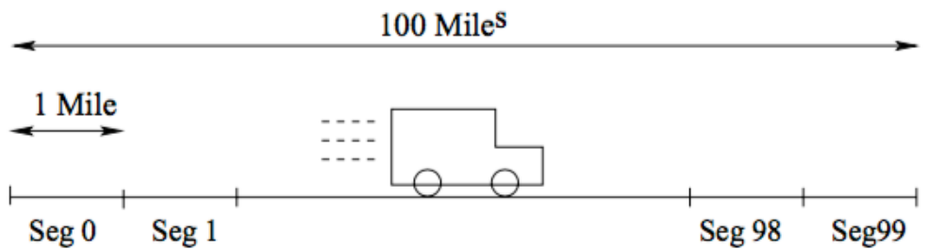

- **The road is divided into 100 segments (of Mile each)**

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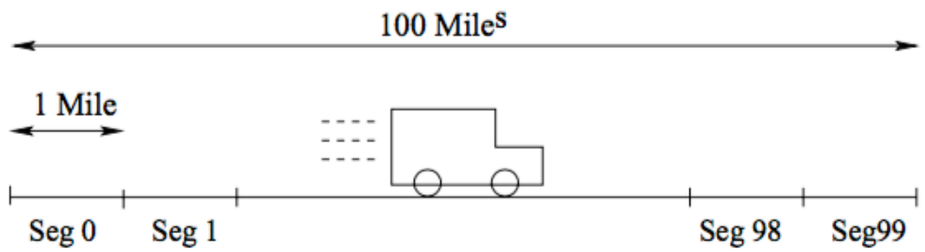

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  - The position given as the distance in feet from the beginning of the road

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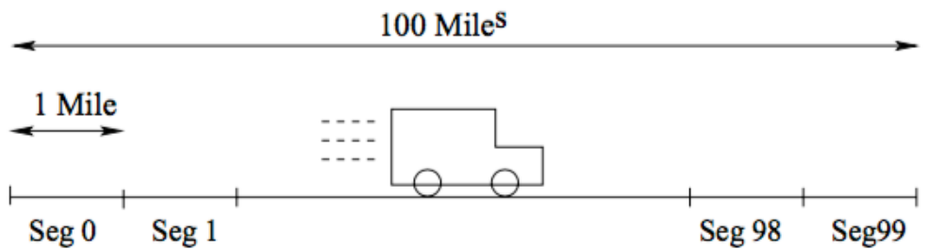

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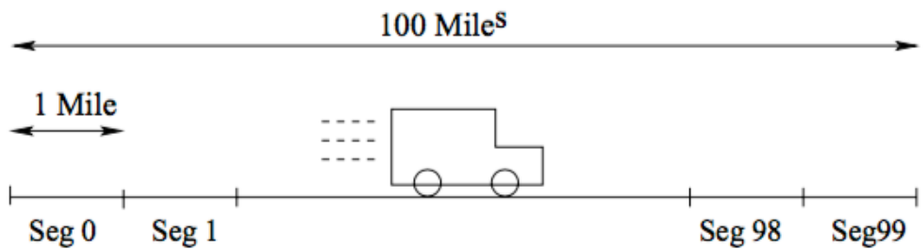

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  - a congested segment pays $2 \times (numCars-50)^2$, where *numCars* is the number of cars in the segment at the moment
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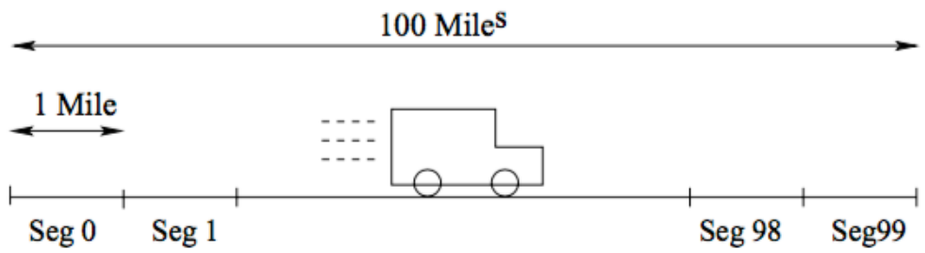

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- **Lets implement this in CQL!**

Linear Road in CQL

5280 feet in a Mile

- **Start by defining a query `SegSpeedStr` that in the input stream replaces the position by the number of the segment**

```
select Istream(carID, speed, position/5280 as segNo)
from PosSpeedStr [Range Unbounded];
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select segNo, count(carID) as numCars
from ActCarSegRel                                (segNo, numCars)
group by segNo
```

Linear Road in CQL

PosSpeedStr(carID, speed, segNo)

Linear Road in CQL

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- **SegSpeedStr - (carID, speed, segNo)**

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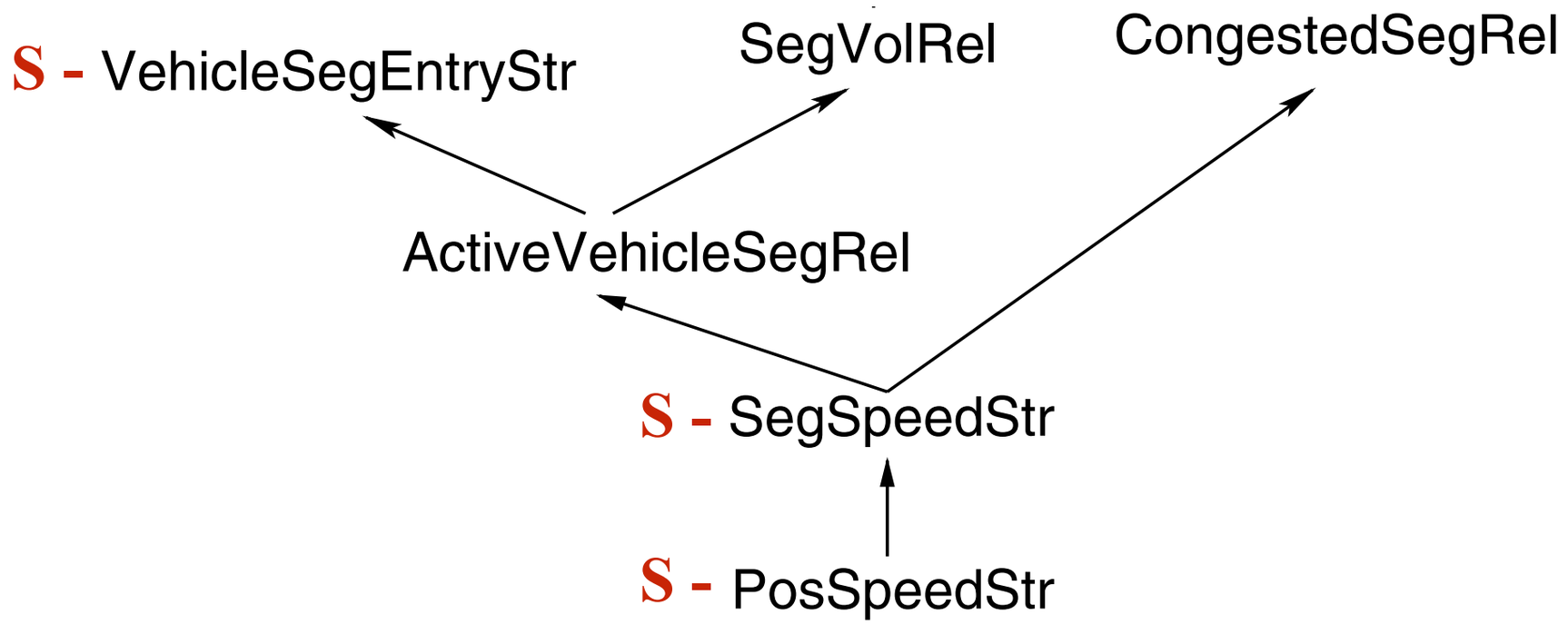
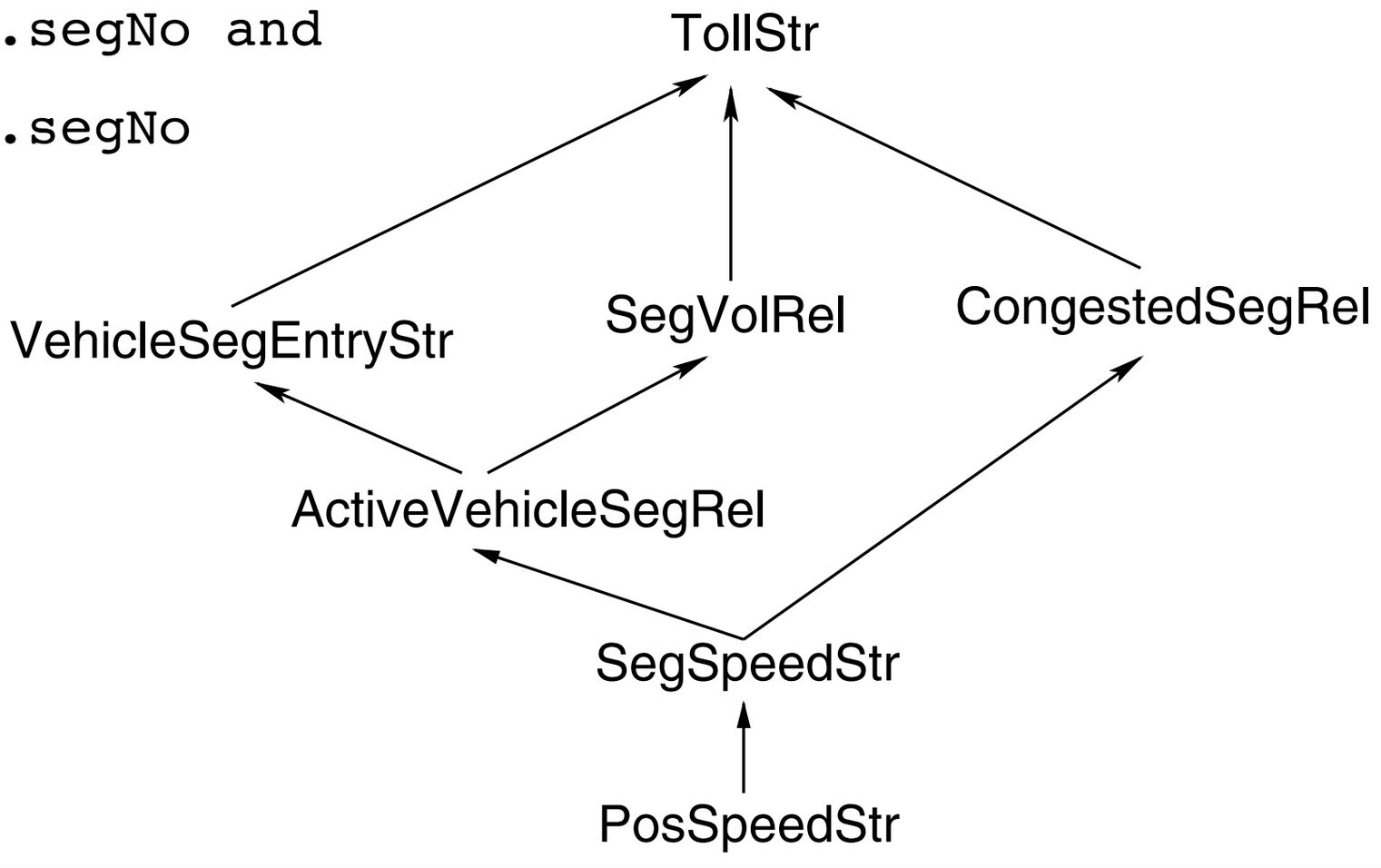


Linear Road in CQL

- **The query that outputs the desired stream is:**

```
select Rstream(E.carID,2*(V.numCars-50)**2)
from CarSegEntryStr [Now] as E,
     CongestedSegRel as C, SegVolRel as V
where E.segNo = C.segNo and
      C.segNo = V.segNo
```



The complete query (just for the sake of completeness)

```
select Rstream(E.carID,2*(V.numCars-50)**2)
from
   ( select Istream(*)
     from
     ( select carID, segNo
       from
       ( select Istream(carID, speed,position/1000 as segNo) from PosSpeedStr [Range Unbounded]
       ) [Range 30s]
     )
   ) [Now] as E,
   ( select segNo
     from
       ( select Istream(*)
         from
         ( select Istream(carID, speed,position/1000 as segNo) from PosSpeedStr [Range Unbounded]
         ) [Range 30s]
       ) [Range 5min]
     group by segNo
     having avg(speed) < 40
   ) as C,
   ( select segNo, count(carID) as numCar
     from (select carID, segNo
           from (select Istream(carID, speed,position/1000 as segNo) from PosSpeedStr [Range Unbounded]
                )[Range 30s] )
     group by segNo
   ) as V
where E.segNo = C.segNo and C.segNo = V.segNo;
```

Some variants

- **Additional fixed price per segment (when segment is congested)**

```
select Rstream(E.carID,P.price+2*(V.numCars-50)**2)
from CarSegEntryStr [Now] as E,
     CongSegRel as C, SegVolRel as V, SegPrice as P
where E.segNo = C.segNo and
      C.segNo = V.segNo and V.segNo = P.segNo;
```

```
select Rstream(E.carID,2*(V.numCars-50)**2)
from CarSegEntryStr [Now] as E,
     CongestedSegRel as C, SegVolRel as V
where E.segNo = C.segNo and
      C.segNo = V.segNo
```

Some variants

- **Charging the customer: having the prices being output upon exit of the cars**

```
select Rstream(A.NIF,P.price+2*(V.numCars-50)**2)
from CarSegEntryStr [Now] as E,
     CongSegRel as C, SegVolRel as V,
     SegPrice as P, Cars, Accounts as A
where E.segNo = C.segNo and
      C.segNo = V.segNo and V.segNo = P.segNo
      E.carID = Cars.ID and Cars.owner = A.client;
```

Another variant

- **Fixed price per segment (charged always), plus variable toll:**

```
select Rstream(E.carID,P.price+2*(V.numCars-50)**2)
from
   (CarSegEntryStr [Now] E inner join SegPrice S
       on(E.segNo = S.segNo))
   left outer join
   (CongSegRel C inner join SegVolRel V
       on(C.segNo = V.segNo))
on(E.segNo = C.segNo)
```

Other variants

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  - Again this may be problematic
  - Note that when one applies a s2r operator, the relation loses the timestamps

Some common queries

- **Stream filters:**
  - Either use
    - `Rstream` and `[Now]`, or
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  - Either use
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  - Note the **Istream-Unbounded** window combination is the **default** for streams whose window specification is omitted

Some common queries

- **Stream-relation joins:**
  - When a stream is joined with a relation, it is usually **most meaningful to apply a Now window over the stream** and an **Rstream operator over the join result**
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- **Example: Get prices for purchased items:**

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  - The 2nd does that plus, whenever a price changes, it outputs all the items purchased so far, with the new price

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  - Suppose a new tuple of S2 is identical to the tuple 10 positions earlier

Some common queries

- **Sliding windows joins:**

```
select Istream(*)

from S1 [Rows 5], S2 [Rows 10]

where S1.A=S2.A;
```

  - A new tuple is produced whenever a tuple in the last 5 elements of S1 matches with one in the last 10 elements of S2

- **But if both S1 and S2 can have duplicates in attribute A, it may work differently!**
  - Suppose a new tuple of S2 is identical to the tuple 10 positions earlier
  - Then the new S2 tuple does not produce any join result tuples, even if it joins with one of the last 5 tuples of S1.

Stream aggregations

Aggregation produces relations, not streams, in CQL since **aggregations** are **relation-to-relation operators**

- **Stream the value of aggregation whenever it changes:**

```
select Istream(Count(*))

from PosSpeedStr [Range 1min];
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  - Outputs the number of measurements over the last minute, once a minute
  - If the count does not change, then it output nothing!
    - It is possible, with a more complex query, also to output in that case.

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L is any **select-list**, *S* is any **stream** (including a subquery producing a stream), and *C* is any **condition**.

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from S [Range Unbounded]
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- **Filter-Window commutativity - the two are equivalent**

```
(select L from S where C) [Range T]
```

```
select L from S [Range T] where C
```

  - the execution of the 1st query should be more efficient, because it filters before applying the window
    - If the system uses a query strategy that materialises the window, materialising only the filtered tuples requires less steady-state memory

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- **CQL was first implement in the prototype system STREAM**
  - Currently there are other implementations (e.g. Oracle)
- **One of the nice things about declarative languages is that they hide quite a lot of the implementation details**
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- **CQL was first implement in the prototype system STREAM**
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- **One of the nice things about declarative languages is that they hide quite a lot of the implementation details**
  - We can use them without having any idea of how things are implemented
- **But, in the end, the declarative language must be implemented!**
  - If one wants to use the system efficiently, it is good to have an idea of how things are implemented, and run

CQL Query Plans

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  - The first plan is generated taking into account several simple heuristics
    - But while running, with concrete data, it may be adapted
  - A **new query plan is then merged with existing ones**
    - This way, **parts of the plan that are common to more than one query are only (continuously) executed once**
    - At least the parts of incoming streams, are usually common

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CQL Query Execution

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  - **r2r** operators transform **changes** in the input relations into **changes** in the output relation.
  - **r2s** operators transform changes in the input relations into new items in the output stream
- **We need components associated to operators, to:**
  - store **intermediate changes** - inserts and deletes (***queues***)
  - store **intermediate results** - e.g. with materialised windows (***synopses***)

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- **A tagged tuple is a tuple plus a tag with:**
  - a timestamp
  - an indication whether it is an insertion of a deletion
- **Streams can only have insertion tags**
- **Relation can have both.**
  - Relations are thus represented as a set of insert/delete operations that give rise to the current state of the relation

Queues and Synopses

- ***A queue* connects two operators O_i and O_o**
  - At any time, contains a sequence of tagged tuples
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- **Two operators are always connected by a queue, but many operators need no synopsis**

Example plan

- **Q1**

```
select B, max(A)
from S1 [Rows 50000]
group by B;
```

- **Q2**

```
select Istream(*)
from S1 [Rows 40000]
     S2 [Range 600s]
where S1.A = S2.A;
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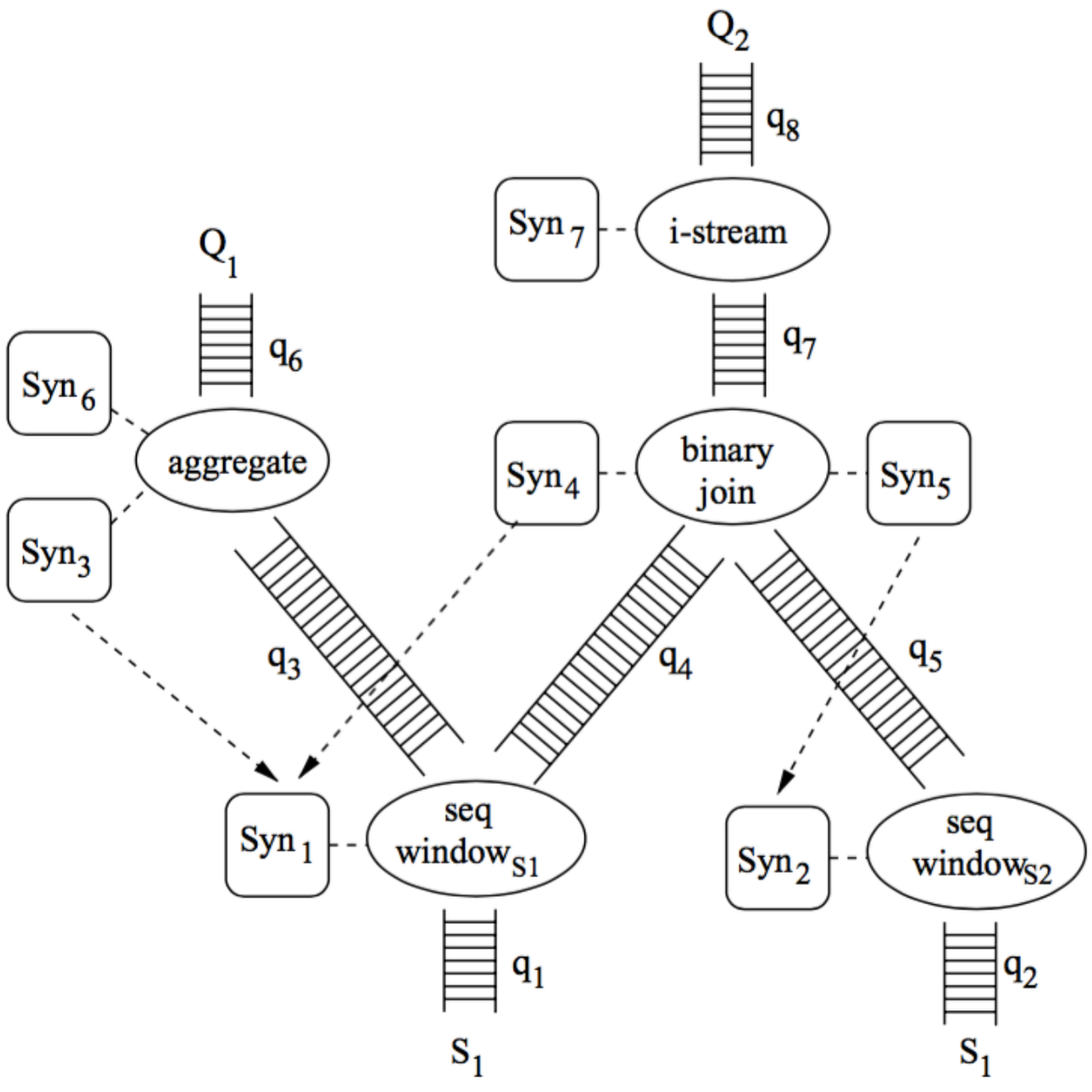
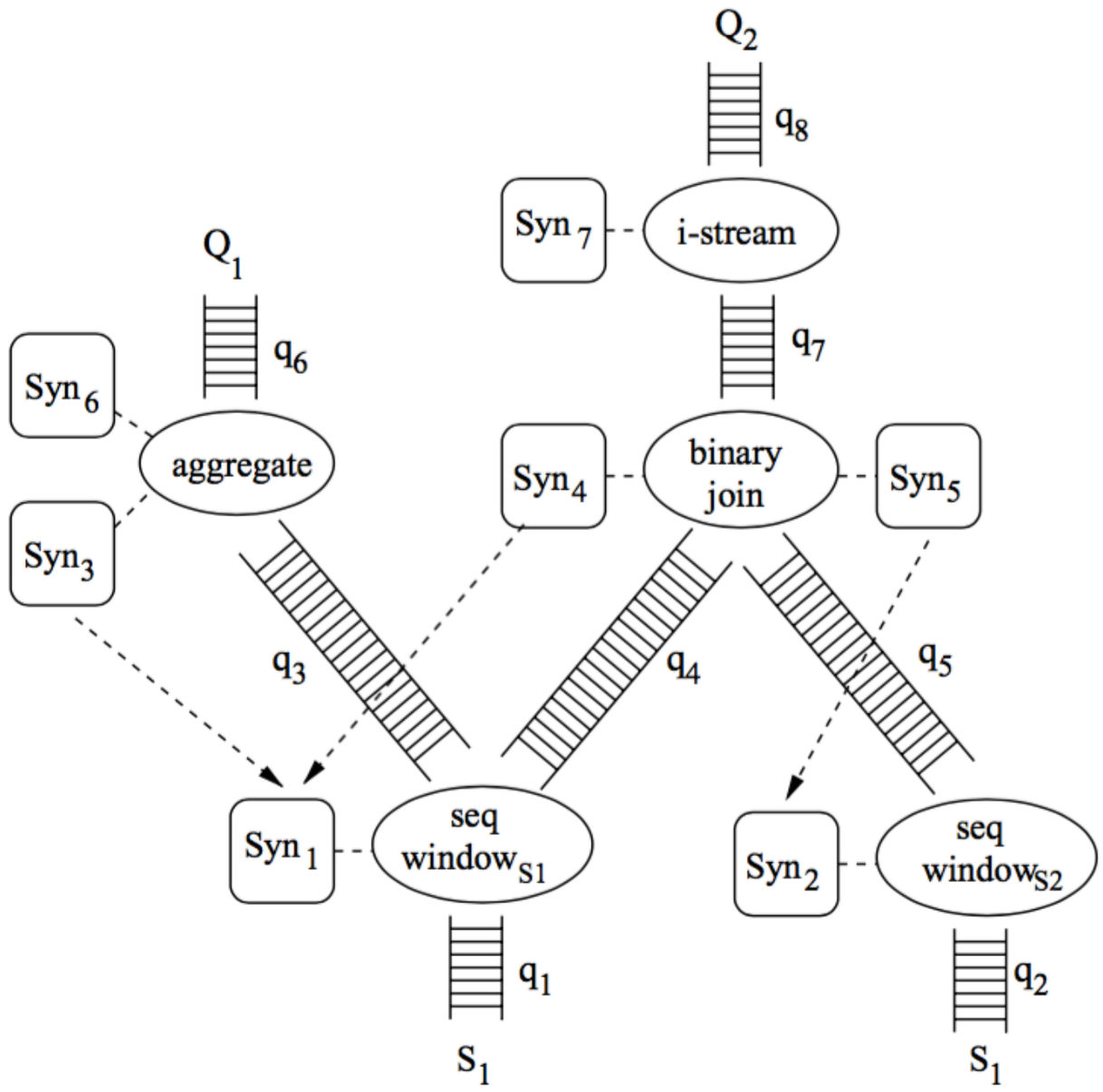


Example plan

- **This plan contains**

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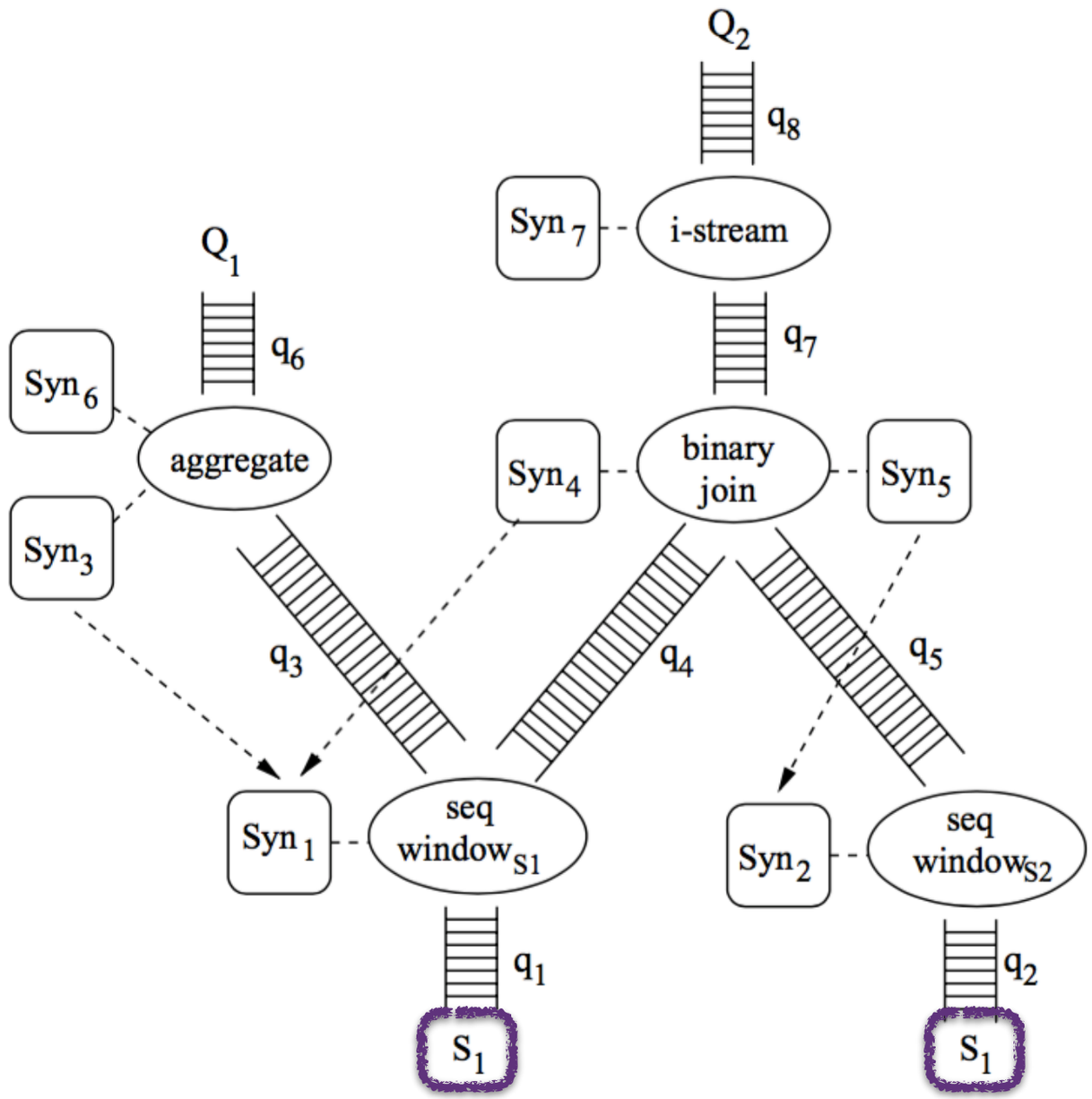
Example plan

- **This plan contains**
  - 2 input streams

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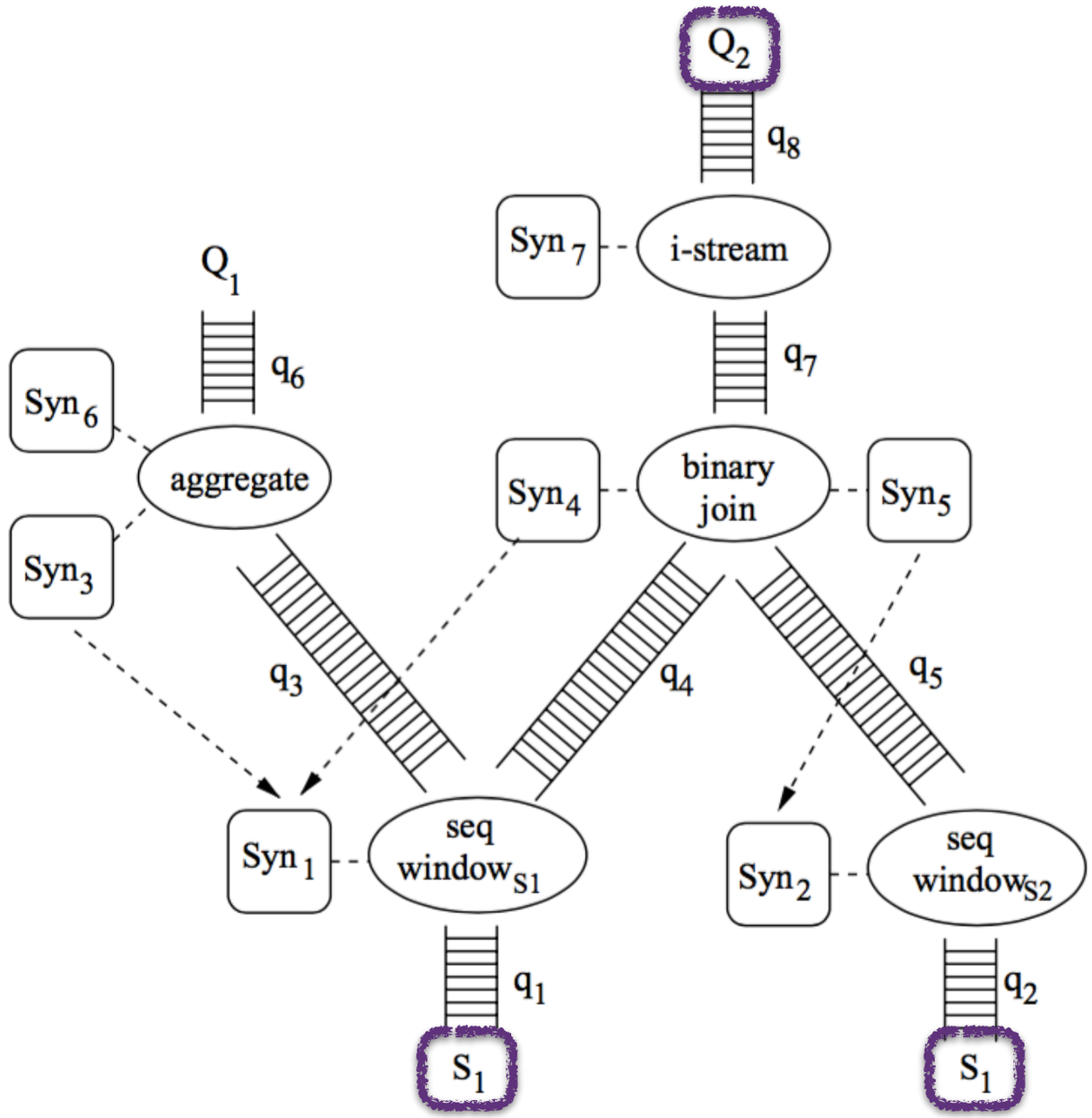


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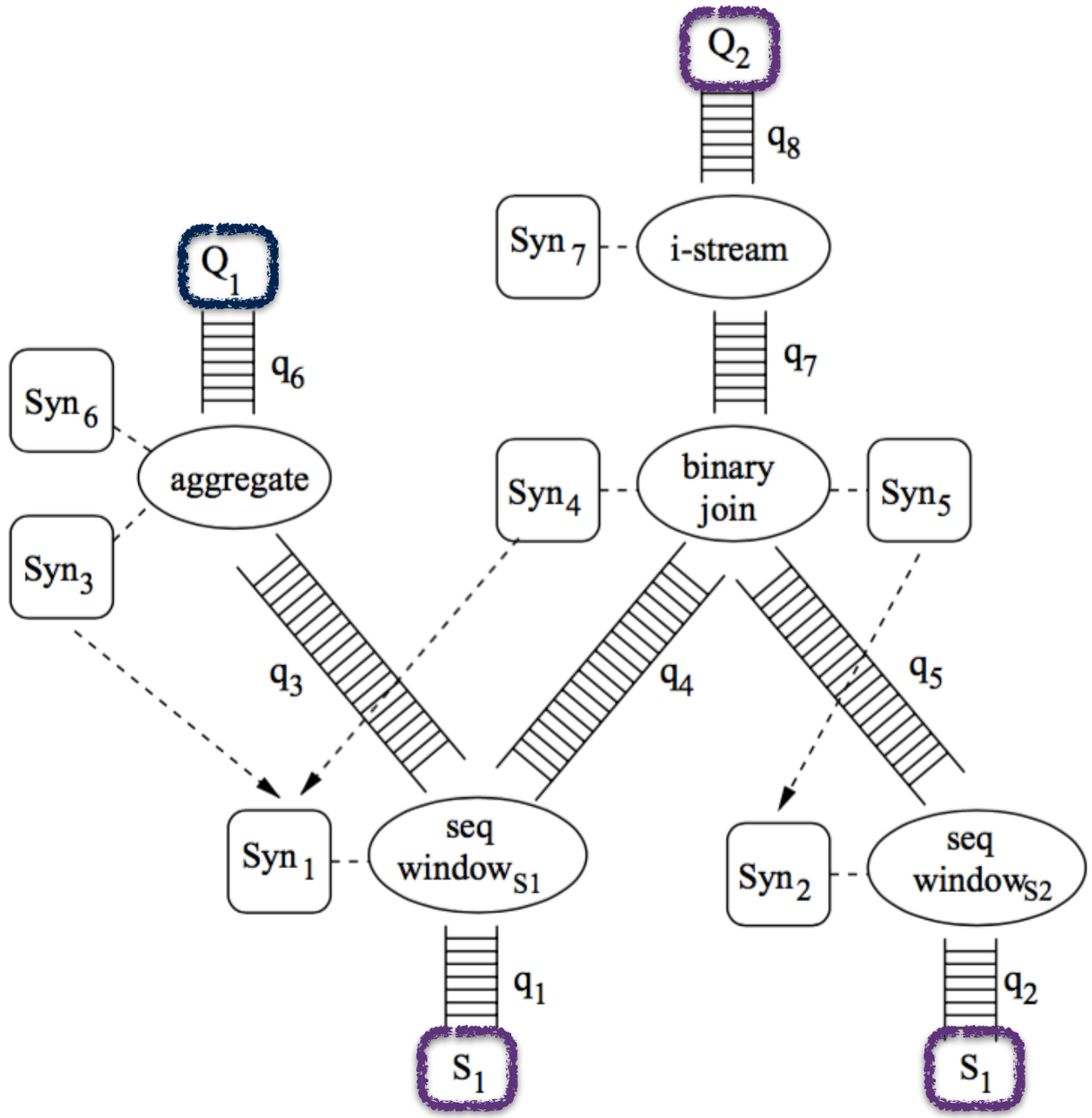


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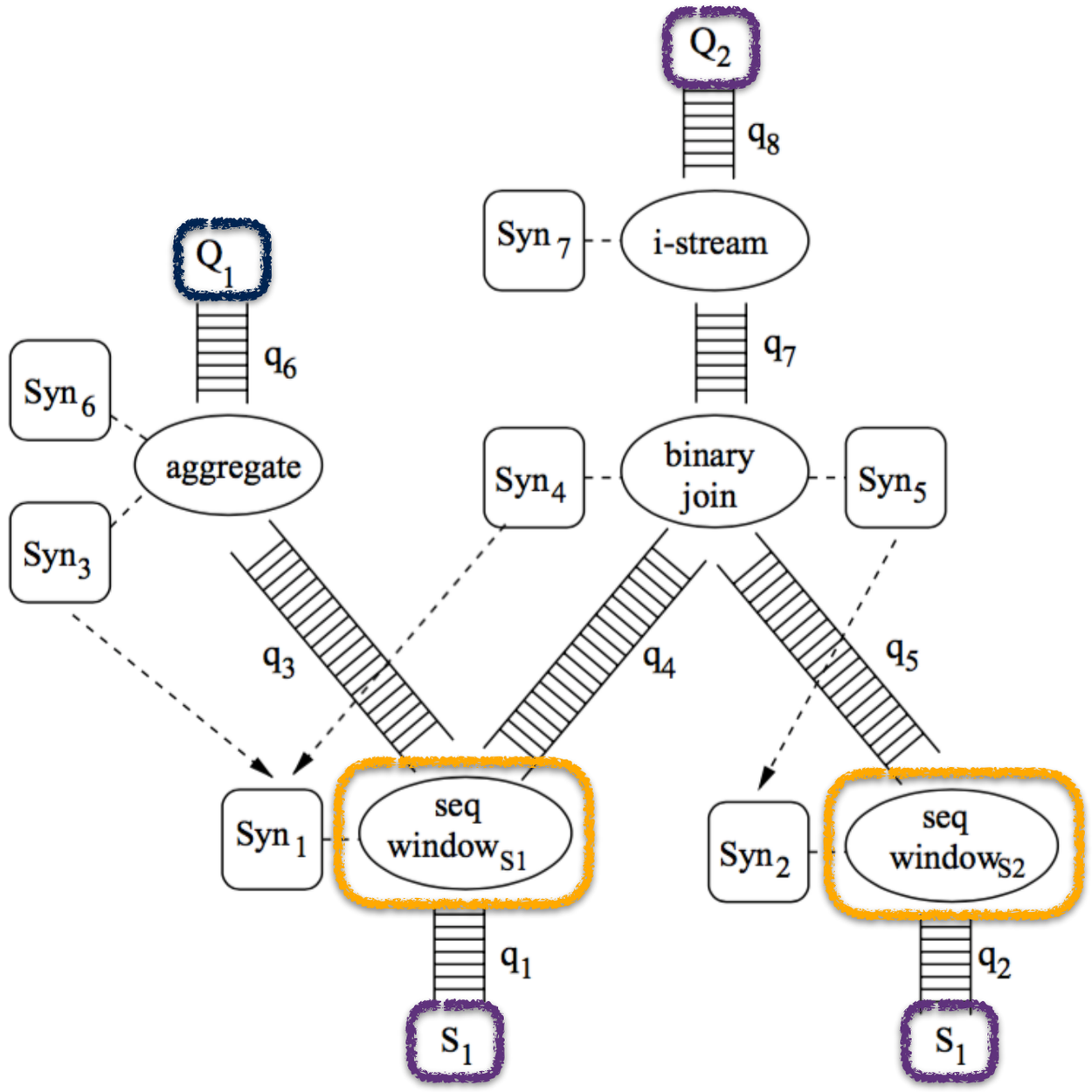
  - 2 s2r operators

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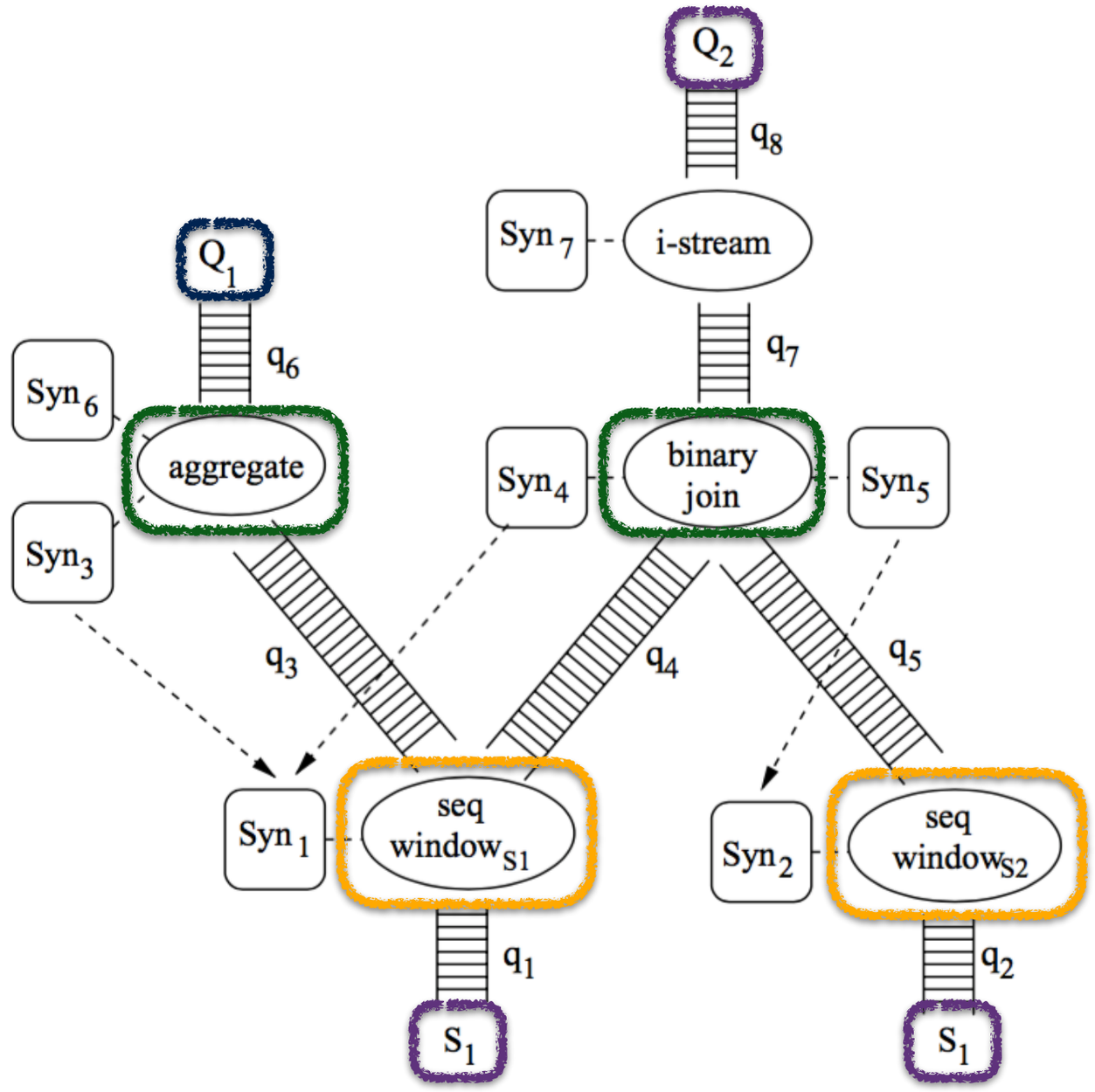


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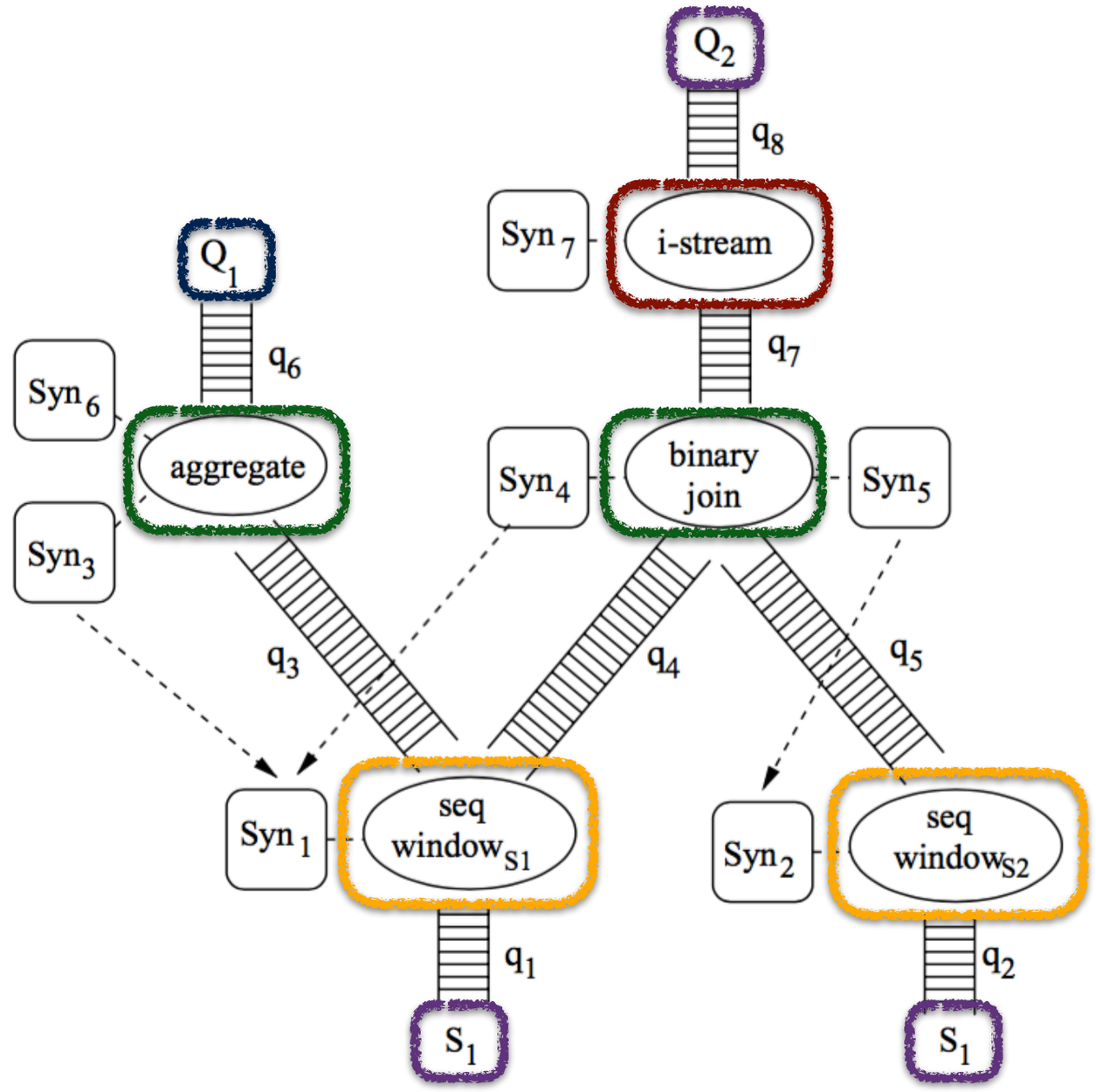


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- **This plan contains**
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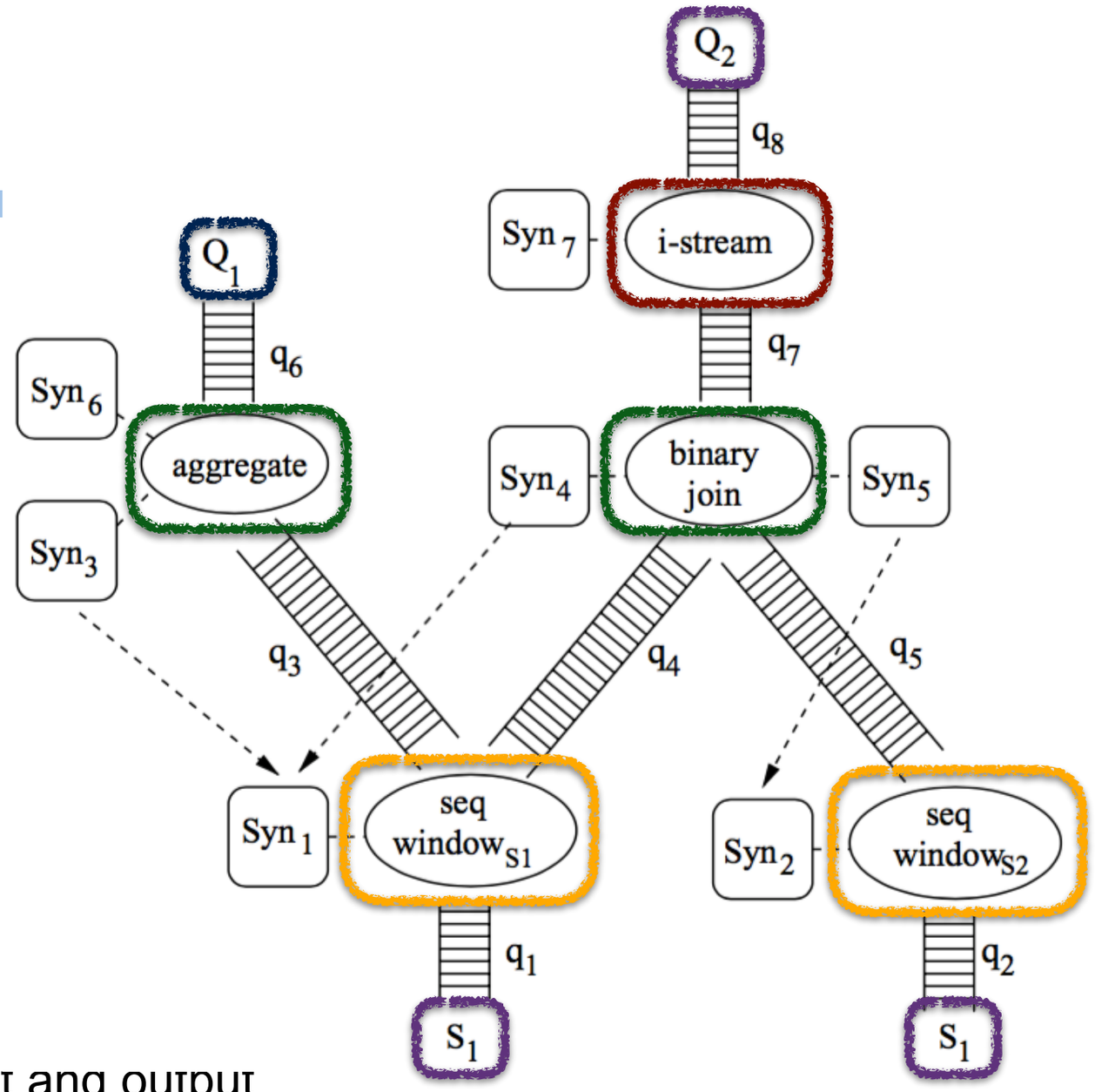


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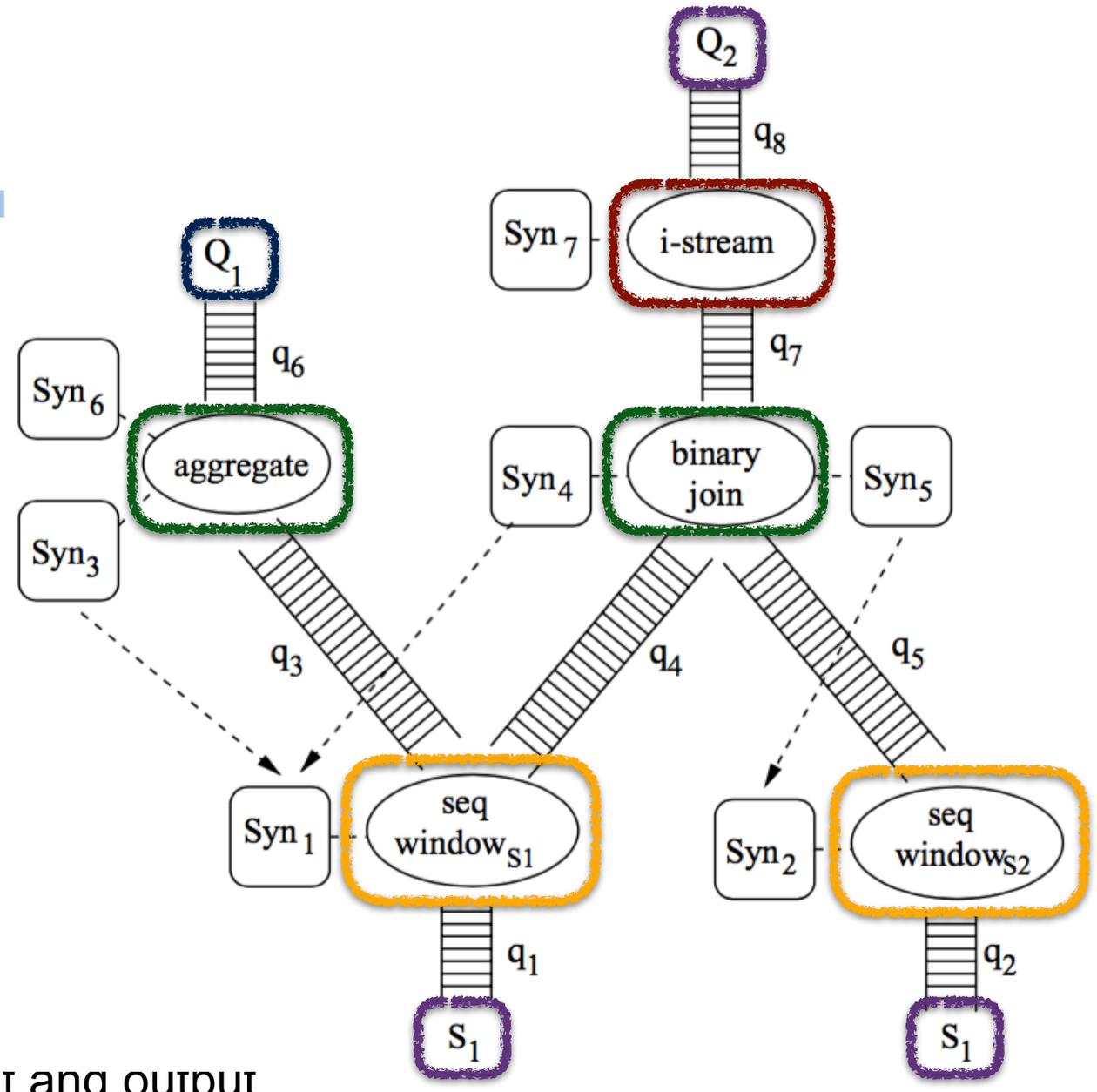
  - 7 synopses associated to operators

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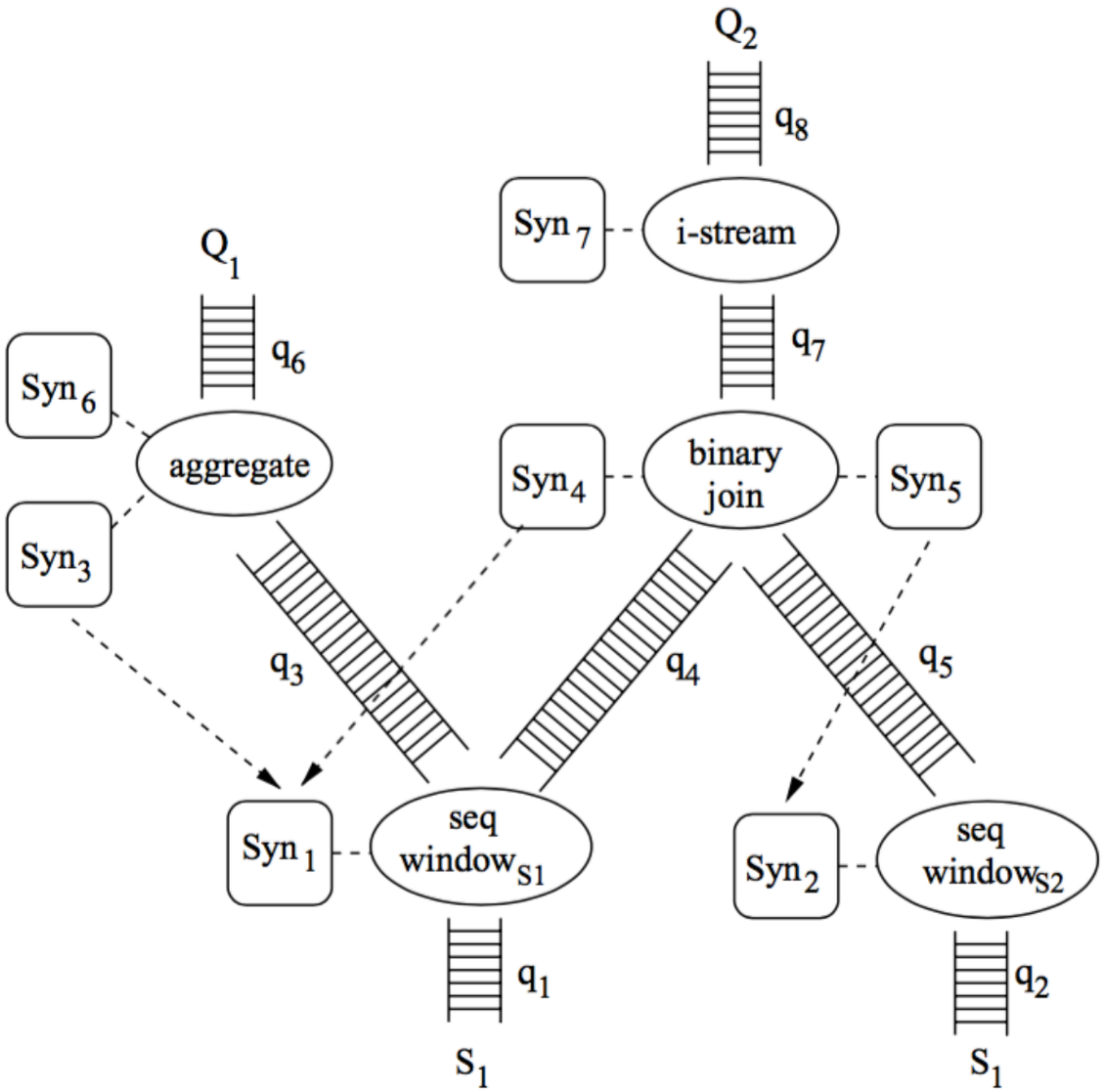
  - Reads stream S_1's tuples
  - Outputs *insertions and deletions in the window* in **both q_3 and q_4**

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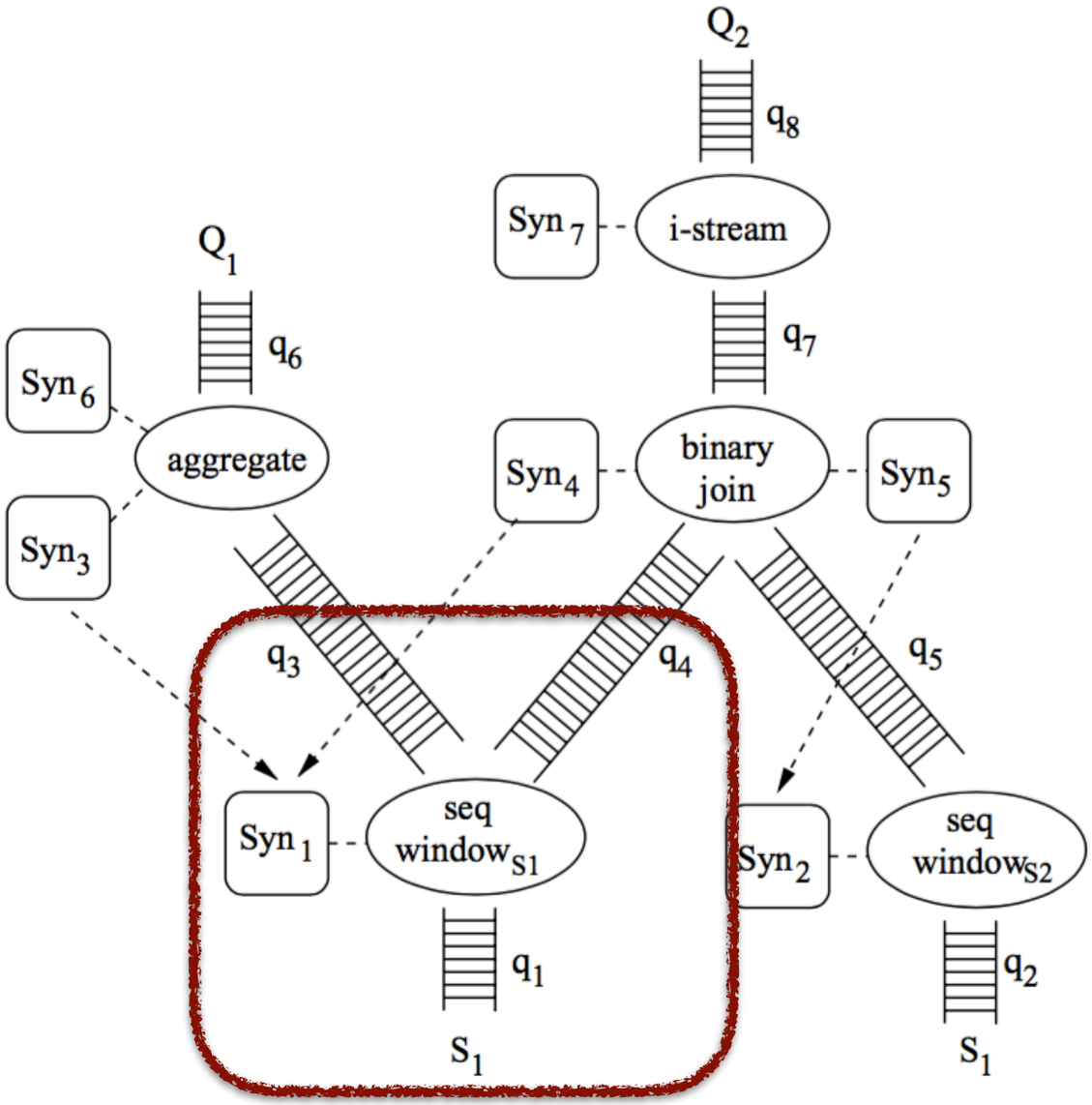


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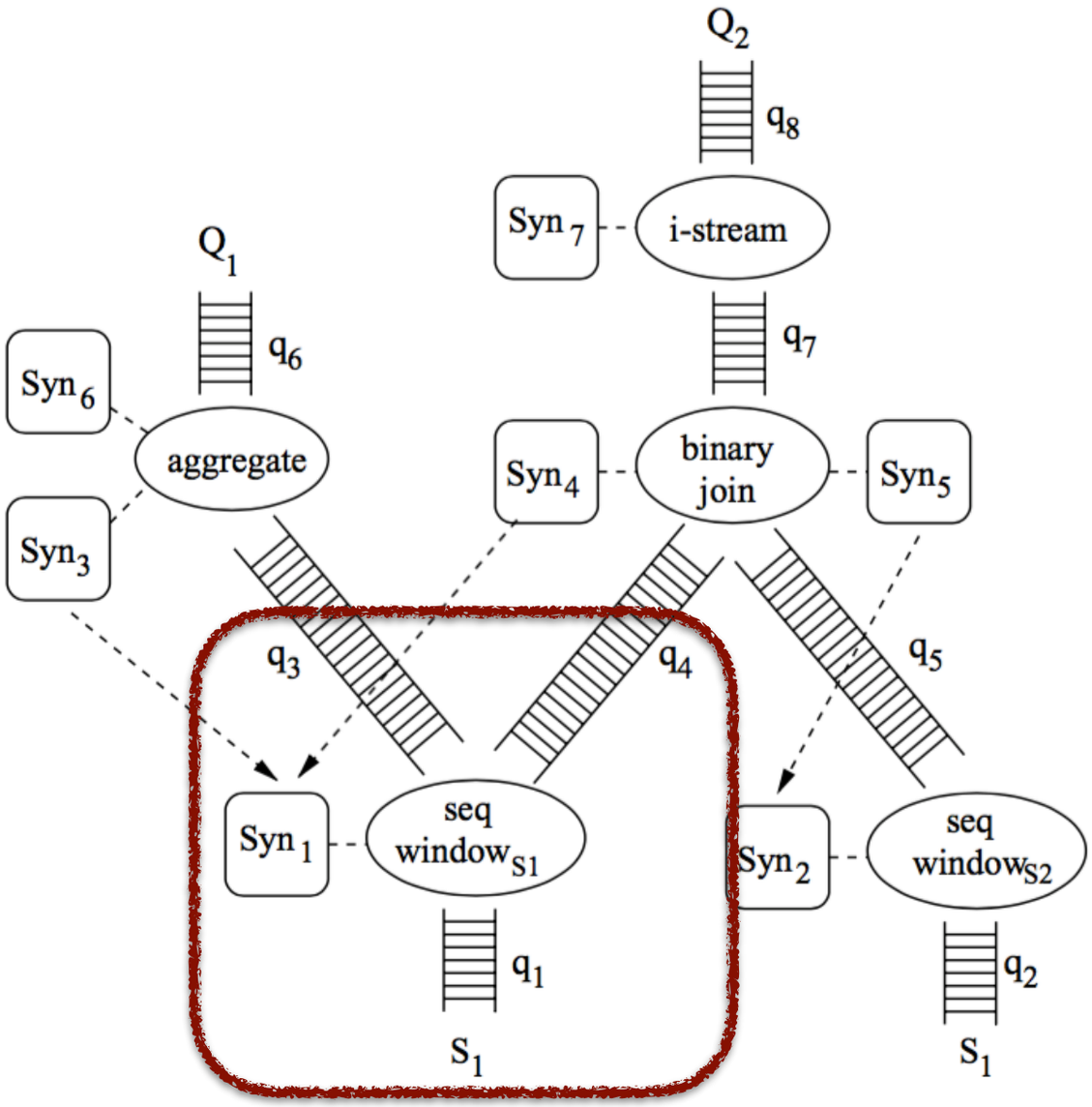
- **Synopsis Syn$_1$ stores the last 50.000 tuples that arrived in Stream 1**

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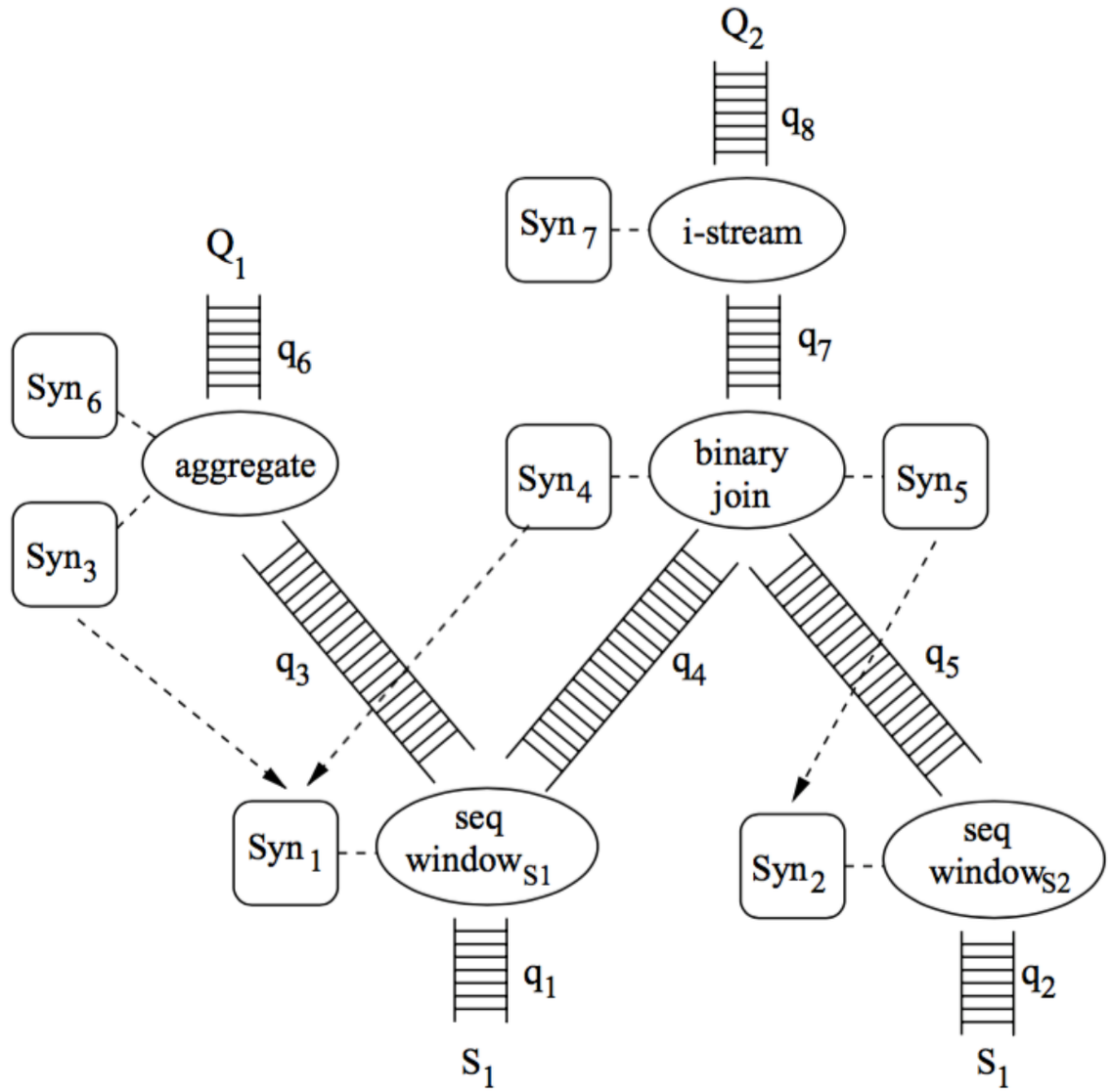


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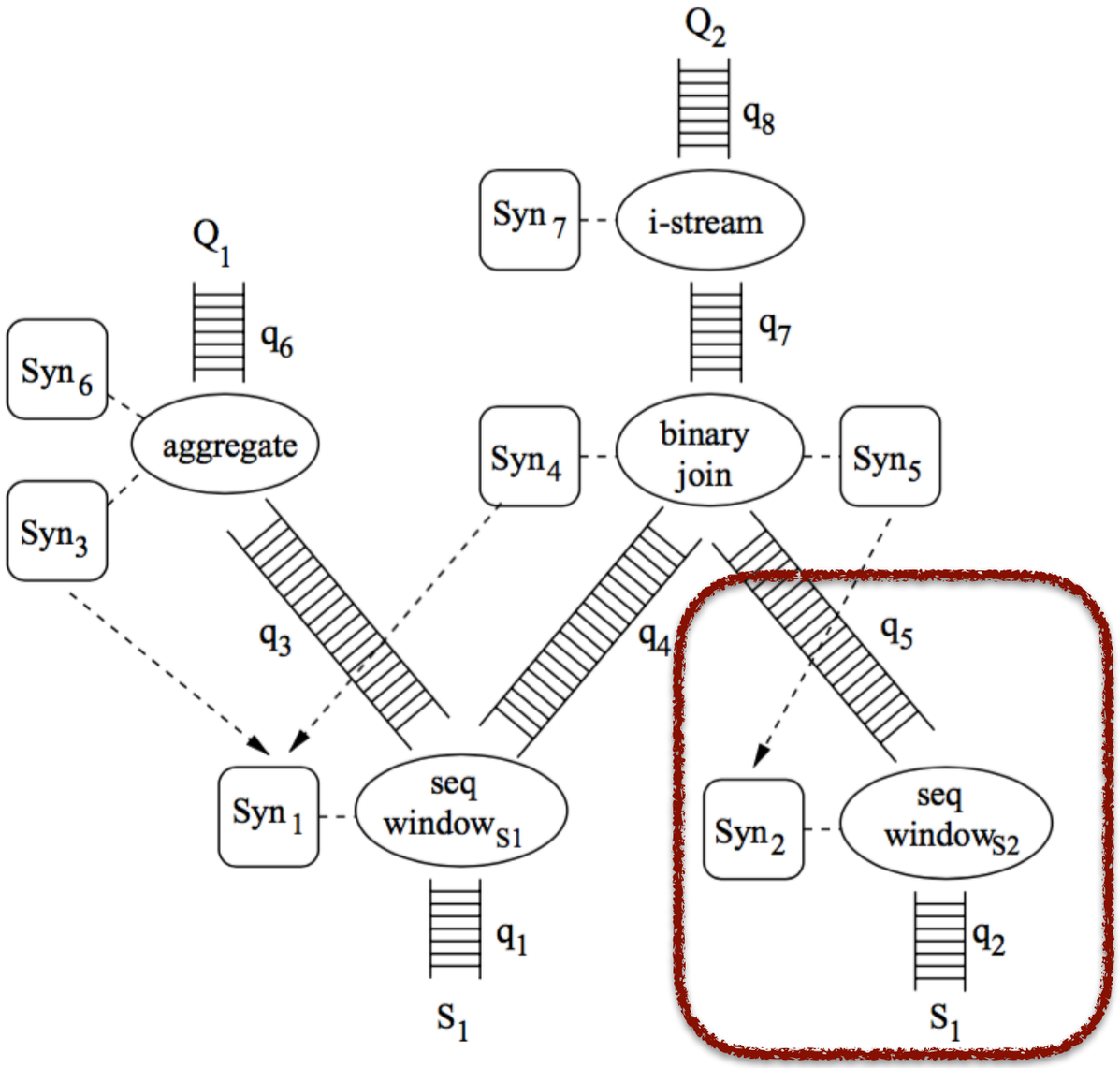
- **Sliding window operator seq-window$_{S2}$**
  - Reads stream S_2's tuples
  - Processes them to know the ones that arrived in the last 10 minutes
  - Outputs in q_5, the insertions and deletions in the window
- **Synopsis Syn$_2$ stores the items that arrived at S2 in the last 10 minutes**

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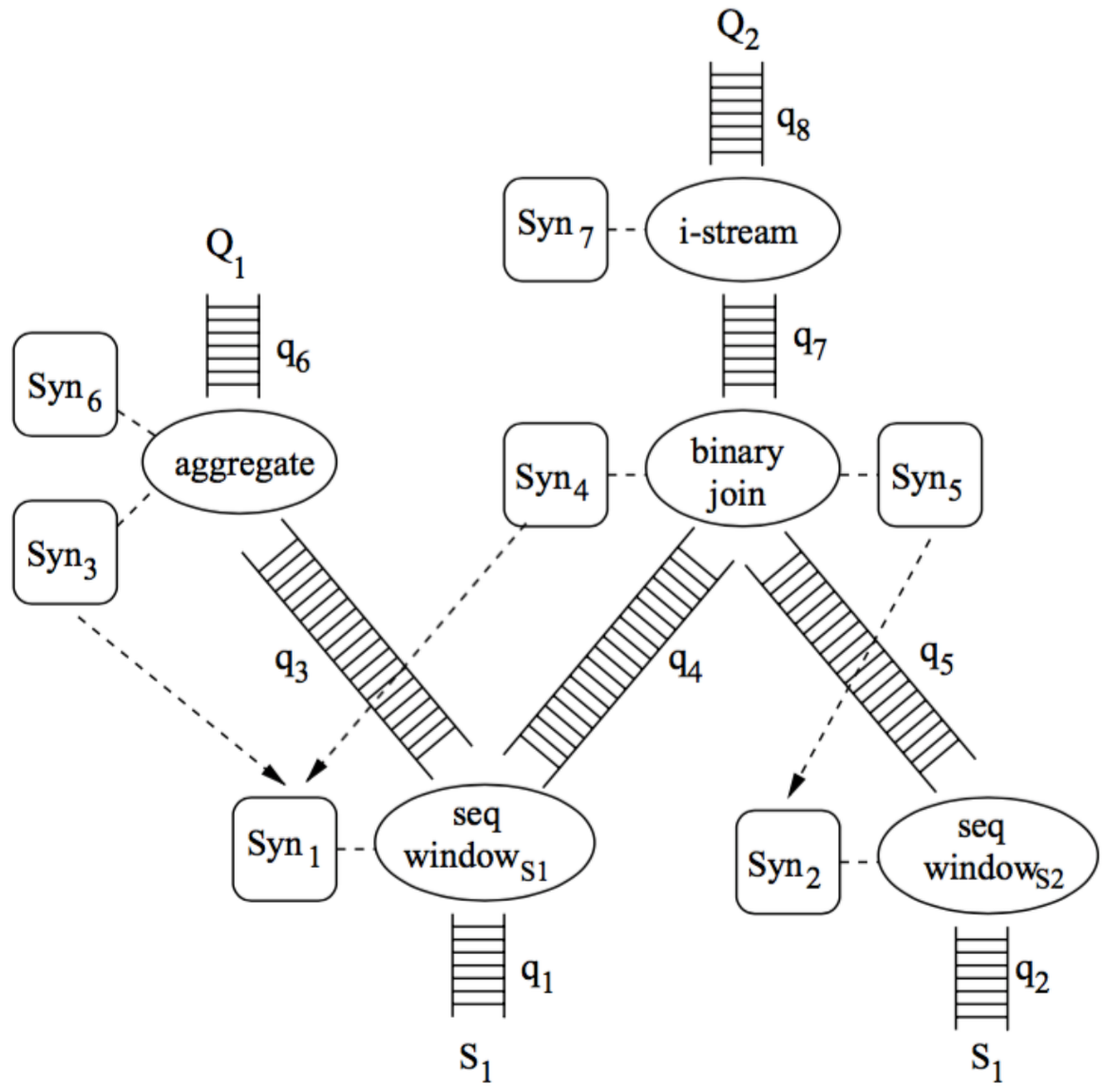
    - Uses insertions and deletions in q_4 and q_5, to produce insertions and deletions in q_7

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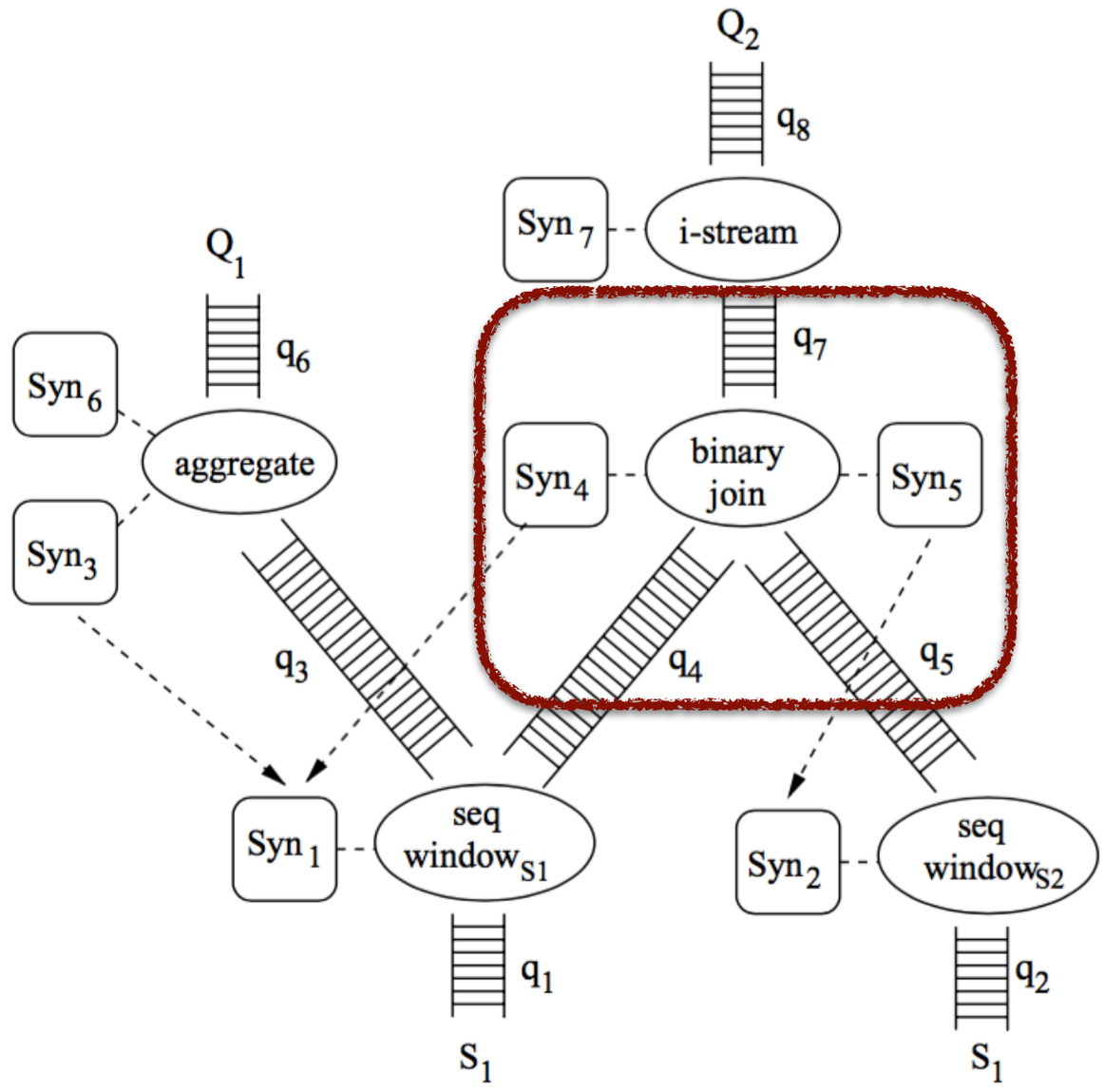


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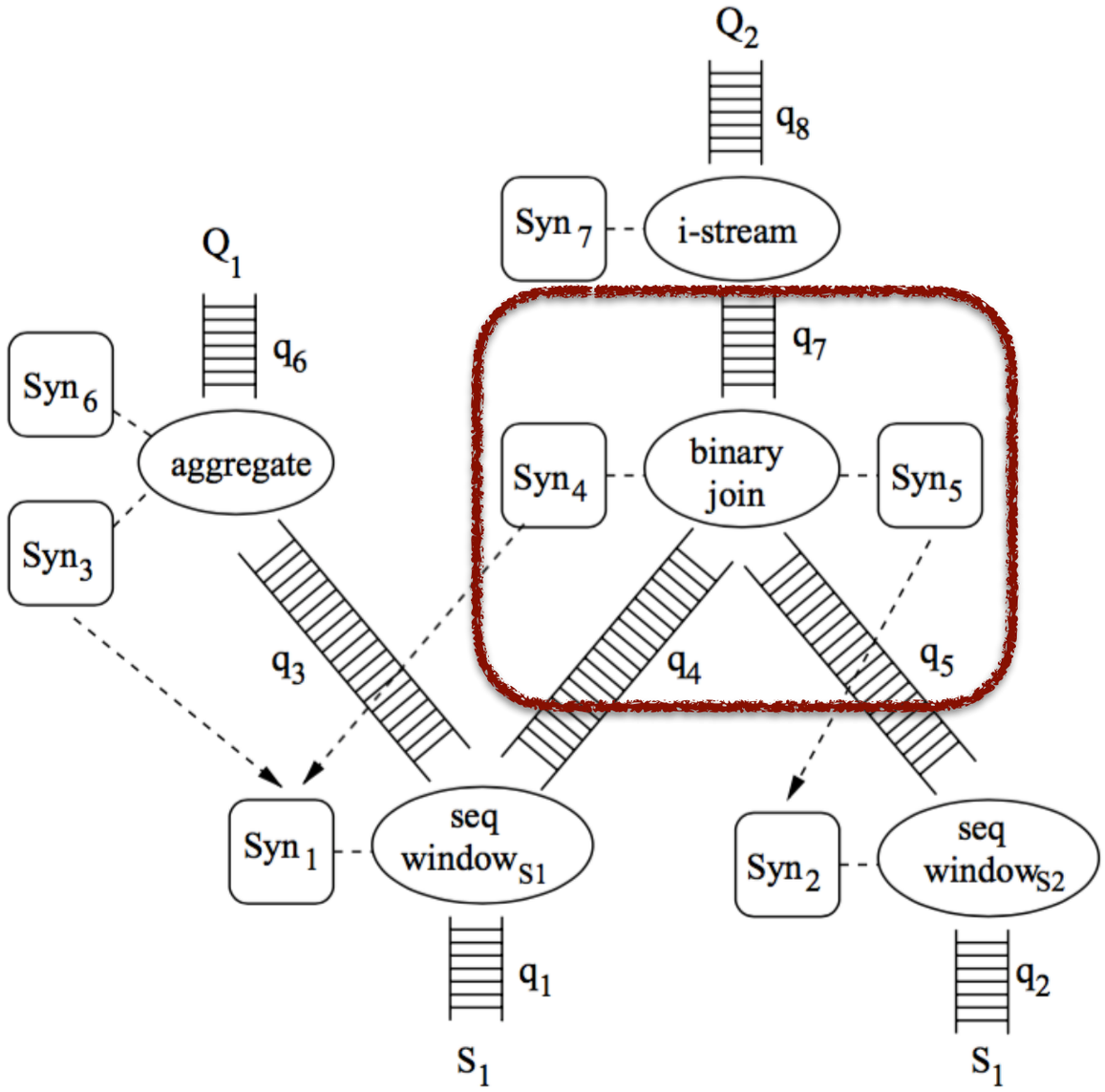


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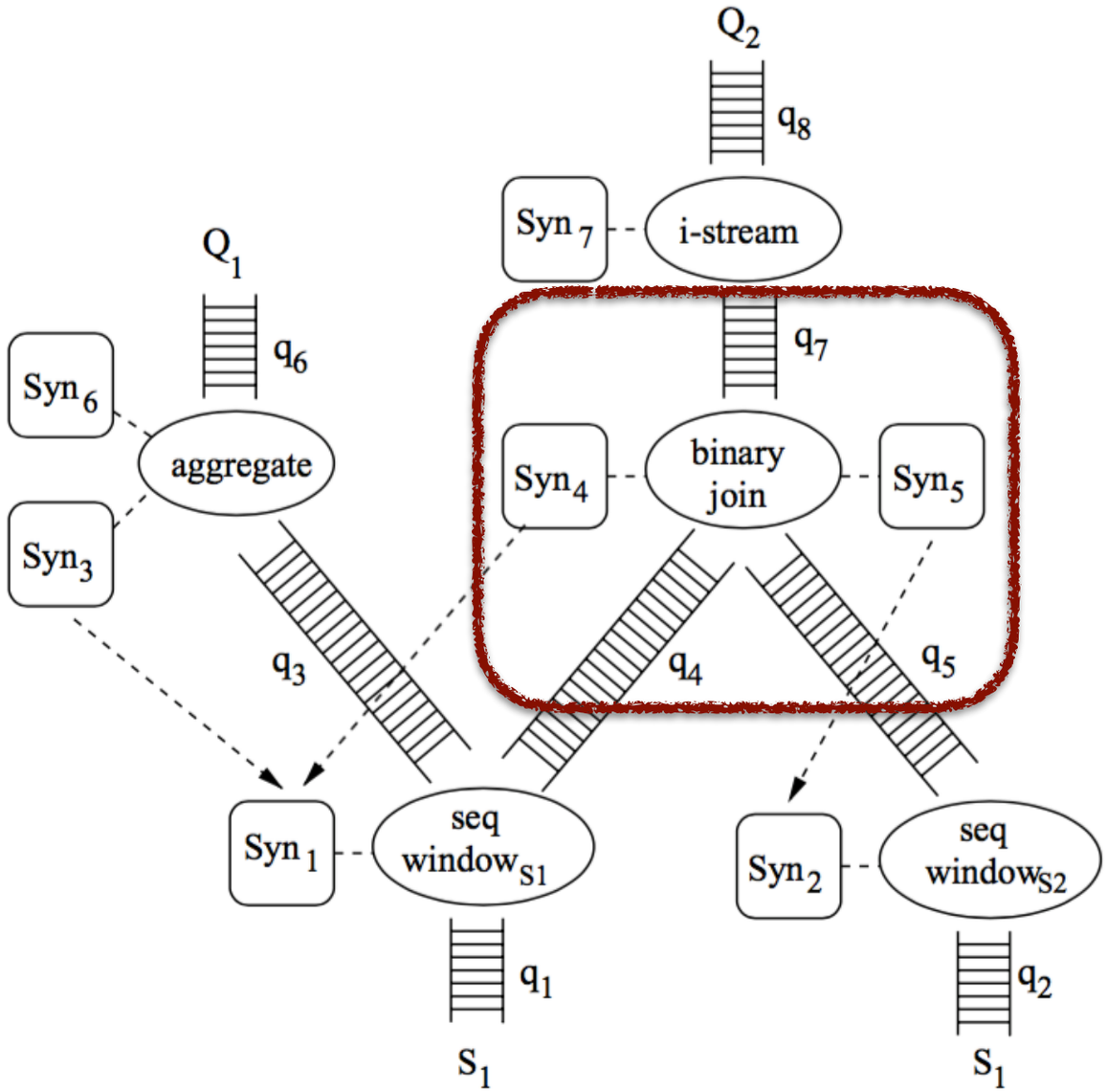
- **When joining with a table, the queue *reports* changes, and the synopsis *is* the table content**

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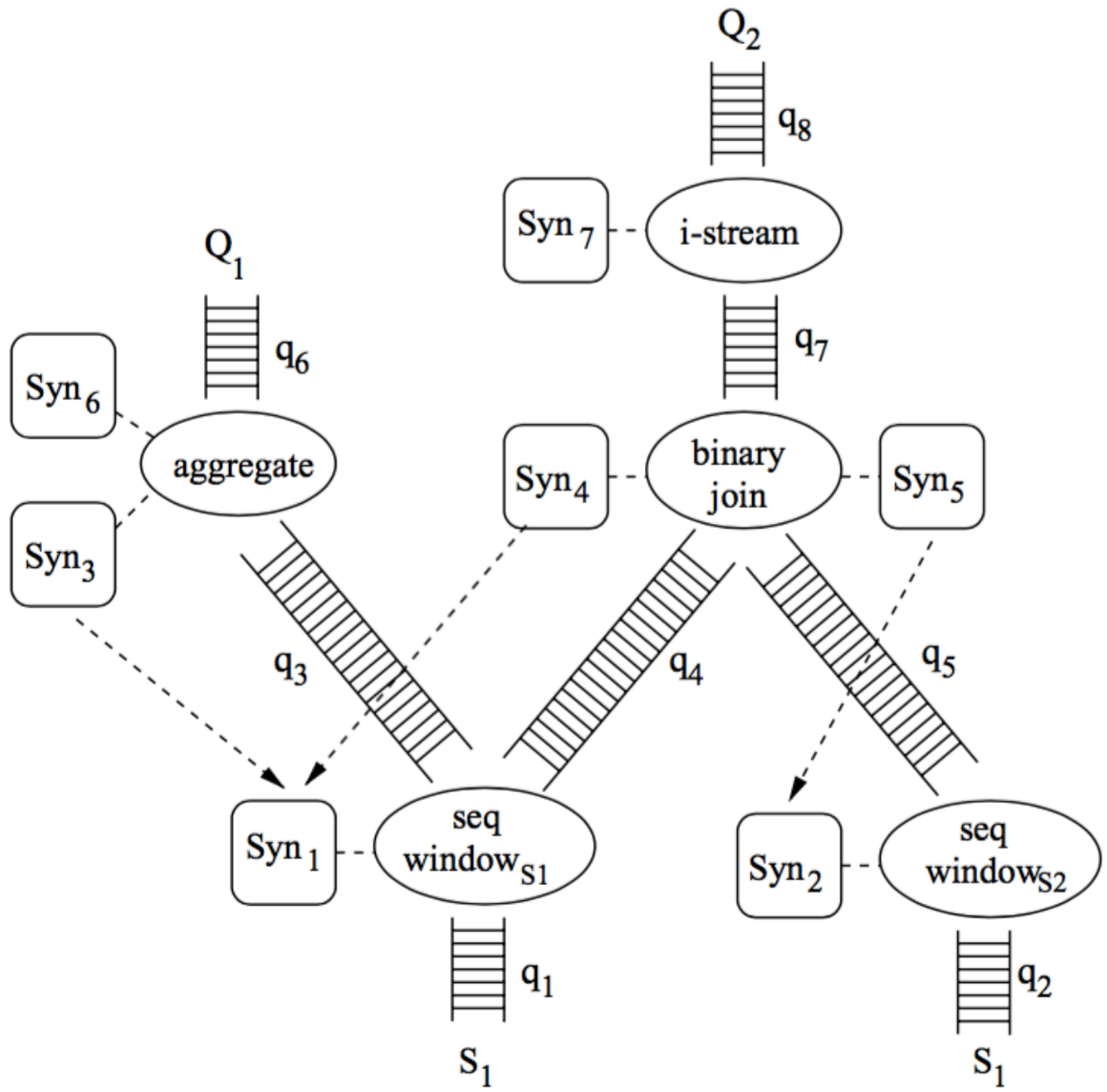
- **operator aggregate**
  - (Incrementally) maintains the max value of A for each distinct B
  - Synopsis Syn_6 stores those max values

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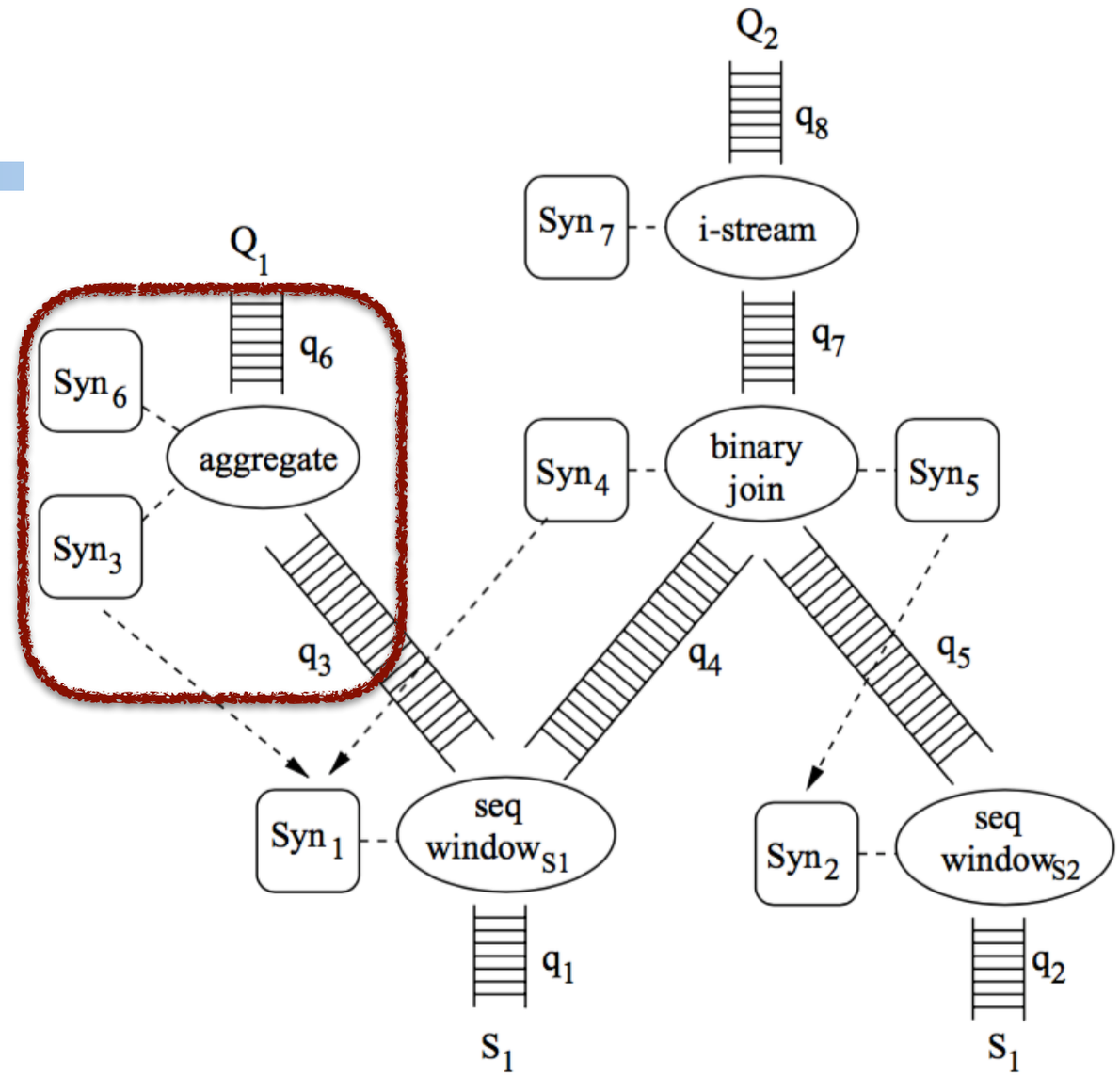


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- **Any time an insertion (resp. deletion) appears in q_3, the operator must look at Syn_6, and see whether that changes a max value**
  - When a max is deleted, it must consult the values in the window; that is in Syn_3
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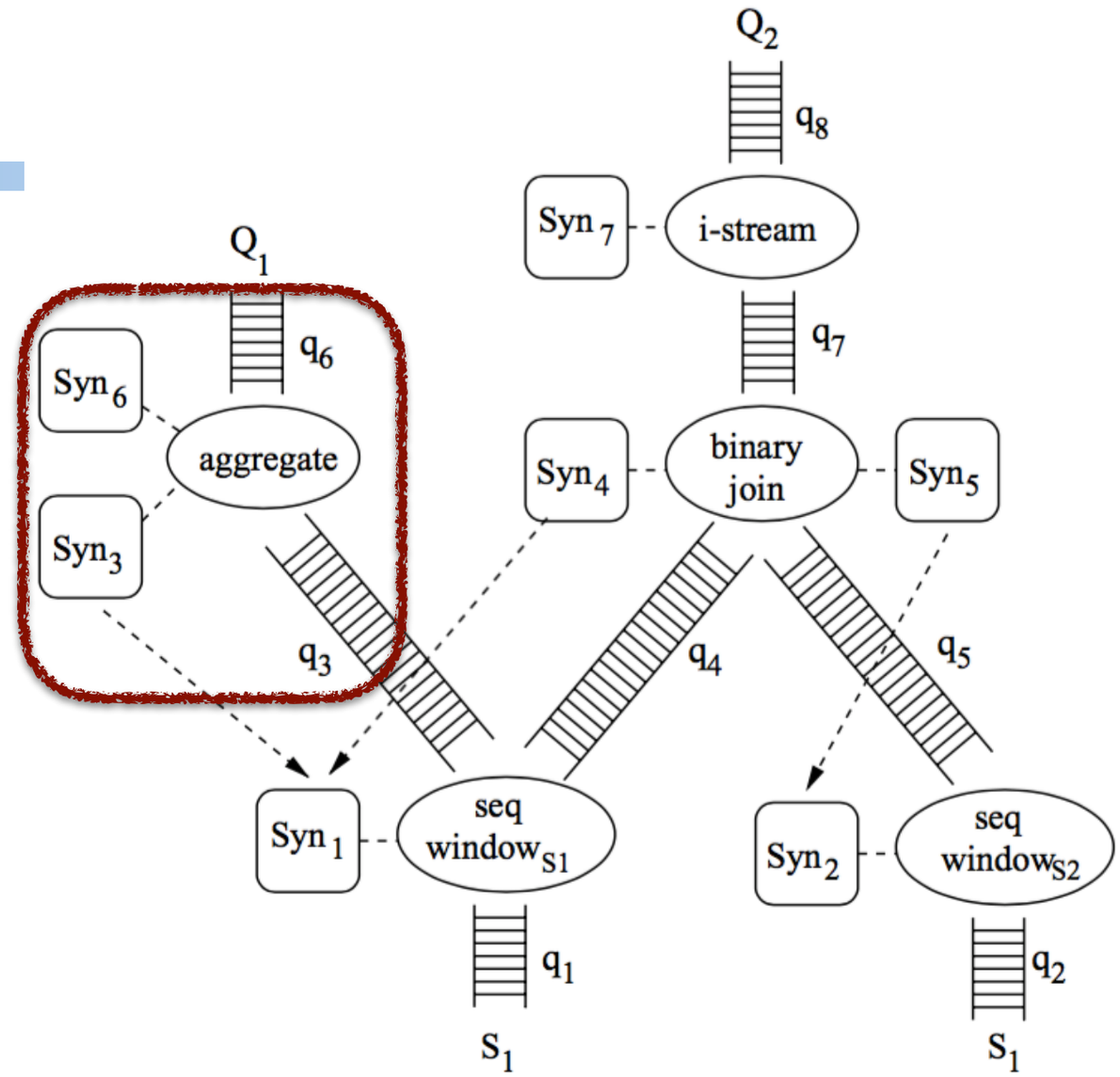


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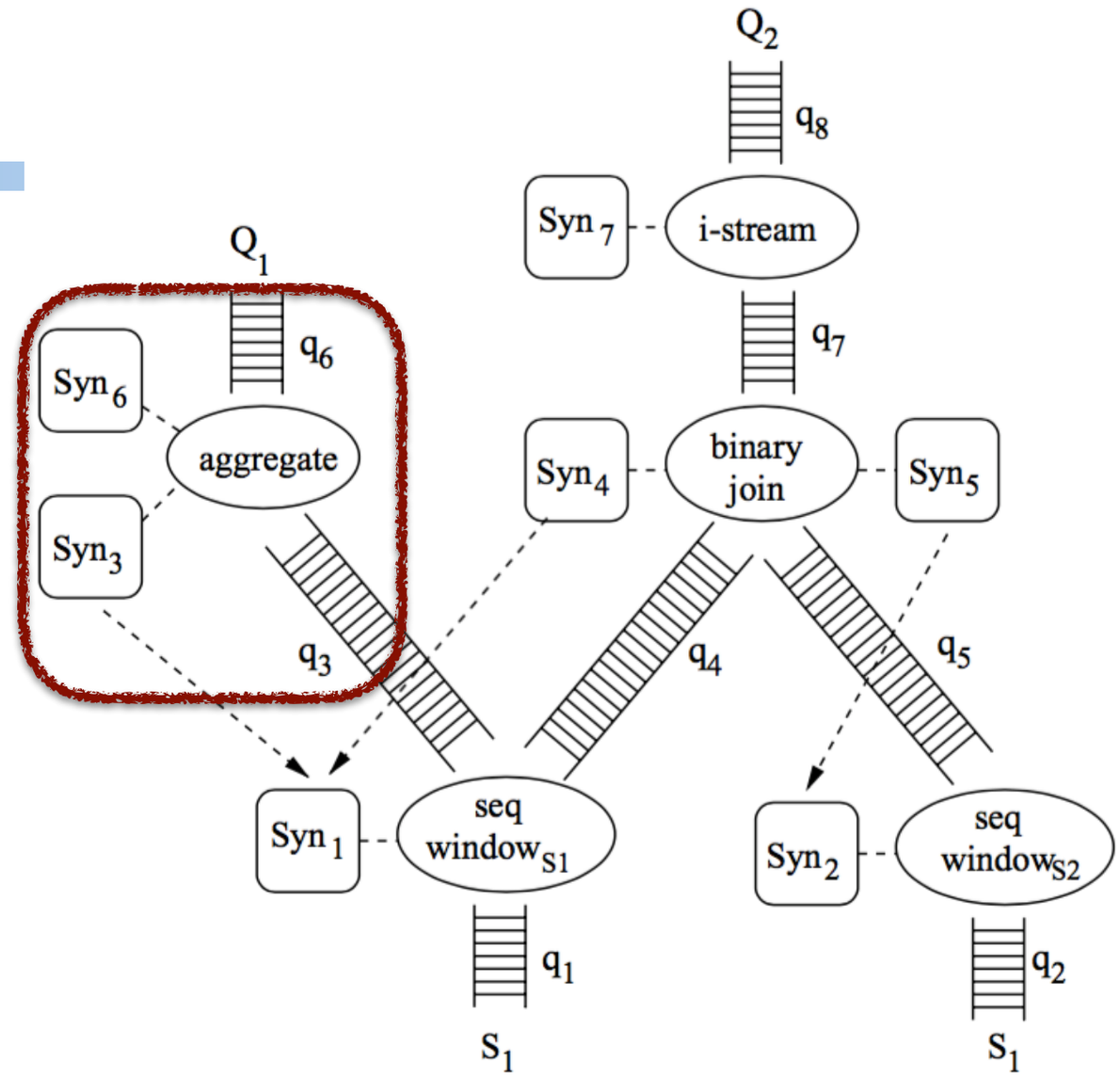
- **Note that this operator is non-monotonic**

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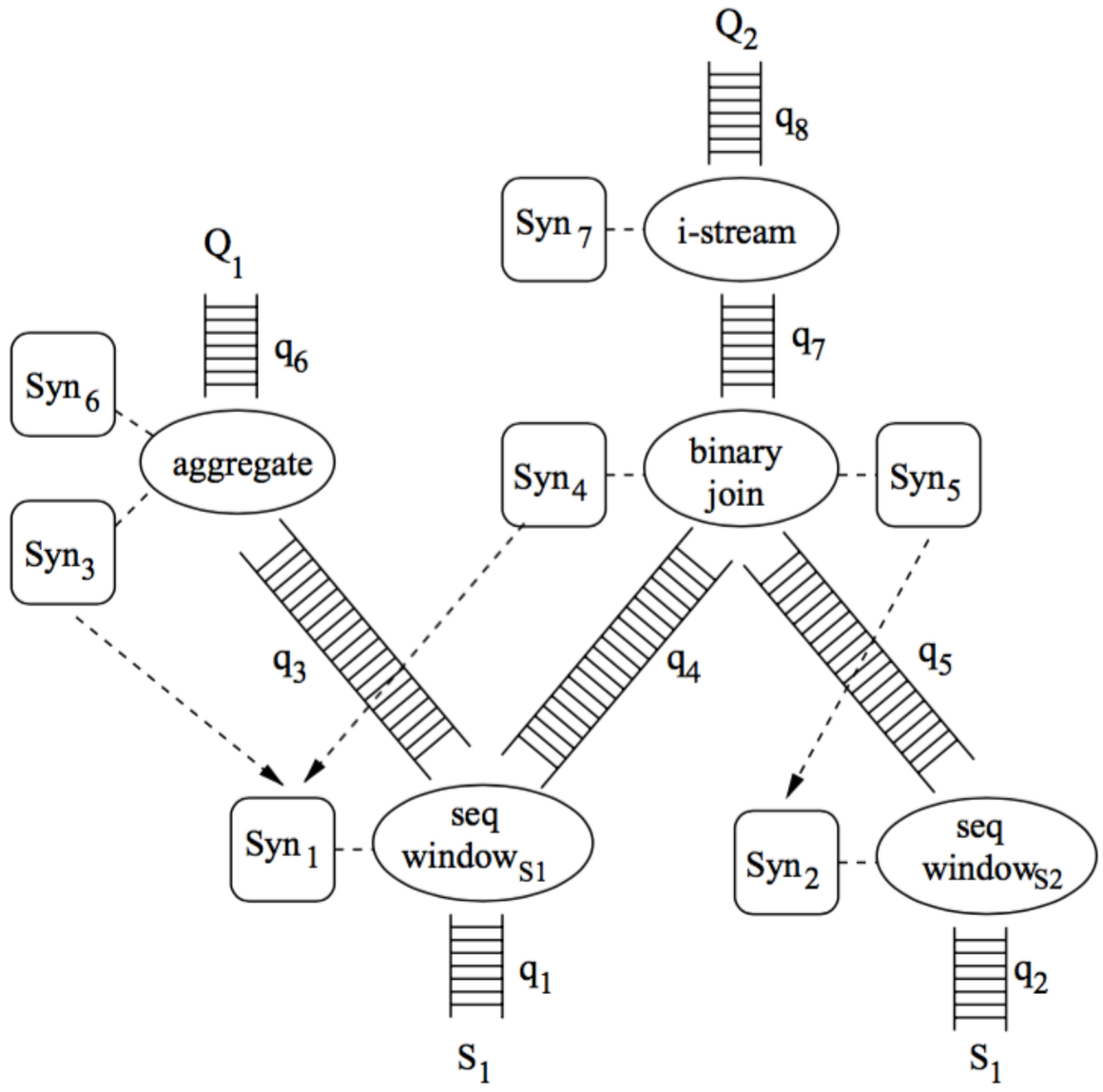
  - This seem to be exactly the meaning of `Istream`

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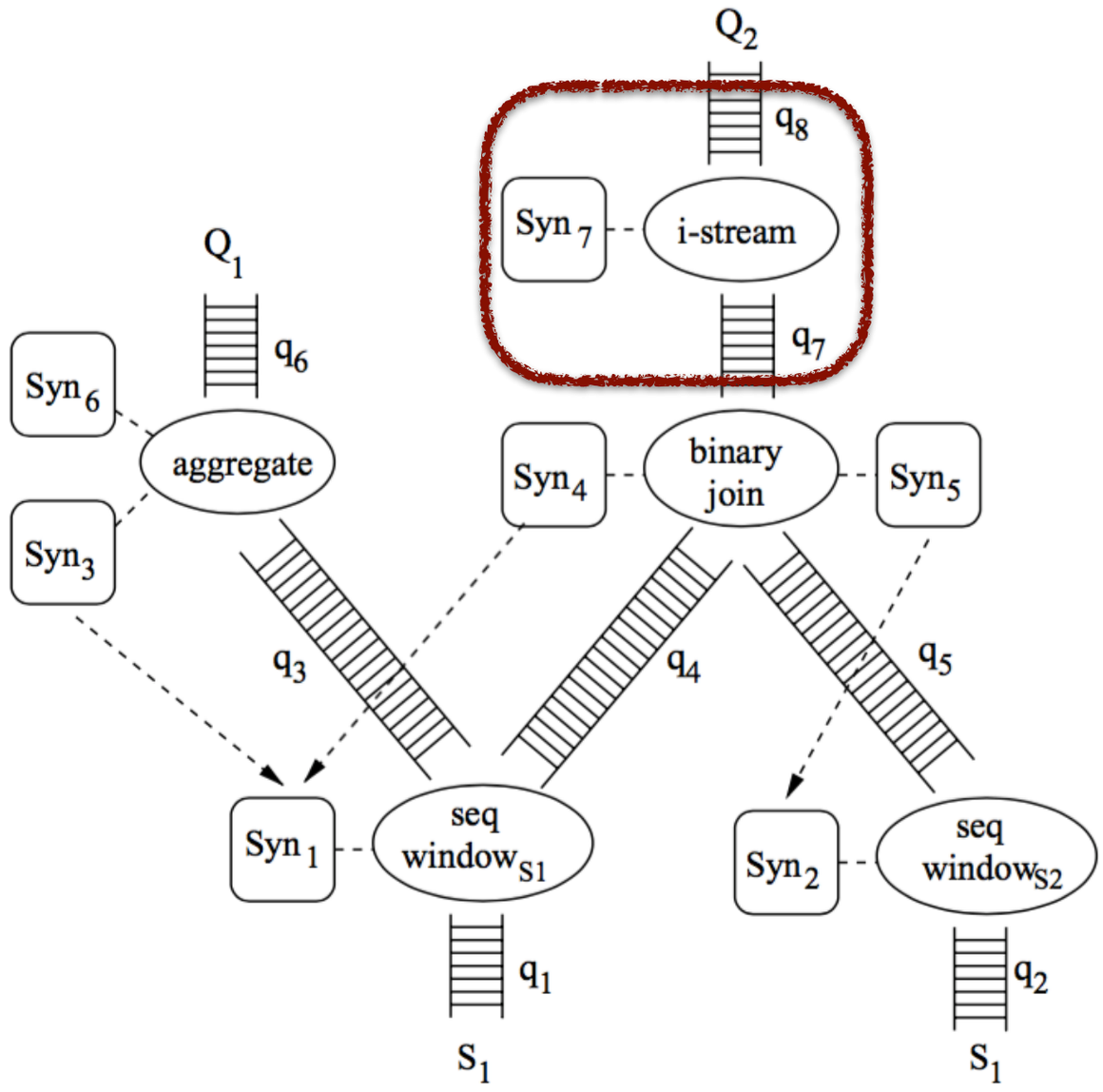


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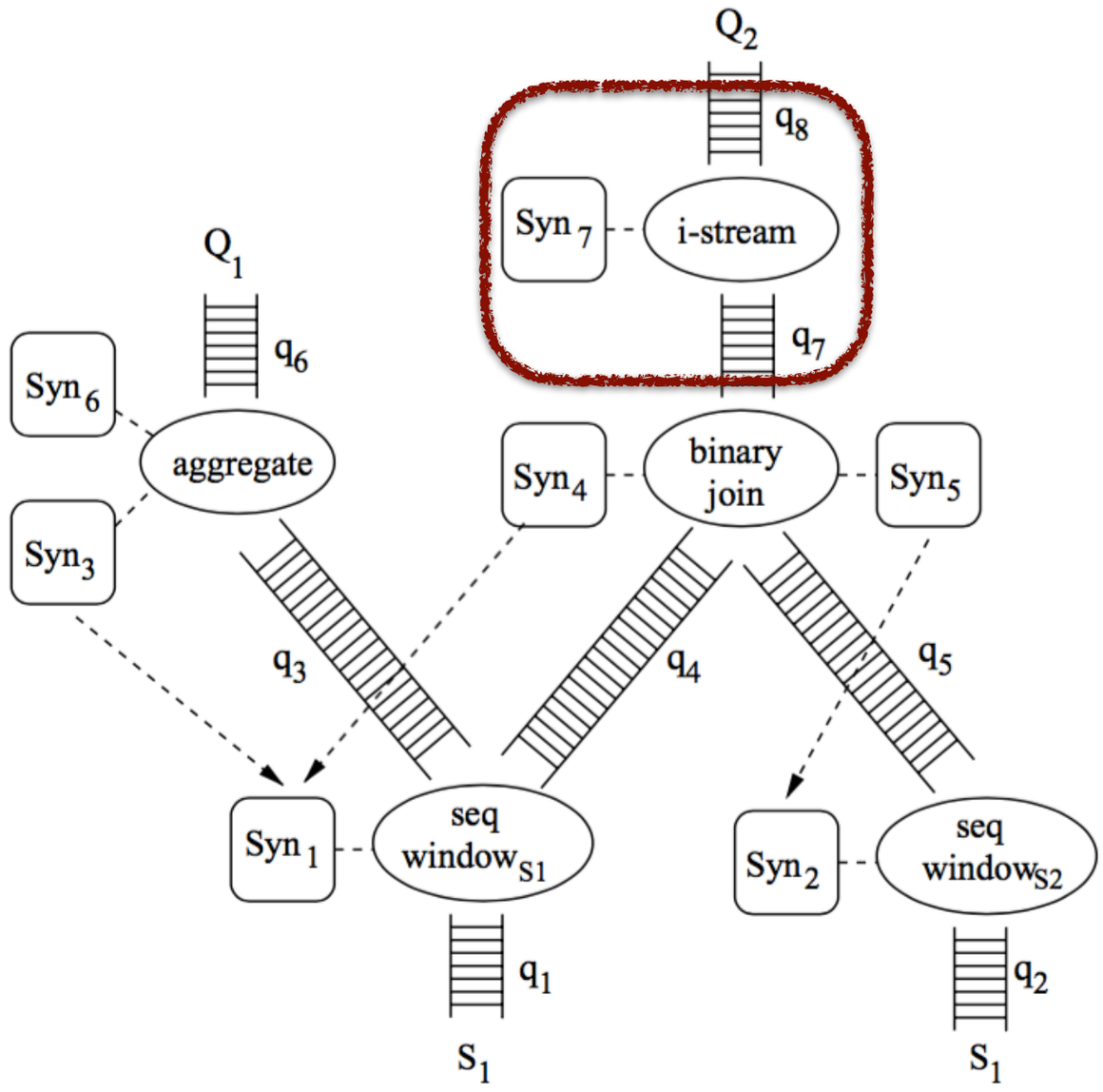


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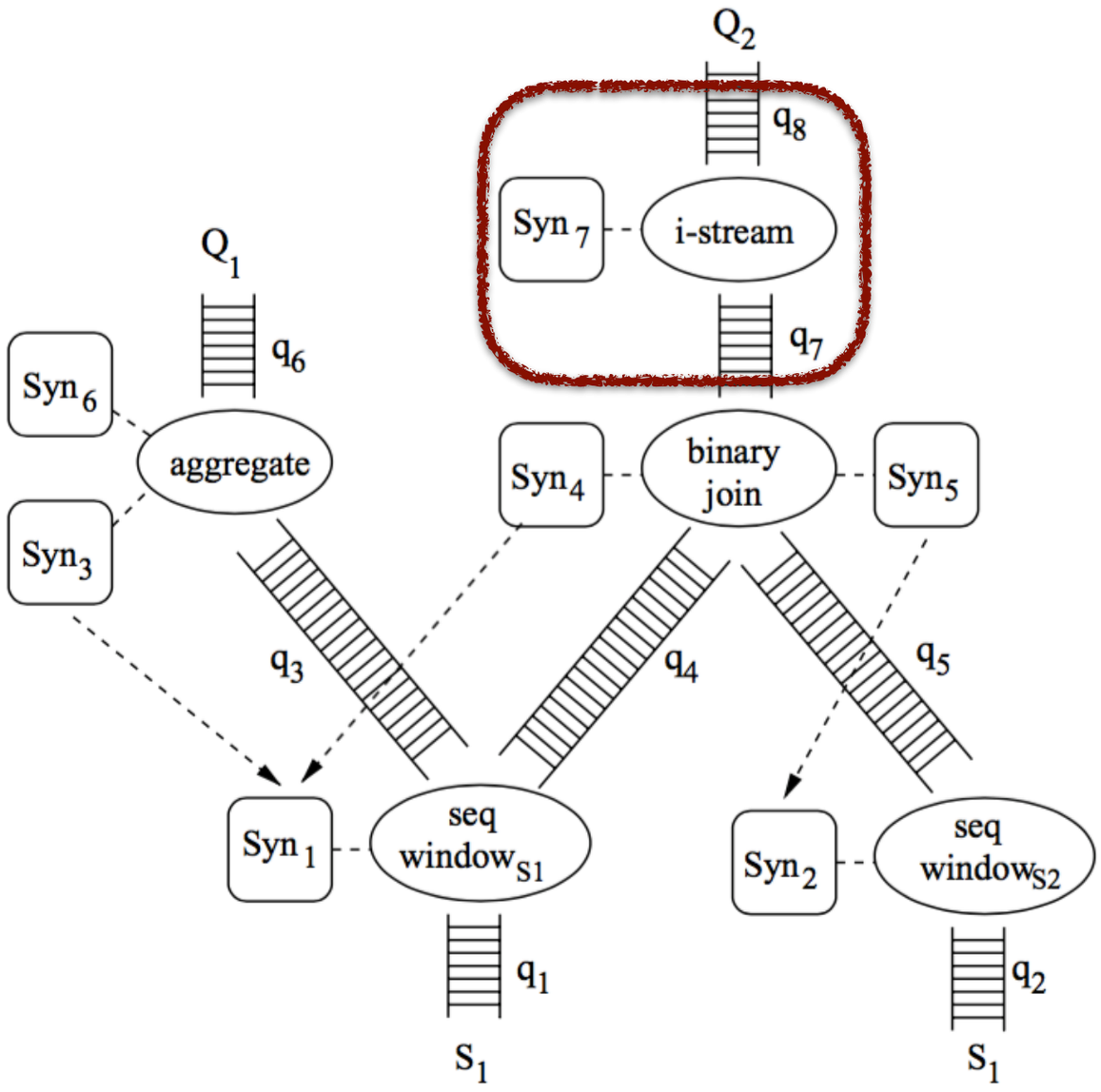
- **Syn_7 buffers the insertion and deletion at a given time *t***
  - The operator outputs insertions without deletions at *t* to q_8

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  - A tuple arriving at *t* in a stream with a time based window with size *T*, generates an insertion at *t*, and a deletion at *t+T+1*
    - The *+1* depends on the granularity of the system

System operators

- **Real systems have some more operators, to deal with several low-level details. E.g.**
  - To asynchronously receive the tuples from an input stream, and transforming them to the internal representation
  - To manage load balancing
  - To merge plans from views
  - To send stream results to remote clients
  - …

STREAM operators

Name	Operator Type	Description
`seq-window`	Stream-to-relation	Implements time-based, tuple-based, and partitioned windows
`select`	Relation-to-relation	Filters tuples based on predicate(s)
`project`	Relation-to-relation	Duplicate-preserving projection
`binary-join`	Relation-to-relation	Joins two input relations
`mjoin`	Relation-to-relation	Multiway join from [43]
`union`	Relation-to-relation	Bag union
`except`	Relation-to-relation	Bag difference
`intersect`	Relation-to-relation	Bag intersection
`antisemijoin`	Relation-to-relation	Antisemijoin of two input relations
`aggregate`	Relation-to-relation	Performs grouping and aggregation
`duplicate-eliminate`	Relation-to-relation	Performs duplicate elimination
`i-stream`	Relation-to-stream	Implements `Istream` semantics
`d-stream`	Relation-to-stream	Implements `Dstream` semantics
`r-stream`	Relation-to-stream	Implements `Rstream` semantics
`stream-shepherd`	System operator	Handles input streams arriving over the network
`stream-sample`	System operator	Samples specified fraction of tuples
`stream-glue`	System operator	Adapter for merging a stream-producing view into a plan
`rel-glue`	System operator	Adapter for merging a relation-producing view into a plan
`shared-rel-op`	System operator	Materializes a relation for sharing
`output`	System operator	Sends results to remote clients

Query plan generation

- **Apply heuristics to generate a first plan**
  - Execute selections before joins (as in DBMSs)
  - Use indexed nested loop joins for joining with synopses
  - Apple filters before ranges
  - Share synopses and operators whenever possible

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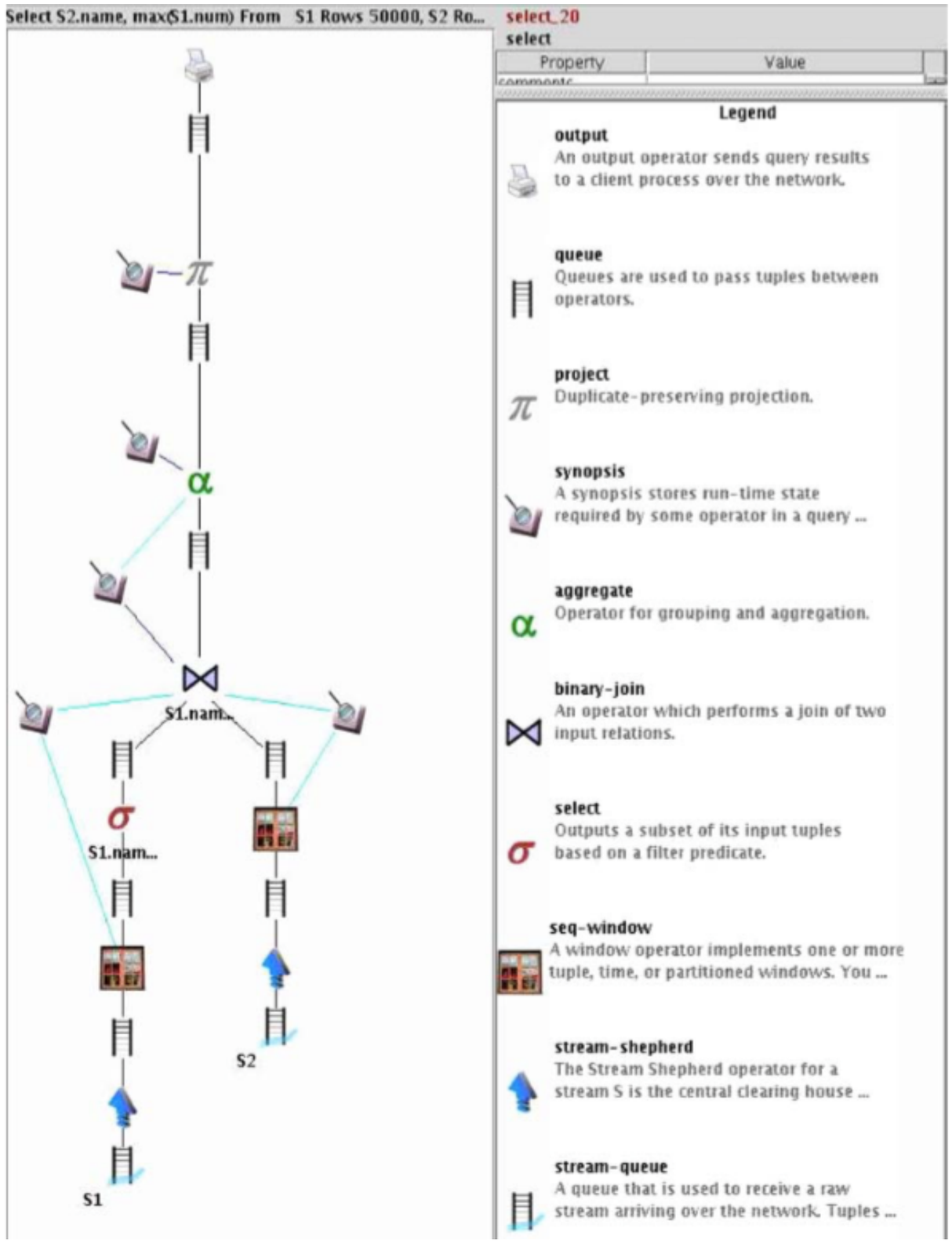
  - Use indexed nested loop joins for joining with synopses
  - Apple filters before ranges
  - Share synopses and operators whenever possible
- **Upon execution, statistical data on what has been executed can be used to rearrange initial query plans**
  - Requires a *monitor* for monitoring the plans that are being executed
  - It can use optimisation techniques similar to those of DBMSs, based on what has been monitored

Query execution

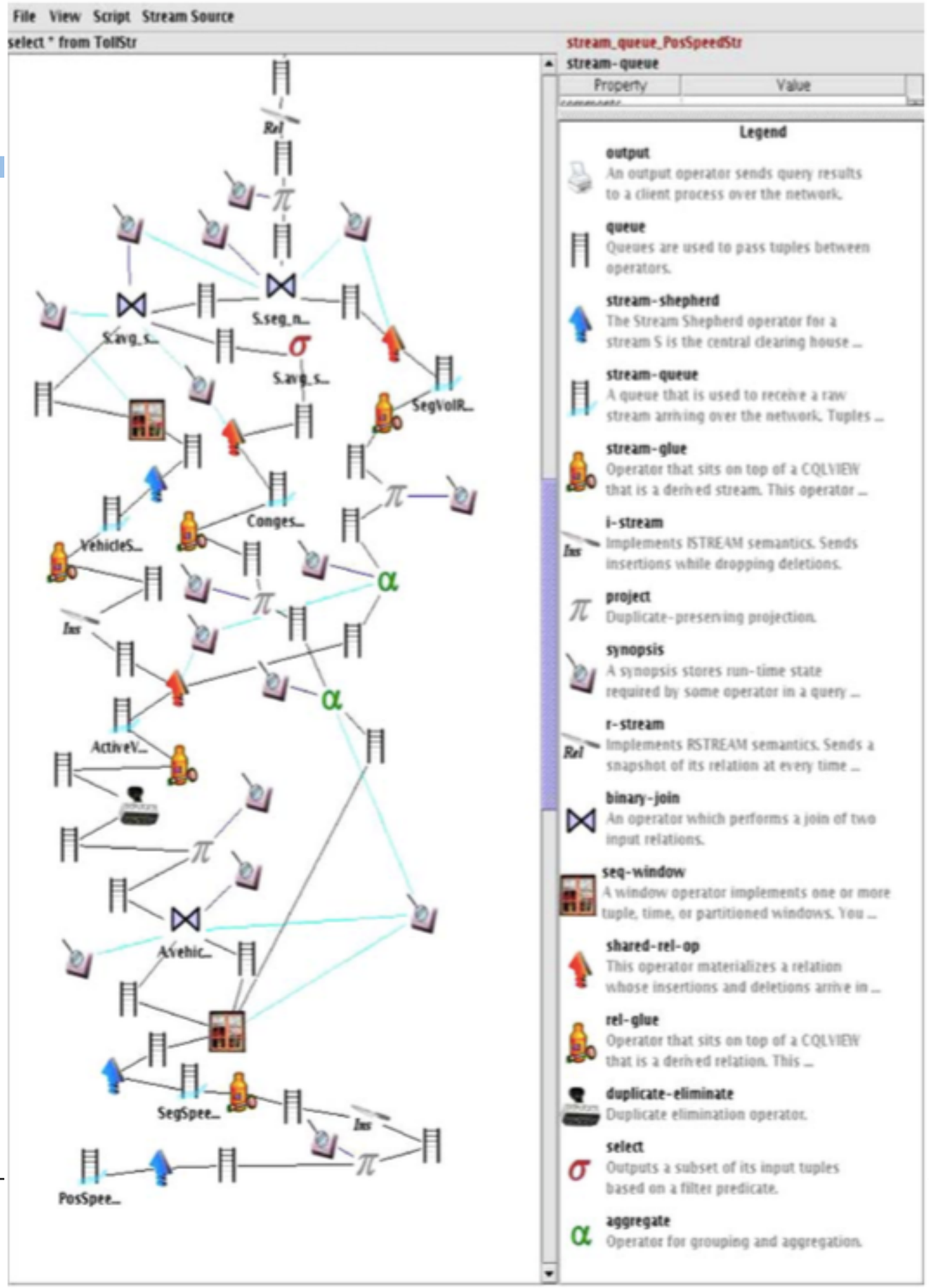
- **The execution of a plan is controlled by a global scheduler**
- **The scheduler is invoked periodically**
  - It selects an operator to execute
  - Calls a specific procedure for the operator, passing it the required parameters (with data from queues and synopses)
- **The scheduler can be a simple round-robin over operators, but may include parallel execution, and more sophisticated scheduling algorithms**
  - This is outside the scope of this course

An example plan in STREAM

```
select S2.name, max(S1.n)
from  S1 [Rows 50000]
      S2 [Rows 50000]
where S1.name <= 'i' and
      S1.n = S2.n
group by S2.name;
```



Linear Road plan



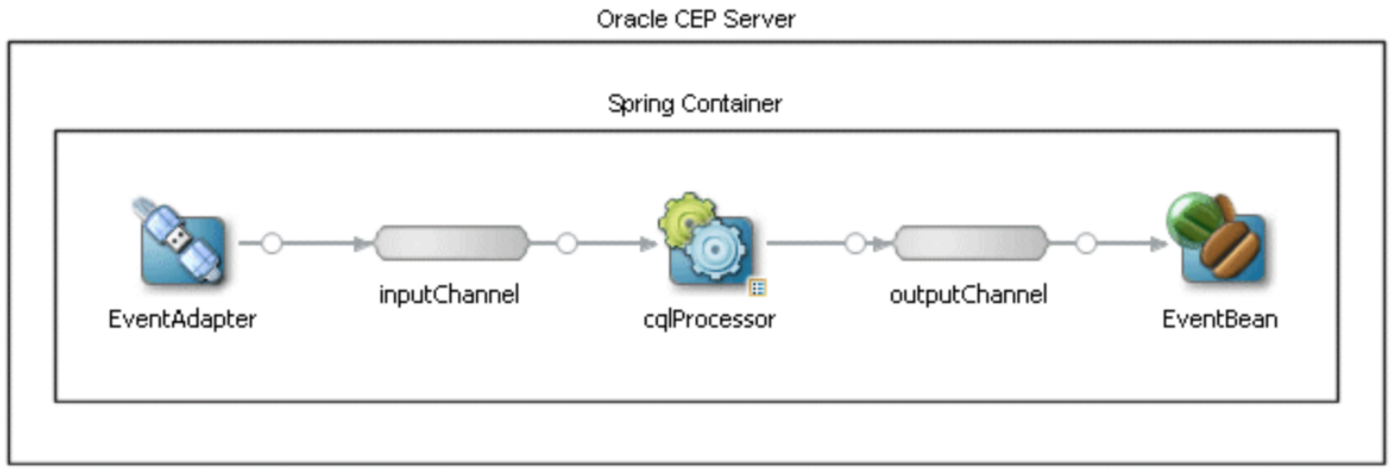
CQL in Oracle CEP

Oracle Event Processor

- **Java Server for event driven applications**
  - A lightweight Java application container
  - Includes a service engine that allows one to write CQL queries
- **Provides tools for developing applications**
  - Oracle CEP IDE for Eclipse
  - Oracle CEP Visualizer

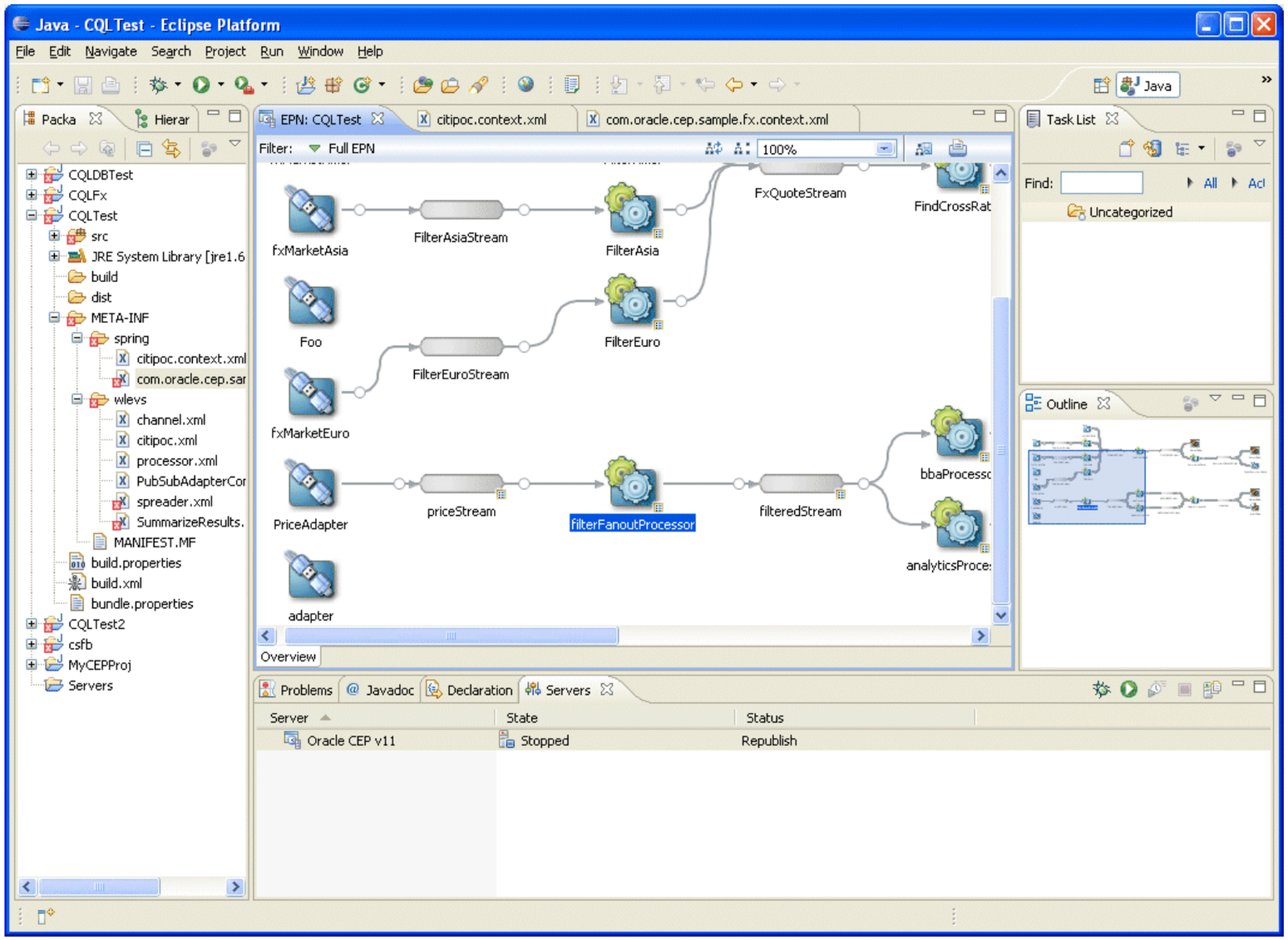
Using Oracle CEP

- **With the IDE for Eclipse and the Visualizer, one can:**
  - Create an Event Processing Network
  - Associate CQL queries to Oracle CQL processors
  - Package applications and deploy them to Oracle server
- **Event adapters support several datasources: JMS, http publish-subscribe, spring beans, relational tables, files, etc**



Event Processing Network (EPN)

- **One can connect the output of an event processor to the input of another event processor**
  - This way we form an EPN
  - Each processor contains a CQL query (possibly with views)



Oracle’s support of CQL

Oracle's support of CQL

- **Pretty much everything that we covered in the course!**
  - With some extra features (details, functions etc)
  - And some (small) differences in the syntax

Putting it to work

- **A lot of “bureaucracy” involved :-(**

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  - Configuring input adapters

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  - Assembling and deploying applications

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  - Configuring input adapters
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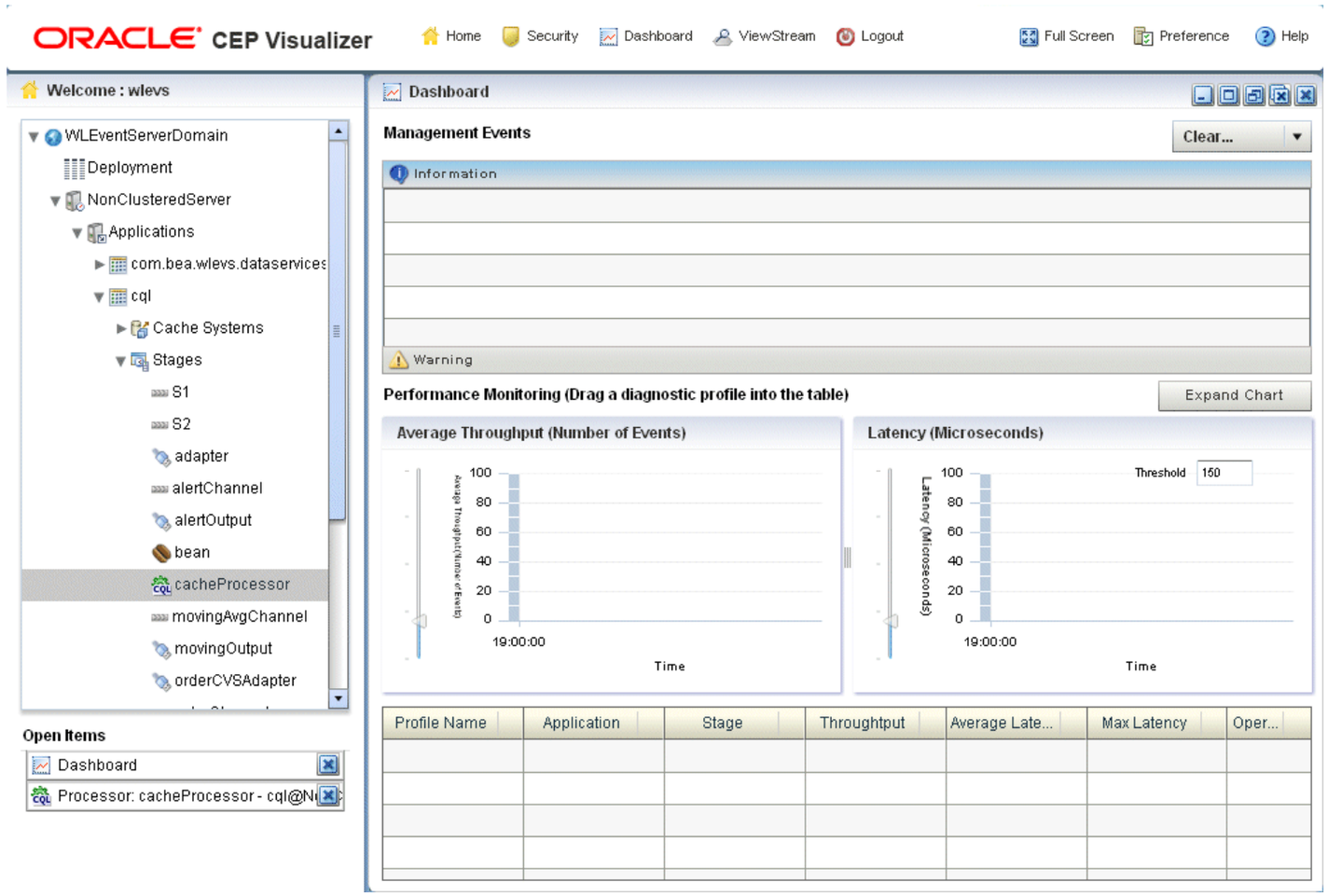
  - Configuring caching
  - …
  - Assembling and deploying applications
- **All of this can be done on Eclipse, which helps…**

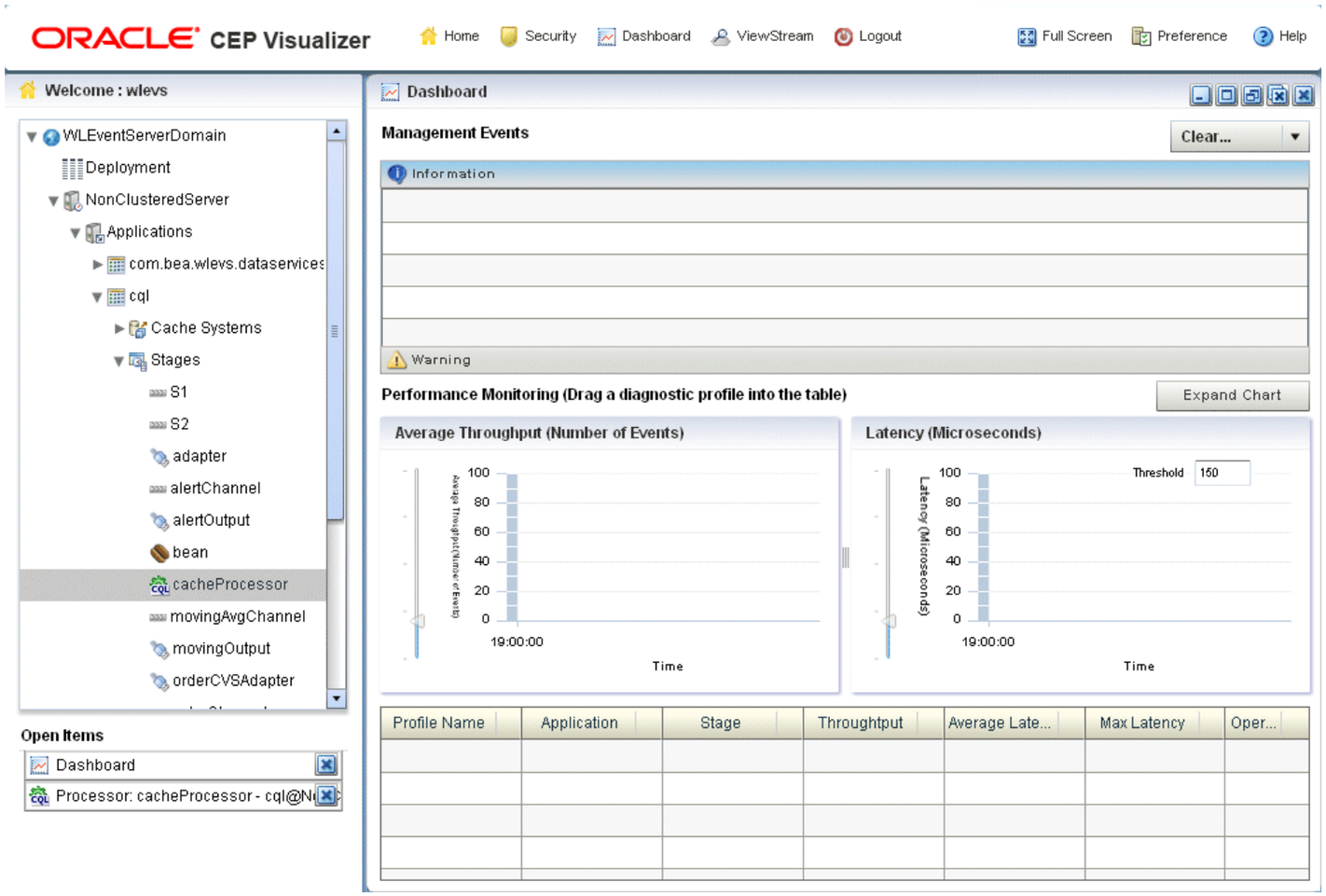
Event Processor Visualizer

- **A browser based tool where one can develop, configure and view aspects of event driven applications**



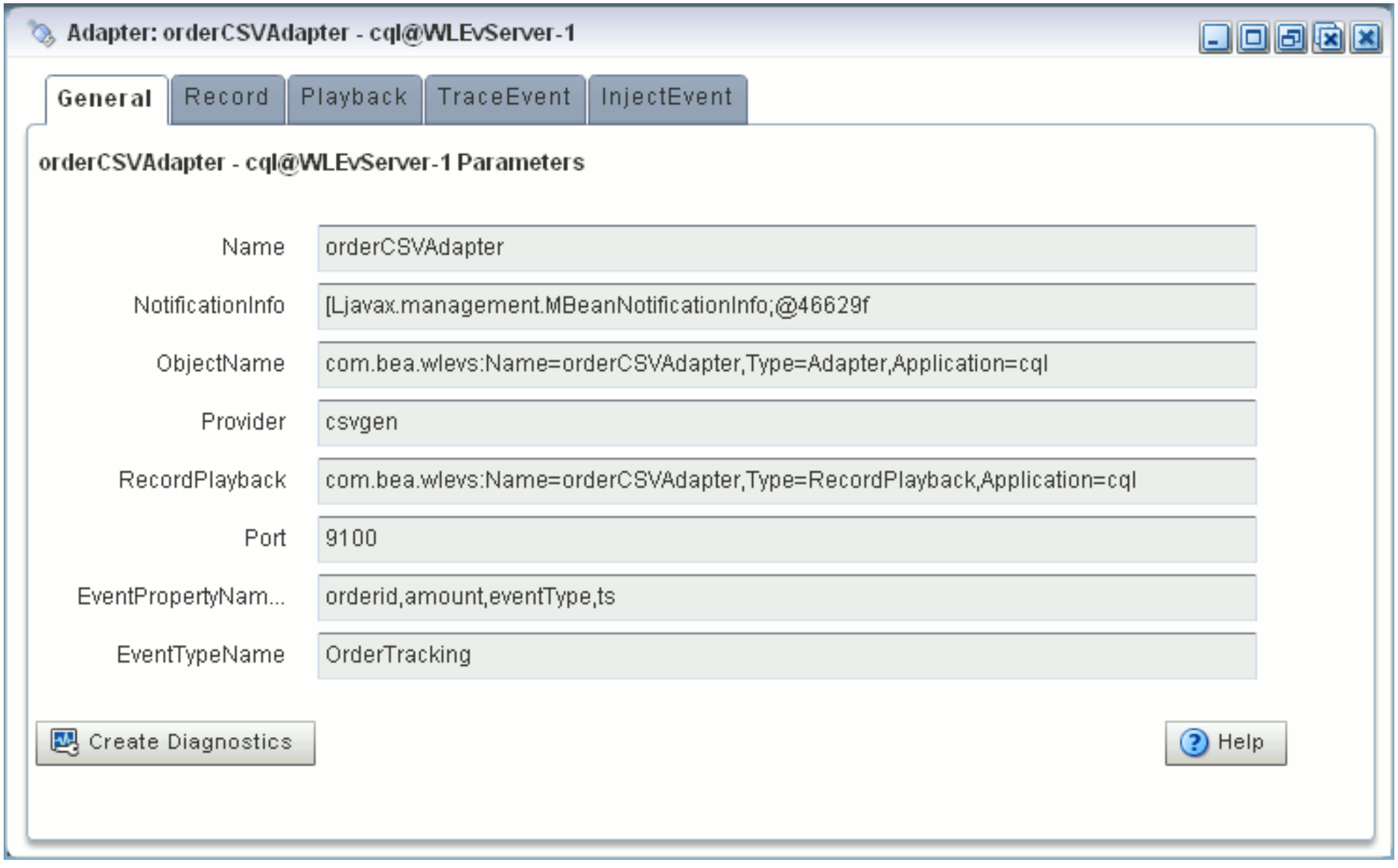
Event Processor Visualizer

- **A browser based tool where one can develop, configure and view aspects of event driven applications**
- **More specifically, one can:**
  - Define EPNs
  - Register CQL queries
    - Including a CQL query wizard
      - (for non-CQL-experts)
    - A query plan viewer
  - Configure event adapters
  - View events in dashboards
  - View event statistics



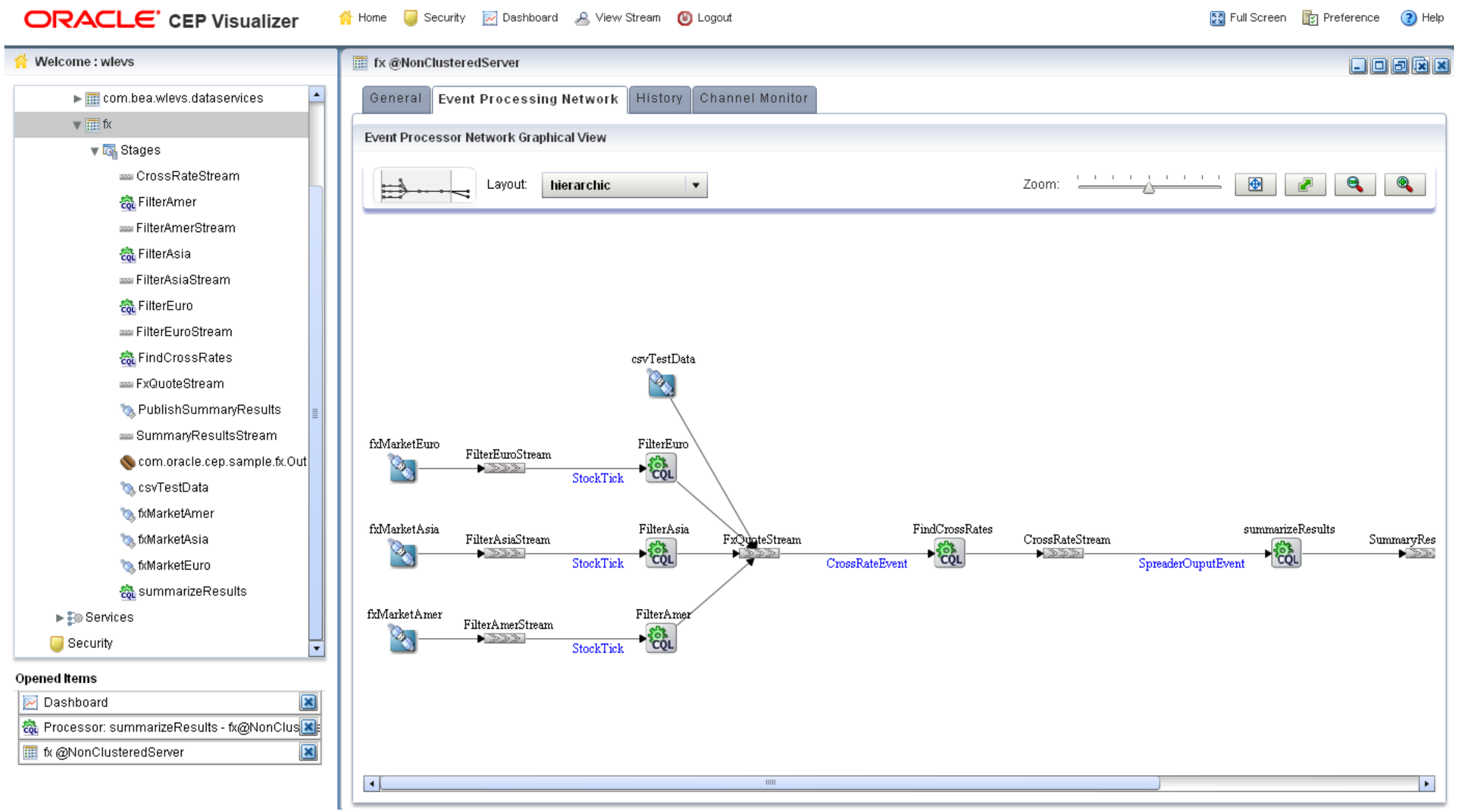
Some Visualizer snapshots

Defining an adapter



Some Visualizer snapshots

Defining an EPN



Some Visualizer snapshots

Defining a CQL query

Processor: summarizeResults - fx@NonClusteredServer

General | Record | Playback | Query Wizard | **CQL Rules** | Query Plan | Trace Event | Inject Event

View ◯ Query ◉ All Rules

Rule ID	Rule	Type	Running
Rule	select crossRate1 || crossRate2 as crossRatePair, count(*) as totalCount, avg(internalPrice) as averageInternalPrice from CrossRateStream group by crossRate1,crossRate2 having count(*) > 0	QUERY	true
SummarizeResultsRule	select crossRate1 || crossRate2 as crossRatePair, count(*) as totalCount, :1 as averageInternalPrice from CrossRateStream group by crossRate1,crossRate2 having :2	QUERY	true

Working Area - for Modify and Delete Operation, select a rule from the table

Query ID: SummarizeResultsRule

Query: select crossRate1 || crossRate2 as crossRatePair, count(*) as totalCount, :1 as averageInternalPrice from CrossRateStream group by crossRate1,crossRate2 having :2

Enable: ◉ true ◯ false

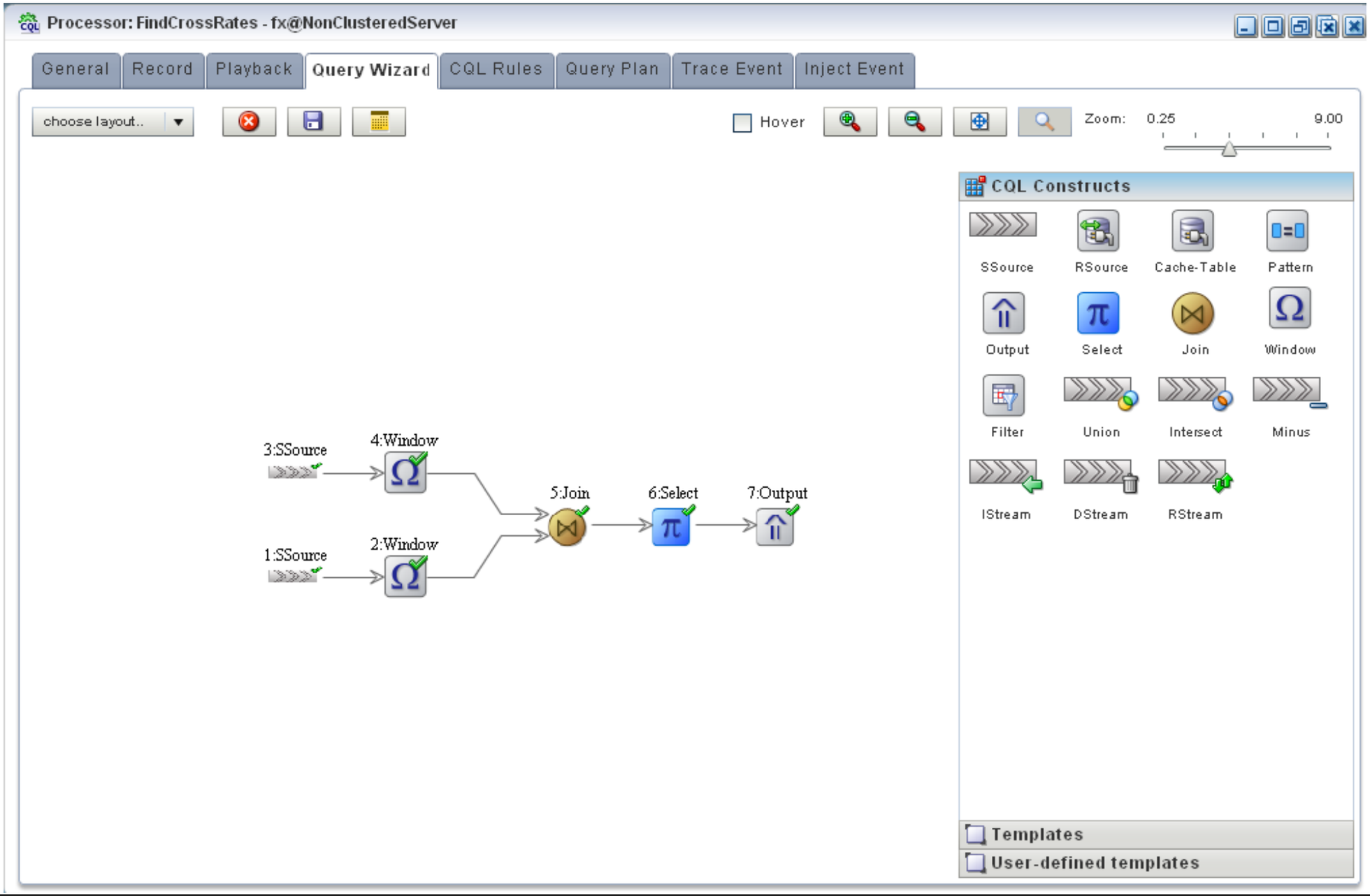
Parameters

Binding Name	1	2
avgcount	avg(internalPrice)	count(*) > 0

Delete Query | Edit Query | Add Parameter | Replace Parameter | Delete Parameter | Stop | Save | Cancel | Help

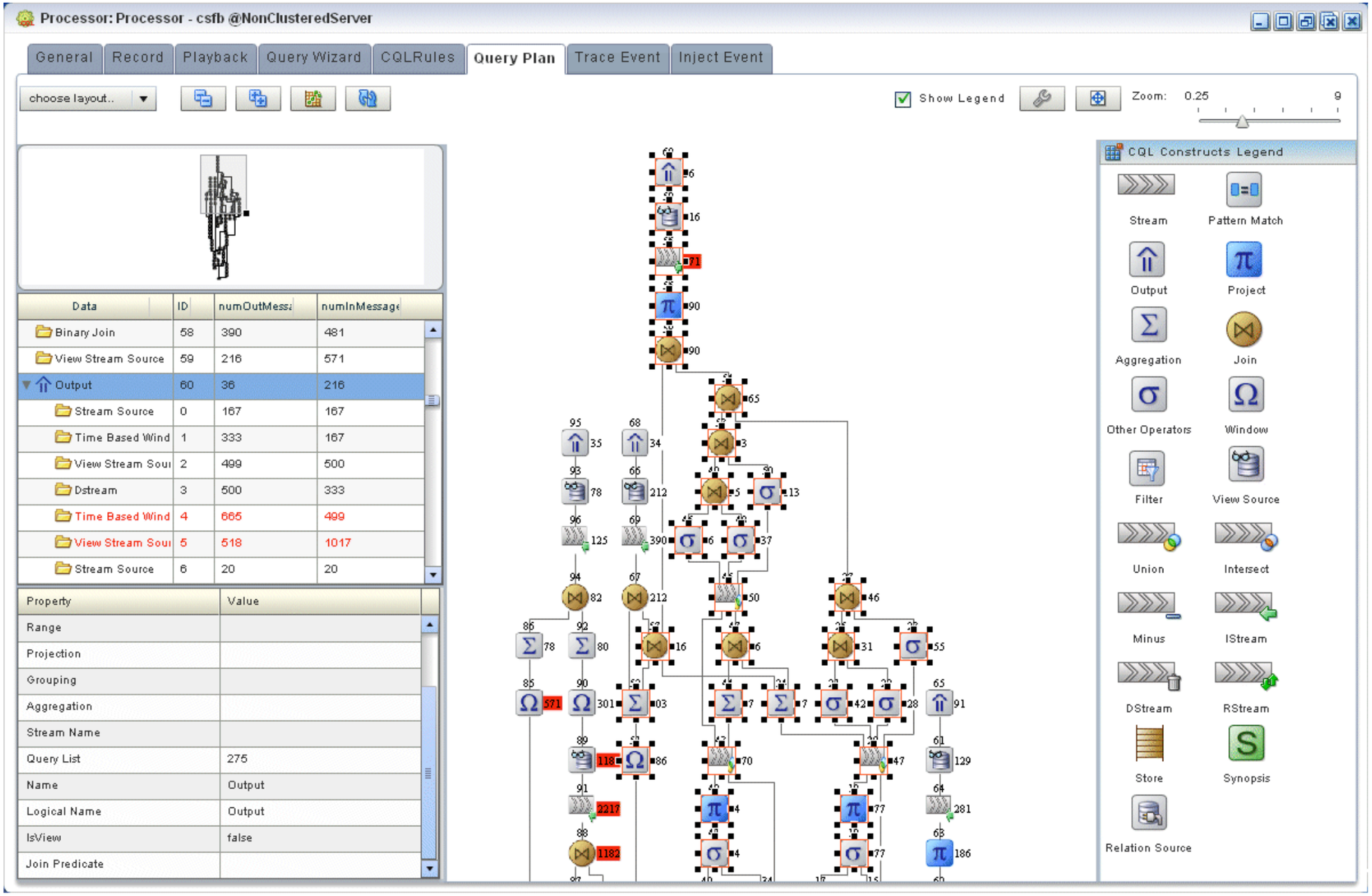
Some Visualizer snapshots

CQL “for dummies” (not for you!)



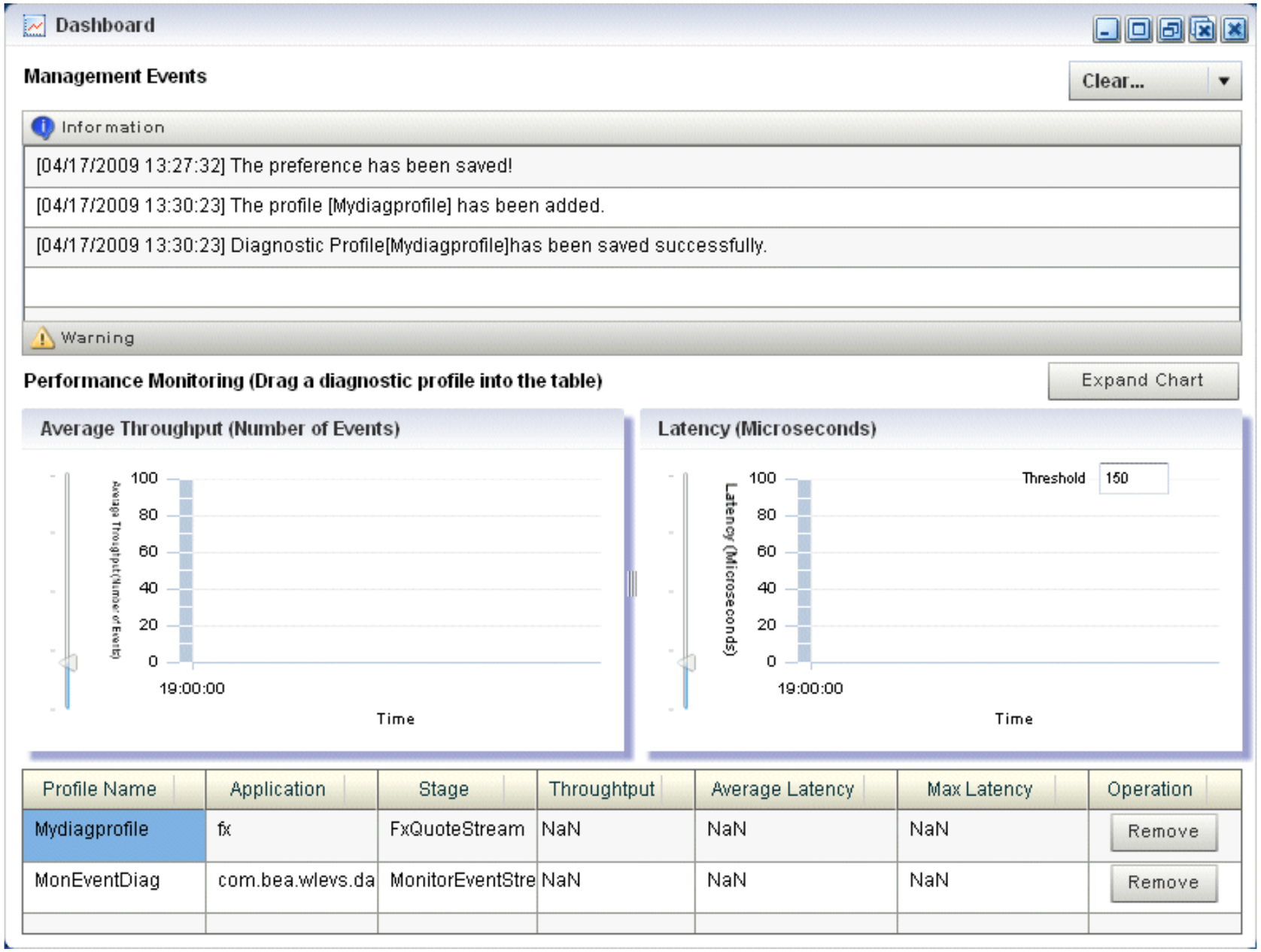
Some Visualizer snapshots

Query plans



Some Visualizer snapshots

Event dashboard and statistics



Readings

- **Oracle CEP CQL Language Reference**
  - https://docs.oracle.com/cd/E16764_01/doc.1111/e12048/toc.htm
- **Oracle CEP IDE Developer's Guide for Eclipse**
  - https://docs.oracle.com/cd/E16764_01/doc.1111/e14301/toc.htm
- **Oracle Event Processing Visualizer User Guide**
  - http://docs.oracle.com/cd/E28280_01/doc.1111/e14302/toc.htm
- **CURRENT DOC**

https://docs.oracle.com/middleware/1213/eventprocessing/index.html

Further Reading and Summary

Q&A

Further Reading

- **Recommend Readings**
  - Arvind Arasu, Shivnath Babu, Jennifer Widom: The CQL continuous query language: semantic foundations and query execution. VLDB J. 15(2): 121-142 (2006)

- **Supplemental readings:**
  - Arvind Arasu et al.: STREAM: The Stanford Data Stream Management System. Stanford InfoLab Tech. Rep. (2004)
  - Arvind Arasu et al.: Linear Road: A Stream Data Management Benchmark. VLDB 2004: 480-491
  - Arvind Arasu, Jennifer Widom: A Denotational Semantics for Continuous Queries over Streams and Relations. SIGMOD Record 33(3): 6-12 (2004)

Further Reading and Summary

Q&A