Vertically Scalable solutions illustrated via EPL and Esper

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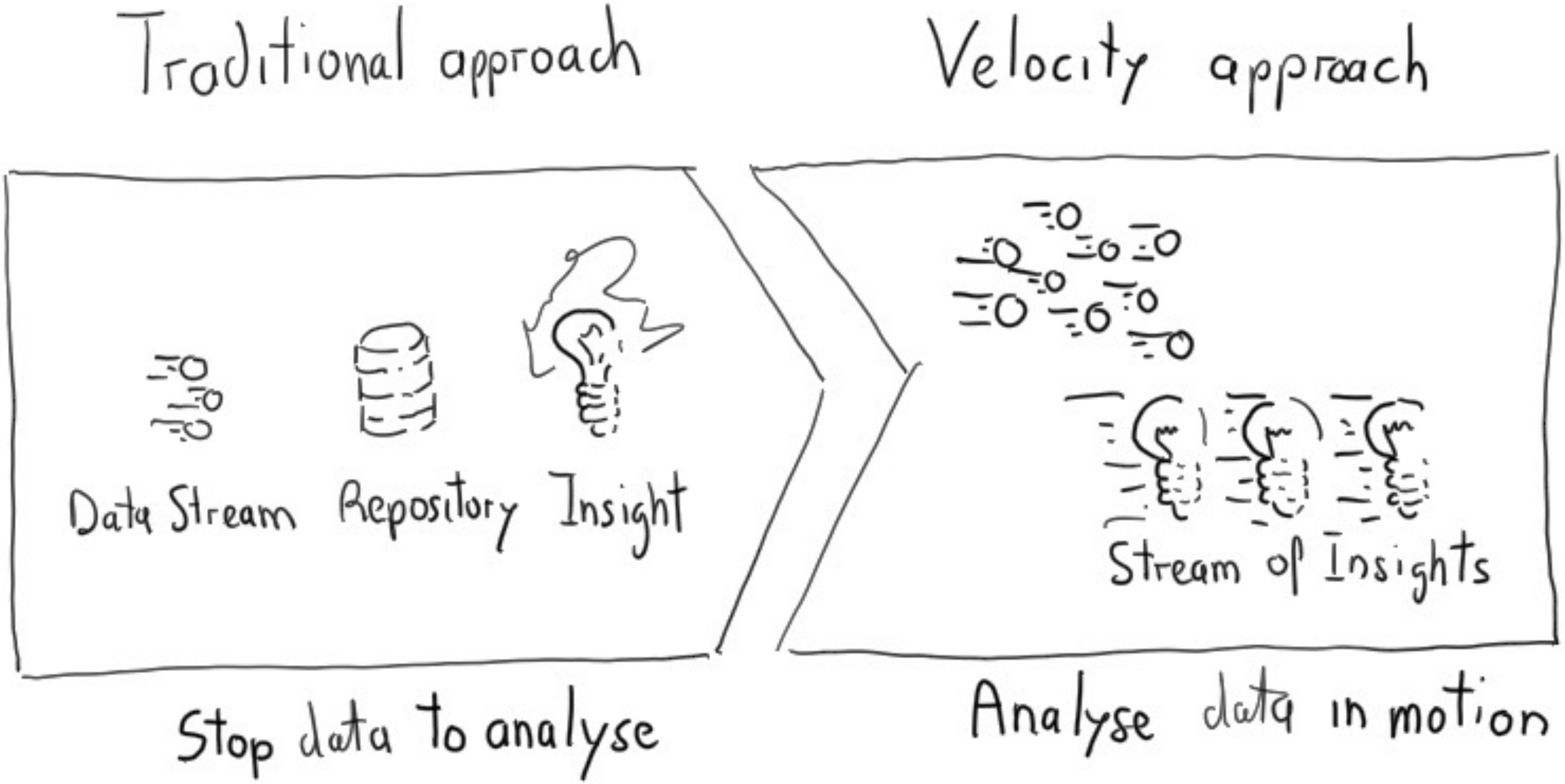
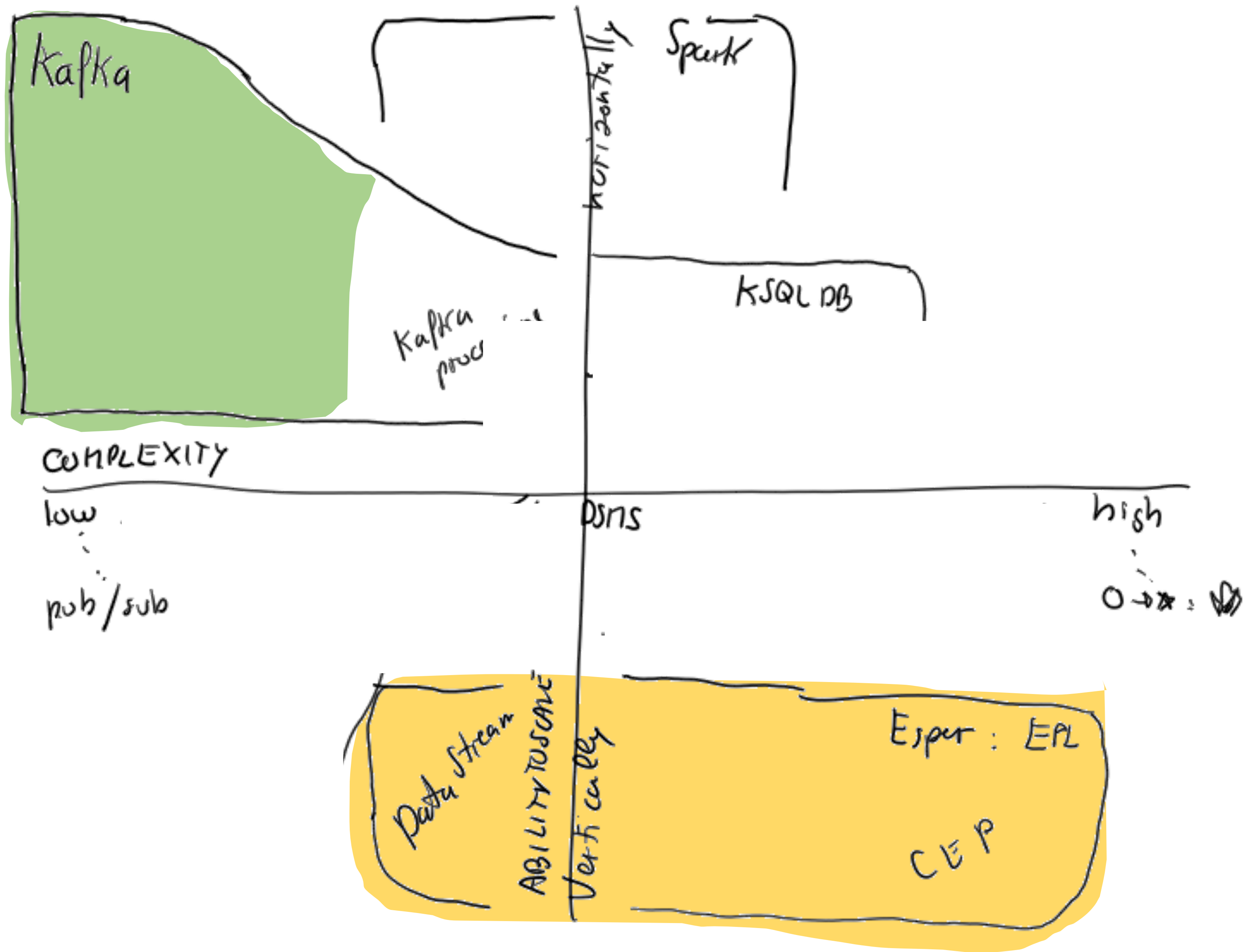
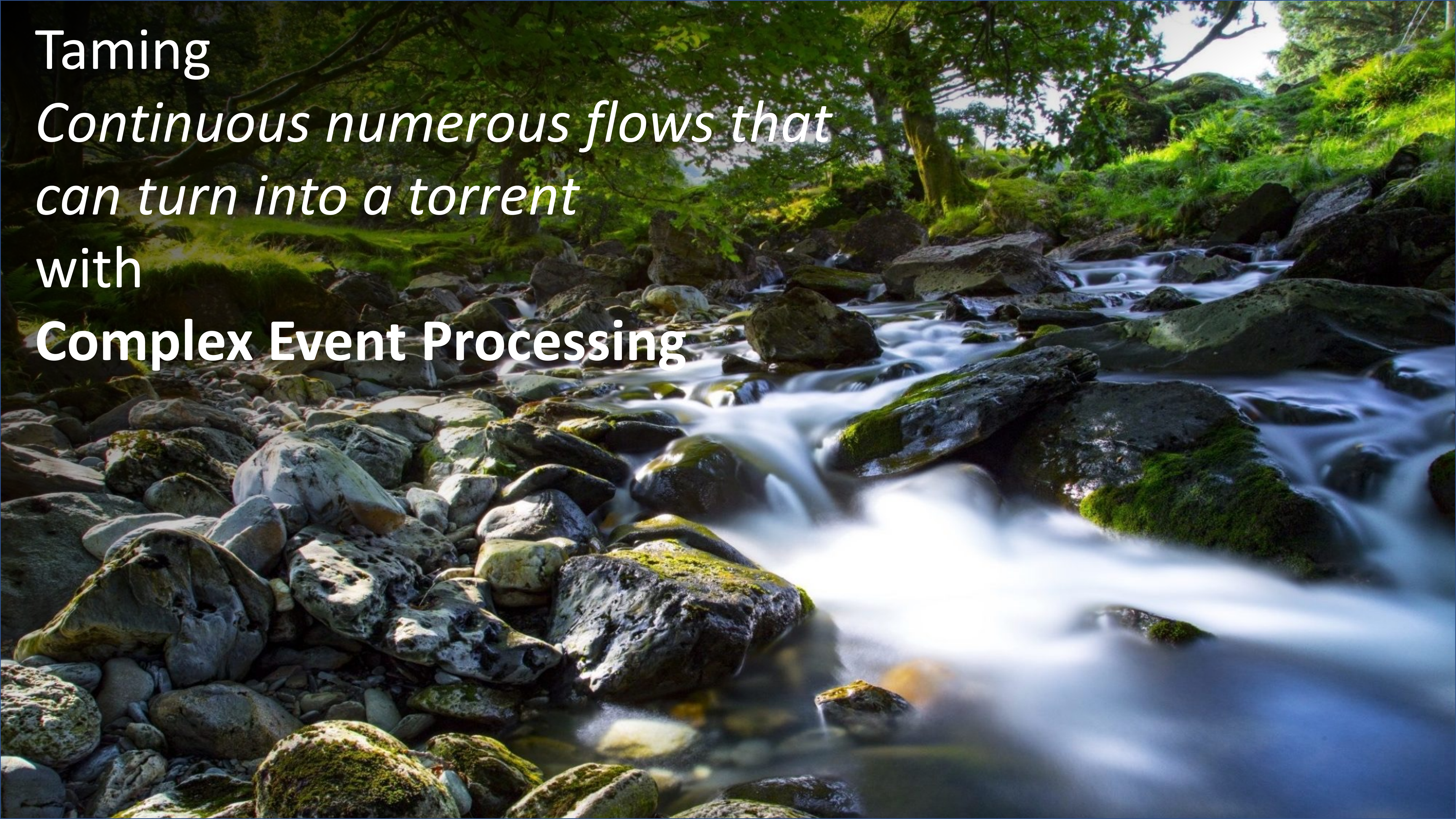
Positioning this lecture

1st premises: continuity matters




Kafka
Spark
horizontally
KSQL DB
Kafka proc
COMPLEXITY
low
DSMS
high
pub/sub
Data Stream
ABILITY TO SCALE
vertically
Esper : EPL
CEP



Taming
Continuous numerous flows that can turn into a torrent
with
Complex Event Processing

The Event Processing Language & its reference implementation Esper

Esper in a nutshell

- Implemented as a Java library
  - Can be embedded in any JVM application
- Designed for performance
  - High throughput
  - Low latency
- Tree-based recognition algorithm
- Inverted indexes to dispatch incoming events to EPL statements
- Builds indexes to quickly retrieve events with given properties among those stored

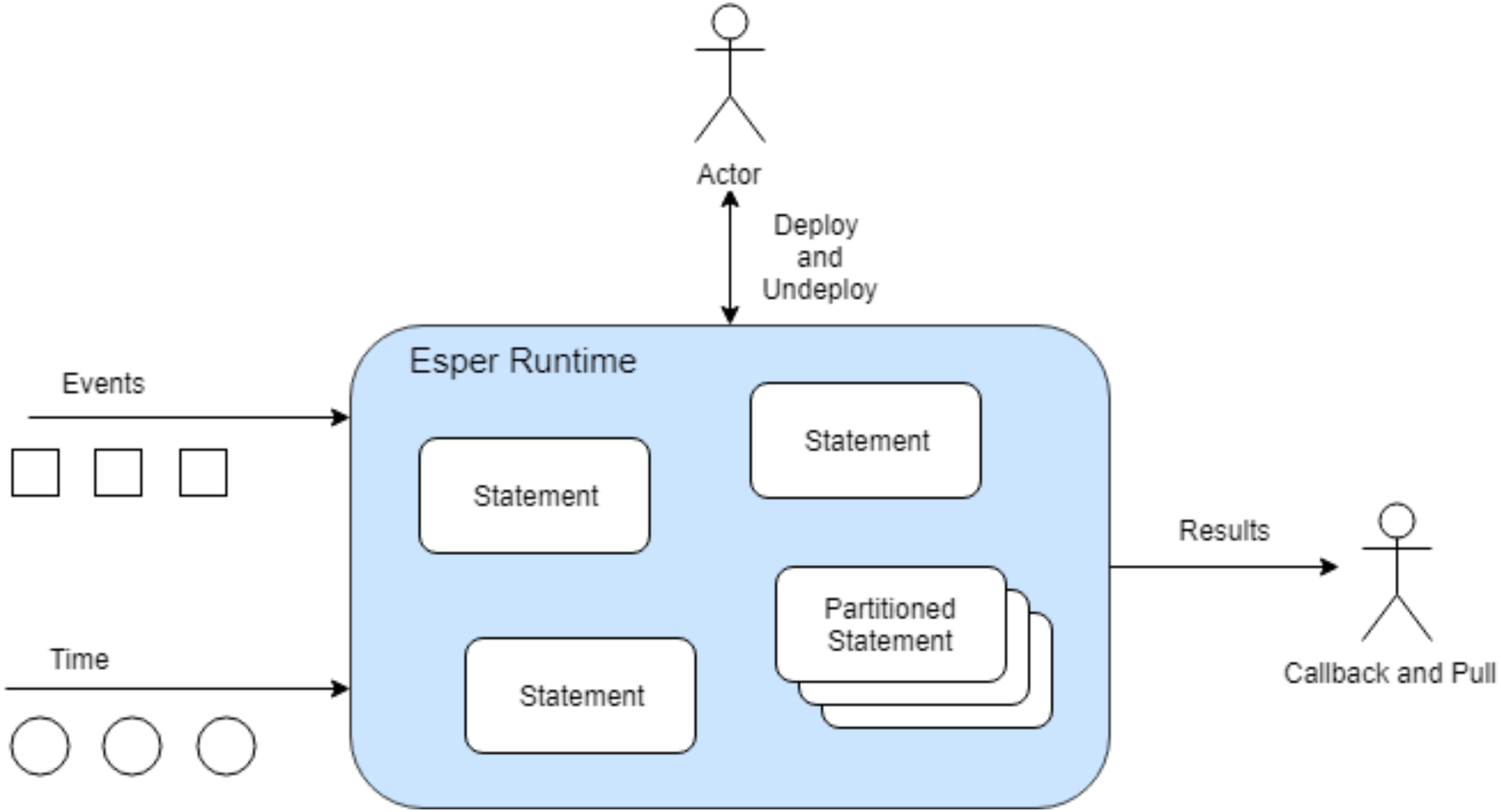
Esper in a nutshell (cont.)

- Interaction with static / historical data
- Configurable push or pull communication
- Several adapters for input/output
  - CSV, JMS in/out, API, DB, Socket, HTTP
- Esper HA
  - High Availability
  - Ensures that the state is recoverable in the case of failure

EPL in a nutshell

- EPL: rich language to express rules (a.k.a., statementa)
- Grounded on the DSMS approach
  - Windowing
  - Relational select, join, aggregate, …
  - Relation-to-stream operators to produce output
- Queries can be combined to form a graph
- Includes complex event recognition abstractions
  - Pattern detection

Esper & EPL



Actor
Deploy and Undeploy
Esper Runtime
Events
Statement
Statement
Results
Partitioned Statement
Time
Statement
Callback and Pull

The **Basics** of the **E**vent **P**rocessing **L**anguage

Running example

- Count the number of fires detected using a set of smoke and temperature sensors in the last 10 minutes
- Events
  - Smoke event: String sensor, boolean state
  - Temperature event: String sensor, double temperature
  - Fire event: String sensor, boolean smoke, double temperature
- Condition:
  - Fire: at the same sensor smoke followed by temperature>50 within 2 minutes

Declare event types

- Two ways
  - EPL *create schema clause*
  - Runtime configuration API *addEventType*
- Syntax

```
create schema
schema_name [as]
(property_name property_type
[,property_name property_type [,...])
[inherits inherited_event_type
[, inherited_event_type] [,...]]
```

Running example

```
create schema SmokeSensorEvent(
      sensor string,
      smoke boolean
);

create schema TemperatureSensorEvent(
      sensor string,
      temperature double
);

create schema FireComplexEvent(
      sensor string,
      smoke boolean,
      temperature double
);
```

Event Processing Language (EPL)

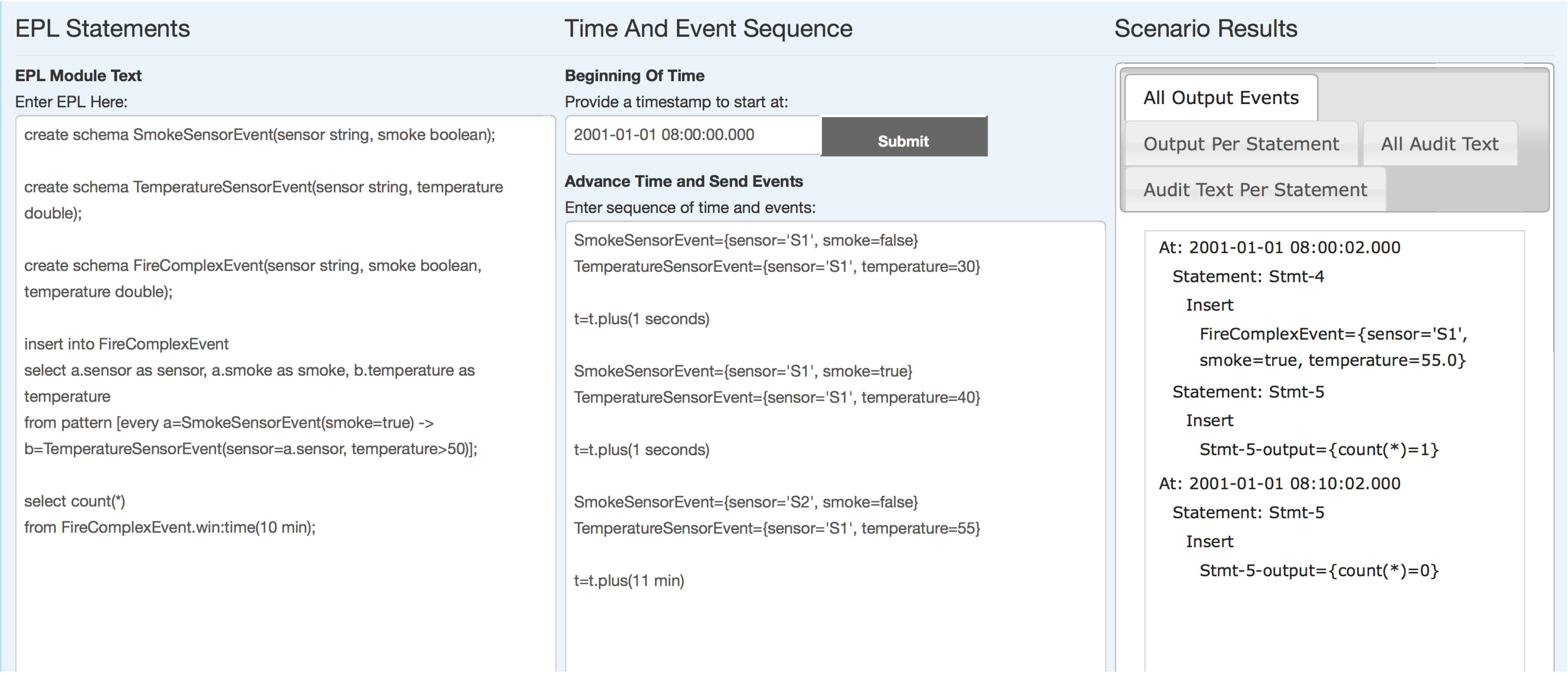
- EPL is similar to SQL
  - Select, where, …
- Event streams and views instead of tables
  - Views define the data available for the query
  - Views can represent windows over streams
  - Views can also sort events, derive statistics from event attributes, group events, …

EPL syntax

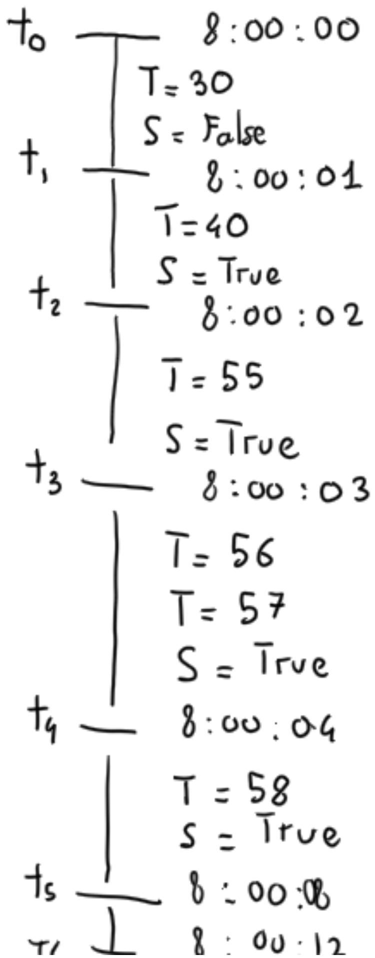
```
[insert into insert_into_def]
select select_list
from stream_def [as name]
[, stream_def [as name]] [,...]
[where search_conditions]
[group by grouping_expression_list]
[having grouping_search_conditions]
[output output_specification]
[order by order_by_expression_list]
[limit num_rows]
```

Running example

http://esper-epl-tryout.appspot.com/epltryout/mainform.html

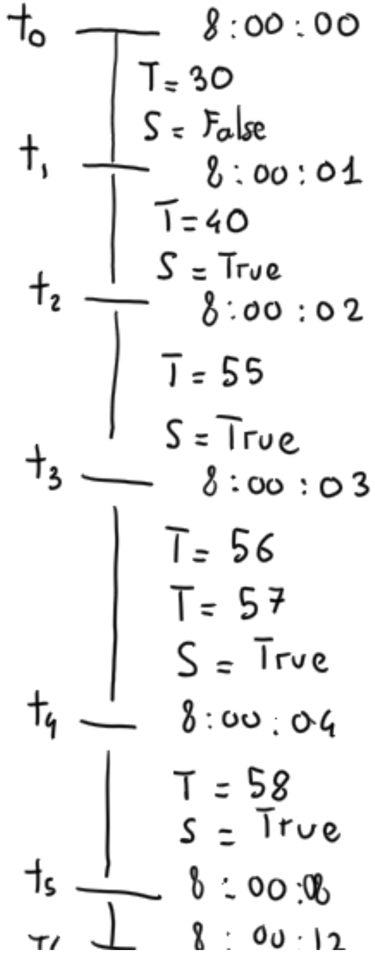


Time line



t_0
8:00:00
T = 30
S = False
t_1
8:00:01
T = 40
S = True
t_2
8:00:02
T = 55
S = True
t_3
8:00:03
T = 56
T = 57
S = True
t_4
8:00:04
T = 58
S = True
t_5
8:00:12

Filtering



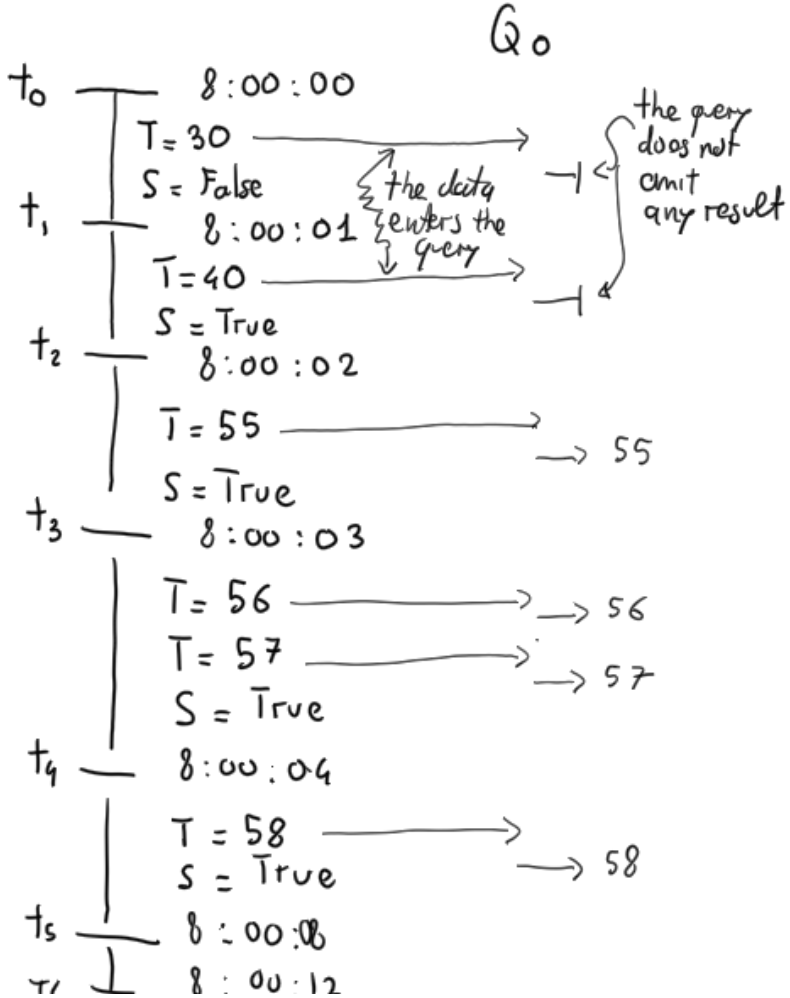
Q0 - the SQL-style

```
select *
from TemperatureSensorEvent
where temperature > 50;
```

Q0bis - the Event-Based System Style

```
select *
from TemperatureSensorEvent(temperature > 50) ;
```

Filtering the SQL style



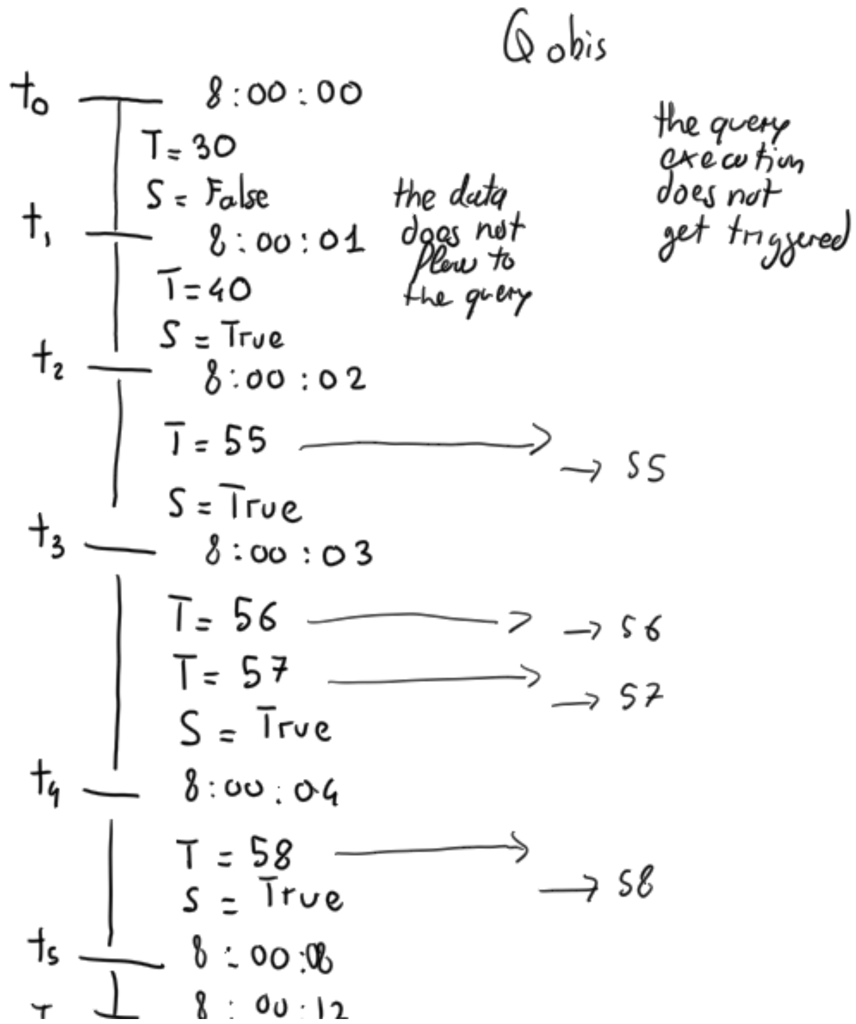
Q0 - the SQL-style

```
select *
from TemperatureSensorEvent
where temperature > 50;
```

Execution mode

Data points enter the query that filters them

Filtering the Event-Based System Style



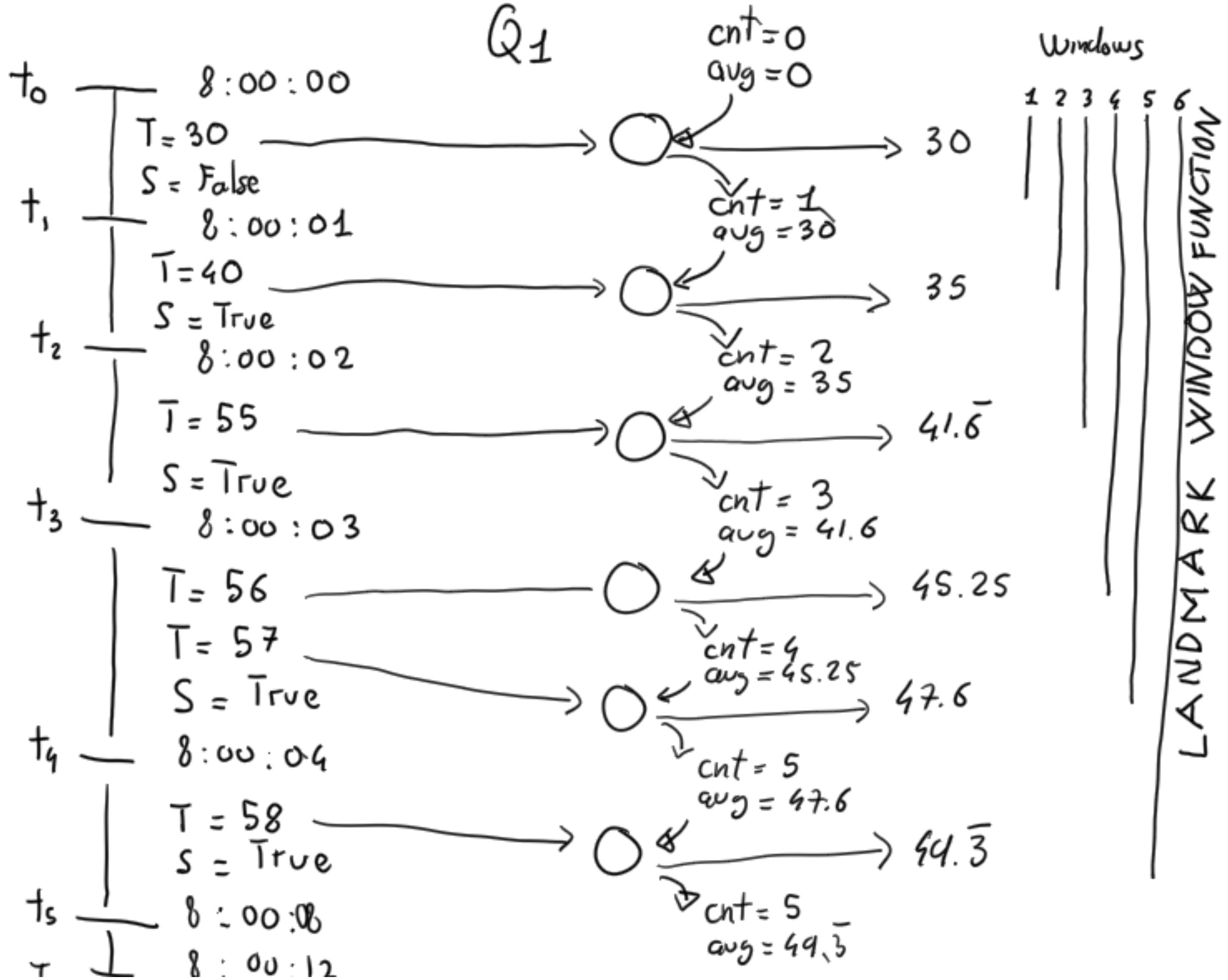
Q0bis - the Event-Based System Style

```
select *
from TemperatureSensorEvent(temperature > 50)
;
```

Execution mode

Data points are filtered before flowing into the query and the query execution does not get triggered

Basic Aggregation




```
select sensor, avg(temperature)
from TemperatureSensorEvent
group by sensor;
```

Execution mode

From a **logical** perspective, **data points cumulate in the landmark window,** and the query emits a new avg for every data point

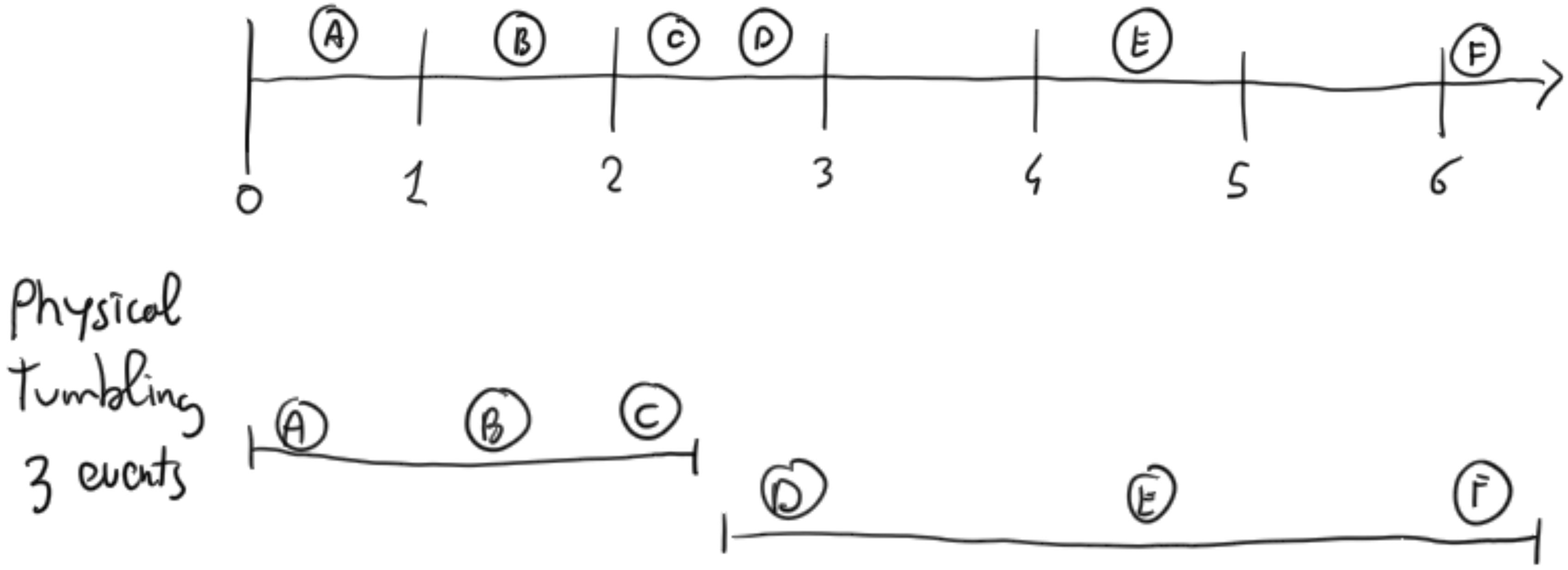
From a **physical** perspective, **the query is evaluated incrementally** and **maintains a state** that captures the number of events (cnt) seen so far and the previous avg. The new average only depends on the state and the new data point entering the query. Old data can be forgotten.

Data Windowing

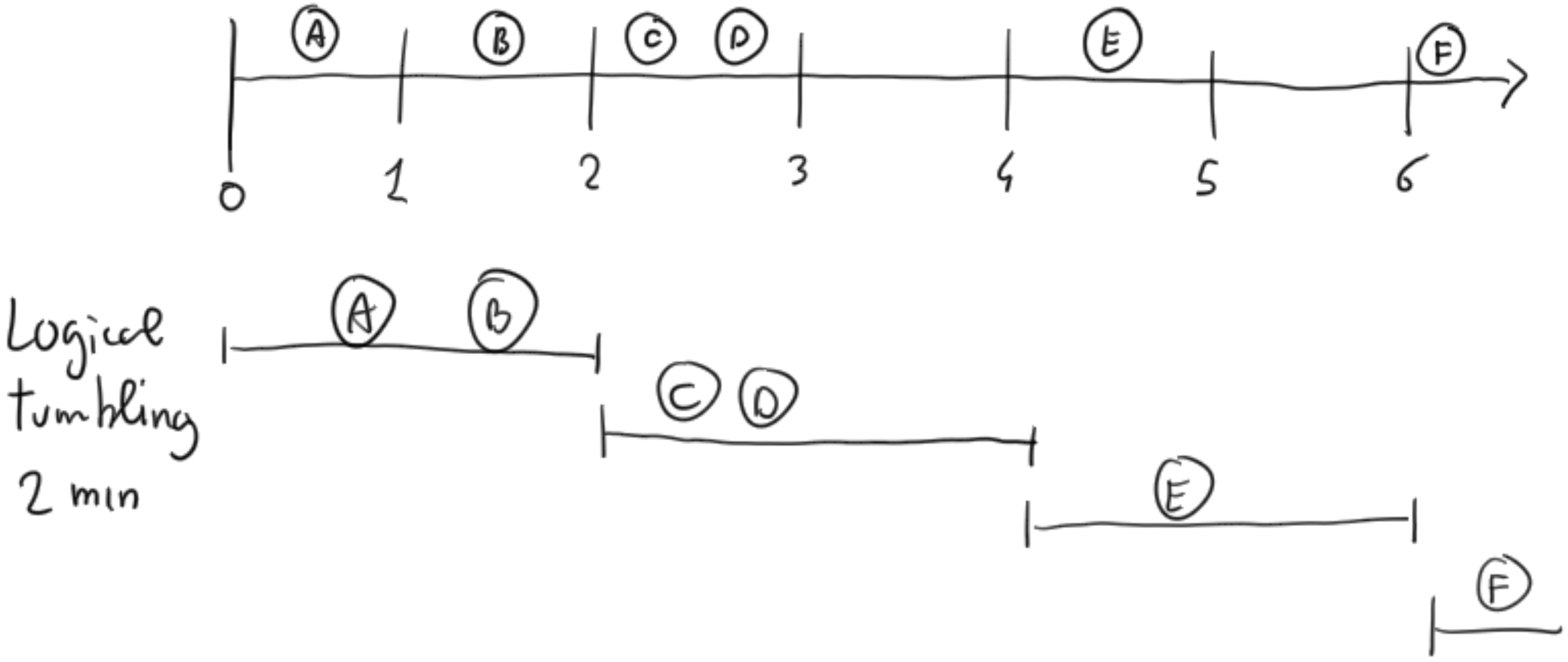
	Physical # events	Logical # time units
sliding moves on every event	native	native
tumbling	native	native
hopping	output claus	output clause

+ session window

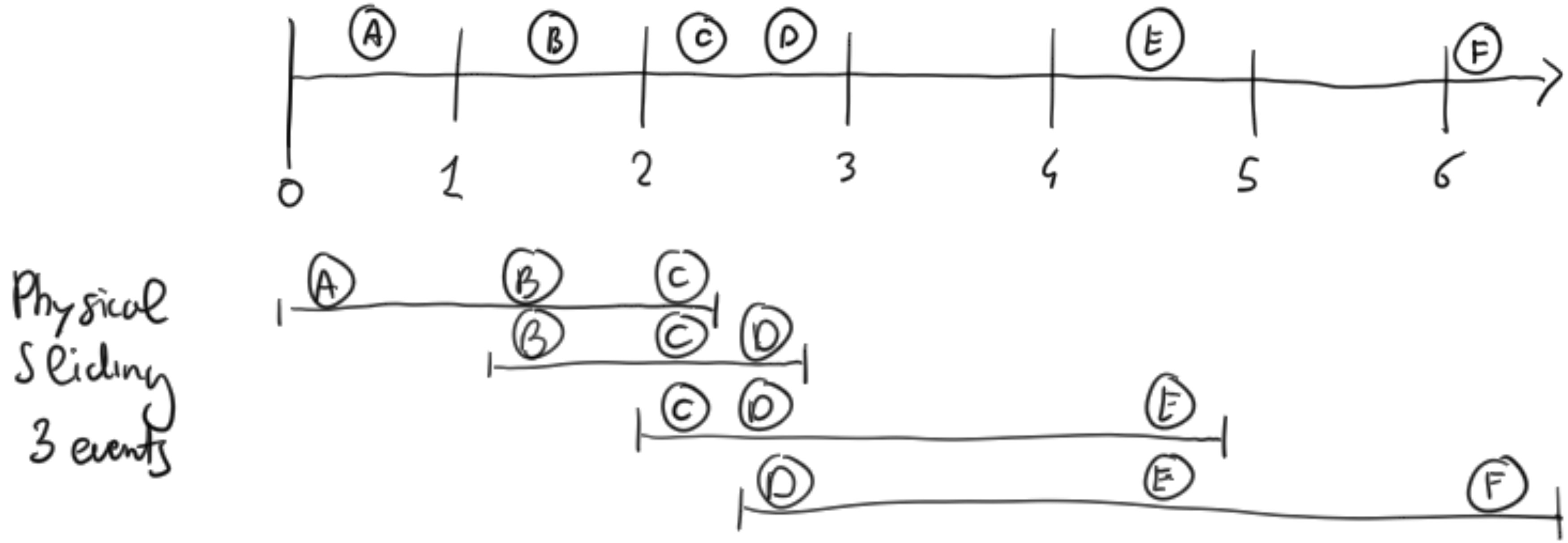
Physical tumbling windows



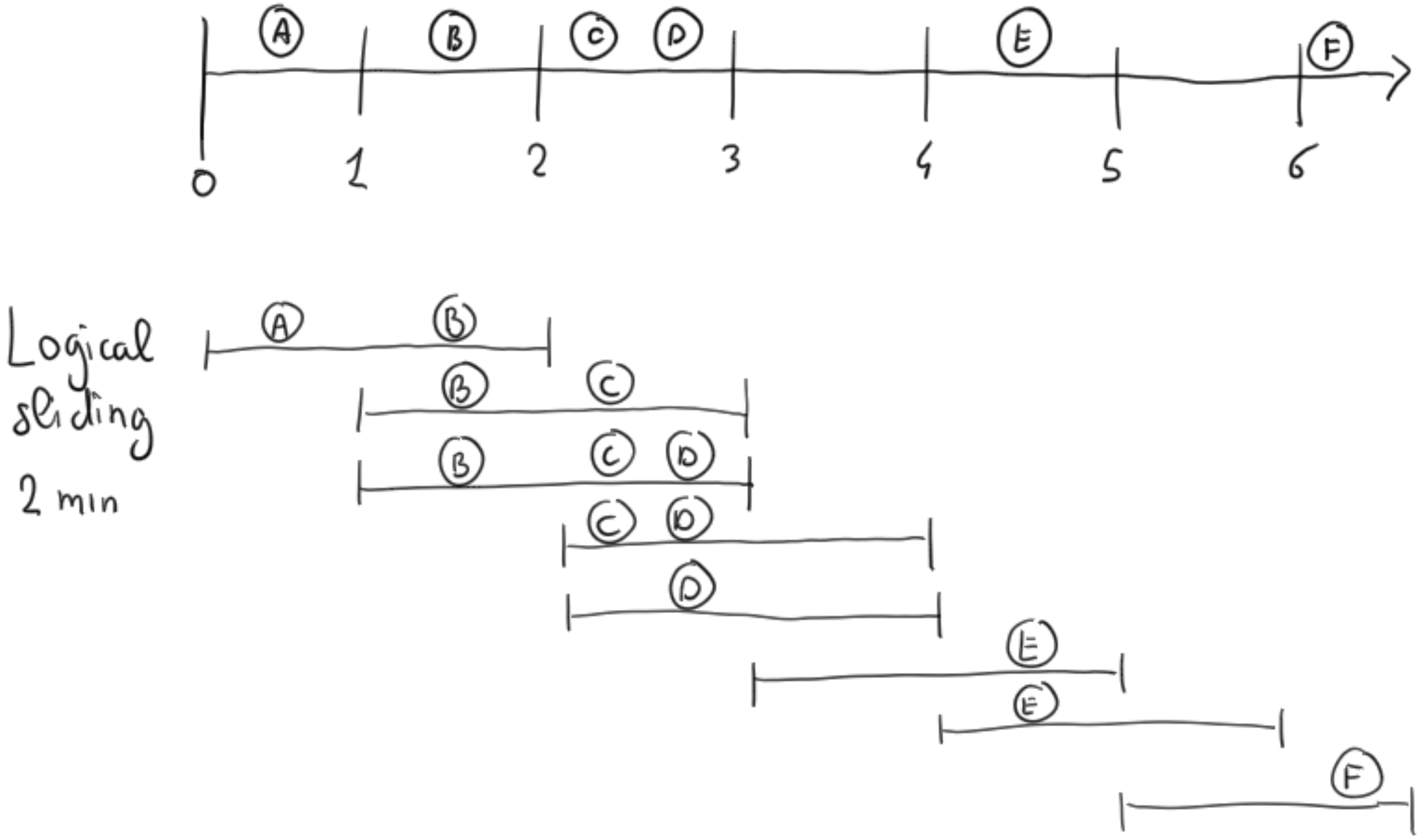
Logical tumbling windows



Physical sliding windows



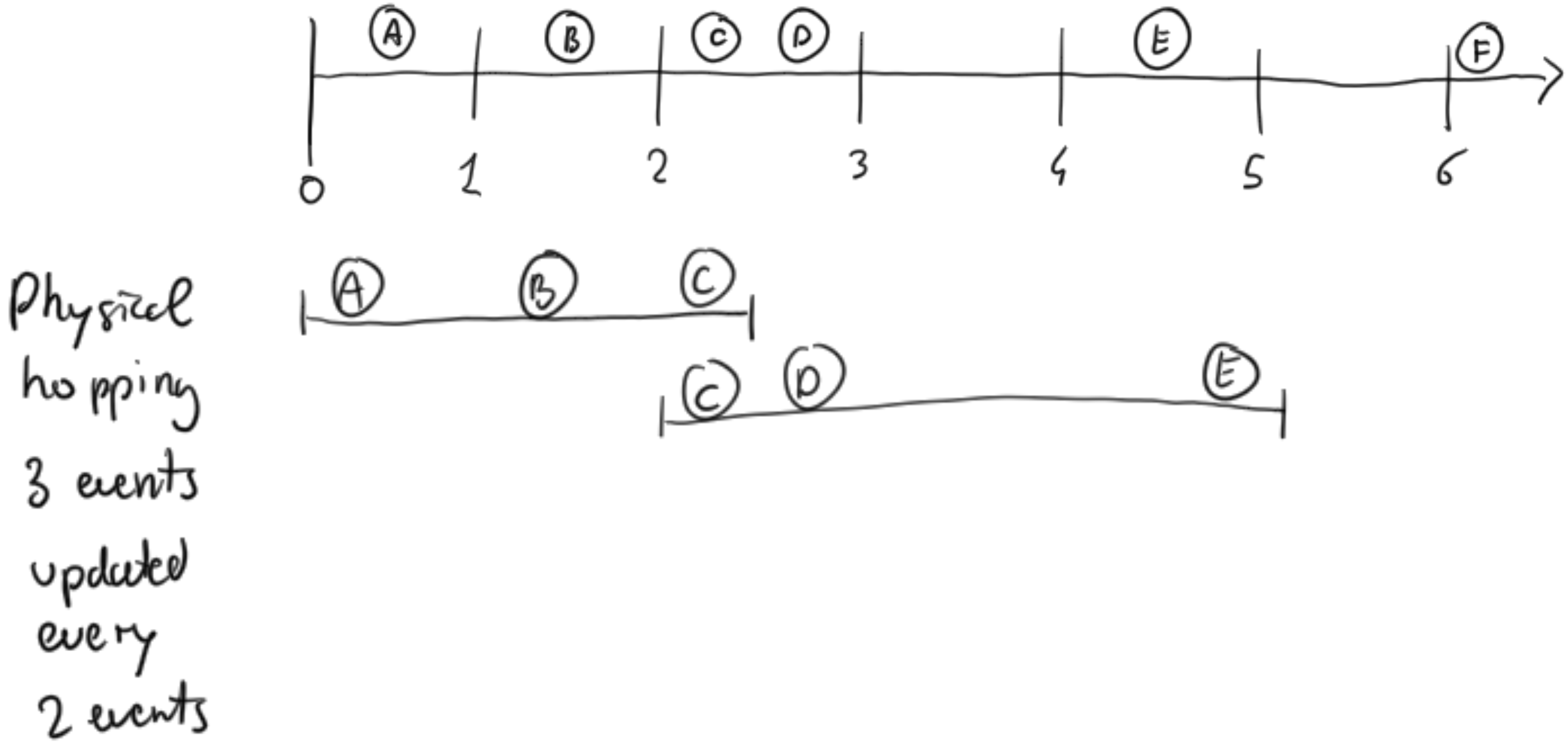
Logical sliding windows



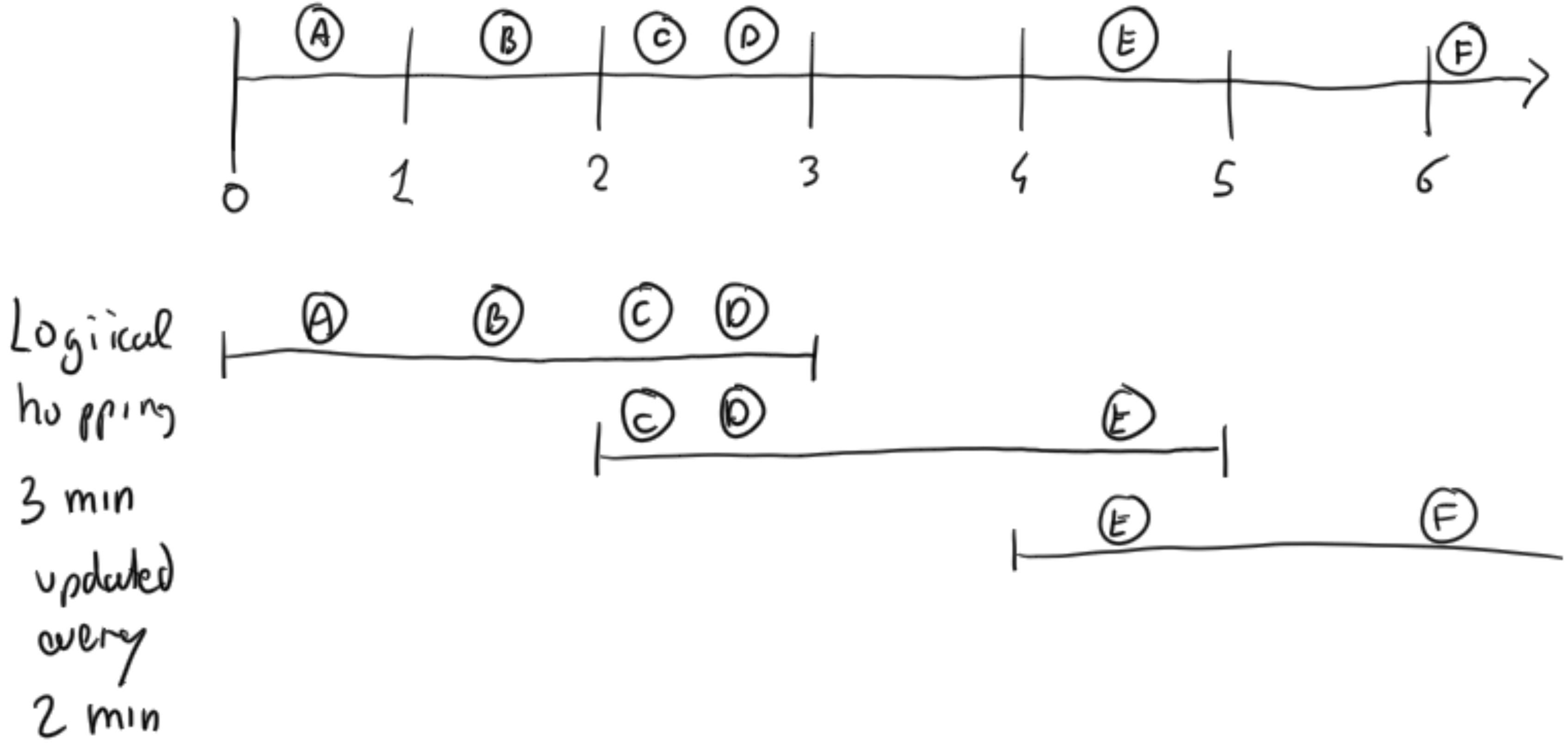
EPL window syntax

Type	Syntax	Description
Logical Sliding	win:time(*time_period*)	Sliding window that covers the specified time interval into the past
Logical Tumbling	win:time_batch(*time_period* [, *reference point*] [, *flow control*])	Tumbling window that batches events and releases them every specified time interval, with flow control options
Physical Sliding	win:length(*size*)	Sliding window that covers the specified number of elements into the past
Physical Tumbling	win:length_batch(*size*)	Tumbling window that batches events and releases them when a given minimum number of events has been collected

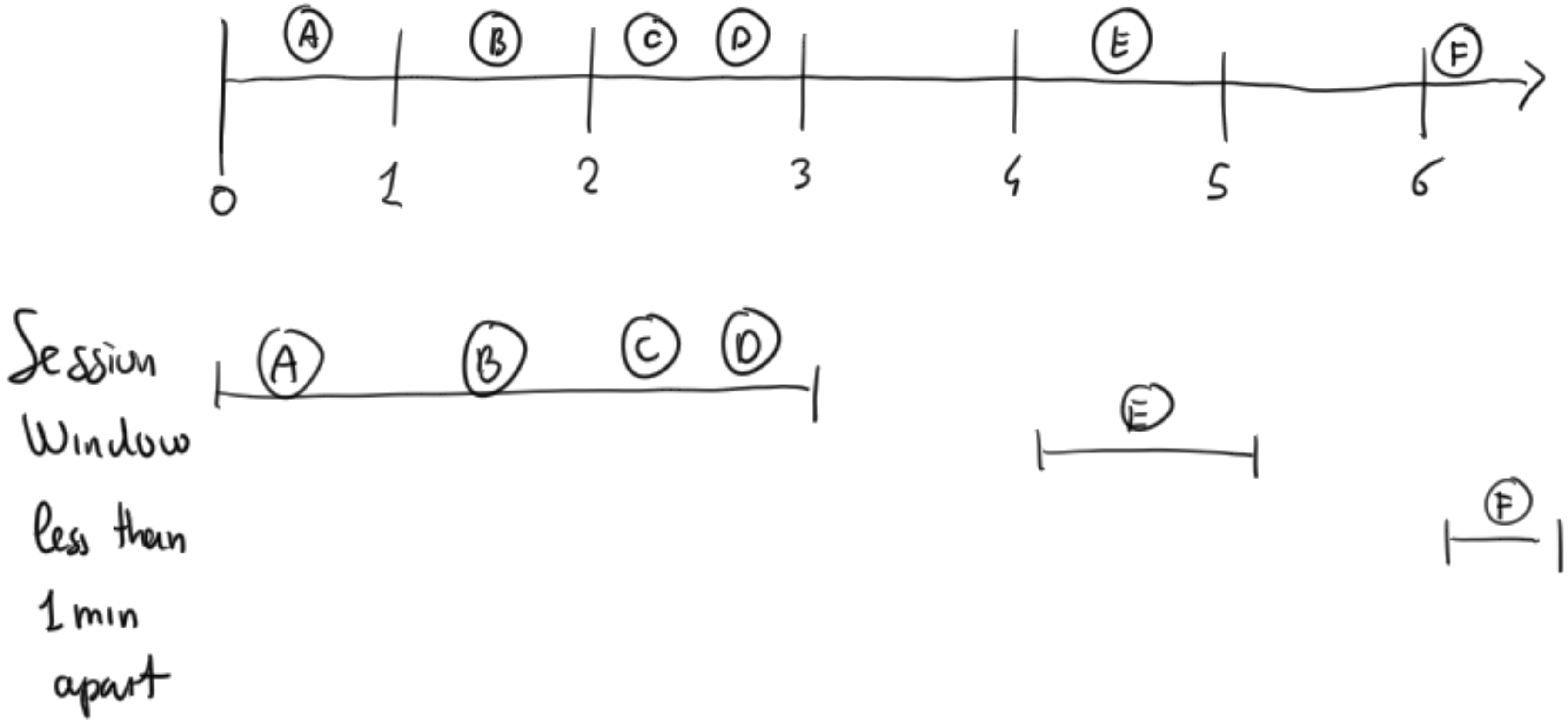
Physical hopping windows



Logical hopping windows



Session windows (not supported in EPL)



EPL Output control syntax

- The *output* clause is optional in Esper
- It is used to
  - Control the output rate
  - Suppress output events

```
output     [all | first | last | snapshot]
every output_rate [seconds | events]
```

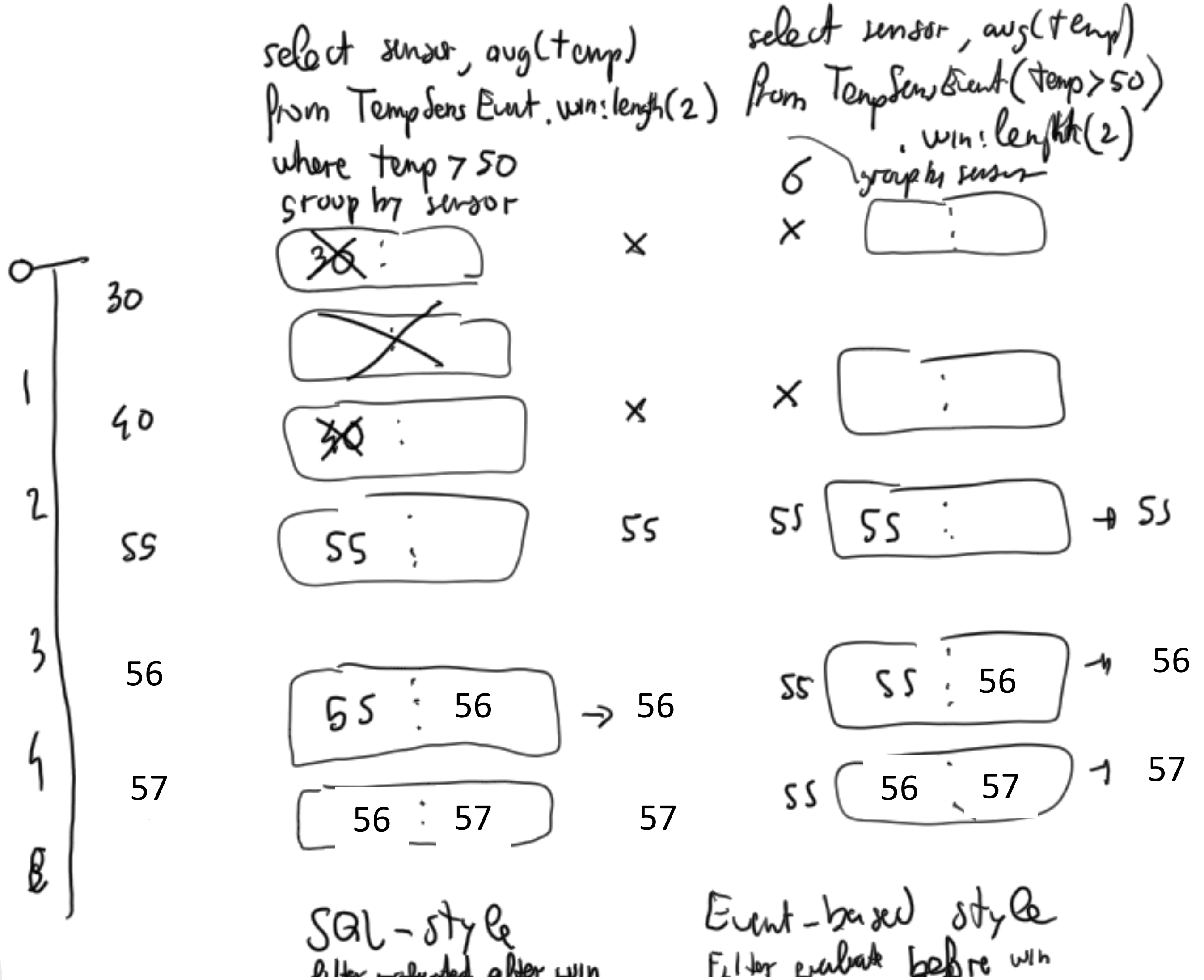
Output control and Hopping Windows

- Control advancement of sliding windows

```
select      avg(temperature)
from        TemperatureSensorEvent.win:length(4)
output      snapshot every 2 events
```

```
select      avg(temperature)
from        TemperatureSensorEvent.win:time(4 sec)
output      snapshot every 2 sec
```

A digression on data windowing and SQL-style vs. Event-base style filtering



The **Pattern Matching** clause of the **E**vent **P**rocessing **L**anguage

Pattern matching

An event pattern emits when one or more event occurrences match the pattern definition, which can include

- Constraints on the content of events
- Constraints on the time of occurrence of events
- Conditions for pattern creation / termination

Pattern matching

- Content-based event selection

```
TempStream(sensor="S0", val>50)
```

- Time-based event observers specify time intervals or time schedules

Fires after 10 seconds

```
timer:interval(10 seconds)
```

```
timer:at(5, *, *, *, *)
```

Every 5 minutes
Syntax: minutes, hours, days of month, months, days of week

Pattern matching operators

- Logical operators
  - *and, or, not*

- Temporal operators that operate on event order
  - *-> (followed-by)*

- Creation/termination control
  - *every, every-distinct, [num] and until*

- Guards filter out events and cause termination
  - *timer:within, timer:withinmax* and *while*-expression

Pattern matching

```
select a.sensor from pattern
[every (
  a = SmokeEvent(smoke=true)
  ->
  TempEvent(val>50, sensor=a.sensor)
  where timer:within(2 min)
)]
```

Pattern matching

- *every expr*
  - When *expr* evaluates to true or false …
  - … the pattern matching for *expr* should re-start
- Without the every operator the pattern matching process does not re-start

Pattern matching

- This pattern fires when encountering an A event and then stops

```
A
```

- This pattern keeps firing when encountering A events, and does not stop

```
every A
```

Pattern matching

A1 B1 B2 A2 A3 B3 A4 B4

```
every (A -> B)
```

Detect an event A followed by an event B: at the time when B occurs, the pattern matches and restarts looking for the next A event

B1	{A1, B1}
B3	{A2, B3}
B4	{A4, B4}

Pattern matching

A1 B1 B2 A2 A3 B3 A4 B4

```
every A -> B
```

The pattern fires for every A followed by a B event

B1	{A1, B1}
B3	{A2, B3}, {A3, B3}
B4	{A4, B4}

Pattern matching

A1 B1 B2 A2 A3 B3 A4 B4

`A -> every B`

The pattern fires for an A event followed by every B event

B1	{A1, B1}
B2	{A1, B2}
B3	{A1, B3}
B4	{A1, B4}

Pattern matching

A1 B1 B2 A2 A3 B3 A4 B4

```
every A -> every B
```

The pattern fires for every A event followed by every B event

B1	{A1, B1}
B2	{A1, B2}
B3	{A1, B3}, {A2, B3}, {A3, B3}
B4	{A1, B4}, {A2, B4}, {A3, B4}, {A4, B4}

Pattern matching

- With the every operator
  - Multiple (partial) instances of the same pattern can be active at the same time
  - Each instance can consume some resources when events enter the engine
- End pending instances whenever possible
  - With the *timer:within* construct
  - With the *and not* construct
- Note: the data windows on a pattern do not always limit pattern sub-expression lifetime

Pattern matching

A1 A2 B1

Pattern	Results
every A -> B	{A1, B1}, {A2, B1}
every A -> (B and not A)	{A2, B1}

The *and not* operator causes the sub-expression looking for {A1, B?} to end when A2 arrives

Pattern matching

A1@1 A2@3 B1@4

Pattern	Results
every A -> B	{A1, B1}, {A2, B1}
every A -> (B where timer:within(2 sec))	{A2, B1}

The *timer:within* operator causes the sub-expression looking for {A1, B?} to end after 2 seconds

Combine queries

- The insert into clause forwards events to other streams for further downstream processing

```
insert       into FireComplexEvent
select       a.sensor as sensor,
             a.smoke as smoke,
             b.temperature as temperature
from         pattern
             [every a=SmokeSensorEvent(smoke=true)
             ->
             b=TemperatureSensorEvent(
             sensor=a.sensor, temperature>50)];
select       count(*)
from         FireComplexEvent.win:time(10 min);
```

Reference

- Esper documentation online
  - https://esper.espertech.com/release-8.8.0/reference-esper/html_single/
- Esper EPL online
  - http://esper-epl-tryout.appspot.com/epltryout/mainform.html

License and Acknowledgment

- The original slides where prepared by Alessandro Margara for the PhD course on “Stream and Complex Event Processing in the Big Data Era” offered in 2019

http://streamreasoning.org/events/scep2019

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